The role of users and suppliers in the adoption and diffusion of consumer electronics. The case of portable digital audio players.

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I hereby declare that this thesis has not been, and will not be submitted in whole or in part to another University for the award of any other degree.

Signature: ………………………………….

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Summary

The diffusion of innovations is a fundamental aspect of the innovative process, to which the literature on innovation dedicated a lot of attention. This voluminous literature covers a variety of themes, such as different kinds of innovations, potential adopters, and mechanisms by which the innovation spreads among its potential users. However, some aspects of this vast literature still deserve some further investigation. The objective of the thesis is to study the adoption and diffusion of a consumer technology, the portable digital audio player (DAP) market in Europe and Japan. The methodology is quantitative and consists on the collection and analysis of two original datasets. The first dataset regards the demand-side consisting in a survey of 1562 young potential adopters from 9 countries (France, Germany, Italy, Portugal, Netherlands, Spain, Switzerland, UK, and Japan). The other source of data is a dataset of 585 DAPs marketed between 2001 and 2009, including information on product characteristics (storage space, size, etc.) and price. The analysis of the data is carried out at three levels. The first one regards the demand-side, with the aim of assessing how users' characteristics shape the adoption decision, and providing a classification of potential adopters that goes beyond the usual classification based on timing of adoption or on the distribution of a single variable such as income. The second level concentrates on the supply-side, testing if there is a systematic relationship between product price and its objectively measurable characteristics and evaluating how technical change in the sector influences the diffusion path by matching products' quality change with users' preferences and patterns of adoption over time. Finally, the third level aims at providing evidence on whether conventional models of diffusion are able to provide an adequate explanation of the diffusion of DAPs, and moreover, on how the assumptions underlying these models might be combined or synthesised into a coherent framework.

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3G	3^{rd} Generation (Mobile Telecommunications)
3M	Minnesota Mining and Manufacturing Company
AAC	Advanced Audio Coding
AIFF	Audio Interchange File Format
AT&T	American Telephone & Telegraph
ATM	Automated Teller Machine
ATRAC	Adaptive Transform Acoustic Coding
BASF	Baden Aniline and Soda Factory (in German: Badische Anilin- und Soda-Fabrik)
BMG	Bertelsmann Music Group
BPI	British Phonographic Industry
CBS	Columbia Broadcasting System
CD	Compact Disc
CD-I	Compact Disc Interactive
CD-R	Compact Disc Recordable
CD-ROM	Compact Disc Read Only Memory
CD-RW	Compact Disc ReWritable
CD-V	Compact Disc Video
CEO	Chief Executive Officer
CF	Compact Flash
CFA	Confirmatory Factor Analysis
CPU	Central Processing Unit
DAP	Digital Audio Player
DAT	Digital Audio Tape
DCC	Digital Compact Cassette
DEA	Digital Economy Act
DRM	Digital Rights Management
DVD	Digital Versatile Disc
ECIS	Eindhoven Centre for Innovation Studiesf
EFA	Exploratory Factor Analysis
EMI	Electrical and Music Industries
ESP	Electronic Skip Protection
ETH	Swiss Federal Institute of Technology (in German: Eidgenössische Technische Hochschule)
FM	Frequency Modulation

GB	GigaByte
GPS	Global Positioning System
HADOPI	Higher Authority for the Distribution of Works and the Protection of Rights on the Internet (in French: Haute Autorité pour la Diffusion des Oeuvres et la Protection des Droits sur Internet)
HD	Hard Disk
HD-TV	High Definition Television
Hi-Fi	High Fidelity
Hi-MD	High Capacity MiniDisc
HP	Hewlett Packard
IBM	International Business Machines Corporation
ICT	Information and Communication Technology
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IFPI	International Federation of the Phonographic Industry
IP	Internet Protocol
IPR	Intellectual Property Rights
ISCTE	Lisbon University Institute (in Portuguese: Instituto Universitário de Lisboa)
ISO	International Organization for Standardization
ISP	Internet Service Provider
IT	Information Technology
KMO	Kaiser-Meyer-Olkin
LAN	Local Area Network
LN	Natural Logarithm
LP	Long Playing
MB	MegaByte
Mbit/s	Megabit per second
MCA	Music Corporation of America
MD	MiniDisc
MP1	MPEG-1 Audio Layer 1
MP3	MPEG-1 Audio Layer 3
MP4	MPEG-4 Part 14
MPAA	Motion Picture Association of America
MPEG	Moving Picture Experts Group
NHK	Nippon Hōsō Kyōkai (Japan Broadcasting Corporation)
OS	Operating System

P2P	Peer-to-peer
PASC	Precision Adaptive Sub-banding Coding
PC	Personal Computer
PCM	Pulse-Code Modulation
PDA	Personal Digital Assistant
RCA	Radio Corporation of America
RIAA	Recording Industry Association of America
RPM	Revolutions Per Minute
RSS	Really Simple Syndication
SD	Standard Deviation
SEM	Structural Equation Modelling
SPSS	Statistical Package for Social Science
UMG	Universal Music Group
USB	Universal Serial Bus
VCR	Videocassette Recorder
VHS	Video Home System
WAV/WAVE	Waveform Audio File Format
WEA	Warner Elektra Atlantic
Wi-Fi	Wireless Fidelity
WIPO	World Intellectual Property Organization
WMA	Windows Media Audio
WMG	Warner Music Group

Acknowledgements

My first acknowledgement goes to an astronaut. If I try to trace back the events that eventually led me to do this DPhil, I should probably start from my undergraduate studies in Economics at Bocconi University in Milan. It was 2001 and I had to decide which optional courses to attend from a broad list offered by Bocconi. My main interests at that time were rather mainstream, tending towards international economics and monetary economics. However, one course attracted my attention, the ‘economics of innovation’. In particular, the course convenor's name sounded familiar: Franco Malerba. One of my housemates told me that he knew who Franco Malerba was; he was an astronaut, the first Italian to participate in a Space Shuttle mission. Not wanting to miss the opportunity to be taught a course on innovation by an astronaut, I signed up. Once the course started, I soon realized that I had made a mistake and that the lecturer and the astronaut were not the same person, they just happened to have the same name. However, despite this mix up, I found Prof Malerba’s lectures extremely interesting, so much so that they probably changed my life. I followed the course with great enthusiasm, and then I asked Prof Malerba if he was willing to supervise my final dissertation. After finishing my undergraduate, I went on to work at the research centre that he directed at Bocconi University. It is thanks to that job that I came to know about SPRU and I had the chance to meet with some of SPRU’s alumni. This experience contributed to my decision to do an MSc at SPRU and eventually to apply to the DPhil programme. In conclusion, I can say that most of my career, and personal life, has been shaped by a simple mistake. For this reason, my first acknowledgement goes to Franco Malerba (the astronaut) for his unconscious contribution to make that mistake.

Having said that, I would like to thank some of the people and institutions who really did support me during this long process.

First of all, I express my gratitude to my supervisors, Nick von Tunzelmann and Ed Steinmueller. Nick helped me especially during the first phases of my DPhil, and I am particularly grateful to him for that. Ed supervised both my MSc and DPhil theses, and I feel greatly indebted to him for his dedication and availability. His supervision has been very thorough, stimulating, and challenging. Moreover, his help and support went beyond his academic duties, extending to moral and personal support, which at times has been more important than the academic kind.

I would like to acknowledge several funding sources that made this thesis possible. First of all, I acknowledge the financial support of an ESRC Studentship that covered my university fees. Second, a PRIME Circulation Grant that financed a very fruitful visiting period of 8 months at INGENIO (CSIC-UPV, Valencia). In addition, I would like to thank all the people that gave me the possibility to work part-time on research projects in order to finance my DPhil. I am very grateful to Franco Malerba (the professor), Nicoletta Corrocher, Roberto Fontana, and to Stefano Brusoni for hiring me as research assistant on three research projects at KITeS (Bocconi University, Milan). Also thanks to Jordi Molas and Pablo D'Este for accepting me at INGENIO (CSIC-UPV, Valencia) as a visiting student and then for hiring me as research assistant. These projects represented more than just a funding opportunity; in particular I would like to thank Franco Malerba for his constant encouragement and optimism, Nicoletta and Roberto for their friendly assistance and Pablo for his kind support.

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Those who have been engaged in a DPhil know that it is much more than just a university degree. At least it was for me. Therefore, last but not least, I would like to thank the people that supported me from a non-academic side. First of all, I am very grateful to my parents for their unconditional support, for always believing in me, and for all they have done for me. This thesis is dedicated to them. In conclusion, one final and special thought concerning my friends from Italy, UK, Spain and other countries: trying not to be too sentimental, I wish to thank all of them, for all they have been able to share with me during these years, for making my life happier, and for helping me understand what is really important in life. My life would be very different without them.

If the human brain were so simple that we could understand it,
we would be so simple that we couldn't.
(Emerson M. Pugh)

If you see a bandwagon, it's too late.
(James Goldsmith)

PART I - BACKGROUND OF THE THESIS

CHAPTER 1. INTRODUCTION TO THE THESIS

1.1. Introduction

The community of scholars in the field of economics of innovation and technical change has often been accused of paying disproportionate attention to the supply-side and of neglecting the demand-side. At the same time, however, in parallel with the emergence of a literature on innovation and technical change emphasising the supply-side, a growing body of literature has been concentrating on the diffusion of innovations. Diffusion, unlike innovation, has been treated, for the most part, as a demand-side phenomenon.

The diffusion of innovations is about how innovations are adopted by a population of potential users, a process that is essential for there to be innovation and technological change. Diffusion is required for adopters to benefit from the innovation, and it is a measure of an innovation's success. The literature on innovation has dedicated considerable attention to this phenomenon, producing a vast and comprehensive literature on the topic.

Everett Rogers, one of the main authors in the field, has traced how this literature has grown over the last 50 years by pointing out that when the first edition of his famous book, *Diffusion of Innovations*, was published in 1962 he found 405 publications about the topic. When the second edition was published in 1971, the publications on diffusion numbered about 1,500. At the time of the third edition in 1983, the publications were more than 3,000, while the fourth edition counted around 4,000 publications. Finally, when the fifth and most recent edition was published in 2003, the publications on innovation diffusion numbered more than 5,200 (Rogers, 2003). This literature is not only voluminous from a quantitative point of view, but is also very extensive in qualitative terms.

The diffusion of innovation has been studied by many different disciplines, including economics, sociology, rural sociology, marketing, anthropology, and geography. One of the reasons for such a broad production of literature is that the definition of innovation itself is also broad, and so the diffusion of many kinds of innovation has been studied:

not only technological innovations such as innovative products or processes, but also new ideas and organisational or managerial arrangements. Combinations of these types of innovation have also been studied, particularly in connection with the extensive changes accompanying the growing use of ICTs. Diffusion studies have concentrated on different kinds of adopters, including individuals, households, firms or societies. The different mechanisms by which the innovation spreads among the potential users have also been considered. In some cases, the diffusion of an innovation has been seen as depending on the spread of information about the innovation itself; in other cases, it has been treated as the result of a shift in market equilibrium.

Sometimes these varying views on the diffusion of innovation do not even refer to each other. It is interesting to point out that the two most famous books on the diffusion of innovation, which have become very important references for all the scholars working in the field, Stoneman (2002) for economics and Rogers (2003) for sociology, do not mention or cite each other. In his book, Rogers reviews the most important diffusion research traditions. In this review, he cites nine different disciplines (Rogers, 2003, p.43), but does not include economics in this list, only taking into consideration marketing. On the other hand, Stoneman, in the introduction of his book, says only that other approaches such as sociology 'are outside the remit of this volume' (Stoneman, 2002: p.3).

The fact that the literature on the diffusion of innovation is so extensive and thorough makes it difficult to accommodate further large advancements. However, some of its aspects, especially regarding the diffusion of new consumer products, still deserve further investigation. The research presented in this thesis is offered as a contribution to this body of literature, and it is motivated by the existence of some specific shortcomings in the literature.

In particular, three aspects of the diffusion literature seem to require some further examination. The first regards the way in which the demand-side is conceived. One of the most often studied aspects of the diffusion process regards the existence of differences among adopters, an alternative to the initial simplifying assumption of homogeneous adopters. Many different diffusion models have explained the adoption and diffusion of an innovation as depending on some specific characteristics of the adopters. However, in many cases, these differences are based on the contrast between early and late adopters. This means that the timing of adoption is a feature only observable after the adoption process has taken place, making it difficult to explain the differences among adopters based on their characteristics without invoking circular reasoning – i.e. the characteristics favouring adoption are those that favoured adoption. In many models, differences are summarised by a single variable, most often income, risking an overly simplistic view that might omit other relevant, maybe sector-specific, differences. One motive of this work is to provide a classification of adopters that goes beyond the simple kinds of classifications most often available in the literature.

A second gap in the literature is related to the role of the supply-side. Paradoxically, while the literature on innovation has often been accused of paying too much attention to the supply-side, a common criticism of the models of innovation diffusion is the lack of a supply-side. It is true that some models have included some supply-side aspects, such as the perception of the innovation's characteristics by the adopters, or have introduced some dynamic elements, recognising that the product's features and price are not static, but rather change over time, influencing the propensity to adopt. Other models specifically including the interaction between demand and supply have been based on the assumption that the price of the innovation may decline over time, and on the fact that the demand-side may be able to (at least partially) anticipate this decline through the formulation of expectations. However, either these approaches are still based on the perception of the product by the demand-side, or technical change is still viewed as exogenous or simply treated as learning-by-doing. As a consequence, the relationship between technical change on the supply-side and demand-side preferences remains undeveloped in the literature. Remedying this gap requires detailed data about both the technical characteristics of the product and its price, as well as considerable detail on the patterns of adoption.

The third, and perhaps the most evident, aspect that deserves further attention is the lack of a comprehensive and shared model or framework for the diffusion of innovations, especially regarding new consumer products. As noted above, many aspects of the adoption and diffusion process have been considered by specific models of diffusion. However, each of these approaches is limited to a specific set of influences, and the literature lacks comparisons between these approaches. There is a lack of tests of the relevance of different models for explaining the diffusion of the *same* innovation, a research agenda that would make it possible to evaluate whether several theories are simultaneously relevant or if one of them prevails over the others.

This thesis aims to study the adoption and diffusion of a consumer technology by addressing each of the above-mentioned gaps in the context of the digital audio player (DAP) market. A digital audio player, or MP3 player, is a portable device for storing, managing, organising and playing digital music files. These music players were developed around the end of the 1990s, after the introduction of digital music compression standards, such as MP3 (which allowed a reduction in the amount of memory needed to store digital music files without a discernable decrease in sound quality), and have encountered tremendous success over the last decade.

The DAP sector is a particularly favourable context for the kind of analysis carried out in this thesis. First, DAPs have been one of the most successful consumer electronic products of recent years; this makes it easier to find a sufficient number of adopters to survey. However, as in the case of many other innovative products, their diffusion has not been immediate, as these products encountered some resistance during the first stages of the diffusion process, before becoming very popular. Second, DAPs are also quite a recent technology, allowing users to easily identify the product and remember some details of their first purchase (adoption). Third, these products have undergone significant technical improvements over the last few years, becoming smaller, with more storage space, and equipped with several new features. This means that the case of DAPs could be relevant also from the supply-side point of view. Fourth and finally, this sector provides some grounds for generalisation, since its history is similar to that of other consumer electronic products, especially those that, similar to portable music players, experienced a shift between analogue and digital media (e.g. digital cameras, camcorders, video players and eBook readers).

For all these reasons, the DAP market represents a very suitable sector for addressing the above-mentioned gaps in the diffusion of innovations literature. In particular, each of the three gaps identified above will lead to a specific research question, the first one on the demand-side, the second on the supply-side, and the third, a more general one, on the comparison of different theories. The methodology of the thesis involves collecting two original datasets and providing a coherent framework of analysis in order to answer the three research questions using quantitative statistical techniques. The first dataset will examine the demand-side based on a survey of potential and actual adopters of DAPs. In particular, a questionnaire was submitted to a sample of students from eight European countries and Japan, containing questions on several factors influencing the adoption of a DAP. The second dataset is about the supply-side, including technical characteristics, prices and launch dates of a number of DAPs launched in the period 2001-2009.

The analysis of these two sets of data will be carried out in three empirical chapters, each dedicated to one specific research question. The first empirical chapter will concentrate on the demand-side, and employs cluster analysis to attempt to provide a classification of the adopters that goes beyond the usual classifications put forward by the literature based on the timing of adoption or on the distribution of adopters according to a single variable (such as income). Instead, the classification in this thesis is based on several characteristics, such as demographic and economic variables, user innovativeness, responsiveness to social factors and so on. Furthermore, a test is conducted using ordered logistic regression to see if these differences affect the adoption decision and its timing. The second empirical chapter will first try to measure the technological changes in the sector and to estimate the effect that the evolution of the product's technical characteristics has had on price. It will then combine both datasets and attempt to match the evolution of the product's technical characteristics with their perception over time by the potential adopters. The third empirical chapter will analytically compare, using the DAP case, the effects implied by the different models that have been proposed to explain the diffusion of new technologies. A survival analysis (duration model) will be employed in order to estimate the probability of adopting a DAP at a certain period of time without having adopted it before. The results coming from a number of models of diffusion will then be tested on this probability, to compare their performances in explaining the diffusion of DAPs.

There are three main outcomes of the thesis. First, the thesis offers a classification of adopters that both confirms and expands some of the classifications put forward by the literature. This classification will still be compatible with the usual division between early and late adopters, but offers a more elaborate and possibly a more complete view of the role of early adopters. This result can be considered a theoretical contribution to knowledge from the thesis. Second, the analysis of the interactions between demand and supply indicates that the DAP sector has been a very innovative and competitive market, with several players engaged in both product and price competition. Moreover, the analysis does not highlight any correspondence between technical change and user preference over time. However, although users apparently do not change their preferences on product characteristics, they do appear to take these changes in characteristics into consideration in the timing of adoption decisions by formulating expectations on product prices and technological improvements. This thesis will show that these expectations have an impact on the timing of adoption on the demand-side, and, in turn, an effect on the competitive activity on the supply-side. Finally, the comparison of different models of diffusion indicates that all the models tested on the DAP sector have some value in estimating the probability of adopting a DAP. This means that having had a pre-conceived idea about the relevant model of diffusion to employ in studying DAP diffusion would have resulted in a misleading or at least in an only partial view of the reality that can be discerned from the empirical data. As a consequence, one of the conclusions of the thesis, which can be considered an empirical contribution to the literature on diffusion, is a call for more comparative studies on the diffusion of innovations, and for multiple views on the diffusion process.

1.2. Thesis outline

The thesis is divided into three parts. The first part is about the background of the thesis, the second about methodological issues and the third about the empirical analysis.

The first part includes two chapters. In particular, Chapter 2 considers the literature on the diffusion of innovations. As indicated by the scale of the body of literature on diffusion noted above, providing a complete and detailed review of the literature on the diffusion of innovations would constitute a voluminous monograph in its own right. Therefore, Chapter 2 will concentrate on systematising the most relevant literature and on identifying more precisely the gaps that will be addressed by this thesis. For this reason, instead of being based on some of the usual criteria used in reviews of this kind of literature, such as by discipline (e.g. economics, sociology, etc.), by economic theory (e.g. neoclassical or evolutionary economics) or by types of diffusion model (e.g. static or dynamic), this thesis will follow a different approach. The review of the literature will start from the epidemic model of diffusion and show some departures from this basic model. In particular, these directions of research will be based on the main focus of the diffusion models reviewed, dividing them into models focusing on the adopter, on the innovation or on the diffusion process. The conclusion of Chapter 2 will be dedicated to highlighting the three aspects of the literature that deserve further research. The other chapter in the first part of the thesis is Chapter 3, which focuses on the history of the DAP sector. This is particularly important because DAPs are not isolated products; they have precursors and followers. In particular, DAPs are part of a more general shift of audio players from analogue to digital and then to compressed digital music. The chapter will present this history mostly from the technological point of view, also indicating how the history of the recorded music industry has been strongly influenced by these technical advancements. Another issue that this chapter will consider is so-called online file sharing, which is the exchange of music and other files through the Internet, as this phenomenon has significantly influenced both the diffusion of DAPs and the entire music industry.

The second part of the thesis is comprised of two chapters explaining the methodology of the thesis. The first one (Chapter 4) will review the three gaps in the literature proposed in Chapter 2 and present the three research questions that stem from them. It will then describe which datasets have been collected in order to answer these questions and will explain why it has been necessary to collect them. Finally, it will outline the three empirical chapters that will follow, presenting the methods of analysis used and how they will help to answer the research questions. Chapter 5 examines in detail the two original datasets collected in order to answer the research questions. First of all, it will focus on the demand-side dataset, which has been collected through the submission of a questionnaire to a sample of students from different European countries and Japan. The chapter will explain in detail how the questionnaire was designed, piloted and finally submitted. In addition to this, since the questionnaire contains several items meant to build some series of variables that are supposed to influence the timing of the adoption of a DAP, this chapter will also present the validation process of these measures, which has been carried out through exploratory and confirmatory factor analysis and reliability analysis. Finally, the chapter will present the supply-side dataset regarding the technical characteristics of a sample of DAPs, indicating the main sources of data and the list of variables collected.

The last part of the thesis is dedicated to empirical analysis and to conclusions. This part is comprised of four chapters; the first three are dedicated to each of the research questions, while the last chapter presents the conclusions of the thesis. Chapter 6 is the first empirical chapter, and focuses on what can be learned about the demand-side from the data collected through the questionnaire. This chapter will first provide a descriptive analysis of the data collected through the questionnaire and highlight some of the trends that will form the basis of further analysis of the data. The second objective is to provide a classification of the adopters that goes beyond the usual classification into early and late adopters by using cluster analysis in order to categorise the adopters. A third aim is to use ordered logistic regression in order to examine which factors have influenced the timing of adoption. Chapter 7 is the second empirical chapter and it is focussed on the supply-side and on the interactions between demand and supply. The analysis will be based on both the results of the questionnaire and on the products' datasets. The objectives of this chapter are three. The first is to analyse how technical innovation in the sector occurred in the period 2001-2009. The second objective is to measure technological change in the sector by using hedonic price estimation, and to create a price index that takes into consideration the technical changes occurring in the sector. The last objective is to study whether there is a relationship between the patterns of adoption of DAPs over time and the evolution of the technical characteristics in the sector. Chapter 8 will be the last empirical chapter, aiming to test alternative models of adoption by comparing their performances in explaining the adoption and diffusion of DAPs. The methodology used to achieve this objective is duration analysis, and the datasets used will be about both demand and supply. The chapter will also present the models of diffusion that will be tested on the data regarding DAPs, describing the duration models estimated and the hazard functions used in the estimation, as well as the variables used in the regressions. Finally, Chapter 9 will be the conclusive chapter of the thesis. First of all it will briefly recapitulate the purpose of the thesis and the methodology used. It will then provide an answer to the three research questions in light of the analysis carried out in the previous chapters. The chapter will then propose the original contributions to knowledge of the thesis, as well as some policy implications. The last section of the chapter will outline some avenues for future research and conclude the thesis.

CHAPTER 2. A SELECTED REVIEW OF THE LITERATURE ON DIFFUSION OF INNOVATIONS

The multi-disciplinary area of study addressing the 'diffusion of innovations' provides concepts and tools for examining the adoption of an innovation by a population of potential adopters. The research literature stemming from this area of study has engaged with several themes, such as different types of innovations (process or product innovations, new consumer products, new ideas or attitudes), different types of potential adopters (firms, individuals, households, societies, etc.) and different mechanisms by which the innovation spreads among potential users. Several authors have attempted to provide an exhaustive review of this voluminous literature.[1] This chapter is not an effort in that direction; instead, the objective of this chapter is twofold. Its first purpose is to identify and examine the literature on diffusion of innovations that is particularly relevant for developing the analytical framework of the thesis. Its second purpose is to identify the gaps in this literature that still deserve some further investigation, and which offer a foundation for asking specific research questions and building the methodology of this thesis.

The chapter is organised as follows. The starting point will be the so-called epidemic model of diffusion, which can be considered as a meeting ground for strands of diffusion studies coming from different disciplines. This epidemic approach, together with the reasons behind its importance, as well as its many weaknesses, will be explained in the first section of this chapter (Section 2.1). The literature on diffusion, in trying to address each of these weaknesses, has departed in several directions, proposing different types of diffusion models. The remainder of the chapter will examine some of these paths by analysing the models that they have produced and by providing a taxonomy of diffusion models more generally, which underlies the analytical framework of the whole thesis. In particular, the lines of departure from the epidemic model and the models associated with these departures will be grouped into three categories, each reflecting a predominant focus: i) focus on the adopter; ii) focus on the innovation; and iii) focus on the diffusion process. These three groups of models will be presented in Sections 2.2, 2.3, and 2.4 respectively. This taxonomy of diffusion models will represent the analytical framework of the thesis. Finally, this chapter will consider three aspects of this literature that deserve further research (Section 2.5). These three gaps will be investigated in the thesis.

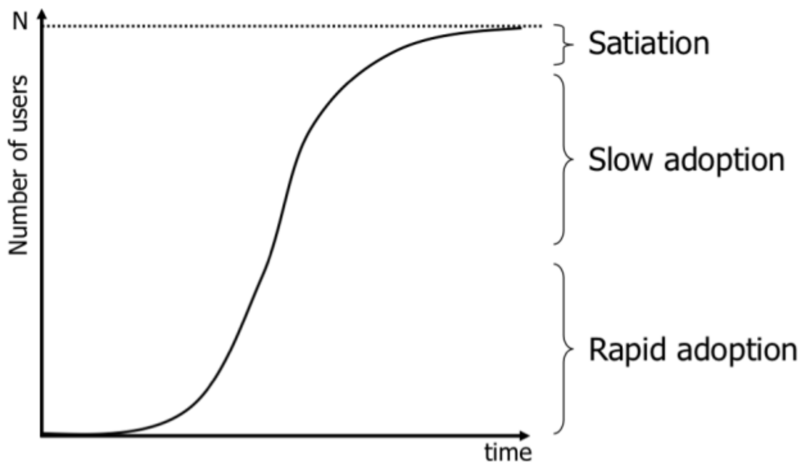
[1] For instance: Dosi, 2000; Geroski, 2000; Hall, 2005; Lissoni, 2000; Lissoni and Metcalfe, 1994; Metcalfe, 1988; Sarkar, 1988; Stoneman 1991a, 2002; Thirtle and Ruttan, 1987.

2.1. The epidemic model of diffusion

One of the major questions that scholars involved in diffusion studies have tried to answer is: why is there a diffusion of an innovation or a new technology[2] where adoption takes time, rather than being instantaneous?

Diffusion theory has been built upon stylised facts, which diffusion models attempt to validate and formalise. The most important of these is simply a restatement of the question above. We observe that behaviour changes over time – at one point individuals may choose not to adopt and at some later point they may become adopters – hence a fundamental departure point is a stage theory of behaviour over time in the life of a technology or innovation. In particular, at the beginning of its life, an innovation finds few or no adopters. After some time, the initial period of early adoption ends, as a greater number of potential adopters start to adopt the innovation, and the numbers of those who have adopted it, i.e. users, start to rise at a more rapid rate. The next period, rapid diffusion, is defined by the adoption rate, which is dramatically increasing during this period. This is followed by a final period in which the adoption starts to slow down as it asymptotically approaches a maximum, variously represented as the total available market, the total population, or the *ex post* defined peak in adoption, an end state sometimes referred to as complete diffusion. This process is often pictured by a sigmoid or s-shaped curve of diffusion (Figure 2.1).

Figure 2.1 S-shaped diffusion curve



[2] We prefer to view innovation and technology as having somewhat different definitions, with the latter being a broader 'envelope' potentially containing many specific commercialised products (innovations). However, the more narrowly a technology is specified, the more the terms 'technology' and 'innovation' will be indistinguishable. Since the context of the thesis is the MP3 players market in general, i.e. without regard to specific models or configurations, the terms 'innovation' and 'technology' will be used as synonyms in this thesis.

The fact that the diffusion of an innovation follows a sigmoid curve is one of the most common stylised facts of diffusion theory. One of the first diffusion models that was able to provide some theoretical grounds for this kind of regularity was the epidemic model. This kind of model was very popular during the 1950s and it became the basis for research on innovation diffusion in many different disciplines (Thirtle and Ruttan 1987: p.79).

Following Thirtle and Ruttan's notation (1987: p.80-82), a simple form of epidemic model can be described by the following differential equation.

$$\frac{dn_t}{dt} = \beta \frac{n_t}{N}(N - n_t) \tag{1}$$

where n_t is the number of users who have adopted at time *t*, N is the (fixed) population of potential adopters, and β is the probability of adopting the innovation. This parameter can be described as the attractiveness of the innovation. If this is set to be equal to 1, it means that all the potential adopters will necessarily start using the innovation once they get in contact with the innovation. If β holds constant, the number of new adoptions $\frac{dn_t}{dt}$ at time *t* depends on two opposing forces: the number of current non-adopters $(N - n_t)$ multiplied by the proportion of population that has already adopted $\frac{n_t}{N}$ (and by the probability of adoption β). The solution to equation (1) is:

$$n_t = \frac{N}{1 + e^{-\alpha - \beta_t}} \tag{2}$$

where α is the constant of integration. Equation (2) is also the cumulative density function of the logistic frequency distribution, which has an s-shaped (sigmoid) distribution.

The epidemic model can be considered the starting point for the modern work on the diffusion of innovations in many different disciplines, including economics (Griliches, 1957; Mansfield, 1961; Bain, 1964), sociology[3] (Ryan and Gross, 1943), and marketing[4]

[3] Ryan and Gross (1943) early study on the diffusion of hybrid corn seeds in two Iowa communities is not an epidemic model as formally described above. However, as pointed out by

(Bass, 1969; Karshenas and Stoneman, 1995: p.270). The early diffusion studies in these disciplines were mainly about agricultural, medical or educational innovations, and specifically about innovations in these areas that clearly represented a more useful opportunity than any existing option (Lissoni and Metcalfe 1994: p.110). The epidemic model could quite easily be applied to the kinds of innovations studied by these disciplines.

This model gained popularity for at least two reasons. Firstly, it confirms some of the most common empirical regularities regarding diffusion (Sarkar 1998: p.134): the adoption of an innovation takes time; the rate of diffusion varies across firms, technologies and sectors; and the diffusion path often follows an s-shaped curve. Secondly, the model is easy to estimate, since it can be represented by a logistic curve or a modified logistic curve whose parameters can be estimated using ordinary least squares regression.

These sorts of models are considered disequilibrium models, in the sense that in every time period, the actual adoption of the innovation is always less than its equilibrium or optimum level (Stoneman 2002: p.31). Diffusion can then be considered as an adjustment process from the original equilibrium, which has been disturbed by the introduction of the innovation, to the new equilibrium.

The term 'epidemic' is based on the fact that in many cases in these models, the adoption of the innovation has been associated with the spread of information about the innovation itself. In many formulations of epidemic models, the innovation represents a superior choice with respect to all the actual options; therefore potential adopters will start using the innovation as soon as they are informed about it. Moreover, the only way the information about the innovation can spread among the adopters is by personal contact (word-of-mouth). Within this framework, the only reason why a potential adopter may be delayed in adopting the innovation is because he or she does not (yet) know about it. In this way, the diffusion of an innovation resembles the spread of an infectious disease (Geroski, 2000: p.604). Treating diffusion as an information asymmetry has been a simple way of making diffusion

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Rogers (2003: p.34), one of their conclusions is that the main factor influencing the adoption of the innovation was interpersonal communications and farmer-to-farmer exchanges, linking, in this way, the diffusion process to the spread of information. For this reason, we can include this kind of study with others examining the epidemic type of diffusion.

[4] The Bass model (1969) is not a typical epidemic model, since it includes sources of information other than word-of-mouth. However, Geroski (2000: p.606-7) demonstrates how this model can be analytically encompassed in the epidemic model literature (see Section 2.2.3).

theory consistent with at least one of the tenets of the prevailing model of consumer choice in economics: utility maximisation. The hypothesis that the potential adopter does not immediately choose the superior alternative or novel technology because he or she is unaware of the innovation is a simple modification of the perfect information postulate. The epidemic model offers a useful basis for this kind of solution.

However, two further considerations should be examined. First of all, it is true that many early economics models of diffusion were based on the estimation of a logistic curve (or similar), like the epidemic models. However, not all of them were primarily based on the role of information spread; see for instance Griliches (1971), who explains the parameter β in terms of innovation's profitability and only indirectly links it to an information asymmetry.[5] Second, more generally, not all the diffusion models in economics have been epidemic disequilibrium models. A relevant stream of economic literature involves so-called *equilibrium* models. These models will be presented in detail in Sections 2.2.1 and 2.4.1.

If one of the main factors of the success of the epidemic model is its simplicity, this also represents one of its main criticisms. In fact, the epidemic model is based on some strong assumptions that may not be entirely realistic. For instance:

- Homogeneous adopters: potential adopters do not differ in any characteristics, be they innate personal traits, income (or size in the case of firms), preferences, risk aversion, etc.
- Only one source of information: the only way the information about the innovation can spread is by personal contact.
- All variables are static except the underlying spread of information through personal contact:
    - The ceiling (i.e. the population of potential adopters) is fixed *ex ante* and unchanging during the period of diffusion;
    - There is only one isolated product (no multiple competing technologies);
    - There are no further improvements (new products substituting for obsolete ones).
- The adoption choice does not depend on the characteristics of the innovation, other than its superiority to alternatives, or on possible changes in the preferences of the adopters.

[5] '... in a world of imperfect knowledge, it takes time to realize that things have in fact changed. The larger the shift the faster will entrepreneurs become aware of it, "find it out", and hence they will react more quickly to larger shifts' (Griliches, 1971: p.516).

The literature on diffusion of innovations, after the first attempts with the epidemic model, evolved significantly, with many efforts being made in the fields of economics, marketing and sociology. New approaches to diffusion have been less concerned about the s-shaped curve and more interested in the underlying mechanisms behind the diffusion of an innovation. These approaches have concentrated on each of the above-mentioned weaknesses of the epidemic models, and have produced a new set of diffusion models that may be able to better explain one or more of these aspects.

In particular, these diffusion models can be classified according to several different criteria. For instance, a conventional review of diffusion models would divide them into: equilibrium models (neoclassical), disequilibrium models (evolutionary), dynamic models (dealing with risk, uncertainty and learning), marketing models and sociological models. However, in order to highlight some gaps in the literature, the classification used in this thesis is based on specific focus areas that cut across and therefore unite disciplines, namely:

1. Models focussing on the adopter;
2. Models focussing on the innovation; and
3. Models focussing on the diffusion process.

2.2. Focus on the adopters

One of the most unlikely assumptions of the epidemic model is that all adopters will behave in the same way when facing the presence of a new product or technology. This section will include those approaches in which the presence of differences among potential adopters represents an intrinsic element of the diffusion process. Three approaches will be taken into consideration. The first will be the equilibrium approach, mostly used by neoclassical economists. In particular, rank or threshold models will be analysed (other equilibrium models not specifically focussed on the heterogeneity of adopters, such as stock models, will be analysed in Section 2.4.1). The second approach will be the marketing tradition, emerging from the seminal work of Bass (1969), in which diffusion depends on the presence of two different groups of adopters and on the presence of two different sources of information. The third approach is the sociological one, introduced by Roger's book, *The Diffusion of Innovations* (2003). Rogers' framework is broad and complex; however, one of its founding blocks is that adopters can be classified into five groups, depending on the timing of their adoption. Each group is characterised by different personality traits and specific behavioural differences.

2.2.1. The rank or threshold models

By the end of the 1970s, economists had accumulated enough empirical evidence on the diffusion of innovations, especially regarding the s-shaped diffusion path (Lissoni and Metcalfe, 1994: p.107). Since then, most of their efforts have been concentrated on providing theoretical grounds for the study of innovation diffusion.

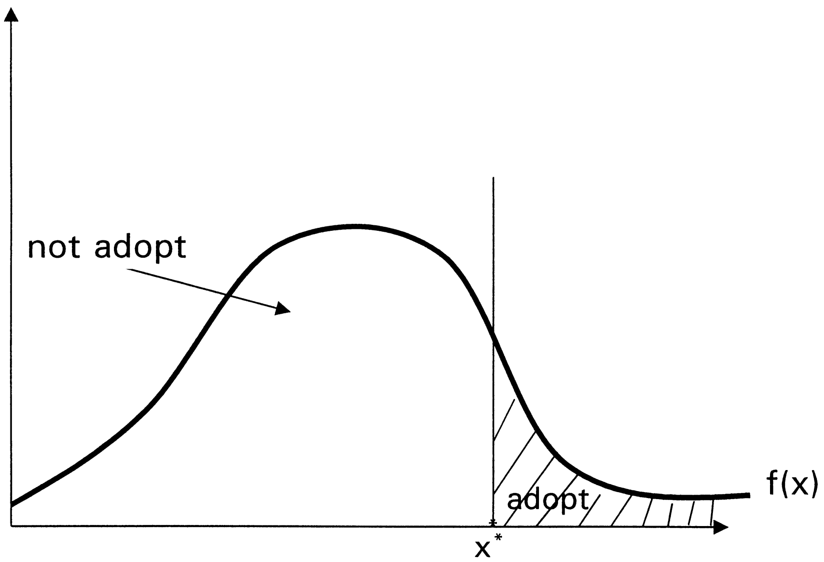
The epidemic model provided a basis to understand the process of innovation diffusion, in particular why diffusion follows an s-shaped curve. However, these models are in a constant state of disequilibrium, in the sense that in every period the number of adopters is lower than the equilibrium level. The model is therefore self-perpetuating. In other words, it is the current sub-use of the new technology that stimulates its use in the future (Stoneman, 2002: p.31). Moreover, these models lack a specific theory behind the adoption of an innovation and do not consider any kind of heterogeneity among the population of adopters. Other streams of economic models of diffusion have managed to cope with these issues by embedding diffusion theory in the neoclassical framework, characterised by the equilibrium mechanism, unbounded rationality and fully-informed agents (Sarkar, 1998: p.149).

One of the most important efforts in this direction has been the development of the so-called *rank* (or *probit*[6]) models (David, 1966, 1969; Davies, 1979). Rank models are equilibrium models populated by rational, maximising and fully-informed agents, which describe the diffusion of a new technology as a process having an s-shaped curve. The main reason why these models lead to adoption levels being mapped as a sigmoid curve is the existence of differences among the adopters. The main idea behind the rank models is that adoption is not instantaneous because adopters are not identical. In particular, potential adopters differ in some characteristic x, which directly affects the benefits from adoption and consequently the timing of adoption. Each customer has a different x, hence x_i. This characteristic is distributed across the population according to some function $f(x)$.

[6] These equilibrium models are usually labelled *rank* models because they rank the population in terms of benefits from adoption, or *threshold* models because they assume that adoption takes place when a specific variable, influencing the profitability of an innovation, exceeds a certain threshold level. In some cases they are also called probit models because they are close to other probit models, such as those applied to study unemployment (Stoneman, 2002: p.34).

The rank model approach is grounded in the standard logic of adoption: an economic agent (individual, household or firm) is facing the decision to adopt a new technology or not. The economic agents are maximising, fully informed and rational. All potential adopters know about the existence of the new technology and there is no uncertainty about its payoffs. The cost of acquisition in time *t* is $c(t)$, and it is assumed to be the same for all the agents, while the benefit from acquisition in time *t* is $B(x,t)$, where one may think of these costs and benefits as the present value of all future costs and benefits from adoption at time *t*. An individual potential adopter will adopt if $B(x,t) \geq c(t)$. Since the benefits from adoption depend on the level of x, there will be a certain level x^* above which the gross benefits from adoption will exceed the costs. Generalising these individual decisions, at any given time *t*, the proportion of the population that will adopt is represented by the area under the frequency distribution of $f(x)$, where $x \geq x^*$. This proportion is represented by the shaded area in Figure 2.2.

Figure 2.2 The rank approach



Source: Geroski 2000: fig. 2, p.611.

The explanation given so far leads to a market in equilibrium, not yet to a diffusion curve. The trigger of the diffusion process is any force that makes x^* shift to the left, allowing more and more adopters to find it profitable to adopt the new technology. The diffusion process is seen then as a sequence of shifting static equilibria, and the shape of the diffusion curve depends on the distribution of $f(x)$. For example, if the characteristic is normally distributed across the population of potential adopters, its cumulative frequency distribution, and hence the diffusion path, will be a symmetrical s-shaped curve. This can be restrictive: it is not necessary that a diffusion curve should be symmetrical; on the contrary, only rarely are actual diffusion curves symmetrical (Geroski, 2000: p.609).

One of the first and most important rank models in the literature was developed by David (1966). In this model, a population of farmers, endowed by lands of different sizes, face the possibility of adopting a reaper machine that would allow the cutting of production costs. However, the cost reduction depends on the size of the land owned by each farmer. At a certain time *t*, if the size of the land is big enough to exploit sufficient economies of scale and thus to benefit from the adoption, the farmer will adopt the reaping machine; otherwise he or she will delay the adoption. The diffusion path comes from the rising costs of production due to the continuous increase in the workers' wages in the US. The growing wages represent higher costs for farmers, making it profitable for more and more farms to adopt the machinery. In brief, in David's rank model the critical characteristic is the size of farm, while the trigger, which shifts the threshold, is the rise in the labour costs.

As in the case of David's model, many rank models have been applied to the study of the adoption of a process technology by a population of firms. Moreover, firm size has very often been used as a critical variable in distinguishing adopters. This is the case, for example, for Davies (1979). However, as pointed out by Stoneman (2002: p.41), this type of model can also be applied to households. In this case, potential adopters will compare the utility of purchasing with the buying cost, and the ranking variable may be their income. This is the case of Bonus (1973) and Stoneman and Battisti (2000).

Rank models represent a very important step in the study of innovation diffusion for at least two reasons. First of all, from a theoretical perspective, it has been important to embed the diffusion of innovation into the neoclassical economic framework by developing a set of diffusion models, which could create an efficient and predictable diffusion path. Moreover, rank models make it possible to generate a list of potential determinants of diffusion at firm (or individual) level that could influence the diffusion speed of a particular innovation (Geroski, 2000: p.614). This is particularly important because it could provide a set of useful levers for policy-makers in order to accelerate or slow down the diffusion of a particular technology (Geroski, 2000: p.614).

However, if we consider rank models on the basis of the classification of adopters that they propose, at least two considerations can be raised. Firstly, it is true that these models are based on the heterogeneity of adopters. However, these differences are not really determinants of the diffusion process; they only determine the state of equilibrium. Diffusion depends on an exogenous force[7] that makes this equilibrium shift over time, and does not directly depend on the differences among adopters. Secondly, the choice of only one variable (e.g. size of firms or income of individuals) may not take into consideration some specificities of the sector or type of innovation studied. For instance, other variables could be taken into consideration, or perhaps the ranking according to that variable could influence adoption only within particular clusters of potential adopters.

2.2.2. The sociological tradition

Everett Rogers is one of the main authors in the diffusion of innovation literature, and surely the most influential in sociological literature on diffusion (Rogers, 1962, 1976, 2003; Rogers and Shoemaker, 1971). Rogers' dissemination work started with the publication of his famous book *Diffusion of Innovations* (1962), followed by another four editions. Rogers' work can be considered a milestone of innovation diffusion theory for at least two reasons.

Firstly, in every edition of his book, Rogers summarises and systematises a vast part of the literature on diffusion coming from different research traditions, such as anthropology, sociology, rural sociology, education, public health and medical sociology, communications, marketing and management, geography and other traditions. Secondly, since his first edition, Rogers has organised the book around a general diffusion model, based upon a classification of adopters, the importance of the attributes of the innovations and the importance of diffusion networks. The most recent edition (Rogers, 2003) is the fifth one, and still retains the bases of Rogers' model of diffusion that appeared in the first edition.

The part of Rogers' model that is addressed in this section is that regarding the classification of the adopters.[8] In fact, one of the bases of the sociological tradition is that the members of a system cannot be considered as homogenous units. This has been confirmed since some very early sociological studies on diffusion of innovations (such as Ryan and Gross, 1943), which have found that some potential adopters are more inclined to adopt earlier than others. These early adopters have been called

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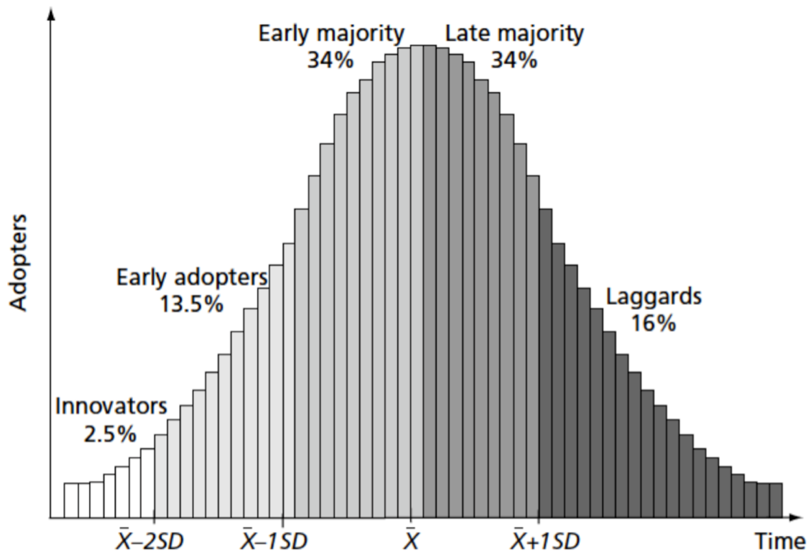
[7] Section 2.4.1 will present some equilibrium models in which the trigger of diffusion is endogenous, but in which the adopters are considered homogenous.
[8] This section is almost completely based on Rogers 2003: ch.7.

different names, such as 'experimentals' or 'ultraadopters', while those who delay adoption have been called 'drones', 'parochials', etc. The dominant way to classify adopters, and so the basis for comparison for all studies on diffusion, was developed by Rogers (1962), who proposed a method of adopter categorisation based on the s-shaped curve, and who demonstrated the usefulness of this technique within diffusion research.

Rogers' classification starts from the concept of innovativeness, defined as the propensity of an individual 'to be relatively earlier in adopting new ideas than other members of a system' (Rogers, 2003: p.267). Rogers claims that this personal attribute, as with many other personal characteristics (e.g. weight or height) or personal traits (e.g. intelligence), should follow a bell-shaped curve, approaching normality (Rogers 2003: p.273). Moreover, the presence of an s-shaped diffusion curve was already supported by many empirical studies on diffusion at the time of Rogers' writing.

Rogers' classification of adopters is based on two statistics of the normal distribution of adopters: the mean ($\bar{X}$) and the standard deviation (SD). Figure 2.3 indicates the normal frequency distribution divided into five adopter categories, and the percentage of adopters falling into each category. The five groups are: (1) innovators, (2) early adopters, (3) early majority, (4) late majority and (5) laggards.

Figure 2.3 Rogers' classification of adopters



Source: Greenhalgh et al., 2005: fig. 5.1, p.101.

This classification is based on statistical cut-off points; however, each group shares a common set of characteristics and values. The first group (innovators) is rather small, and includes adopters who are unusually venturesome and innovative. This group is the first to consider the adoption of an innovation, having not only the necessary financial resources, but also the knowledge needed to adopt. They are also prepared to accept the risk of a setback or disillusion. In general, this group is not well respected by the other members of the system; in other words, since they are not seen as opinion leaders, their behaviour does not directly influence that of other people. However, they play the fundamental role of importing the innovation into the system, making it accessible to other members.

The second group (early adopters) are less open and innovative than the first; however, they are an integral part of the system. They are opinion leaders and they are respected by other members of the system. Once the innovation has entered into the system, they are naturally attracted by it, and their behaviour will represent a model for the mass. The third group (early majority) represent almost one-third of the members of the system. Their role is in making the diffusion process take off, by massively adopting the innovation. The fourth group (late majority) is generally sceptical towards innovations. They are later adopters and their decision process is cautious and takes more time. In general they adopt because of peer pressure and imitation. The last group (laggards) is very cautious about adopting new innovations. They have to be completely sure before adopting, and their only reference is the behaviour of other people in the past. For this reason, they are the last group to adopt an innovation.

This classification is supported by several diffusion studies. In particular, Rogers lists a series of generalisations coming from empirical studies of diffusion. These generalisations can be arranged into three groups. The first group regards socioeconomic characteristics. For instance, early adopters are more educated, have a higher social status and a greater degree of upward social mobility than later adopters. Moreover, early adopters are often wealthier than later adopters, or at least they have larger-size units (farms, schools, companies, etc.). This seems to be consistent with the main idea behind several rank models, in which size (or income) is taken as the major influence behind the diffusion process. The second group of generalisations is about some personality variables. For instance, early adopters seem to be more rational, more able to cope with uncertainty and more inclined towards change than late adopters. The third group is about communication behaviour. In particular, early adopters have a higher level of social participation than late adopters. They are more active seekers of information and are more exposed to both mass media and personal communication. Finally, early adopters have a higher degree of opinion leadership than late adopters.

In conclusion, Rogers proposes a model of diffusion in which one of the most important factors driving diffusion is that adopters differ in the way they interact with an innovation. In particular, adopters' innovativeness, which synthesises several differences in personal characteristics or personality traits, is the major drive of an early or late adoption.

Rogers' categories of adopters represent an important step in the study of innovation diffusion. In fact, the division between early and late adopters is one of the most important issues behind several models of diffusion. For instance, it is one of the foundations of the well-known Bass model of diffusion, which is a key paper in the marketing tradition.

However, Rogers' classification, and more generally all classifications based on the timing of adoption (i.e. early and late adopters) suffer from at least two drawbacks. Firstly, Rogers' classification is based on arbitrary cut-off points (Gatignon and Robertson, 1985: p.861; Greenhalgh *et al.*, 2005: p.101) and not on fixed personality traits. Secondly, the classification is based on a *post-adoption* characteristic of adopters, i.e. a characteristic that is only observable after the adoption process has taken place. Therefore, for example, late adopters are defined as those people who adopted later than others, and who happen to have some similar characteristics. This makes it difficult to answer the most basic question regarding the diffusion of innovations – why diffusion is not instantaneous – without incurring a tautology.

2.2.3. The marketing approach: the Bass model

Parallel to the development of the heterogeneous adopters assumption, one of the first steps towards a more convincing model of diffusion was to relax another assumption of the epidemic model and incorporate an external and constant source of information. This is the case of Pyatt (1964) and Bain (1964). In fact, in epidemic models, the only way by which a potential adopter could get in touch with the innovation is by word-of-mouth. However, it is possible to realistically assume that adopters may know about the innovation through other external or constant channels that do not depend on the number of previous adopters, for instance through advertising and mass media (Thirtle and Ruttan 1987, p.90-1). In addition, Lekvall and Wahlbin (1973) point out the presence of two influences, referring to personal contact as *internal influence*, and to advertising and mass media as *external influence*. They also claim that for most innovations a different combination of both influences will be present.

The presence of different influencing forces and differences among the adopters became the base of an important new stream of literature that has its origin with the seminal work of Bass (1969), whose diffusion model effectively combines the existence of different sources of information with a population of heterogeneous adopters.

The main idea behind the Bass model that differentiates it from an epidemic model is that there are two groups of adopters. The first group includes those individuals who adopt an innovation without taking into consideration the decisions of other members of a social system. These individuals are defined as *innovators* and they base their decision only on information sources such as mass media or advertising. The other group is made of individuals who base their decision only on word-of-mouth. These individuals are called *imitators*.

Analytically, the Bass model is based on the assumption that the probability of adopting at time t, given that it has not yet happened, is a linear function of the number of previous buyers. Thus,

$$f(t)/[1-F(t)] = p + qF(t) \tag{1}$$

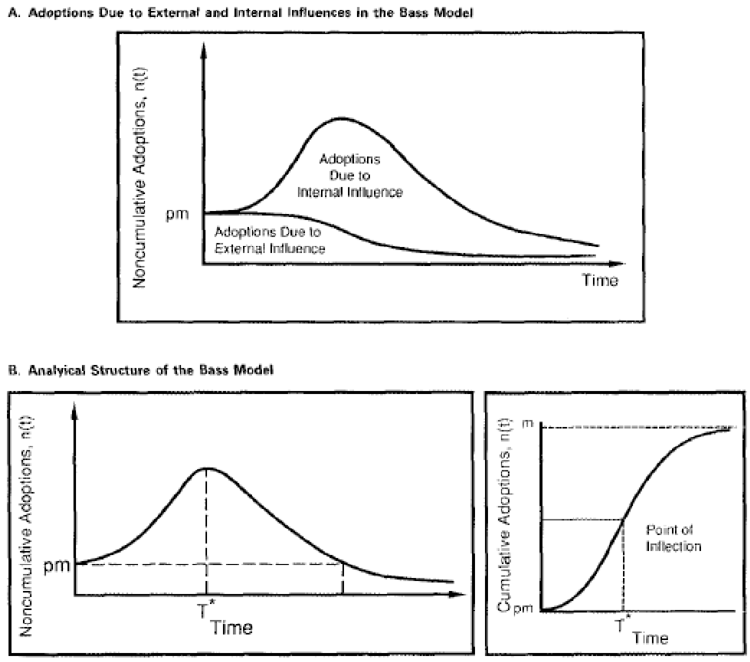
where $f(t)$ is the probability of adopting at time t, $F(t)$ is the cumulative probability of having adopted at time t, and p and q are constants. The number of adopters at time t is $n(t) = mf(t)$, and the cumulative number of adopters at time t is $N(t) = mF(t)$, while m is the potential number of total adopters. As a consequence, substituting $F(t) = N(t)/m$ and equation (1) into the equation $n(t) = mf(t)$, yields

$$n(t) = p[m - N(t)] + q/mN(t)[m - N(t)] \tag{2}$$

The number of adopters at time t depends on two terms. The first, $p[m - N(t)]$, represents the adoption due to innovators, and parameter p can be considered as the 'coefficient of innovation'. The second term, $q/mN(t)[m - N(t)]$, is the number of imitators. Parameter q, defined as the coefficient of imitation, represents the pressure to adopt for imitators, represented by the number of previous adopters. At time $t = 0$,

$n(t) = pm$, which means that at the beginning of the diffusion process, only innovators will adopt; their role will be present all along the process but will decrease over time. On the other hand, the imitators, after $t = 0$, will begin to adopt, and their role will gradually increase over time as the number of previous adopters, $N(t)$, increases. However, the number of imitators will also eventually decline, when the vast majority of the potential buyers have already adopted. This process leads to a diffusion process, which follows an s-shaped curve. The role of innovators and imitators is represented in Figure 2.4A, and the adoption curves in Figure 2.4B.

Figure 2.4 The Bass diffusion model



Source: Mahajan, Muller and Bass, 1990: fig.1, p.4.

Bass (1969) tested the validity of his model by estimating the parameters on eleven different consumer durables. The regression analysis confirmed the models' assumptions. This model gained increasing popularity, extending its use throughout different research areas, such as marketing management, management and marketing science and consumer behaviour. The use and spread of this model in these research areas, as well as several developments of the Bass model, have been reviewed by Mahajan and Muller (1979) and by Mahajan, Muller and Bass (1990).

The Bass model has been applied to different areas and extended in the literature over time. One of the most interesting examples examines the fact that Bass' division between innovators and imitators recalls Rogers' (2003) classification of adopters. Bass confirms this by affirming that the first groups of the two classifications (both defined as innovators) coincide, while the group of imitators includes the Rogers' remaining four categories (early adopters, early majority, late majority and laggards) (Bass, 1969: p.216). Moreover, Mahajan, Muller and Srivastava (1990) confirm that the Bass model embeds Rogers' classification. Firstly, Mahajan, Muller and Srivastava reinterpret the Bass model in terms of internal and external sources of information (following Lekvall and Wahlbin, 1973), thus having two populations of adopters influenced by one source or the other. Secondly, they demonstrate that the logic behind Rogers' classification (i.e. one or more standard deviations away from the mean of a population of normally distributed adopters) can be applied to the modified Bass model. Finally, they confirm that this scheme could also support five categories of adopters and not only two.

Tanny and Derzko (1988) provide another example of an extension of Bass' model. They claim that assuming that only innovators are influenced by mass media and advertising is too reductive. Therefore, they develop a diffusion model with two groups of adopters, potential innovators and potential imitators, in which both groups are influenced by mass media, but only potential imitators are influenced by word-of-mouth.

In conclusion, the Bass model has the merit of having efficiently combined different sources of information influencing adoption with a heterogeneous population of adopters (which has then been proven to be compatible with Rogers' classification). However, even if it is true that the Bass model represents a significant improvement on the epidemic model, it has been possible to analytically encompass this model in the epidemic model literature. In particular, Geroski (2000: p.606-7) demonstrates how a model embedding both common sources of information and word-of-mouth can be considered as an improved version of an epidemic model that leads to an s-shaped pattern of diffusion. Moreover, the Bass model has also encountered some difficulties, especially on the empirical side. In fact, in cases in which prior data on the product is not available, the three parameters of the model (p, q, and m) present some difficulties of estimation, making it necessary to estimate them using alternative methods. For instance, in some cases these parameters have been taken using an estimation procedure based on management judgements (see for example Mahajan and Sharma, 1986; Lawrence and Lawton, 1981). Moreover, Bass' model has failed in one of its most important prerogatives: forecasting diffusion (Chandrasekaran and Tellis, 2007: p.49).

A final consideration regards the classification of adopters put forward by the Bass model. In the previous section we criticised the classification of early and late adopters because they were based on a post-adoption characteristic of adopters (i.e. the timing of adoption). The Bass model is undoubtedly a step forward, since it characterises early and late adopters not just depending on the time of adoption, but also on their propensity to rely upon different sources of information. However, the fact that the Bass and Rogers classifications are explicitly made compatible creates a sort of incongruence. The problem is that Rogers' innovators are, by definition, early adopters, in the sense that they adopt only in the earliest phases of the diffusion process. In contrast, Bass' innovators are present all over the diffusion path, although decreasing in number. For this reason, the issue of the post-adoption classification has not been solved, since the Bass model does not explain why some innovators are, in fact, late adopters.

2.3. Focus on the innovation

The literature reviewed so far has explored the diffusion of an innovation from the demand-side. In this literature, the innovation has been considered a more advantageous solution than any existing option, so the main question has been why it did not diffuse instantaneously. No questions have been raised regarding the qualities of the innovation, e.g. does the innovation have all those features that are considered useful by the final users? Or, are the suppliers of the innovation able to influence its adoption and diffusion? In other words, the literature detailed above has not focussed on the innovation. This difference in focus has led some researchers to a deeper consideration of the object of the diffusion process, the innovation, and also the role of the agents that make the innovation available, i.e. the supply-side. This literature has followed three main directions.

The first direction is about the characteristics of the innovation. The only characteristic that has been taken into consideration by demand-side models is the price. However, potential adopters evaluate other kinds of characteristics. Some of these are technical and measurable, such as the size or the performance of the innovation, while others are more difficult to measure, but are nonetheless potentially important, such as the innovation's ease of use or accessibility. This section will focus on these characteristics and their perception by the adopter (Section 2.3.1). In fact, it may be possible that potential adopters, aside from their individual differences, decide not to adopt simply because the innovation does not have the characteristics they desire. The second direction (Section 2.3.2) explores the fact that in many cases innovations are not isolated products. In some cases, a new technology may substitute an existing one. In other cases, two technologies may be somehow linked, making the adoption of one of them dependent on the diffusion of the other. The last direction (Section 2.3.3) deals with uncertainty and risk. Uncertainty may exist about the real payoff of the innovation or about its evolution in the future. In fact, one of the reasons why potential adopters might delay adoption is because they are still uncertain about the real value of the innovation or its characteristics. However, as stated by Rosenberg, the innovative process is rarely static; on the contrary, 'technical progress consists of a steady accretion of innumerable minor improvements and modifications' (Rosenberg, 1982: p.7). The innovation, be it a new product or a new process, goes through a series of improvements and changes over time. Diffusion models should take into consideration the evolution of the product in its price or characteristics, because it may be possible that non-adopters are delaying adoption because they are waiting for a newer version of the innovation with some desired characteristics, or for a price reduction. This section, examining the models that focus on the innovation itself will conclude with a final sub-section that briefly recapitulates the role of the supply-side in influencing the diffusion of innovations (Section 2.3.4).

2.3.1. Attributes of innovations

The literature focusing on differences among adopters provides some explanations for why the diffusion of an innovation usually takes time and follows an s-shaped curve. However, it has failed to answer to questions such as why some innovations diffuse faster than others. Rogers (2003: ch.6) has tackled this issue, affirming that innovations differ in some of their attributes. Potential adopters, when evaluating an innovation, have a perception of some of these attributes on which they will base their adoption decision. In particular, the decision to adopt may be influenced by five innovation attributes: *relative advantage*, *compatibility*, *complexity*, *trialability* and *observability* (Rogers, 2003: ch.6).

The first attribute, relative advantage, is the degree to which an innovation is considered better than the current available options. This advantage can be articulated as economic profitability, social prestige, or in other ways. The economic profitability is influenced by the cost of adoption, and by the benefits of adoption, such as an expansion in the consumption capability for an individual, or in the reduction of the cost of production for a firm. However, some benefits may not be economic. In many cases, the innovation also conveys a social benefit, for example a higher social status.

Sometimes this kind of benefit may also be predominant in comparison to other economic or utilitarian factors.

The second attribute, compatibility, is how the innovation is perceived as consistent with existing needs, socio-cultural values and past experiences. First of all, the innovation should be compatible with the existing needs of the potential adopters. Some revolutionary innovations encounter resistance because they are addressing new needs that the potential users are not yet able to recognise. Secondly, the incompatibility of an innovation with adopters' values or beliefs could block adoption. This may seem particularly relevant for sociological or anthropological studies; however, it can also strongly affect the adoption of some kinds of consumer products (e.g. genetically modified vegetables or birth control methods). Finally, since one of the most important references for potential adopters is their past, an innovation should be compatible with their previous experience, addressing issues such as brand-loyalty and standardisation.

The third attribute is complexity; in other words, whether the innovation is perceived as difficult to understand or use. This innovation attribute has been found to be negatively related to its rate of adoption. In fact, even when an innovation is recognised as being useful, potential adopters may find that the costs of learning outweigh its performance benefits. Complexity acts as a drawback in the process of technology adoption, since implementing a complex new technology requires learning both at the individual and at the organisational level. Furthermore, as reported by Fichman and Kemerer (1999), complexity does not only influence the adoption decision, but it also negatively affects the use of the technology after its adoption by hampering the complete use or assimilation of the new technology (see for example Cooper and Zmud, 1990; Eveland and Tornatzky, 1990; Liker *et al.*, 1992).

The fourth attribute, trialability, is the degree to which the innovation may be experimented with before adoption. The opportunity of experimenting with a new technology before deciding whether or not to adopt it is an important benefit for all adopters, because it reduces uncertainty about the real value of the innovation. This is particularly relevant for early adopters, since they can only rely upon available information, while laggards can learn from other users' experiences.

The last attribute, observability, concerns the visibility of the results of the innovation. The more the properties and potential benefits of an innovation are easy to explain and demonstrate to others, the more rapid will be its adoption. Oh *et al.* (2003) argue that observability includes both visibility and result demonstrability, which are defined respectively as the degree to which the innovation is visible and the degree to which the results of adopting the innovation are observable and can be communicated to others. Rogers claims that these five attributes of an innovation are able to explain most of the variance in the rate of adoption of innovations (from 49 to 87%) (Rogers 2003: p.221).

One initial consideration regarding Rogers' list of attributes is that two of these attributes seem to be consistent with Davis' Technology Acceptance Model (Davis, 1989). This model, originally designed to be applied to ICTs, indicates that there are two forces that allow a final user to accept new ICT technologies: perceived usefulness and perceived ease of use. These two forces closely resemble two of Rogers' technology attributes: relative advantage and complexity. On the other hand, other studies used more numerous attributes. Moore and Bembasat (1991) developed a study on the adoption of IT innovations relying both on Rogers' and Davis' attributes, with some differences. In particular, they use eight separate constructs in order to explain the adoption of Personal Work Stations by individuals. The first four factors are taken from Rogers' framework: relative advantage, ease of use, compatibility, and trialability. Moreover, they claim that observability could be split into two separate factors: visibility and results demonstrability (see Oh *et al.*, 2003). They then add image (the degree to which the innovation could enhance the image or status of its adopter) and voluntariness (the degree to which the use of the innovation is perceived to be voluntary).

Tornatzky and Klein (1982) review 75 articles regarding the influence of the attributes of innovations on their adoption, and perform a meta-analysis of their main results. From an initial list of 30 attributes, Tornatzky and Klein select the ten that are most frequently addressed: relative advantage, compatibility, complexity, cost, communicability, divisibility, profitability, social approval, trialability and observability. The results of the analysis indicate that three of these attributes have an impact on adoption in almost all the studies reviewed. In particular, relative advantage and compatibility seem to be positively correlated with adoption, while, in contrast, complexity is negatively correlated with adoption.

The innovation diffusion framework based on the innovation attributes developed by Rogers remains one of the most important and most cited works in the adoption literature, as most of Rogers' technology attributes are recognisable, although perhaps in different forms, in the majority of the sociological studies on diffusion (Hall, 2005: p.461). Moreover, many studies in the fields of marketing, organisational behaviour and consumer behaviour examining the impact of product characteristics on the adoption of innovation have also used Rogers' set of attributes (Gatignon and Robertson, 1985: p.862).

However, even though this framework considers the characteristics of the innovation, it does not really consider how the supply-side can influence diffusion, keeping the diffusion of innovations as a demand-side phenomenon, for two reasons. First of all, within Rogers' framework, it is not the characteristics of the innovation that influence adoption, but their perception by adopters. However, in many cases the characteristics of the innovation and hence its attributes cannot be easily evaluated by potential adopters. Secondly, Rogers' features are considered to be invariable over the diffusion process, excluding any potential supply-side effect influencing the rate of adoption over time. In other words, this framework can be used to describe why a certain innovation diffuses faster than others, or why an innovation did not diffuse at all. However, it does not help in understanding whether the profitability of the innovation may change during the diffusion process, and how the supply-side can influence this profitability. For this reason, other models, similarly based on the perception of the value of the innovation, put their focus on the uncertainty related to the evaluation of a new technology, and on the fact that some features of an innovation can change over time. Section 2.3.3 will present this kind of model.

2.3.2. Non-isolated innovations

The models discussed so far have taken into consideration the diffusion of a stand-alone innovation. However, in many cases innovations are in some way close or related to one another. This means that the diffusion of one technology can positively or negatively influence the diffusion of another technology, or may even make the diffusion of one innovation a necessary condition for the adoption of another.

The first case is that of multiple technologies. Multiple technologies can be complementary (e.g. hardware and software for computers), substitute (e.g. broadband Internet connection against other slower kinds of connections), or partial substitute (e.g. mobile phones and fixed phones). Multi-technology models have been analysed by Fisher and Pry (1971), Sharif and Kabir (1976), Mahajan and Peterson (1978) (cited by Thirtle and Ruttan, 1987: p.85), and, more recently, by Stoneman and Kwon (1994), Stoneman and Tovainen (1997) and Colombo and Mosconi (1995).

Stoneman (2002: p.68) considers two technologies, A and B (these technologies could both be process technologies adopted by firms, or consumer technologies adopted by households or individuals). A firm is facing the possibility of adopting only one of them, both of them or neither of them. If adopted, the two technologies would increase the firm's profits of g_A and g_B respectively. However, if the firm adopts both technologies, the gain will be: $g_A + g_B + v$. Depending on the parameter *v*, the technologies will be:

1. Complements if $v > 0$
2. Total substitutes if $v < 0$ and also $g_A + v \leq 0$, $g_B + v \leq 0$
3. Partial substitutes if $v < 0$ and also $g_A + v > 0$, $g_B + v > 0$

Moreover, if $v = 0$, the two technologies will be independent. At any moment during the diffusion process, there will be four types of firms:

(a) those firms having adopted both technologies, which will not necessarily be interested in adopting them again;
(b) and (c) those firms that have adopted technology A or B. In this case, the demand for the other technology is determined by the profit gain g_A or g_B plus the parameter *v*, minus the cost of adoption;
(d) those firms that have adopted neither technology. In this last case the firms will have four choices: buying A, B, both or neither. Each choice will have a different payoff.

The firm will choose the adoption strategy that maximises its payoffs. In the case of complementary technologies, if the parameter *v* is higher, it will be more probable that both technologies are bought; conversely, if the technologies are substitutes (v<0), it is more likely that only one of them will be purchased.

This model, as explained so far, is not yet a diffusion model. Stoneman (2002: p.70) suggests that by simply making g_A, g_B and possibly *v* differ across firms, these differences will be reflected in different adoption times. This type of model is relevant for three reasons. The first is that this model resembles a rank model, but with the presence of two related technologies. Secondly, in this case the diffusion of a technology depends not only on the characteristics of the firm, but also on its history, i.e. on its previous technological investments. Thirdly, the adoption of one technology will also depend on the price of the complementary (or substitute) technology and on its payoffs.

Another type of multiple technologies diffusion model looks at joint inputs. This is the case of two complementary technologies that can exist separately and stand alone. However, one of them, in order to work, needs to be used with other complementary inputs, for example Hi-Fi systems needing CDs or MP3 players needing MP3 files. In these cases, the benefit of a technology will depend on the price of the complementary inputs, and the prices of such inputs strongly influence the decision to adopt a new technology. Gandal *et al.* (2000) studied the interaction between the market of CD players and CD titles in influencing the diffusion of CD players. In particular, they found that the diffusion of CD players is driven by two factors. The first one is direct, and is the declining price of CD players; the second one is indirect, and is the growth in the variety of CD titles. Stoneman (1991b) studies the case of DVDs and DVD players, finding similar kinds of interrelated effects. Furthermore, he claims that this mechanism could make the diffusion process self-propagating, as in the case of the epidemic model. This is because the increasing size of the market for software (DVD titles) will not only influence the hardware market, but will also decrease the prices of DVDs, encouraging further investments in both hardware and software markets.

2.3.3. Accounting for uncertainty and expectations: dynamic models

One of the criticisms of Rogers' framework is that it implicitly assumes that the innovation does not change over the diffusion process (Hall, 2005: p.462). However, very often, new technologies are subject to improvements, which change their characteristics and hence influence the willingness of potential adopters. Therefore, one of the reasons why the diffusion of an innovation is not instantaneous is related to the fact that potential adopters may be waiting for changes in the characteristics or the price of the innovation. Thus, potential adopters formulate expectations of the technical evolution or price trend of the innovation and may deliberately decide to postpone adoption. Another issue is that the characteristics of the innovation, and hence its value or payoff, may not be clear at the very beginning of the diffusion process. The adoption decision under uncertainty may depend on a learning process in which the potential adopter updates his or her beliefs, and on which depends the time of adoption.

The models reviewed in this section will be divided into three groups. The first group takes into account the presence of uncertainty in the estimation of the new technology's payoffs. The second group deals with the presence of expectations about technical improvements. The third group explores the fact that in many cases new technologies do not appear in isolation, but rather have to compete or coexist with other technologies.

Uncertain payoffs

Jensen (1982) develops an adoption model in which adoption depends on the availability of information about the existence of the innovation and on the way this information is treated by potential adopters.

The model considers a situation in which a number of firms are facing the exogenous appearance of a new technology. The decision to adopt or not depends on the fact that there is uncertainty regarding the returns from adoption. However, potential adopters benefit from signals about these returns from an external source (such as the innovation's suppliers or trade journals). The information from the external source is broadcasted at discrete time intervals. The firm will classify each piece of information as favourable or unfavourable to the innovation.

When the innovation appears, each firm assigns an initial subjective belief regarding its returns, which depends on the expertise of the firm's management and their previous experience with similar innovations. The firm will start with its first belief, which will be updated using a sequence of signals through a Bayesian learning process.

This model is relevant because it explicitly considers that the reasons for delaying adoption depend on uncertainty about the real payoff of the innovation. However, within this system, a number of firms get gain access to the innovation at the same time and receive the same information about it. This means that all potential adopters are identical, except for their original beliefs about the innovation. As a consequence, adoption will take place at different dates, followed by a diffusion path, 'if and only if their original beliefs differ' (Jensen, 1982: p.188). For this reason, the rationale behind this model closely resembles a typical rank model, in which the diffusion curve depends on the distribution of a certain characteristic of the adopter, in this case different original beliefs.

Expectations of technical improvements

In the model of Balcer and Lippman (1984), the reason why diffusion is not instantaneous depends on the fact that potential adopters form expectations about the future evolution of the technology, which may lead them to postpone adoption.

In this model, a firm that is already using a certain technology faces the decision to adopt a new innovation. In particular, the decision is whether to adopt immediately or to postpone the adoption. Balcer and Lippman (1984) assume that, since the firm is already using a technology, the adoption of a new technology will result in a switching cost. Therefore, the switching cost depends on the distance between the current state of the technological knowledge (embodied in the new product) and the previous technological knowledge (embodied in the existing technology). Improved versions of the new technology will increment the profit rate, making it reasonable to incur the switching cost. Potential adopters formulate expectations about the technical evolution of the new technology. Based on these expectations, they will decide to adopt the new technology immediately or to defer adoption until (a) the technology has been sufficiently improved, or (b) it is unlikely that a new technology will be launched in the near future (Balcer and Lippman, 1984: p.296).

The relevance of this model is that it links the diffusion of a new technology to the expectations of future technical change. However, it is important to point out that the pace of technical change on which the expectations are formed is governed by a stochastic process exogenous to the model. This means that the supply-side will not be able to take into account these expectations.

<u>Price expectations</u>

In this section, three diffusion models that take into account price expectations are presented: Stoneman and Ireland (1983), Ireland and Stoneman (1986) and David and Olsen (1986). All of these models are rank models, also defined as demand-supply models (Stoneman, 2002: ch.6). The first model (Stoneman and Ireland, 1983) is a rank model in which the threshold is allowed to change over time, depending on changes in the price of the innovation. Benefits from adoption depend on the price of the innovation; the variable influencing the timing of adoption will be the reservation price of the firm. This reservation price will depend on the size of the firm, thus having a diffusion path in which large firms (with higher reservation prices) adopt earlier, and smaller firms (with lower reservation prices) adopt later. The reduction of price over time depends on the learning-by-doing accumulated by the supply-side, as the cumulative output increases. A difference between this model and a typical rank model is that, in this case, the diffusion curve will not depend only on the distribution of the ranking variable of the demand-side, but also on the cost structure of the supply-side.

The second model (Ireland and Stoneman, 1986) maintains the same structure of the first one; however, it takes into consideration not only price expectations, but also technological expectations. On the demand-side, the threshold level is redefined, taking into consideration also the possibility of introduction of new technologies in the future, substituting the existing ones. On the supply-side, the decline in price does not explicitly depend on the learning economies linked with an accumulated production output, but rather depends solely on the time elapsed, making technological change exogenous. This model analyses the impact on the speed of diffusion under different types of expectations (myopic, adaptive and perfect foresight).

The last model (David and Olsen, 1986) is based on two forces influencing diffusion. The first one, on the supply-side, is learning-by-doing, which improves the value of the innovation for adopters by reducing its cost or improving its performance. On the other side, demand is assumed to be able to anticipate the learning-by-doing on the supply-side and thus to foresee the price trend of the technology. This model represents a step forward with respect to the previous models, because the diffusion path no longer depends on the distribution of firms according to their size.

2.3.4. The role of the supply-side in the diffusion of innovations

Section 2.3 presents the literature about diffusion that is mainly focussed on the innovation itself. This literature represents a step forward with respect to both the epidemic model and the models based on heterogeneous adopters, for two reasons. First, it overcomes the assumption that an innovation is, in any case and without doubt, better than any current option. Second, by focusing on the characteristics of the innovation, one can explain why some innovations diffuse quite fast while others diffuse at a slower rate or do not diffuse at all.

While focusing on the object of the diffusion process – the innovation – another aspect that deserves further attention is the role of the producers of the innovations – the supply-side – and how they can influence the adoption and diffusion of an innovation.

As mentioned in Section 2.3.1 the sociological framework based on the characteristics of the innovation does not really take into account the supply-side. Conversely, it is the perception of the innovation by the demand-side that can influence the adoption.

Moreover, Rogers' five product attributes are not related to measurable technical characteristics of the technology, but to attributes that can only be measured through the demand-side.

On the contrary, some of the models reviewed in Section 2.3.3 specifically take the supply-side into consideration. In these cases, the interaction between demand and supply is based on the assumption that the price of the innovation can decline over time, and on the fact that the demand-side can anticipate it (at least partially) through the formulation of expectations. This is the case of the models of Stoneman and Ireland (1983), who also take into account the kind of market structure, and David and Olsen (1986). However, in these models the supply-side dynamics are constructed depending only on learning-by-doing (i.e. the cost of production declines with an increase in the cumulative number of items produced). The evolution of the characteristics of the innovation and the perception of these characteristics by the demand-side are not taken into consideration. Ireland and Stoneman (1986) also embed technical improvements in the model (in the form of new technologies substituting obsolete ones); however, in this case the reduction of the price is made exogenous and simply dependent on the time elapsed.

Another model that is also based on the supply-side is that proposed by Metcalfe (1981). This model was not mentioned in the previous sections focusing on the innovation because it is essentially an epidemic model that embeds the growth in production capacity on the supply-side. In particular, both supply and demand follow a logistic curve, reaching a saturation level both in terms of number of potential adopters and output. Other works on diffusion have also considered the supply-side, such as Chow (1967) and Soete and Turner (1984). The main reason why these models have not been included in the literature review is that they are not, strictly speaking, models of diffusion. Both papers mentioned above try to match technology diffusion with the rate of technical change. Besides the very interesting conclusions of these two models, they provide only a limited contribution to understanding the role of the supply-side in influencing the adoption and diffusion of innovations. Soete and Turner (1984) do not study the diffusion of a particular technology, but consider a whole economy (although at a micro-level) that produces only one homogenous good in which the diffusing good is also the unit measure of both capital and wages. Chow (1967) tries to identify the growth of computer sales dependent on improvements in product characteristics; however, the analysis is done at a macro level.

In conclusion, the literature on innovation diffusion presents a number of models mainly based on the object of the diffusion process (the innovation), some of them also embedding some supply-side elements. However, based on the studies presented in this section, we can conclude that the literature still pays disproportionate attention to the demand-side, and that the role of the supply-side and its interaction with the demand-side is still a neglected issue in the literature on innovation diffusion (Freeman, 1994: p.481).

2.4. Focus on the diffusion process

The diffusion models reviewed so far have focussed on two important sides of the diffusion process: the adopter and the innovation. However, two other issues should be taken into account. First of all, potential adopters are embedded in a social system, which may influence their decisions. Second, when a potential adopter is making a decision, a diffusion process may already be in progress, and the cumulative number of previous adopters may have an impact on his or her decision.

This section will complete the picture of the literature on the diffusion of innovations, by considering those models that tackle these two issues. In other words, this section considers those studies in which the diffusion of an innovation is modelled as depending on the diffusion process itself. Three approaches will be analysed. The first will be the game-theoretic or stock model, the second will be the evolutionary approach to the diffusion of innovations, and the last will be a series of models in which different sorts of increasing returns on adoption lead to situations of herd behaviour or bandwagons.

2.4.1. Stock and order models

The neoclassical economic tradition, when approaching the diffusion of innovations, has produced two kinds of equilibrium models. The first is represented by the so-called rank models, in which diffusion is seen as being driven by differences among the adopters (see Section 2.2.1). *Stock models*[9] represent the other approach, and consider diffusion as the result of the strategic behaviour of potential adopters. Stock models follow a game-theoretic approach, demonstrating that, under some assumptions, identical firms can adopt at different times, producing a diffusion path.

[9] The definition of *stock models* is used to indicate that the benefits decrease with an increase in the number (stock) of previous adopters (Karshenas and Stoneman, 1993: p.504).

In Reinganum's (1981) model of diffusion, two firms are engaged in a duopoly game. Economic agents are supposed to be homogenous (in contrast with the rank models), perfectly rational and maximising. The adoption of a new technology could improve firms' profits by reducing production costs. As in other diffusion models, the cost of adoption is assumed to decrease over time. However, in these models, benefits from adoption also decline over time. In fact, since the adoption of the new technology reduces the firms' costs, one may expect that, eventually, the firms' output price will also decline. Within this framework, each firm faces the decision to adopt early, sustaining higher adoption costs, but also higher selling prices (and hence higher profits), or to delay adoption, paying a lower price, but also gaining lower profits. This decision is assumed to be rational. Each firm forms its best reaction function against any possible behaviour of the competitor, reaching a Nash equilibrium in which each firm pre-commits to a specific adoption date. This model has been refined and extended by Reinganum (1983), Fudenberg and Tirole (1985), Quirmbach (1986) and Mariotti (1989). These models have been applied to the case of firms. In the case of consumer products, the negative influence exerted by the stock of previous adopters can be seen as a *snob effect*, occurring when potential adopters reject the innovation due to trying to look different from others.

Previous adopters in Reinganum's model produce a negative externality to the future adopters. In contrast, another type of game-theoretic model is based on positive externalities from adoption. In many cases, these positive externalities arise from different sources, such as informational externalities, the development of complementary markets or cost reductions due to standardisation. For instance, models with informational externalities build upon the learning models discussed in the previous section. In these models, diffusion can be considered as a *waiting contest* in which each firm prefers to wait until other firms adopt in order to benefit from the informational externality and learn from their behaviour (Mariotti, 1992; Kapur, 1995).

The relevance of stock models within the neoclassical economics approach to the diffusion of innovations is that they make it possible to have a diffusion curve with the assumptions of both identical agents and full information, while in any other equilibrium model these two assumptions would necessarily make impossible the existence of a diffusion curve, having all the agents adopting on the same date. More broadly, these models are also relevant for two reasons. First of all, the returns of adoption depend on the number of previous adopters. In other words, the decision whether or not to adopt has to take into account the behaviour of the others. Secondly, in this model the diffusion process is not driven by the existence of any exogenous force modifying the parameters of the model (e.g. an increase in labour costs that makes the new technology more profitable to firms bigger than a certain size). On the contrary, in game-theoretic models, the parameter change is completely endogenous and depends on the behaviour of the other agents (Sarkar, 1998: p.140).

Another way of considering the effects of the stock of previous adopters in influencing diffusion is by considering that the returns of adoption of an innovation for a certain adopter depend on his or her position in the order of adoption. The main assumption behind this kind of *order effect* is that high-order adopters experience a higher return than low-order adopters (Karshenas and Stoneman, 1993). This effect is often considered as a sort of first-mover advantage by which a firm or an individual, by adopting before the others, is able to reap more benefits from the innovation. In the case of firms, a high-order adoption is supposed to ensure returns such as better geographic position, easier search for skilled labour (Ireland and Stoneman, 1985; Karshenas and Stoneman, 1993) or the exploitation of a temporary monopolistic position (Fudenberg and Tirole, 1985). In the case of consumers, an early move to adopt an innovation can have the advantage of conferring opinion-leader status, hence the ability to influence other individuals in their attitudes or behaviour and to induce imitation.

2.4.2. Evolutionary diffusion models

The evolutionary diffusion models literature is part of the more general criticism of neoclassical economics made by the evolutionary economics tradition. The evolutionary critique of neoclassical diffusion models is based on some of their crucial assumptions, such as perfect information, unbounded rationality, the notion of diffusion as an equilibrium process and the concept of diffusion as a continuous process.

In equilibrium models it seems that late adopters have time to delay adoption without incurring in any serious loss. In other words, selection does not exist, or it is too slow. Evolutionary models, on the contrary, give much more importance to the selection process. A non-timely adoption or the adoption of the wrong technology results in exit from the economic system or significant losses. However, this important decision must be taken without full information about the other potential adopters or about the innovation itself, and with some biological limitations that make them boundedly rational. Following Sarkar (1998: p.142), evolutionary models could be divided into two groups: *selection models* and *density dependent multiple-equilibria models*.

The first group of models is directly inspired by evolutionary theories in the biological sciences. In this case, diffusion is the outcome of a process of selective competition between rival technologies. The competitive advantages of different technologies combined with specific strategic behaviours of potential adopters determine in which way each rival technology diffuses relative to the others. In this kind of model (see for instance Nelson and Winter, 1982; Metcalfe and Gibbons, 1988; Silverberg, *et al.*, 1988), the diffusion process is seen as an adjustment of a disequilibrium industry to a best practice technology. This model embodies a variant of the *replicator dynamics* mechanism borrowed from biology (Fisher, 1930). This mechanism, starting from a series of species characterised by different levels of 'fitness', is supposed to converge to a population made up of the species with the highest fitness.

In parallel, if applied to rival technologies, the selection process will be based on the distance of each technology from the average-practice technology. Potential adopters are both partially informed and imperfectly rational, so the first adopters will choose one technology based on different criteria, such as rules of thumb or behavioural attitudes towards innovation. The diffusion process is then endogenously driven by the signals generated by the early adopters, for instance informative feedback or reinvestments of the profits of adoption. Eventually, the diffusion process may be shown to converge to a situation in which the best technology is selected and the adoption of the lowest-level technology drops to zero.

The other kind of evolutionary model is the density-dependent multiple equilibria type of model (Sarkar, 1998: p.146). The focus is similar to the previous kind of model, for instance Arthur (1988, 1989) focuses on the relative diffusion of competing technologies. The main differences are two. The first is the presence of interdependencies among the decisions of potential adopters that generate increasing returns from adoption. The second is that the diffusion process is subject to the occurrence of small disturbances, such as slight differences among adopters or other minor historical events. These small events cannot be foreseen and appear randomly, and could significantly influence the diffusion path of one of the rival technologies. These influences are so significant that in this kind of model it is not possible to predict *a priori* which technology will diffuse. In other words, this model does not assure that the best technology will be the one selected by potential adopters. The diffusion is then totally path dependent, with the possibility of a lock-in to a lower-level technology.

Unlike neoclassical models, evolutionary models of diffusion are rarely tested using econometric techniques. The complexity of these models and the emphasis they put on history strongly encourage the validation of these models using simulation exercises (see for example Nelson and Winter, 1982; Silverberg *et al.*, 1988; Mokyr, 1994) or detailed historical case studies (see for example Arcangeli *et al.*, 1991; Amendola, 1990; Cainarca *et al.*, 1989).

2.4.3. Bandwagon theories and herd behaviour

The trigger of diffusion in the epidemic model is that previous adopters influence other potential adopters through word-of-mouth. With the exception of some few authors (such as Lekvall and Whalbin, 1973, and Bass, 1969), who describe how this kind of information flows and influences adopters' decisions, this issue has not yet been addressed by the literature reviewed so far in this thesis.

This section fills this gap by presenting a series of models in which adoption by a group of individuals generates pressure towards later adopters to purchase the innovation. Many of these models specify a bandwagon process, which is 'a positive feedback loop in which increases in the number of adopters create stronger bandwagon pressures, and stronger bandwagon pressures, in turn, cause increases in the number of adopters' (Abrahamson and Rosenkopf, 1997: p.289). Bandwagon theories are often used to explain herd behaviour (Geroski, 2000; p.619) and, according to Abrahamson and Rosenkopf (1997), bandwagon theories can be divided into three groups: (1) increasing returns theories of bandwagons; (2) learning theories of bandwagons; and (3) fad theories of bandwagons.

Increasing returns theories of bandwagons

The first group of theories generally assume that the profitability of an innovation is unambiguous and it depends on the number of previous adopters. In other words, an increase in the number of adopters generates a positive externality. The case of negative externalities has been previously analysed by stock models of diffusion (see for example Reinganum, 1981).

One of the most important sources of increasing returns from adoption is the presence of network effects (Katz and Shapiro, 1985, 1994; Farrel and Saloner, 1985; David and

Greenstein, 1990; Choi and Thum, 1998; Belleflamme, 1998). In the presence of network effects, the utility from adoption increases with the number of other adopters that purchase the innovation. In particular, two types of network effects could influence adoption, direct and indirect (Hall, 2005: p.471). A direct network effect arises when the adopter of a certain product becomes part of a network, which connects all the users of that product (e.g. the case of fax machines). An indirect network effect is instead related to the fact that a higher number of adopters of a certain technology increase the probability that this technology will be considered as standard, and that more goods compatible with that standard will be produced. Another case of indirect network effect depends on the fact that when more individuals gain skills in using a particular technology the returns on adoption are higher because there is a higher probability that users will already know how to use the technology. For instance, if many users become skilled users of a particular software, such as Microsoft Word, it would make sense to outfit computers with this software because new employees will be more likely to be already trained to use it.

A known case of network externality applied to the adoption of new consumer technologies has been the competition between two incompatible standards of VCR developed by Matsushita (VHS) and Sony (Betamax). The outcome of the competition has been the *de facto* standardisation of VHS. This is an interesting case, not only because its supposed technological superiority did not help Sony[10] (Rosenbloom and Cusumano, 1987), but also because it was a typical example of indirect network effects. In fact, one of the factors that influenced consumers to adopt VHS instead of Betamax was the wider availability and variety of pre-recorded products and rentals in the first format compared to the second (Katz and Shapiro, 1986; Park, 2004). A similar story comes from the case of the competition between two typewriter keyboard arrangements. David (1985) explains that the reasons for the success of the QWERTY keyboard against the supposedly more efficient Dvorak keyboard depended on the benefits of compatibility, coming both from the familiarity of the QWERTY keyboard to experienced typists and the existence of specific training courses tailored to the QWERTY arrangement.

Salonel and Shepard (1995) apply the concept of network effects to the adoption of ATMs by banks. They find that banks with more branches have been early adopters of ATMs, even controlling for the number of depositors. The main assumption behind the

[10] However, Park (2004: p.7) cites some *Consumer Reports* indicating that there were almost no significant differences in performance or features between the two formats.

model is that consumers prefer a larger network of ATMs, generating a direct and positive network externality.

Learning theories of bandwagons

The next set of theories of bandwagons is based on another crucial aspect of the diffusion process: the flow of information among adopters. The adoption of a new product, especially in the case of incomplete information, can be considered a significant source of uncertainty. Adopters must learn both about the existence of the innovation and its characteristics before adopting it. Two basic types of information contagion model have already been presented: the epidemic model and the Bass model. In the first model, simple personal contact between agents determines adoption. In the second model, only late adopters are influenced by information coming from previous purchasers, while early adopters prefer other sources of information, such as advertising, product brochures and consumer reports.

In the case of incomplete information, potential adopters have to learn about the innovation before purchasing it. Potential adopters will then seek information through social contacts, social interactions and interpersonal communication with other individuals who have already adopted the innovation (Burt, 1987; Rogers, 2003; Valente and Rogers, 1993). In this way, potential adopters will use these pieces of information as informative feedback in order to revise their assessment of the innovation (Feder and O'Mara, 1982; Oren and Schwartz, 1988; Lattin and Roberts, 1989; Chatterjee and Eliashberg, 1990; cited by Abrahmson and Rosenkopf, 1997).

As a consequence, more adopters of an innovation will mean more information supporting its profitability. Therefore, the accumulation of this kind of informative feedback from previous adopters can generate a bandwagon pressure that will strongly influence the behaviour of late adopters (Abrahamson and Rosenkopf, 1993; 1997).

Furthermore, Rogers (2003: p.355-6) claims that the increasing number of previous adopters could generate a bandwagon effect. First of all, Rogers affirms that each potential adopter has a different individual threshold for adopting. This threshold is the number of other individuals who must adopt before he or she will decide to adopt. This means that, depending on the distribution of these individual thresholds among the population of potential adopters, it could be possible that a series of subsequent adoptions could initiate a *domino* effect, instigating all the potential adopters to adopt.

Nelson *et al.* (2004) add that in some cases this kind of bandwagon effect may not lead to the diffusion of the most profitable innovation. This is because it is not certain that the same informative feedback will impact in the same way on all the agents. In other words, different adopters will interpret this feedback in different ways. Moreover, this inability to get persuasive feedback, combined with the above-mentioned increasing returns on adoption could lead to a situation in which diffusion is driven by factors other than technical merit (Nelson *et al.*, 2004: p.683-4), resembling a *socially constructed diffusion* process (Bijker, 1995, cited by Nelson *et al.*, 2004).

In addition, the concept of social contagion has been enriched by at least two additional contributions. The first one takes into account the fact that adopters are part of a social network in which they occupy different positions (Coleman *et al.,* 1966; Burt, 1987; Midgley *et al.,* 1992; Deroian, 2002; Van den Bulte and Stremersch, 2004). In particular, the structure of the social network and the position occupied by potential adopters can influence the timing of adoption and the diffusion process. In particular, following Burt (1987), this element is incorporated into two types of social contagion theory (Burt, 1987; Harkola and Greve, 1995; Van den Bulte and Lilien, 2001). The first type of theory, social contagion by *cohesion*, stresses the role of proximity in influencing the adoption decision. The focus is on the fact that potential adopters will rely on the previous adopters who are closer to them in the social network, socialising with them and relying on their judgements about the innovation. On the other side, *structural equivalence* theories stress the role of competition among members of the social network. In particular, structurally equivalent people are not necessarily close, but they occupy the same position in the social network. In this case, the social contagion works by pushing a potential adopter to take a decision that would appear proper for an occupant of an equivalent position in the social network.

The second contribution focuses on the importance of opinion leaders. Opinion leadership can be defined as the ‘degree to which an individual is able informally to influence other individuals’ attitudes or behaviour in a desired way with relative frequency’ (Rogers, 2003, p.300). From this perspective, the literature about opinion leaders indicates how, in some cases, specific individuals can exercise a significant influence upon potential adopters’ decisions by inducing imitation behaviours (Turnbull and Meenaghan, 1980; Myers and Robertson, 1972; Valente and Davis, 1999; Burt, 1999). Opinion leaders are distinguished by some inherent characteristics, such as greater exposure to mass media, greater social participation, higher socioeconomic status and a higher degree of innovativeness (Rogers, 2003). In addition, opinion leaders are generally considered to be early adopters (Turnbull and Meenaghan, 1980; p.18). Opinion leaders affect the diffusion of an innovation in two ways. Firstly, in many cases they are responsible for introducing an innovation in the social network. Secondly, since they are well-respected by other people in the social network, they can influence these other people to adopt the innovation. In other words, following the contagion metaphor, the existence of opinion leaders depends on the fact that not all the previous adopters are 'infectious' in the same way; some of them are more 'contagious'.

Fad theories of bandwagons

The last group of theories, called fad theories of bandwagons, assumes not only that the profitability of the innovation is unclear but also that information about profitability cannot flow directly from adopters to potential adopters. In this context, it might be optimal for potential adopters to dismiss their private signals and simply imitate the behaviour of previous adopters. In this case, potential adopters, instead of taking their decision by looking at the innovation itself, would rather consider who has already adopted it, generating a social bandwagon effect (Abrahamson and Rosenkopf, 1997). A useful way to understand this kind of phenomena is to see them as informational cascades (Bikhchandani *et al.*, 1992 and 1998; Banerjee, 1992; Geroski, 2000).

An informational cascade occurs 'when it is optimal for an individual, having observed the actions of those ahead of him, to follow the behaviour of the preceding individual without regard to his own information' (Bikhchandani *et al.,* 1992: p.994). Bikhchandani *et al.*'s (1998) cascade model can be specified as a situation in which a series of individuals (A, B, C, D) have to decide in sequence to adopt or reject an innovation. The payoff of adopting, V, is either -1 or +1 with equal probability, while the payoff of rejecting is 0. All individuals know the order in which they will decide. Each individual receives a signal from the innovation, either High or Low. The model assumes that receiving a High signal is comparatively more likely when adoption is desirable (V=1). Now, if the first individual, A, receives a High signal he or she will adopt, while A will reject if the signal is Low. The second individual, B, will not only receive his or her signal, but will also observe the decision of A. Thus, if B receives a High signal he or she will definitely adopt; however, if the signal is Low, the decision of B will depend on the behaviour of A. In fact, B can infer that if A adopted it is because he or she received a High signal. This means that even if B receives a Low signal, if A has previously adopted, B's decision to adopt will still be indifferent, and will then depend, for instance, on the toss of a coin. The third individual, C, faces three possibilities: both A and B adopted; both rejected; or one of them adopted and the other rejected. If both A and B adopted, C will infer that both of them received a High signal (or that at least one of them did, while the other tossed a coin), and will then adopt, regardless of his or her signal. On the contrary, if both A and B rejected, C will surely reject. The only situation in which C's signal could make a difference is if A and B took an opposite decision. From the fourth adopter, D, onward, it will be optimal to dismiss any private signal and to conform to the previous decisions. Each of these subsequent adopters can be considered as in an informational cascade, since information is flowing (cascading) from the first adopters to the followers.

Geroski (2000) demonstrates that this model, if applied to the adoption of two competing technologies, can have, as one of its possible outcomes, an s-shaped curve. However, since the acceptance of the innovation does not depend only on how many High and Low signals have been perceived, but also on the order in which they arrived, this model does not ensure that the most valuable technology will diffuse (Bikhchandani *et al.*, 1998). These powerful results are, however, limited by some kinds of shocks that could occur, and which could modify the informational cascade, for instance, the arrival of better-informed individuals or the release of new public information. Another factor influencing the cascade is the presence of opinion leaders (or fashion leaders). These individuals may impact on an informational cascade in two ways: firstly by breaking it, for example by following their private signals and not trusting the others' sequence; or, secondly, by amplifying it, because their signal will be considered even more powerful by followers (Bikhchandani *et al.*, 1998).

2.5. Concluding remarks

This chapter has presented a selected review of the literature on the diffusion of innovation. The review started with a presentation of one of the most basic and widely-used models of diffusion, the epidemic model, explaining the importance of this model as well as its numerous limitations. Each of these limitations has been the basis for the development of a new set of diffusion models. These departures from the basic epidemic model have been divided into three groups, depending on the main focus of the diffusion model.

The first group of models is focussed on the presence of differences among adopters, presenting three main classes of models. The first is the rank model, representing one of the main efforts of embedding the concept of diffusion of innovations into the neoclassical economic framework. The rationale of this class of model is that the adopters of an innovation differ in at least one crucial characteristic, which influences the benefits or the costs of adoption. The diffusion process is hence driven by the distribution of this characteristic. The second is Rogers' classification of adopters based on normal distribution. The third is the Bass model of diffusion that combines the presence of differences among adopters with different sources of information that influence them.

The second group of models is focussed on the object of the diffusion process; in other words, the innovation, having again three classes of model reviewed. The first is Rogers' framework, in which the rate of adoption of an innovation depends on how its characteristics are perceived by potential adopters. In particular, Rogers finds that five attributes of the innovation are the most important: relative advantage, compatibility, complexity, trialability and observability. The second is related to the fact that in many cases there is uncertainty about an innovation. The uncertainty may be linked to one of at least two different aspects: (1) the technical or price evolution of the innovation in the future; and (2) the real value or characteristics of the innovation. The presence of these sources of uncertainty means that potential adopters form expectations about the innovation, which, eventually, can influence the diffusion of the innovation itself. The last model in this group is developed from the fact that in many cases technologies are not isolated, but instead they are somehow linked, for example in the case of multiple technologies that complement or substitute each other, or of joint inputs. In these cases, the diffusion of one technology will be necessarily linked to the price of the other, and also on the degree of interrelation.

The third group of models is focussed on the diffusion process itself as a driver of adoption. In many cases, in fact, the adoption behaviour of some members of the social system can influence the adoption of other members in the future. Three types of models have been reviewed within this section. The first is the game-theoretic or stock model: a particular kind of neoclassical equilibrium model in which the diffusion process is driven by the strategic behaviour of potential adopters who are facing decreasing (or increasing) returns from adoption. This type of model is relevant because even if it relies on both full information and on identical and rational adopters, it produces a situation in which there will be adoption at different times. Moreover, the main force behind diffusion is endogenous; in other words, it is the diffusion itself that changes the parameters and stimulates further adoption.

The second set of models in which the diffusion process itself is the subject of analysis is the evolutionary approach to the diffusion of innovations, which, in evident contrast to the neoclassical framework, considers the diffusion of innovation as a process dominated by bounded rationality, limited information and disequilibrium. Two main kinds of evolutionary model have been presented. In the first, diffusion comes from a process of selection among technologies (or firms), similar to biological selection, in which the best practice technology will eventually emerge and survive. The second kind of model sees diffusion as a path-dependent process conditioned by a series of uncontrollable small events, or by micro-differences among adopters. These small events will definitely influence adopters who are not fully informed and who are only boundedly rational, and will lead to a final outcome in which not necessarily the best technology is selected.

The third group of models is centred on the diffusion process, and includes several studies that demonstrate how the presence of increasing returns from adoption can generate bandwagon pressures. Bandwagon theories can be divided into three groups. The first group of theories claims that the bandwagon pressure comes from direct or indirect network externalities, which make the profitability of the innovation increase with the increase in the number of previous adopters. In the second group of theories, the bandwagon pressure takes the form of an informational externality that accumulates with an increase in the number of adopters. In fact, the previous adopters represent a significant source of information about the innovation, which potential adopters can access through personal contact and interpersonal communication. The last type of bandwagon pressure is able to explain the presence of herd behaviour or fads, thanks to the concept of the informational cascade. In this case, potential adopters may find it optimal to dismiss their private signals and follow the previous adopters' decisions, trusting the informative signal that previous adoptions represent.

From the analysis of the literature on diffusion three main conclusions emerge, which also represent the basis of the present research. The first conclusion is that, despite the fact that most of the diffusion studies are inclined towards the demand-side, the literature on diffusion puts forward only an over-simplified classification of adopters. The heterogeneity of users has been taken into account in at least three ways. First, the sociological framework developed by Rogers divides the adopters into five categories depending on their distribution (standard deviations far from the mean). In a second step, each group is then portrayed as having distinguishing characteristics. However, these categories are based on arbitrary cut-off points (Gatignon and Robertson, 1985: p.861; Greenhalgh *et al.*, 2005: p.101) and not on fixed personality traits. In the second kind of classification, proposed by the marketing approach (Bass model), users are classified as innovators and imitators, depending on the type of information source by which they are most influenced. This classification is considered compatible with the previous classification, by making Bass' innovators coincide with Rogers' first category. However, in this case we incur a sort of incongruence, because, by definition, Bass' innovators are present all over the diffusion path (although decreasing in number), while Rogers' innovators are necessarily early adopters (Mahajan, Muller and Bass, 1990: p.17). Moreover, in most cases, potential adopters are considered as passive recipients of either internal or external sources of information, while little attention is paid to their role as active seekers of information (Karshenas and Stoneman, 1995: p.273; McMeekin *et al.*, 2002: p.8). In both cases, adopters are somehow divided into early and late adopters. However, if the purpose of an adopter's classification is to explain their patterns of adoption, a classification based on the timing of their purchase appears to be tautological, since the timing of their adoption is a characteristic only measurable after the adoption has taken place. The third variety of model is primarily based on the heterogeneity of users. This is the case of the so-called rank or threshold models. In this case, the benefits of adoption are compared with its cost and depend on a specific variable (e.g. size of firms or income of consumers). In any case, in this type of model, the trigger for diffusion is always an exogenous force. In other words, the adopter's characteristics only define the shape of the diffusion curve, rather than summarising relevant attributes of the adopter that influence the timing of the adoption. These efforts have provided some very interesting results; however, they fail to provide a generalised innovator profile (Gatignon and Robertson, 1985: p.861). The main issue is that these classifications would work perfectly only if the main variables describing individuals were observable (Griliches, 1980, p.1464-5). However, since these variables are not observable, they are often approximated by time of adoption or by other proxies, such as income. This is even more important for the diffusion of consumer products, because the characteristics of individuals and households are much more difficult to measure than those of a firm.

The second conclusion and point of departure of the research of this thesis concerns the supply-side. While the literature on innovation has often been accused of paying too much attention to the supply-side, a common criticism of the models of innovation diffusion is the lack of a supply-side (Freeman, 1994: p.481; Metcalfe, 1981: p.347). It is true that in many studies, diffusion has been considered a demand-side matter, by simply considering the innovation as a better solution with respect to all current options. However, some other models have tried to incorporate some supply-side elements. For example, the sociological framework has included the supply-side by considering the perception of product characteristics by potential adopters. This is an important step, especially because it makes it possible to compare the performance of different innovations. However, this approach suffers from two problems. Firstly, these five (or more) attributes of the innovation are never related to measurable or technical characteristics. This makes it difficult to measure the role of the supply-side in making its product more acceptable and hence enhancing diffusion. Secondly, even if the relevant attributes are about the innovation, the focus of this approach is still on demand. The reason is that the most important element is not the innovation attribute itself, but its perception and appreciation by potential adopters, and this, again, shifts the attention to the demand-side.

Another type of diffusion model, the so-called demand-supply model, has specifically taken into consideration supply-side factors. This kind of model assumes that the innovation is not static over time. On the contrary, the potential evolution of the innovation is considered in at least two ways. First of all, the technology may improve its characteristics over time. Secondly, the price of the innovation may change over time. These models, by introducing some dynamic elements, represent a step forward in the study of innovation diffusion. However, again these supply-side effects are modelled from the perspective of the demand-side, for two reasons. First, in these models, the diffusion process is based upon the formation of expectations on the demand-side regarding either future improvements of the product or a decline in the price. For one or both of these reasons, a potential user could decide to delay adoption waiting for more profitable conditions. Second, the evolution of the product and the decline in the price are usually taken as exogenous, either by considering them as happening as time elapses or randomly. The only way in which they have been endogenised has been by making them generally dependent on learning-by-doing. Some other studies have tried to combine technical change with diffusion (see for example Soete and Turner, 1984; Chow, 1967), at least at a macro level of analysis. In any case, the issue of how the evolution of the technical characteristics of the product and changes in its attributes shape the diffusion path is still only weakly explained.

The third, and perhaps the most evident, conclusion is that there does not exist a comprehensive and shared model or framework for the diffusion of innovations, especially regarding new consumer products. The variety of models has indeed been remarkable. Diffusion models have studied a broad range of innovations, as well as kinds of potential adopters. Some models have focussed on the micro level (individual adoption decisions), and others on the macro level (diffusion paths). In addition, different views have come from different fields, such as sociology, marketing, economics and so on. Moreover, diffusion models have been validated in different ways, such as through empirical tests, forecasting and simulation exercises. In some cases, different views on diffusion have entered into debates, e.g. equilibrium *vs.* disequilibrium models, static *vs.* dynamic models or neoclassical *vs.* evolutionary models. Several models have considered different types of factors, such as the features of innovations, the characteristics of adopters and other social factors. However, none of the approaches seem to be suitable to account for all these influences, and each specific model or view on diffusion omits others. More importantly, prior work on diffusion has not been able to compare alternative approaches to diffusion, or able to prioritise, on an empirical basis, which formulation provides the most consistent and robust account of the diffusion process.

This review of the literature on innovation diffusion has not pretended to be exhaustive; however, it has given an idea of the extreme diversity of modelling approaches in the field of innovation diffusion. This extreme variety, on one hand, has made this topic extraordinarily rich and productive. However, on the other hand, it has created some difficulties. First of all, if the literature on diffusion has tackled almost every aspect of the diffusion of an innovation, it has not provided any instruments with which to decide which model is most suitable depending, for instance, on the type of innovation or on the type of adopter. Some comparisons of diffusion models have been attempted, for instance Karshenas and Stoneman (1993) and Stoneman (2002: ch.10). However, these exercises have mostly been limited to economic models of diffusion (although including some epidemic effects). Secondly, this diversification makes it difficult for a policy-maker to decide which levers to operate in order to speed up or slow down the diffusion of an innovation. It may be useful to empirically study the diffusion of a consumer technology embedding several factors coming from different models. Collecting sufficient data on the adoption and diffusion of a specific consumer product would allow a researcher to test whether the assumptions of various models of diffusion are relevant and applicable.

CHAPTER 3. THE EVOLUTION OF THE DIGITAL AUDIO PLAYERS SECTOR

Mobile listening to recorded music has become a very common practice, beginning at the end of the 1970s when the Sony Walkman was developed and launched (Shaw, 2008: p.140). Technical changes have facilitated mobile music listening and have gradually improved existing music players, as well as providing some radical new products such as CD players and Minidisc players. However, at the end of the 1990s a series of new factors, such as the invention of the MP3 music codec, the development of higher-capacity storage media and the diffusion of the Internet, triggered a pervasive and dramatic change in the way that people listened to, exchanged and consumed music. These changes revolutionised the whole music industry. The central features of these changes were the advent of digital music and the proliferation of the so-called digital audio players or DAPs: portable devices able to load and play digital audio files. The extraordinary success encountered by these products is both a consequence and one of the triggers of the digital music revolution.

The changes accompanying DAPs were not immediate. They were not radically new products. Instead, they were a significant incremental improvement on an existing technological trajectory from analogue to digital music and eventually to compressed digital music, with different kinds of storage media and music players following one another. Thus, the revolution in digital music was a cumulative process involving the co-evolution of DAPs, sources of digital content and user habits and practices.

Bearing in mind that the main focus of this thesis is the adoption and diffusion of digital audio players by final consumers, this chapter will examine the issue within two contexts: the progressive advent of digital compressed music, and the impact that this has had on the music sector. This chapter is organised as follows. The first section (3.1) will concentrate on the history of recorded music, focusing on DAPs' precursors, such as portable cassette players and portable CD players. The second section (3.2) is dedicated to the history of DAPs, briefly summarising the main events, technical innovations and the role of key actors in the evolution of DAPs. The third section (3.3) has a broader focus, and explains some of the issues that accompanied the advent of DAPs, and which involved the entire music industry, such as the exchange of music files through the Internet, and new patterns of music consumption and distribution. The last section (3.4) summarises the main themes of the chapter and draws some conclusions.

3.1. History of the music industry and the precursors of DAPs

A digital audio player, or MP3 player, is a device for storing, managing, organising and playing digital music files (Holmes, 2006). This kind of player was developed around the end of the 1990s, after the introduction of audio compression codecs,[11] such as MP3. In addition to MP3, several other codecs have been developed. However, DAPs are still most often called MP3 players, since in most cases they are compatible with that standard (Holmes, 2006: p.75). During the first decade of the twenty-first century, DAPs diffused very widely, changing behavioural patterns of music listening and consumption.

However, the history of sound recording and reproduction begins more than a century before the advent of DAPs. Over the course of this history, many media have been invented to store music, as well as many kinds of music players. Moreover, DAPs were not the first portable music players. Portable music has been available to consumers since at least the end of the 1970s.[12] For this reason, before concentrating on the history of DAPs, it is useful to provide a brief examination of the precursors of DAPs.

This section will briefly summarise the history of the music recording industry. The main focus will be on the evolution of the technologies that allow the reproduction of recorded music, with particular emphasis on portable technologies. Moreover, the activity of some of the main players will also be taken into consideration, such as the equipment and media producers and the recording companies, as well as the consumer side.

3.1.1. First steps in the music recording industry

The consumer market of recorded music is based on two elements: the 'content', or recorded music, and the technology for the 'playing' of this content. The technological element includes the media on which the sound is recorded and stored, and the devices able to reproduce the sound that has been pre-recorded onto these media. These two technologies are complementary, and they need to be designed to be fully compatible in order to work. However, the success of a particular medium also depends on the other element, which is the availability of a range of quality music recordings to be purchased

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[11] A codec is an electronic program that is able to transform an analogue signal into digital form and to make it more compact, according to a particular algorithm for data compression, such as MP3, Advanced Audio Coding, etc. (Holmes, 2006: p.49).

[12] The idea of 'portable' is a relative concept. Early phonographs that could be hand-cranked were adapted to portability or, in the terminology sometimes used, to 'transportability.' In this thesis, portability is taken to mean 'wearable': able to fit into a shirt, coat or trouser pocket.

by the public (the content).

The history of music recording has been influenced by technical changes occurring in these technologies, and started with the invention of the phonograph[13] by Thomas A. Edison in 1877, followed by Emile Berliner's gramophone in 1888 (Chanan, 1995: ch.2). The main difference between the phonograph and the gramophone was the kind of medium that they were designed to play. The phonograph was made to reproduce music pre-recorded onto cylinders (first made of tin foil, then of wax), while the gramophone was designed to play flat disc records (Chanan, 1995). At the beginning, the main companies operating in the sector were Edison, Victor and Columbia, all of them based in the US, but by the end of the nineteenth century other firms had entered the market (Haupert, 2006: p.55). At least during the first stages, the competition was mainly technological, regarding both the reproduction equipment and the recording media. Cylinders were gradually abandoned in favour of discs, with cylinders finally being discontinued around 1929. The main benefits of discs were that they could ensure a longer recording length (and on both sides) as well as more robustness (Haupert, 2006).

These very early stages of the history of the recording industry, which took place more than a century before the advent of DAPs, are relevant from at least two points of view: the consumer and the business sides. On the consumer side, the gramophone represented a revolution in the way users could consume music. Before the gramophone the only ways people could listen to music were essentially live performances (classical concerts, chamber music, ballroom dancing, jazz sessions and so on), while the most common way of listening to music at home was through use of the piano (Garofalo, 1999: p.319). The revolution brought about by the gramophone was that it allowed people to listen to recorded music both in public places (thanks to jukeboxes) and in private homes (thanks to gramophones).[14]

On the business side, these very early developments are important because they contributed to creating a stable structure for the recording music industry that persisted or resisted change for several decades (Graham *et al.*, 2004). At the

[13] The first models of phonograph were used to both record and reproduce sounds; however, the first phonographs that were commercially successful were only able to play pre-recorded content (Source: The Library of Congress: The history of the Edison Cylinder Phonograph; http://memory. loc.gov/ammem/edhtml/edcyldr.html; last accessed 30/08/2011).

[14] Around the 1920s another form of media was also changing consumers' attitudes towards music: radio broadcasting. However, since this thesis is mainly concentrated on portable players of recorded music possessed by the consumers, the role of radio broadcasting will not be considered.

beginning, there was an identification between technology and recorded music. This means that the companies active in the sector were producing the reproducing equipment (the phonographs and gramophones) and also producing and selling the music records (in the form of cylinders or discs). In some cases this identification was even more extreme. Some early cylinders did not even feature a picture of the artists performing the music recorded on it, but instead showed a photo of Thomas Edison (Haupert 2006: p.57).

However, this situation did not last for a long period. The gramophone and music recording sector that started at the end of the nineteenth century, and which flourished during the 1920s[15] had its first shakeout during the Great Depression. Moreover, in the same period, the sales of gramophones started to decline, mainly because of the saturation of the American gramophone market (Haupert, 2006). This caused the above-mentioned identification between recording equipment producers and recording companies to begin to come to an end, with the Edison Company discontinuing the production of records and phonographs in 1929 (Chanan, 1995: p.64), and other companies (such as Columbia) quitting the production of reproducing equipment in order to concentrate only on the records market (Haupert, 2006).

As pointed out by Chanan (1995: p.32), the music industry is not just an industry with two complementary technologies functioning as hardware and software (such as, for instance, the case of cameras that create a market for photographic films). The success of reproducing equipment not only depended on the availability and quality of the media to be reproduced, but also, and more importantly, on the supply of music content; in other words, on the existence of a sufficiently large and good quality catalogue of pre-recorded records. Recording companies concentrated on the recording side, paying more attention to selling records and promoting artists. It was in this period that the music industry started to become more fragmented, embedding many different specialised actors, such as manufacturers of reproducing equipment and media, recording studios, music labels, music publishers and so on (Williamson and Cloonan, 2007).

Among all these organisations, music labels or publishers historically had a prominent role in the industry. Some of these music labels derived from the very early pioneers in music recording, such as Columbia and Victor. Music labels had the role of

[15] At the end of the nineteenth century only three companies were operating in the market. In 1914, 18 companies were selling phonographs, and over the next five years the number of companies competing in the sector expanded to 166 (Haupert, 2006: p.60).

coordinating the activities of production, manufacture, distribution marketing, promotion and copyright protection of music (Harrison, 2008: ch.8). Moreover, they controlled the distribution channels of pre-recorded music; in other words, they decided which recording media, artists and music genres to promote and distribute (Richard, 2000: p.428). This is particularly important because this central role of music labels in the recording music business has been maintained at least until the end of the twentieth century, when several phenomena, such as the rise of digital compressed music, the diffusion of the Internet and the launch of DAPs, changed the way music is consumed and distributed, as well as the role of music labels[16] (Graham, *et al.*, 2004).

In parallel with these changes in the music industry, both the reproduction equipment and media experienced significant technical improvements, especially after the Second World War (Garofalo, 1999). Although accounting for the technical competition in disc record technology is not a primary purpose of this chapter, the main idea is that the industry experienced a process of innovation and standardisation. First of all, the quality of the music recorded increased over time, with many innovations that improved both sound recording and playback, such as high fidelity monaural reproduction, followed by stereo sound (Chanan, 1995: p.8). In addition, the industry, in which several product designs of disc records had been coexisting for a long time, eventually converged towards standardisation in terms of material, disc size and rotational speed. The material that became the standard was vinyl plastic, which could ensure a higher level of robustness compared to the previous materials. Regarding size and rotational speed, the early discs were produced in a variety of sizes and speeds. One of the rotational speeds that became very common in the early stages was the 78 rpm (revolutions per minute) disc. However, the standards that eventually became predominant were two: the LP (long play), a 12-inch disc rotating at 33 1/3 rpm, and the *single*, a seven-inch disc rotating at 45 rpm (Garofalo, 1999: p.334).

Thanks also to the emergence of new music genres, such as rock and roll, the 1950s represented the take-off of the disc record market, with record sales revenues increasing from US$213 million in 1954 to US$603 million in 1959 (Garofalo, 1999: p.336). During the same period, another medium for music recording was introduced in coexistence with vinyl discs; this was magnetic tape cassettes (Haupert 2006).

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[16] The transformation in the music industry supply chain will be described in more detail in Section 3.3.2

3.1.2. Tape recording and the first portable music players

Similar to the very early stages of recorded music, the next major evolution in the history of the recording industry, the magnetic tape cassette, may also be related to prior technological developments, in particular to the introduction of magnetic tape recording. The first approaches to magnetic recording date back to 1898, thanks to the patent of the Danish engineer Valdemar Poulsen. However, the first magnetic recording device was introduced in Germany in the 1930s: the German magnetophone, developed by Telefunken and BASF (Garofalo, 1999: p.333). One of the first applications of this technology was during the Second World War in Germany, when it was used to facilitate propaganda broadcasts (Garofalo, 1999). Other developments occurred after the war in the US, particularly thanks to the progress made by companies such as the Minnesota Mining and Manufacturing (3M) corporation, and a small Californian company called Ampex (Chanan, 1995: p.97).

Magnetic tape had some advantages over disc recording. First of all, the recording equipment was much less expensive than in the case of discs, which also allowed the entry of much smaller firms into the market (Garofalo, 1999: p.333). Moreover, the magnetic tape was much more versatile. It could be recorded, erased and re-recorded many times. Editing was also made easier by simply physically cutting the tape and re-joining it.

The original format for this kind of recording was the reel-to-reel tape, with pre-recorded reel-to-reel tapes starting to be sold around 1954 (Holmes, 2006: p.188). Among the shortcomings of reel-to-reel tapes was that the tape had to be directly handled by the user, and the size of the reels was relatively large. For these reasons, other product designs were developed in which the tape was safely enclosed in a plastic box (Holmes, 2006: p.188). This is the case, for example, of the 8-track tape, which was popular in the US during the 1960s and 1970s, especially in automobile music systems, but also in home players (Shepherd, 2003: p.510). The success of this product was mainly due to its portability, the presence of a cartridge protecting the tape, and to the fact that 8-tracks allowed more *entry points*, making it easier to search for content on the tape. The format that eventually emerged as the dominant design for magnetic tape recording was the compact cassette, introduced by Philips in 1963. One of the reasons why the cassette rapidly gained popularity was because of Philips' decision not to protect it as a proprietary technology (Haupert, 2006: p.85). Regarding the quality of sound, one of the shortcomings of the first cassette tapes was the hiss produced during recording. This problem was addressed by Dolby Laboratories, which developed a method (Dolby A) to reduce noise for recording studios in 1966, as well as another system (Dolby B) two years later that helped to produce high fidelity cassette tapes (Haupert, 2006: p.82). Pre-recorded music cassettes (launched in late 1965) soon largely replaced pre-recorded reel-to-reel and 8-track tape cartridges for the consumer market. However, they did not displace the reel-to-reel at the professional recording level (Holmes, 2006: p.43).

On the consumer side, cassette tapes significantly extended music consumption habits. Consumers could buy pre-recorded cassettes, but also, since they were recordable, they could create their own compilations by copying music from a vinyl disc, from another cassette or from the radio. This was possible also thanks to the diffusion of home stereo systems, which combined disc players, cassette decks and radio players. One of the most important consequences of the introduction of cassette tapes, especially considering the purpose of this thesis, is that their small size made it possible to launch the first portable player of recorded music, the Walkman,[17] which was introduced by Sony[18] in 1979 (Sanderson and Uzumeri, 1995).

The Walkman was not the first *mobile* use of cassettes. First of all, cassette tapes could be transported from one stereo system to another. Moreover, automobile music systems are, to a certain extent, portable music players. Boomboxes could also play cassettes and were to a certain extent transportable, but not so easily portable (Bull, 2007). However, the Sony Walkman, together with its numerous imitations and improvements, was the first music player of recorded music that was fully portable[19] as a standalone device, and thus represented a true revolution for portable music listening (Sanderson and Uzumeri, 1995).

One of the most revolutionary characteristics of Sony's Walkman was its size. The Walkman was only a little larger than the cassette tape itself. Although it was still not shirt pocket-sized, it was lightweight and could easily be carried in a bag or hung on a belt (Haupert, 2006: p.85). Moreover, another innovative characteristic of the Walkman was the lightweight headphones that allowed faithful sound reproduction

[17] Walkman is a Sony trademark, branding several portable music players, including cassette, CD, Minidisc and MP3 players. However, in this thesis, the term Walkman will exclusively refer to Sony's cassette player, and, in many cases, it will be used to identify the entire category of portable cassette players.

[18] Although the first portable cassette player was patented in Germany in 1977, the first one commercialised was Sony's Walkman. (Source: New York Times: Portable stereo's creator got his due, eventually; http://www.nytimes.com/2005/12/16/world/americas/16iht-profile.html ?_ r=1; last accessed 27/01/2011).

[19] By portable we mean 'wearable' in the sense expressed in footnote number 12.

(Shaw 2008: p.140). The Walkman, thanks to its portability and the use of headphones, represented the first step towards mobile music listening, allowing users to literally *walk* with music anytime and anywhere. It was also a great commercial success, eventually selling 340 million units (Levy, 2006: p.127, cited by Shaw 2008: p.140).

The success of cassette tapes and players (both portable and not) was certainly related to the fact that cassettes were very versatile and recordable. However, one of the key factors was the availability of a large range of pre-recorded cassettes in the market, which depended, as was the case with discs, on the fact that music labels had adopted them as a medium for music distribution. Moreover, it is important to point out that despite the success of cassette tapes, especially in the 1980s, they did not displace the sales of vinyl discs. Both recording media were present in the market for many years, and they also coexisted for a long time with the new digital standard: the compact disc.

3.1.3. The emergence of digital music

After the changes to music recording brought about by the advent of tape recording (notably the launch of the first portable music players), at the beginning of the 1980s the sector experienced another period of change, again led by innovations on the technological side. This was the transition from analogue to digital recording.

Analogue recording means that sound waves are stored on a medium as a continuous signal (one that varies according to the frequency and amplitude of the original sound that was recorded). All the recording media mentioned so far were analogue. Digital recording is another way in which music can be recorded, stored and reproduced. The main characteristic of digital recording is that sound is represented by a sequence of binary signals; the continuous analogue sound is converted into a sequence of discrete numbers through ‘sampling’ (recording frequency and amplitude at discrete, albeit very short, intervals of time), which has in turn to be reconverted into a continuous waveform in order to be heard (Pohlmann, 1992).

The Compact Disc

The first digital audio recorders and players were developed in the 1960s in Japan, where NHK in 1967 and Sony in 1969 presented the prototypes of early digital recorders for the first time (Pohlmann, 1992: ch.1). Other experiments regarded, for example, the prototype of a glass disc that permitted the projection of images and videos, developed by Philips in 1970, and a large-diameter optical audio disc experimented with by Sony in 1976 (Pohlmann, 1992: ch.1). The medium that eventually emerged as the dominant design for digital audio recording was the Compact Disc (CD). The standard for audio CDs, the so-called Red Book standard, was released jointly in 1980 by Sony and Philips, with audio CDs commercially launched in October 1982.

More recently, the CD has been employed to store many different kinds of data. However, the first application of CDs was the storage of digital audio. The capacity of a standard audio CD was 74 minutes of uncompressed audio, later increasing to 80 minutes and eventually reaching up to 99 minutes of playing time. Regarding sound fidelity, there is little difference between digital and analogue media sound quality; both are able to achieve excellent sound fidelity with the appropriate audio systems.[20] The main difference is that sound quality is much easier to preserve with digital media (such as the CD) than with analogue media (such as the vinyl LP) (Peek *et al.*, 2009: p.60). This is because vinyl LPs had to be handled very carefully in order to preserve their quality, while the audio signal data stored in a CD is protected by a transparent layer that shields it from scratches and dust. One of the main advantages of the CD was in fact its robustness; the fact that CD playback did not involve any physical contact or friction, unlike in the case of compact cassettes and vinyl records, ensured that the disc would not wear out due to playback (Holmes, 2006: p.86). In addition to this, digital recording also permits the use of techniques, such as error correction, to improve the reliability of the sound stored in the digital medium (Pohlmann, 1992: p.7).

Although experiencing only a slow diffusion at the beginning, probably due to the high cost of the early hardware equipment, and also to the fact that CDs were more highly-priced than LPs (Garofalo, 1999: p.344), CDs encountered considerable success, and gradually displaced the sales of cassette tapes and vinyl records. Another reason for the success of CDs was that the supply of pre-recorded CDs did not just involve new albums, but also already-published LPs and tapes, creating a market for replacement (Kusek and Leonhard, 2005: p.82). However, the advent of CDs did not mean an immediate abandonment of analogue musical recording and playback; the three media (vinyl discs, cassettes and CDs) co-existed in the market for several years. The sales of vinyl records had reached their peak in 1978 (942 million units) and were already declining when the CD was introduced. World sales of CDs increased from five million in 1983 to 400 million in 1988, when CD sales surpassed vinyl record sales; the vinyl

[20] Even though some music enthusiasts claim that there are some qualities of analogue audio that are not captured by digital recording (Holmes, 2006: p.54).

disc standard was finally displaced in 1996, when only 20 million vinyl LPs were produced (Shepherd, 2003: p.508). The displacement of cassette tapes by CDs took longer. The cassette market continued to grow until 1992 when sales reached their peak of 1,552 million. In 1996 the sales of cassettes were 1,380 million, compared to those of CDs, which were 2,136 million (Shepherd, 2003: p.508). This persistence of cassettes may reflect the *installed base* of cassette players, which were prevalent not only in portable applications, such as the Walkman, but also in home and automobile stereos.

However, music represented only one potential application of the new format, since CDs have also been applied to several other uses. CD-ROM was introduced, again by Philips and Sony, in 1985 (the Yellow Book standard) as a format that could incorporate any kind of digital data, such as documents, databases and software.[21] CD-I (CD-Interactive) and CD-V (CD-Video) are (among others) two specific applications of CD-ROM, the first able to combine audio, video graphics and text, while the second could be used to play videos (Pohlmann, 1992: ch.6).

A potential disadvantage of CDs over cassettes was that CDs were initially not recordable.[22] This weakness was solved by the introduction of two recordable CD formats. The first was the CD-Recordable (CD-R), which could be recorded only once, and which was introduced in 1988. More recently, in 1997, the CD-ReWritable (CD-RW) was able to be recorded, erased and re-recorded several times (Pohlmann, 1992: ch.6). CD-R and CD-RW could be formatted to store both audio and data. However, the operation was not very straightforward, since writing audio or data onto these types of CDs needed special equipment called a CD recorder (or CD burner).[23] Moreover, CD recorders were initially rarely used in home stereo systems, because they were not fast enough to allow real time recording. CD recorders for PCs were too expensive for non-professional use until the mid-1990s, when the first CD recorder under US$1000 was released by HP.[24]

On the consumer side, the CD did not only offer a safe and robust medium for high-quality music, but also offered some new possibilities to users. The first was a very high amount of storage space. In 1985, when the CD-ROM was introduced, the hard drives

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[21] http://en.wikipedia.org/wiki/Compact_disc.
[22] As indicated by the CD-ROM acronym itself: Compact Disc – Read Only Memory.
[23] In addition, not all the commercially available CD players could play CD-RWs (Holmes, 2006: p.44).
[24] Roxio: History of CD recording; see Web Archive (http://web.archive.org) capture of the 8 February 2001 version of the site: http://www.roxio.com/en/support/cdr/historycdr.html; last accessed 20/09/2011.

for PCs did not exceed 23MB,[25] while the CD-ROM could store the equivalent of 650MB. Another innovation for consumers brought about by CDs was the possibility to create, with suitable equipment, an exact copy of the content of an audio CD (or CD-ROM) without having any quality loss, as was the case for compact cassettes. Moreover, users did not have to wait for a long time in order to have their first portable digital player. Sony confirmed its primary role in the market of portable music devices by launching in 1984 the first portable CD player, the Discman (or CD Walkman).[26] Portable CD players, with appropriate headsets, ensured a higher sound quality than cassettes, and a portability level comparable with the previous cassette players. However, the portable CD player did not achieve the same success as the portable cassette player. One of the reasons may be related to the relatively cumbersome method required for users to produce their own programming (they must use a computer system equipped with a CD burner rather than a home stereo) compared to the more straightforward way in which users could record their own cassette tapes. Moreover, some other issues also limited the portability of CD players (Smith, 2002: p.880). Portable CD players were in fact initially inferior to portable cassette players, at least in some applications such as listening to music while jogging, because vibrations could make the laser reader skip tracks. This problem was solved in some later portable CD players featuring ESP (Electronic Skip Protection), a memory buffer pre-reading some seconds of music from the CD and preventing CD skipping when the players was shaken.[27]

On the business side, the technological advancements brought first by cassette tapes and then by CDs did not significantly change the music industry's structure. Throughout this period, the distinction (noted above) between the producers of technology and the labels, as the publishers of pre-recorded music, persisted.[28] The music labels kept strict control over the methods of music recording and distribution (Richard, 2000: p.428), and from the 1980s a process of consolidation and concentration started, with the result that in the early years of the first decade of the twenty-first century, only four companies, the so-called *big four*, EMI, Sony, UMG and WMG,[29] controlled between 85 and 90% of the market (Graham *et al.*, 2004; Garofalo,

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[25] http://ns1758.ca/winch/winchest.html; last accessed 11/09/2011.
[26] Sony Celebrates Walkman's 20th Anniversary; http://www.sony.net/SonyInfo/News/Press_Archive/199907/99-059/; last accessed 27/01/2011.
[27] http://en.wikipedia.org/wiki/Electronic_skip_protection; last accessed 11/09/2011.
[28] With the notable exception of Sony that was both an equipment manufacturer and (initially through acquisition of CBS records) one of the major music labels.
[29] In the 1980s these companies were six: EMI (Electrical and Musical Industries), CBS (Columbia Broadcasting Systems), BMG (Bertelsmann Music Group), PolyGram, WEA (Warner Elektra Atlantic) and MCA (Music Corporation of America). The *big six* then became the *big five*

1999). This tight control of music labels over the distribution channels of recorded music became unstable when a series of concomitant factors allowed users to obtain a large quantity of music (without respecting copyright), bypassing the ordinary distribution channels (this issue will be examined further in Section 3.3)

Other portable digital music players

Once the CD became the undisputedly dominant design for digital audio storage, the next step of digital music development was the attempt to store a greater amount of music on storage media. This was initially motivated by the cost and limited capacity of solid state memory, and these constraints as well as lack of portability for hard disk drives. The result was a collection of new storage media types: the Digital Audio Tape (DAT), the Digital Compact Cassette (DCC) and the Minidisc (MD) (Rohlfs, 2001: p.99-103). The first storage media, DAT, employed magnetic tape similar to a compact cassette (but with a smaller size), which could record digital audio rather than analogue. DAT was launched by Sony in 1987. DATs had a capacity of up to 180 minutes of uncompressed music, with the same sound quality as a CD. However, DATs never attained market success, being used almost solely in professional and semi-professional markets (Holmes, 2006: p.68). The second format was DCC, launched in 1992, representing the response of Philips and Matsushita to DAT. DCC, similar to DAT, was a magnetic tape able to record digital music. DCCs had the same size as previous analogue cassettes, meaning that the new DCC players and recorders were backwards compatible with the previous standard. In this case, some portable players were also developed and launched for the consumer market (Rohlfs, 2001: p.101). The last format was the Minidisc (MD), launched by Sony in 1992. In terms of usability, MDs were simpler and cheaper than Sony's DAT, and more able to compete with DCC. The main difference between MD and the other two formats was that MD used a magneto-optical disc to store music instead of a tape (Peek *et al.*, 2009: p.151).

A novelty of both DCC and MD was that they used digital audio compression, while the DAT used an uncompressed digital format (like CDs' PCM encoding). This meant that while DAT copies had exactly the same quality as a CD, the music stored on DCCs and MDs was of slightly lower quality, although, according to the producers, this lower

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when Sony Music acquired CBS in 1987, and eventually the *big four* when Sony Music acquired BMG in 2004. Moreover, through other mergers and acquisitions, WEA became WMG (Warner Music Group) and MCA became UMG (Universal Music Group). It is interesting that two of these companies stem from the very early pioneers in the recording music industry: CBS from Columbia Phonograph, and BMG from Victor Talking Machine Company (through the acquisition of RCA, Radio Corporation of America, which previously acquired Victor in 1929).

quality was imperceptible to human hearing.[30] In 1994, Sony introduced the Hi-MD, a newer version of the MD that offered the possibility of storing uncompressed audio (CD quality). However, the most innovative capability of Hi-MD was the possibility to accommodate both data and audio in the same disc, raising its capacity to 1GB and transforming the Hi-MD into a general-purpose storage medium. Another innovation brought about by these new formats was a certain degree of flexibility that previous digital media, like CDs, did not allow. MD players allowed users to edit, combine, move and delete music even when using portable devices. They also had the capability to store a song's artist name and title. Moreover, some of these portable devices started to be able to interface with computers, making it possible for the first time to organise music and create personalised playlists. Philips provided DCC with the possibility of connecting to a PC using a link cable. This capability was offered in 1995. However, it was available with only one particular player, the DCC-175, which was not available outside the Netherlands.[31] Some models of the MD could also be connected to a PC, allowing editing and combining music (for instance by using SonicStage, Sony's proprietary PC-based software).

However, these new products failed to succeed. DCCs were discontinued in 1996. MDs never encountered a worldwide success, as in the case of its predecessors such as audio cassettes and CDs. It only partially diffused in Japan, where Sony has a loyal customer base. One explanation for this failure is that only few pre-recorded albums were available in DCC and MD formats. Another potential reason was that during the 1990s many innovations diffused, such as computers with more powerful CPUs, CD-ROM players and CD-R recorders, bigger hard drives and faster Internet connections. Moreover, very powerful audio compression codecs (such as the MP3 in 1993) were introduced. Users started to convert their CD collections to the MP3 format, and also to share these MP3 files over the Internet. All these innovations made it possible to treat digital music not just as a feature of CD players, but as a computer file, which could be stored in different kinds of digital memory devices, edited and manipulated, making it possible to separate the music from its physical storage medium, a practice that is called format shifting. This was the prelude to the DAP era.

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[30] DCC used a codec called PASC (Precision Adaptive Sub-banding Coding), based on MPEG-1 Audio layer I (MP1), with a compression ratio of around 4:1; MD used Sony's proprietary codec, ATRAC (Adaptive Transform Acoustic Coding), allowing a compression of around 5:1.
[31] http://en.wikipedia.org/wiki/DCC; last accessed 30/11/2010.

3.2. The advent of DAPs[32]

3.2.1. The rise of digital audio compression: the MP3 encoding format

The advent of DAPs started with the introduction of technologies of digital audio compression (audio codecs).[33] An audio compression codec is a program that is able to process an uncompressed digital audio track (e.g. a Red Book standard encoded PCM CD track) according to a given compressing algorithm, and to output a file with a smaller size than the original one. There are two types of compression codecs: lossless and lossy. A lossless compression is an algorithm able to reduce the size of an audio file without compromising its quality. In other words, an audio file with lossless compression could always be expanded to an exact copy of the original file. This kind of compression is almost always unable to reduce file sizes as dramatically as lossy methods. Lossy audio compression involves a trade-off between the reduction in required storage space and audio quality. In other words, the quality of the compressed audio file is reduced in order to achieve a substantial size reduction. These kinds of compression methods were designed using knowledge gained from the field of psychoacoustics, the study of sound perception. Thus, although the reproduced signal uses less information, it is difficult or impossible for humans to perceive a difference in sound quality.[34]

Before the introduction of these codecs, users could still copy the digital content of audio CDs onto internal hard drives as WAV files.[35] However, this operation was quite costly, as it required hard drives with considerable capacity. In addition, WAV files were still too big to be quickly transferred online. For these reasons, during the 1990s a number of audio compression codecs were introduced. However, one of them, the MP3, soon became a standard for audio compression, giving its name to the entire category

[32] This section is partially based on the insights drawn from the exploration of an original dataset collected for the purpose of this thesis, described in detail in Chapters 4 and 5.
[33] The invention of compression codecs that took place during the 1990s was very timely, especially considering that the then-current hard drive sizes and Internet connection speeds were limiting the use and transfer of digital music. In fact, the increase in hard drive sizes (and the drop in their price) and the diffusion of much faster Internet connections that was experienced in the following years would eventually have allowed users to rip their music onto their computers and portable players and transfer it online without needing any compression codec. For these reasons we can say that the invention of compression codecs has most probably influenced the timing of the introduction of DAPs, but probably not determined their existence.
[34] Fraunhofer Institut, 20 Years of Audio Coding; http://www.iis.fraunhofer.de/en/Images/AUDIO_fest_low_tcm183-35355.pdf; last accessed 13/09/2011.
[35] WAV or WAVE (Waveform Audio File Format) is a common standard for converting the digital music on CDs (stored as defined by the Red Book) to a format readable by personal computers. Another similar encoding format is AIFF (Audio Interchange File Format), mostly used in Amiga and MAC computers.

of devices able to read compressed audio files (Holmes, 2006). MP3 is the abbreviation of MPEG-1 Audio Layer 3, and is a digital audio codec developed by MPEG that was adopted by ISO/IEC[36] in 1991 and then published in 1993, becoming an international standard. The Moving Picture Experts Group (MPEG) is a working group of experts established by ISO and IEC in 1988 with the specific purpose of developing standards for audio and video encoding.[37] The expert group was formed by members from industry, universities and research institutions, and worked on some international standards that become very widespread, such as MPEG-1 (the encoding used for Video CDs) and MPEG-2 (used for Digital TV and DVD Video). An MPEG standard contains several encoding algorithms for both audio and video. MP3 is one of the audio codecs included in MPEG-1, and also used in the more recent MPEG-2 standard. MP3 allowed for the considerable compression of digital audio, achieving a compression ratio of 10:1 or even 12:1 (depending on the bitrate) without a discernable reduction in the human perception of musical quality.

Although MP3 is an ISO international standard whose technical features are published, the use of this standard requires a license that provides access to patents underlying the standard. The MPEG sub-group engaged in the development of audio codecs (including the MP3) was formed by several engineers from different public and private organisations, such as AT&T, Thomson and the Fraunhofer Society. In particular, the latter has had a prominent role in the development of the standard, and holds some key patents regarding MP3s.[38] More recently, the Fraunhofer Society joined its patents with those of Technicolor (formerly Thomson) and started to ask for royalties for the use of their MP3 patent portfolio. As such, since 1998, MP3 is licensed to developers and manufacturers of software applications and hardware devices, while private, non-commercial users are not required to pay any royalties for the use of MP3 codec.[39]

The main consequence of the introduction of the MP3 was that it rapidly became a *de facto* standard for home audio encoding (Holmes, 2006: p.203). In 1994, the Fraunhofer Society released *l3enc*, the first MP3 encoding software, allowing users to encode their own MP3 files and listen to them using their PCs.[40] Moreover, in the same period, new computers were equipped with more powerful CPUs, which allowed music

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[36] ISO is the International Organisation for Standardisation, while IEC is the International Electrotechnical Commission.
[37] http://en.wikipedia.org/wiki/MP3; last accessed 26/10/2010.
[38] http://www.mp3-tech.org/patents.html; last accessed 15/04/11.
[39] http://www.mp3licensing.com; last accessed 15/04/11. This is the official website providing information on MP3 licensing by Technicolor and the Fraunhofer Society.
[40] http://en.wikipedia.org/wiki/MP3; last accessed 26/10/2010.

from a CD to be converted into MP3 files in seconds, instead of minutes. Digital audio allowed audio tracks to be treated as simple data files; audio compression contributed to making them more manageable, more easily storable and transmittable through the Internet. Bigger hard drives allowed the storage of many MP3 files, allowing users to create large music libraries by converting entire collections of CDs into MP3 files. To manage these files, systems of *tags*[41] were developed that could be added as metadata to each MP3 file (O'Hara and Brown, 2006: p.59, 116). Tag metadata might include the artist name, title, album, track number and so on. These tags made it very simple to organise even large collections of music, and made such collections easily searchable. Software able to reproduce MP3 files (such as Winamp), or able to organise music libraries (such as Musicmatch Jukebox) become popular. At the same time, Internet broadband connections were diffusing rapidly. New Internet applications allowed users not just to download music, but also to share their personal music library with all other members of a community. This was the case of Napster and a multitude of other *peer-to-peer* (P2P) applications.[42]

3.2.2. The early stages

The success of the MP3 format for home applications at the end of the 1990s was remarkable, immediately preceding the launch of portable MP3 players. MPEG standards enabled the MP3 device market because the encoder is more complex than the decoder. This means that while the encoding of video or audio can take a significant amount of time and greater computational resources, the decoding is much more immediate and requires less powerful CPUs.[43] Thus, the MP3 standard was suitable for the design of portable players where only modest computational power would be available.

Regarding the reproducing equipment, initially CD players did not have the capacity to play MP3 encoded files. Later models of CD players were able to reproduce MP3 files (MP3-CD). However, at that time, the only way to acquire recorded music in a digital format was by buying a CD. This meant that users had to create their own compilations of MP3 files, burn them onto recordable CDs (CD-R or CD-RW) and play them using compatible CD players.[44] The media used by this kind of player were in fact CD-ROMs,

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[41] Although the MP3 format does not define any specific tag, other standards for tags rapidly diffused, such as ID3v1 and ID3v2.

[42] P2P file sharing will be presented in more detail in Section 3.3.1.

[43] http://en.wikipedia.org/wiki/Mpeg; last accessed 02/12/2010.

[44] In any case, only a limited number of this kind of player was launched; for instance, CNET.com has reviewed only 27 portable MP3-CD players (Source: http://reviews.cnet.com/cd-

on which MP3 files were saved as data files. In this way, a single CD could include much more music.[45] In any case, this kind of player encountered only a limited success, most probably due to the advent of the first DAPs.

It is true that these CD players compatible with MP3s and Sony's MD players could be considered portable players of digital audio. However, one of the major developments brought about by audio compression was the freeing of music from any specific storage medium. In other words, now songs could be stored in every kind of memory, such as a hard drive or a flash memory. For this reason, the term digital audio player (or MP3 player[46]) is most commonly used to describe a portable device able play compressed digital audio files that are stored on an internal memory, without referring to any specific medium (Holmes, 2006: p.75). According to this definition of a DAP, which will be the one adopted for the purpose of this thesis, MP3-CD and MD players are only considered precursors of DAPs, because they are both linked to a specific storage medium and those media are external to the device.

DAPs can be classified into several categories: flash players, hard drive (HD) players and Microdrive players, depending on the storage medium they use. Flash players are usually small and lightweight devices, but a with limited storage space, while HD players are generally bigger and heavier, but with a much higher storage capacity. The last group of DAPs used a Microdrive, a branded variety of hard drive with a very compact size, which was used to produce DAPs more similar in size to flash-based players. Microdrive players only achieved a limited use, since flash memories quickly overtook Microdrives' capacity, making them economically obsolete for DAPs.[47]

In general, although some highly miniaturised MP3 players do not have a display, DAPs are usually equipped with a screen (at the beginning monochromatic, then with colour). The DAP's display allows for browsing the music library stored in the internal memory, and selecting songs to play. MP3 players are generally able to read metadata contained in the MP3 files' tags, showing the artist name, song title and other

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mp3-players/; last accessed; 13/09/2011).

[45] While an ordinary music CD cannot contain more than 15/18 tracks, a CD-ROM can store up to 200 MP3 files (depending on songs' length and encoding bitrate).

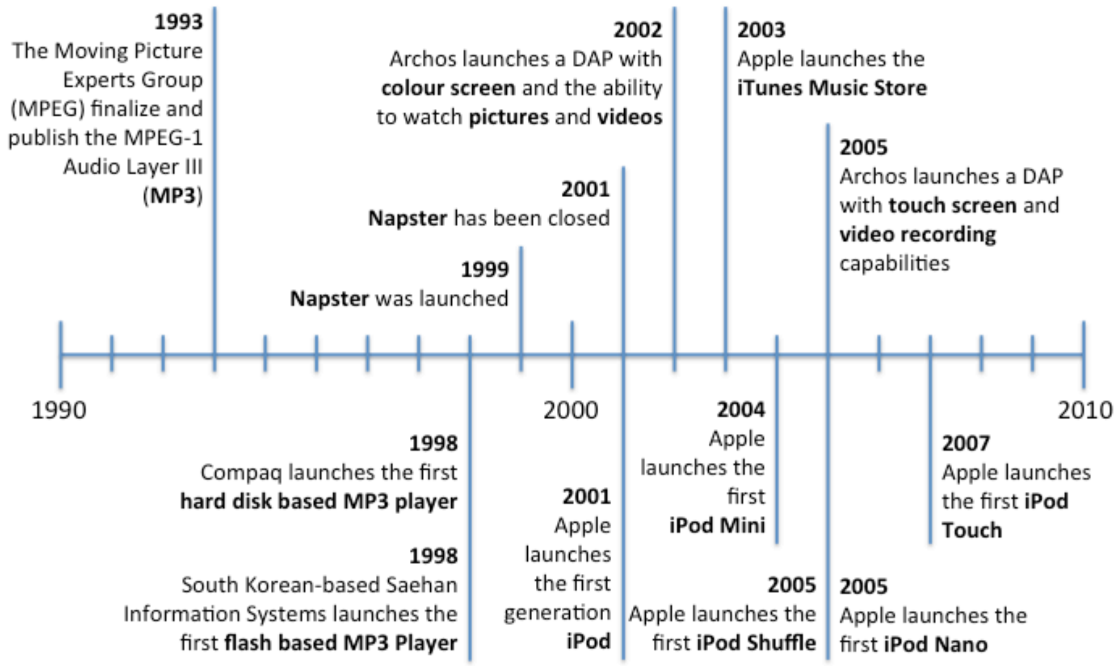
[46] Although we recognise that there is a difference between the terms 'digital audio player' and 'MP3 player', for simplicity, they will be used as synonyms in this thesis.

[47] Microdrive is a registered trademark by IBM and Hitachi. The first Microdrive was released by IBM in 1999. This kind of product is a hard disk with such a miniaturised size that it could fit into a flash memory slot (CompactFlash, CF Type II slot). The first series of Microdrives had a storage space of 170MB, reaching up to 8GB in 2005 (Source: http://hjreggel.org/hdtechdat/hd-micro.html; last accessed; 11/09/2011).

information during playback.

The history of DAPs begins around the end of the 1990s (some of the major events in the evolution of DAPs are depicted in Figure 3.1), when some companies started to patent inventions regarding MP3 players or announce the launch of new products. In any case, the first MP3 player available was the MPMan created by the South Korean company SaeHan[48] in 1998, followed by the Rio PMP300 launched by Diamond Multimedia (a US-based company) a few months later (Knopper, 2009, p: 166). Both players were equipped with a 32MB flash memory, therefore providing a very limited space for storing MP3 files (not more than ten or 12 songs). A potential solution to this lack of storage space was to use a hard drive as memory for DAPs. In 1998, Compaq used a 2.5" laptop hard disk to create the first hard drive-based DAP (Knopper 2009), the Personal Jukebox (PJB-100), manufactured under license by HanGo Electronics. This player had a 4.8GB hard drive, making it possible to store more than 1000 songs. In 2000, Creative launched the Nomad Jukebox, equipped with a 6GB hard drive. These hard drive-based DAPs addressed the issue of limited storage space of the first flash players; however, they had the disadvantage of being heavy and quite slow in loading the MP3 files (Knopper, 2009: p.167).

Figure 3.1 Major events regarding the evolution of DAPs



In fact, the first DAPs suffered from at least three issues. (Knopper, 2009; Kahney,

[48] The MPMan was distributed in North America by Eiger Labs under the name MPMan F10. The company SaeHan Information System was acquired by iRiver in 2004.

2005). First of all, they had limited storage capacity. At this point, flash memories still had limited storage space, while 2.5” hard drives (the same drives usually installed in laptops) could store much more music, but were bulky and heavy, limiting the portability of the DAPs. Secondly, the first MP3 players had slow music loading speeds. Aside from the very first models equipped with parallel links, most of the players had a USB 1.1[49] connection cable. This type of connection was fast enough for flash players containing only a few songs, but was inconveniently slow when filling a 5 or 6GB hard drive. Thirdly, these first players were still not very user-friendly. In particular, the user interface was not very easy to use, and also the software to organise music and load it onto the player was still at a very early stage (Kahney, 2005).

3.2.3. Apple’s iPod

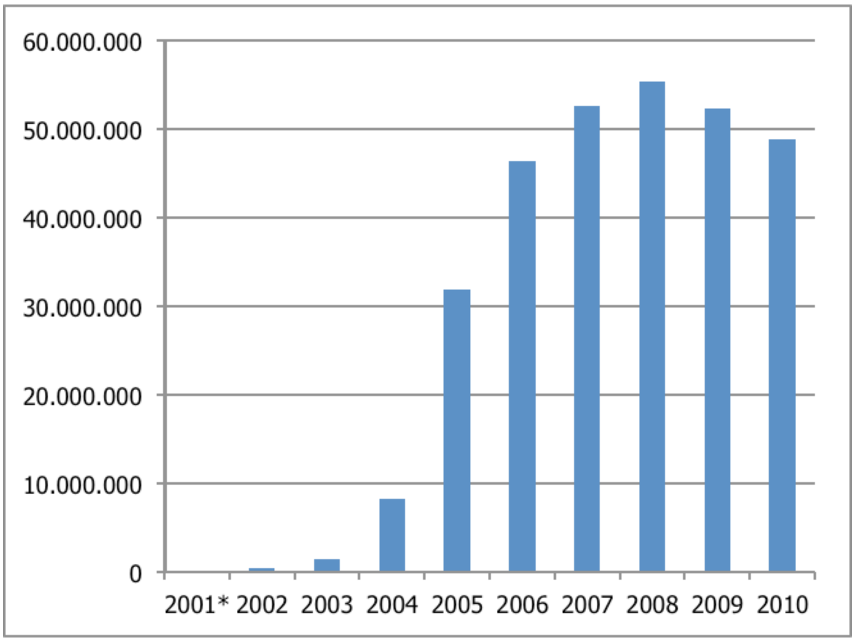
In October 2001, Apple entered into the MP3 players market by launching its first iPod.[50] The original iPod was only the first of a long series of MP3 players that the Cupertino company launched, and which eventually allowed Apple to take over the DAP market. With this product, Apple attempted to provide a response to each of the above-mentioned issues that early DAPs were facing. One of the major advantages of the first Apple iPod was the storage medium. Apple used a Toshiba 1.8” hard drive with 5GB storage space. This drive was significantly smaller than the hard drives used in the other DAPs (usually a laptop 2.5” hard drive), making the iPod much smaller than competitors’ HD players (Knopper, 2009: p.167). In addition, Apple signed an exclusive deal with Toshiba, preventing competitors from using the same technology (Knopper, 2009: p.168). This hard drive could be used to store both audio and data files, potentially making the iPod also a backup device. Regarding the transfer speed, Apple opted for a FireWire[51] connection, which was much faster than parallel and USB 1.1. All the MACs sold in that period were equipped with a FireWire port; in addition, the FireWire cable was used to recharge the iPod’s battery. The iPod was also equipped with quite a large screen for the time, and with a very intuitive user interface based on a mechanical scroll wheel. The software that connected Apple’s iPod to MAC computers was iTunes. Thanks to iTunes, users were able to organise and manage their music libraries. The iTunes software was also the only way to load music onto the iPod. The origins of the iTunes software derive from the fact that the first Diamond Rio player

[49] Universal Serial Bus (USB) 1.1 was released in 1998 with a theoretical data transfer rate of 12 Mbit/s.
[50] http://www.apple.com/pr/library/2001/10/23Apple-Presents-iPod.html; last accessed 26/10/2010.
[51] FireWire is Apple’s brand name for IEEE 1394 serial bus interface standard. The first FireWire standard was released in 1995 with a theoretical data transfer rate of up to 400 Mbit/s.

was not compatible with the MAC operating system; therefore some programmers developed Sound Jam software to allow MAC users to organise their music and load it onto the MP3 player. Apple bought Sound Jam, which eventually transformed into iTunes. (Knopper, 2009: p.167).

Apple's iPod was certainly a highly innovative and ground-breaking product (Kahney, 2005: p.39). It was small, compact, with an appealing design and easy to use. However, at the beginning, Apple's market was still limited, since it was quite highly priced (US$399), and not compatible with Windows-based PCs (Knopper, 2009: p.171); the first version of iTunes was only MAC compatible. Moreover, in that period, FireWire connections were mostly used to transfer video streams recorded with portable camcorders, and these connections were not available in many Windows based PCs.

Figure 3.2 iPod sales chart (unit sold by year)



*Note: * Only Oct-Dec. Source: Apple Inc. Press Releases (http://en.wikipedia.org/wiki/File:Ipod_sales_per_quarter.svg; last accessed 27/01/2011).*

Following the first iPod, Apple released several improved versions of its DAP. While the initial device had an electro-mechanical scroll wheel, later releases employed a touch pad scroll wheel. The iPod was then made compatible with the Windows operating system, first in 2002 through the software Musicmatch, and then in 2003 through the launch of iTunes 4.1 for Windows.[52] In addition, the release of the USB 2.0[53] standard

[52] http://www.pcworld.com/article/113336/itunes_forces_windows_users_to_choose.html; http://www.pcworld.com/article/112968/itunes_comes_to_windows.html; last accessed 13/09/2011.

made FireWire unnecessary. For this reason, Apple started selling iPods equipped with both cables, with USB 2.0 eventually substituting FireWire connection for most users.

Apple dedicated a relatively small budget to the promotion of the iPod, spending only US$25 million to promote the launch of the first iPod (Kahney, 2005: p.44). However, since 2001, iPod sales have increased steadily, as reported in Figure 3.2. Sales more than tripled in each of the two years following the iPod's introduction: 125,000 units sold in 2001 (although only from October-December), 470,000 in 2002 and 1,451,000 in 2003. One of the main forces driving the product's success was word-of-mouth, facilitated by the easy recognisability of the white iPod earbuds (an in-ear headphone), and also the constant attention that the media dedicated to the iPod (Kahney, 2005: p.44). A further major increase in sales occurred in 2004, when Apple launched its first iPod with a colour screen, photo display capability and up to 60GB of memory, and also started differentiating the production. In that year, Apple launched the first iPod Mini,[54] based on a Hitachi's 4GB Microdrive. This drive allowed an iPod model that was even more portable than the classic iPod, but with more storage capacity than flash-based players sold by competitors. The combined sales of the iPod Classic and the iPod Mini surpassed eight million units in 2004, contributing to making the iPod the market leader in the DAP sector.

However, Apple's innovative activity continued. In 2005, a new iPod with video capabilities and a memory of up to 80GB was launched, together with two additional models of iPods with flash memory. The first model was the iPod Shuffle,[55] a highly miniaturised player without a screen and with the shape of a USB memory stick. This player was the simplest and most portable device sold by Apple. The other product was the iPod Nano,[56] replacing the Mini, with a very slim size, colour screen and up to 4GB of storage space. Both the iPod Shuffle and the iPod Nano experienced great success, allowing Apple to sell almost 32 million iPods in 2005. After 2005, Apple periodically launched new versions of the iPod Nano, Classic and Shuffle, with new colours, redesigned aesthetics, new features and more storage space. Finally, in 2007 Apple launched another line of DAPs, the iPod Touch,[57] a player with a multi-touch screen that served as a user interface with another set of features, such as Wi-Fi connection, Internet browsing and games.

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[53] USB 2.0 was made available at the end of 2001 and has a theoretical data transfer rate of 480 Mbit/s.

[54] http://www.apple.com/pr/library/2004/01/06Apple-Introduces-iPod-mini.html.

[55] http://www.apple.com/pr/library/2005/01/11Apple-Introduces-iPod-shuffle.html.

[56] http://www.apple.com/pr/library/2005/09/07Apple-Introduces-iPod-nano.html.

[57] http://www.apple.com/pr/library/2007/09/05Apple-Unveils-iPod-touch.html

Certainly, one of the factors that has contributed to the iPod's success has been its seamless integration with the iTunes software (Kahney, 2005). iTunes evolved with the iPod, making it possible to load videos, share music within local networks, rip and burn CDs and so on. Moreover, since April 2003, iTunes has become a digital media online store,[58] selling legal music in digital format, and later also video content, such as movies and TV series episodes.[59] Figure 3.2 shows a slight decline in sales in 2009 and 2010. This may stem from two causes. First of all, in 2007 Apple launched its famous smart phone, the iPhone, sales of which are not reported in the iPod figures. This phone is also a DAP, and has possibly attracted some previous or potential iPod customers. Secondly, another possible cause may be related to the fact that even considering replacements, the diffusion process of DAPs (including iPods) was already reaching its final phase at this time, since most potential adopters had already purchased one.

3.2.4. Technical evolution of digital audio players

From a technical point of view, DAPs significantly improved during the first decade of the 2000s in two ways.[60] First, the technical characteristics of new DAP models improved, e.g. increased memory and reduced size. The main technical improvement of DAPs was in terms of storage space or memory. In this period, HD players gradually increased their capacity, reaching 320GB in 2008 (64 times bigger than the first 5GB hard drive player). Flash memories lagged behind for some years, but caught up rapidly. Early models of flash players had such a limited storage space that they might be more useful as voice recorders than as music players. Until 2004 the storage space of flash players was not more than 1GB; however, flash memory capacity increased dramatically around the end of the 2000s, reaching 64GB in 2009 (more than 2,000 times bigger than the first 32MB flash player). DAPs also became smaller and smaller. This trend mostly affected flash players, which, considering the very small size of a flash memory, were more suitable for miniaturisation. The use of more powerful and slimmer batteries also contributed to the development of more miniaturised models. In

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[58] http://www.apple.com/pr/library/2003/04/28Apple-Launches-the-iTunes-Music-Store .html.

[59] More recently, in July 2008, Apple launched the App Store. This service allows users to browse and download applications for the iPod Touch and iPhone from the iTunes Store; in some cases the download was free, in other cases it required a payment (Source: http://www.apple.com/pr/library/2008 /07/10iPhone-3G-on-Sale-Tomorrow.html).

[60] This section is mainly based on the analysis of the dataset on product characteristics that will be presented in Chapters 4 and 5. A more detailed analysis of the technical evolution of DAPs will be presented in Chapter 7.

addition, as noted previously, the vast majority of DAP producers gradually discontinued non-rechargeable batteries in favour of rechargeable lithium batteries.

Second, in addition to the main function of music playing, DAPs have been progressively equipped with an increasing number of additional features, starting with FM radio players or voice recorders. Following this, many more functions have been added, such as photo display, video playback, games, alarms/calendars and so on. Some of the features that were installed in early players, including early models of flash-based players, included voice recording, FM radio players and FM radio recorders. Visual features were added later, including the proliferation of colour displays. At the beginning of the 2000s, most DAPs had very small monochromatic screens, sometimes with only two to three lines of text. Early models with colour displays began to be offered in 2002; however, this feature was widely diffused only in the period 2004/2005. Together with colour displays, DAPs started to be equipped with several additional functions such as photo display and video playback (especially in the case of HD players that had a sufficiently large memory to store video files). In addition, some models have even been equipped with video cameras, making it possible to take pictures and record videos. Regarding the batteries, DAPs are generally low power consumption devices, since they do not require mechanical parts, in comparison to a CD player, which has to spin a CD in order to play it. This means that DAPs generally have a longer battery life. The main difference among DAPs regarding the battery is whether the player is equipped with a rechargeable battery or not. Some players initially used one or two AA or AAA batteries. In such cases, users could use both disposable batteries, which had to be substituted each time, and rechargeable batteries, which could be separately purchased by users and recharged with a separate charger. Other players used built-in rechargeable batteries (usually lithium polymers or lithium ions batteries). Over time, the number of players using disposable batteries, or those rechargeable only with separate chargers, gradually decreased; eventually all newly-launched DAPs came equipped with built-in rechargeable batteries.

Another feature that has achieved some success is audio and video podcasting.[61] A podcast is a series of audio or video files periodically released and centrally maintained on a distribution server. In general, podcasts are associated with a specific topic, author, TV or radio show, etc. Podcasts are distributed through the Internet usually

[61] The name 'podcast' derives from the combination of the words *pod* (from Apple's iPod) and broadcast. However, this naming could be misleading, since the use of podcasts is not limited to iPods; all computers and several portable devices can download and play podcasts (Source: http://en.wikipedia.org/wiki/Podcast; last access 14/10/2010).

using web feeds (such as RSS), and downloaded thanks to specific client application software (such as iTunes). This kind of software is able to automatically check for updates and download any new files in the series. Podcasts gained popularity in late 2004, also thanks to the diffusion of MP3 players. Once downloaded, the files can be stored on any computer or portable device, making their use particularly suitable for digital audio players.

At the end of the decade, there were further technical developments in the user interface, with the launch of some models controlled through sophisticated touch screens. In general, these kinds of product also had several other capabilities, such as Internet browsing and emailing through wireless connections, game playing and so on. In some cases, such as the Apple iPhone, these DAPs have been involved in a process of convergence taking place at the end of the 2000s, by which many consumer devices such as DAPs, photo and video cameras, mobile phones, portable gaming consoles, and so on were merging into a single device, the so-called *smart phone.*[62]

One last consideration regards the use of DAPs by final consumers. The use of DAPs is not as immediate as it was with previous portable players, such as cassette or CD players. In order to operate a DAP, a computer is needed. Software such as iTunes facilitates loading music onto the player; however, this operation still requires a certain degree of computer knowledge. Moreover, even downloading or exchanging music over the Internet requires having more expertise than the average user possesses. These considerations raise questions about why users decide to adopt these kinds of products and how they would be able to accommodate these innovative products in their lifestyles, which is one of the purposes of this thesis.

3.2.5. Competition in the digital audio players sector

Besides Apple, many companies have entered into the DAP business. CNET, a website specialising in reviewing consumer electronics, includes a specific section devoted to DAPs. Since 1999, CNET authors have reviewed a large number of MP3 players, listing about 80 different producers. However, none of them have achieved a volume of sales comparable with those of Apple.[63] These firms can be divided into two groups: incumbents and diversifying players.

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[62] Chapter 4 will explain why smart phones are not considered in the analysis carried out in this thesis.

[63] http://www.wired.com/gadgetlab/2009/09/apple-liveblog-999/; last accessed 12/09/2011.

The incumbents, such as Sony and Philips, are companies that had shaped the portable music player market for decades. However, they failed to maintain their leadership in the newly emerging market for DAPs. These companies reacted to the iPod's success, launching new products that were not distant from Apple in terms of price, characteristics, features and so on. However, they had much lower sales than Apple's products. There are a number of possible explanations for this.

First of all, some incumbents were focussed on producing a *recorder* for digital music, which implied a non-digital transfer of music (e.g. through a microphone or audio signal connector). Second, at the end of the 1990s, when the MP3 codec was invented and DAPs began to emerge, incumbents were still concentrating on existing modes of distribution of music, mainly the CD, in some cases developing CD players compatible with MP3s, or developing new storage media, such as the Minidisc, DCC and DAT (as shown in Section 3.1.3). However, all these efforts were still concentrated on adapting existing technologies to the new possibilities offered by music compression, without considering that compression codecs freed music from any of the above-mentioned storage media (Knopper, 2009).

Moreover, Sony had for many years a sort of disregard for MP3, aiming at diffusing its proprietary codec (ATRAC1, ATRAC3, and ATRAC3plus) (Rayna *et al.*, 2009: p.45). For this reason, some early Sony DAPs were not MP3-compatible. This meant that users' entire collections of MP3 files had to be converted to ATRAC3 before they could be loaded onto the player. It is true that other competitors also had a preferred audio coding, starting with Apple, which sold songs in AAC. However, the majority of DAPs (including the iPod) were still compatible with the MP3 format (Holmes, 2006: p.75). One important reason for Sony's promotion of proprietary standards may have been their dual role as both a DAP producer and a music label (Sony Music Entertainment). Sony was selling MP3 players, which could also contain audio files exchanged through the Internet, but at the same time it was a member of the RIAA (Recording Industry Association of America), an organisation strongly opposed to file sharing (Knopper, 2009: p.174). For this reason, since MP3 files do not have a copy protection feature (DRM[64]), Sony may have hoped that its proprietary standards, with DRM, might prevail (Rayna, *et al.*, 2009: p.45).

The second type of competitor is represented by companies that, like Apple, diversified their activities and started producing portable players. These diversifying players can in

[64] See Section 3.3.1 for more information about DRMs.

turn be divided in two sub-groups. The first group includes companies, in general large companies, that expanded their product mix by adding a new product line and started producing DAPs. These companies could generally build upon some proprietary assets or leverage on an existing product's reputation, which, in principle, could have represented a strategic advantage with respect to Apple. This is the case, for instance, of Creative and Microsoft. Creative Technology is a company based in Singapore, which was established in 1981 and is one of the world's market leaders in the production of sound cards for computers, sound systems and speakers, as well as other 'peripherals' such as keyboards, webcams and tablets that are attached to personal computers· It also entered into the DAP sector quite early, offering one of the first HD-based players, the Nomad, followed by the Muvo and Zen series. However, Creative never managed to achieve an advantage from the transfer of its knowledge acquired through the production of sound and audio components into the market for portable devices, and become a follower of Apple.

Microsoft entered into the market in 2006, attempting to challenge Apple's leadership by offering a product bundle including hardware (Zune), software (Zune Software) and service (Zune Marketplace) very similar to the iPod, iTunes and iTunes Store. The initial product was followed by a series of improved models with higher storage capacity and more functions. Zune worked with Zune software, an application similar to iTunes, which also started selling audio and video content through the Zune Marketplace. One of Microsoft's advantages was its very large customer base already using Microsoft operating systems. Moreover, even though Microsoft did not have any direct experience in portable audio players, it had some expertise in digital audio. In fact, Microsoft had a proprietary audio codec, WMA[65] (Windows Media Audio), which was mostly used for online streaming applications. Furthermore, most of its customers already used Microsoft software to manage and listen to music in the form of Windows Media Player, which was bundled in the Windows operating system from the very early versions of Windows 95. In any case, despite these potential advantages and a considerable economic and advertising effort, Microsoft's Zune sales never approached those of Apple's iPod.[66]

The other group of diversifying firms is represented by firms that are more similar to new entrants in terms of size and innovativeness. These firms are still already-

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[65] An audio codec that could embed a copy protection feature (Windows Media DRM).
[66] In September 2009, Apple released some figures on the DAP market, indicating that Microsoft had a 1.1% market share, compared to Apple's 73.8% (Source: http://www.wired .com/gadgetlab/2009/ 09/apple-liveblog-999; last accessed 12/09/2011).

established companies differentiating their production; however, the DAPs, rather than just an expansion, represented for them a major new direction. This is the case, for instance, for Diamond Multimedia and Archos. Diamond Multimedia is a company specialising in video cards for computers and other peripherals. Diamond was also a very early entrant into the DAP sector, selling one of the first DAPs in the United States, the Rio PMP300, the first DAP encountering a certain success (Knopper, 2009: p.166). Being the first DAP launched in the US, this player also received the attention of the RIAA, which sued Diamond Multimedia, claiming that the player violated music copyright, and in particular the Audio Home Recording Act (Knopper, 2009: p.166). Archos is a French company established in 1988, initially producing different kinds of computer peripherals during the 1990s. Archos was also an early entrant into the DAP market, soon emerging as one of the most innovative and venturesome companies in the sector (Rayna *et al.*, 2009). In fact, Archos has been a pioneer for many incremental innovations of DAPs.[67] For instance, Archos Multimedia Jukebox, launched in September 2002, had a colour display and the capability of showing pictures and video two years before the launch of iPod Photo and three years before iPod Video. Moreover, Archos PMA400, launched in January 2005, was equipped with a touch screen, Wi-Fi connection and the possibility of recording video, more than two years before the launch of the iPod Touch.

Apple was neither the first player entering into the market, nor the first one to introduce some of the major innovations (hard drive, colour screen, touch screen interface and so on). Moreover, Apple could not count on specific knowledge of audio players, since it did not have direct experience in the sector.[68] In addition, Apple's iPods were not necessarily superior to its competitors' products, at least from a purely technical point of view. However, none of the above-mentioned players have managed to weaken Apple leadership in the sector. Some of the major strengths of Apple have been its attention to usability and to product design (both architectural and aesthetic design) and to the demand-side. In particular, Apple has been able to recognise and in some cases to anticipate users' needs, and to continuously innovate in order to fulfil them (Kahney, 2005). Another aspect that deserves particular attention is the iPod's seamless integration with iTunes. In fact, Apple did not just sell a DAP, but a bundle of products and services, materialising in a piece of hardware, but usable only thanks to a piece of software (iTunes), which expands the iPod capabilities by offering an

[67] At least according to the original dataset on DAPs' product characteristics (explained in detail in Chapters 4 and 5).
[68] However, Apple had at least some audio capabilities prior to the launch of the iPod, since MACs were equipped with sound cards at least from the 1980s.

additional series of services to users such as an online music store. This point, together with the broader issue of online file sharing, will be analysed in the next section.

3.3. Compressed digital music and its impact on the music industry

The diffusion of the Internet and the broader phenomenon of media digitalisation and convergence in ICTs has brought pervasive changes that have involved several industries as well as the lives of many consumers, users and citizens. New economic and business models have been introduced in order to face significant changes in the demand for digital products (music, films, games, news and so on). In addition to this, people have changed the way that they communicate with each other; new cultural norms have emerged, as well as different perceptions of moral and legal behaviour online.

Music represents no exception with this regard, with significant changes both from the demand- and the supply-sides. The advent of compressed digital music has changed the way in which music is listened to, thanks in particular to the launch and diffusion of MP3 players, allowing users to listen to large libraries of music anywhere and at anytime.

However, the advent of compressed digital music, and the above-mentioned factors, did not only mean the advent of DAPs. Two other phenomena occurred in parallel with the diffusion of MP3 players: the first has been the sharing of music files over the Internet, and the second involves some broader changes to the music industry in general, regarding the way music is commercialised, distributed and consumed (Kusek and Leonhard, 2005). The next two sub-sections will concentrate on these two issues respectively.

3.3.1. Online file sharing

As mentioned in the previous sections, starting from the end of the 1990s, the introduction of powerful audio compression codecs combined with the diffusion of broadband Internet connections has allowed users to exchange music files over the Internet, thanks in particular to the so-called peer-to-peer (P2P) types of software.[69]

[69] Although the diffusion of broadband Internet connections significantly expanded users' possibilities to share copyrighted material, file sharing does not necessarily have to take place on the Internet, since the lending of physical media such as flash memory sticks or hard drives can also be considered an offline way to share files.

P2P file sharing is the 'making available of files from a user's own computer for copying and transmission to other users over the Internet, and the receipt of files made available this way' (Dixon, 2009, p.14-5).

Peer-to-peer software allows users to share their personal collections of music (and also movies, software and so on) and to access that of any other user in the network. A P2P technology is a network of computers in which all nodes are able to interact without the use of any centralised server. In this way, all computers are linked with each other and can exchange data directly, acting both as servers and clients (Strowel, 2009: p.2). In practical terms, P2P file sharing software allows the user employing it to search for files on other users' computer hard drives and to download them, and to upload files for other users to access.

Napster, introduced in 1999, was the first P2P technology that became widely popular (Liebowitz, 2008; Waldfogel, 2010). With Napster, although the music files were stored on users' personal computers, the network relied on a centralised indexing system to identify which computers held particular files. This made it possible to identify a unique agent as responsible for the traffic in copyright-infringing digital songs (Shaw, 2008: p.142). Napster was closed down in 2001 as a consequence of a lawsuit promoted by the Recording Industry Association of America (RIAA). After that, a proliferation of second generation P2P software developed, which facilitated searching without maintaining a centralised index. New file sharing networks were now based on decentralised servers. In these cases, any computer in the network could potentially act as an indexing server, making it more difficult to sue a central organisation for hosting or organising the P2P network (David, 2010: p.35). This was the case, for instance, of Gnutella, Kazaa, Grokster, WinMX, Emule (all of them launched between 2000 and 2002) and many others. In these kinds of peer-to-peer systems of file sharing, the file to be downloaded is located on a single computer. Other kinds of P2P systems, such as Bit Torrent (developed in 2001), also allow users to download a file using multiple hosts simultaneously, having, as a consequence, a substantial reduction in the bandwidth required.

However, not all sharing networks are P2P. Another kind of file sharing system that drove the attention of many users is based on services such as Rapidshare, Megaupload, Hotfile and so on. In this kind of file sharing technology there is no direct exchange between users (client to client), but the exchange is mediated by hosting services that allow users to upload personal files onto the service's servers, making them available for download by other Internet users, sometimes requiring a password. The links to these files and sometimes the passwords that might be needed are made available thanks to a multitude of forums or blogs, which are even searchable by the most popular search engines (such as Google and Yahoo). Another version of this type of file sharing is represented by so-called *streaming sites*. In this case, files are also shared by users by uploading them onto online servers. The main difference is that digital content is not downloaded onto users' computers, but rather watched or listened to online. These services take advantage of the recent increments in broadband bandwidth, allowing the streaming of music, but also movies, TV series episodes and even live events (sports events, pay-TV shows, etc.).[70]

The main issue regarding file sharing is that although P2P technologies can be used for many legitimate purposes, such as the distribution of digital content or e-learning, most of the Internet traffic produced by these technologies is related to the exchange of copyright-protected files (Liebowitz, 2006; Peitz and Waelbroeck, 2006a). This implies that in most cases, the activities carried out with P2P applications involve the infringement of copyright. On these grounds, the growing phenomenon of file sharing has become a concern for media content producers (such as music labels) and policy-makers (Peitz and Waelbroeck, 2006a: p.450). Music labels, their associations, artists and policy-makers have strongly reacted against file sharing, based on the hypothesis that file sharing is the major cause of the decrease in sales of music that has been experienced since the end of the 1990s.[71]

Efforts against file sharing

The measures against file sharing can be divided into three groups: legal actions, technological solutions and new laws or regulations.

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[70] In principle streaming content cannot be downloaded, but just watched or listened to online. However, recently some effective means have been developed to *capture* streamed files, allowing them to be stored (i.e. downloaded).

[71] Over the last decade, several scholars have entered into this debate, focussing on the impact of P2P file sharing on music and movie sales, and producing a substantial body of literature, both theoretical and empirical. See for example Liebowitz (2006, 2008); Oberholzer-Gee and Strumpf (2007, 2010); Peitz and Waelbroeck (2006a, 2006b); Rob and Waldfogel (2006); Smith and Telang (2010); Tschmuck (2010); Waldfogel (2010); Zentner (2006). On one hand, most of the literature has confirmed that file sharing has had a displacement effect on music sales. However, other works have demonstrated that this conclusion is much less univocal, indicating that file sharing could have also had some positive effects, or at least that the decline in sales of recorded music is not only imputable to file sharing. Although this literature is very interesting and has relevant policy implications, this thesis will simply treat file sharing as a potential factor affecting the adoption and diffusion of DAPs, without entering into the debate concerning its effect on the demand for recorded music distributed by music publishers.

The first measure against file sharing of copyright-protected material has been legal action. One of the first lawsuits involved Diamond Multimedia, sued by the RIAA for producing the first MP3 player available in the US (Rio PMP300). The RIAA claimed that this kind of product violated the Audio Home Recording Act[72] (Richard, 2000: p.436). The lawsuit was unsuccessful, since the only way to load music onto the Rio was using a computer, and computers were not included under the Audio Home Recording Act. Another stream of lawsuits have targeted the online file sharing services or other *facilitators*.[73] Following the shutting of Napster as a result of the RIAA lawsuit mentioned above, other lawsuits were initiated in an attempt to suppress other P2P services. For example, in 2001 the RIAA and the MPAA (Motion Picture Association of America) sued file sharing software distributors Morpheus and Grokster. The two companies were first considered not liable for copyright infringement. However, this decision was reversed in 2005 by the US Supreme Court. After this decision, most P2P companies decided to settle with the entertainment industry (Oberholzer-Gee and Strumpf, 2010: p.9). Similar legal action campaigns against P2P companies or file sharing facilitators took place outside the US, for instance in the Netherlands (Kazaa), Japan (Japan MMO), Korea (Soribada), Taiwan (ExPeer and Kuro), Finland (Finreactor), Sweden (The Pirate Bay) and Australia (against ten companies and individuals related to the Kazaa peer-to-peer service) (Dixon, 2009: p.24-9).

Another target for these legal actions has been Internet users. Since 2003, the RIAA has begun to pursue individual users of P2P services. To date, some thousands of users have been sued for downloading copyrighted material in the US and in European countries (Knopper, 2009: p.183). Considering the vast number of users of these kinds of services, the victims of these legal actions were selected almost at random. In most cases these lawsuits were resolved by asking for a monetary settlement from users in partial compensation for the amount of copyright-infringing material downloaded.

The real effectiveness of these lawsuit campaigns in discouraging the use of file sharing services is questionable. The first lawsuit against Diamond Rio was unsuccessful, and this allowed many other brands (including Apple) to enter into the MP3 player market without incurring any liability. The lawsuits against P2P services and other facilitators had the immediate effect of closing down some P2P services or related sites. However,

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[72] The Act imposed the payment of a royalty whenever a new device able to allow more than one copy of a recording was produced.

[73] This is the case of third parties who do not commit any direct infringement, but in some ways assist or facilitate the infringement by final users, for instance by directly hosting copyrighted material or by providing links to copyrighted material (Dixon, 2009).

as noted previously, regardless of the fact that some of them were closed down, file sharing services on the Internet have become not only more numerous, but also much more technically differentiated. Regarding the lawsuits against individual users, it is difficult to measure their actual effect in discouraging the use of file sharing services; however, in any case, they have attracted popular discontent against the RIAA and music labels (Knopper, 2009: p.188).

The second kind of reaction against file sharing has been on the technological side. One of the reasons for such widespread sharing of songs is that a standard audio CD is very easy to be converted into MP3s. For this reason, a potential solution to the issue has been the development of Digital Rights Management (DRM) technologies, resulting in the production of audio media or tools preventing users from making copies of copyrighted music. A DRM is a technology that can limit the use of a digital product by inhibiting some kinds of uses not desired by the content provider.[74] DRMs have been mostly used by online music stores, in order to set a maximum number of computers (or portable players) onto which a song can be copied. One of the most famous DRM technologies used is FairPlay, a technology created by Apple and implemented on all the songs purchased at the iTunes Music Store prior to 2007. FairPlay DRM allowed up to five (originally three) computers to be simultaneously authorised to play a music file; however, this system has been gradually dismissed by Apple (see the next section for more details).

The effectiveness of these technologies has been limited, since all the DRMs ever used have been broken by hackers (Kusek and Leonhard, 2005: p.152). In other cases, notably with FairPlay, the DRM could be easily circumvented by any average user burning the protected song onto a standard CD and then ripping the CD again, obtaining DRM-free files. Moreover, DRMs have often been perceived as an unfair restriction of consumer welfare. In fact, a DRM represents a limitation of users' flexibility that, in some cases, could make original copies less attractive than pirated ones (Peitz and Waelbroeck, 2006b). This could discourage the purchase of legal products in favour of file sharing of illegal files without any restrictions (Ahn and Shin, 2010: p.342; Peitz and Waelbroeck, 2006b).

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[74] An unfortunate case of DRM applied to audio CDs related to Sony's rootkit. In 2005, Sony Music sold several million CDs containing a rootkit, which automatically installed software on users' computers, preventing them from make excessive copies of the CD. The problem with this kind of rootkit was that the files were installed without informing the users, and moreover, the software was seen as a malicious program by some antivirus programs (since the software might allow outside hackers to install viruses and other malicious programs onto users' computers). As a consequence, Sony had to withdraw the CDs sold with this kind of technology, facing reputational damage (Knopper, 2009: p.222).

The third kind of measure has been on the regulatory side and has involved the role of governments and other policy-makers.[75] First of all, the regulation of copyright infringement through Internet file sharing is treated in very different ways by different countries. A legislative trend that is gaining increasing interest has been the promulgation of laws that involve the support of ISPs in trying to facilitate the tracking down of some persistent infringers (IFPI, 2009; 2010). This is the case for instance of the US Digital Millennium Copyright Act (1998), and more recently of the HADOPI law in France (2009), and the UK's Digital Economy Act (DEA), which came into force in 2010.

According to these laws, ISPs are asked to collaborate with the copyright industry in order to identify suspected infringers. In particular, the copyright industries engage other companies to monitor Internet traffic, which results in an identification of the IP addresses of infringers. The role of the ISP is to keep track of the IP addresses used by actual Internet users, thus making it possible to translate complaints against an IP to complaints against a person (ISP subscriber), with potential actions ranging from simple notifications, suspension of Internet connection or even legal actions. However, the activity of governments and other organisations has not only been directed towards the suppression of file sharing. In fact, over the last decade, several other activities have been promoted, such as awareness campaigns and education programmes, as well as the promotion of different means for accessing digital material by right-holders.

If it was difficult to measure the effectiveness of the previous two efforts, it is even more difficult to do so in the case of these laws and regulations. For instance because these laws differ from country to country, and because of methodological issues, there are no consolidated and extensive statistics on file sharing. However, the available figures indicate that despite all the above-mentioned efforts, file sharing is a very diffused and growing activity (Waldfogel, 2010). Some reports cited by Oberholzer-Gee and Strumpf (2010: p.12) claim that file sharing accounted for between 40 and 60% of all bandwidth usage in the period 2002-2008, indicating that file sharing is a phenomenon still far from being stopped. However, another way to discourage file sharing that has not yet

[75] The analysis of these measures is complicated, first of all because they consist of the promulgation of laws regulating to very different matters, such as Intellectual Property Rights (IPR), third party copyright liability, Internet Service Providers (ISP) regulation, etc. Moreover, such measures involve very different actors, including national governments, supranational organisations such as the European Union, international institutions such as the World Intellectual Property Organisation (WIPO), and also the lobbying activity of actors such as the RIAA, MPAA, and BPI (British Phonographic Industry).

been taken into consideration in this section is the possibility of offering an alternative way to acquire digital music from the Internet. This possibility will be explored in the next section.

In conclusion, despite the fact that file sharing has created a substantial debate involving many actors, such as scholars, policy-makers, copyright owners, Internet users and so on, this chapter has limited its interest to only those issues that are directly related to the purposes of the thesis. That being said, the main conclusions regarding the rise of file sharing are two. The first is that file sharing may have influenced the diffusion of DAPs. This is because, as pointed out many times in this chapter, the success of any particular music medium (such as vinyl discs, cassettes or CDs) and of their respective players has depended on the availability of pre-recorded material in that format. For instance, the success of CDs would not have been possible without an effort to offer many new and pre-existing music albums using this new format. Regarding the specific case of DAPs, compressed digital music has first of all unlinked music from any specific medium. Second, it has allowed users, mainly through online file sharing, to accumulate a large quantity of music, in many cases without paying for it. For these reasons, this very large availability of free, or almost free, music content in digital format could have influenced the diffusion of portable players of such kinds of files (David, 2010: p.37). This speculation will be analytically tested in Section 6.3 and then in Chapter 8. The second conclusion is that file sharing has been one of the most strongly determinant factors that has contributed to the emergence of much broader changes in the music industry, especially in the way music is consumed and distributed. This issue will be presented in the next section.

3.3.2. A new paradigm for music retailing

As has been said before, the music business is composed of a number of sub-sectors with specific competencies, such as media and player manufacturers, recording studios, music labels, music publishers, artists' managers and so on (Harrison, 2008). Music labels have emerged as having a prominent role in the music industry by coordinating the activities of all these companies (in some cases owning or controlling them) and, most importantly, by exerting a tight control over the supply of music content, the use of certain recording media and distribution channels (Richard, 2000: p.428).

This traditional structure, based on the prominent role of music labels and on the fact that music was almost a synonym for the physical medium in which it was recorded (be it a vinyl disc, a cassette tape, a CD, a MD, etc.) was almost unchanged for at least 60 years (Graham *et al.*, 2004). However, starting from the end of the 1990s a combination of factors made the situation unstable. These factors were the diffusion of broadband Internet connections, the advent of compressed digital music and the growth of the file sharing phenomenon. The combination of these factors enabled users to exchange a large quantity of digital audio files through the Internet, bypassing the usual distribution channels. Considering that the majority of the files exchanged on the Internet contained copyright-protected material, the growth of the file sharing phenomenon has raised the concerns of copyright holders, provoking the measures against file sharing presented in the previous section. However, the above-mentioned factors have also produced broader changes in the way music is consumed, purchased and distributed.

At the end of the 1990s, music consumers were facing a curious paradox regarding digital music retailing, since in that period, the only way to get digital music in a legal way was to buy a physical CD. Therefore, consumers were forced to choose between acquiring copyright-infringing copies of songs using P2P applications and buying a physical CD (possibly containing some songs that he or she did not want) (Waldfogel, 2010: p.306). This paradox has been solved by providing consumers with a legal way to obtain music. As in the case of the iPod, it has been Apple that has taken over the market of online digital music. However, as has been the case with some major innovations regarding the DAP sector, Apple was not the first company introducing these innovations, but rather the first to make them successful. In a similar way, iTunes was not the first online music store; in fact, since 1998 a few firms started selling legal music through the Internet. This was the case, for instance, of eMusic (1998) (Waldfogel, 2010: p.308). In 2001, the five major music labels entered into the business, founding MusicNet and Pressplay. MusicNet was an online service launched by three major labels (Warner, Bertelsmann, and EMI) that allowed users to download 100 songs per month in exchange for a US$9.95 monthly fee. However, these songs could not be loaded onto any DAP or burned onto a CD, and expired after 30 days. Pressplay (a joint venture between Sony and Universal) first offered the possibility of downloading 50 songs and streaming another 500, then allowed unlimited downloads for US$179.40 per year. These services were not successful. The main reason might have been that they imposed limitations on users' flexibility in terms of making use of their purchases (e.g. copying to multiple devices) (Waldfogel, 2010: p.308).

Apple launched the iTunes Music Store in 2003. The music store had a large music library and a very simple pricing structure: US$0.99 for a single song. All the songs purchased from the iTunes Music Store were compatible with any Apple iPod. The launch of the iTunes Music Store was possible thanks to a deal signed between Apple and the five major record labels at the time: EMI, Universal (UMG), Warner (WMG), Sony Music and Bertelsmann (BMG). The songs purchased at the iTunes Music Store were AAC[76] files with a DRM technology called FairPlay (as mentioned in the previous section). At the beginning, Steve Jobs (Apple's CEO) was opposed to DRMs; however, Apple implemented a DRM technology in order to sign the deal with the music labels (Knopper, 2009: p.172). In 2007, Jobs published an open letter entitled 'Thoughts on Music' on the Apple website,[77] inviting big music labels to sell their music without any DRMs. Since then, iTunes has progressively abandoned FairPlay, first by selling DRM-free songs for a premium price, and then by having all the music on the music store with no DRM restrictions since 2009.

Figure 3.3 Comparison between traditional and iTunes pricing models

Traditional pricing model

Selling unit:	Artist		Label		Manufacturing		Shipping		Retailer		Customer
CD	8%	+	49%	+	8%	+	5%	+	30%	=	100%

iTunes Music Store pricing model

Selling unit:	Artist + Label		Label		Customer
Song	67 cents	+	22 cents	=	$0.99

Source: Kusek and Leonhard, 2005: p.32.

The iTunes Music Store made it possible for users to buy digital music produced by the five major music labels without infringing any copyright. However, with the launch of the music store, Apple also changed the existing CD pricing model (Figure 3.3). The first innovation was the pay-per-track model, allowing users to buy a single song instead of the whole CD. Secondly, iTunes simplified the pricing model by simply holding 22 cents for each song sold and leaving the rest to the artist and the music label.

Music labels were accustomed to selling music embedded in physical media such as

[76] Initially released in 1997 and subsequently standardised by ISO and IEC, AAC is an encoding audio standard developed by the Moving Picture Expert group and part of the MPEG-2 MPEG-4 standards that was designed to be the successor to the MP3 (http://en.wikipedia.org/wiki/Advanced_Audio_Coding; last accessed 26/10/2010).

[77] http://www.apple.com/es/hotnews/thoughtsonmusic/

cassettes or CDs. With the iTunes Music Store, this trend changed significantly. Now users were free to listen to brief samples of all the songs on an album and choose single tracks to buy and download. However, the statistics indicate that users purchase more songs embedded in albums (i.e. by acquiring the whole album) than they acquire by purchasing individual songs. The iTunes Music Store was another great success for Apple, reaching 100 million songs sold in 2004, one billion songs in 2006 and 10 billion songs in 2010. iTunes has progressively expanded to many other countries, enlarged its music library and also started to sell movies and TV series episodes. However, iTunes is not the only existing online digital music store, although it accounts for around three-quarters of the market for digital music (Waldfogel, 2010: p.306). Some recent figures published by IFPI (2011) indicate that the number of licensed digital music services worldwide has increased to more than 400, and that the value of the digital music market increased by 1000% in the period 2004-2010.

In summary, this new paradigm for music consumption and distribution has had different effects on different kinds of players. First of all, consumers have mostly benefited from this new paradigm. On one hand, they have bypassed the control of music labels over the distribution of music, and have been able to download large quantities of music without paying for it. However, this has happened at the expense of artists, performers, music labels and, in general, copyright owners. On the other hand, consumers have had the possibility of buying songs legally and respecting copyrights from a certain number of online music stores. In addition, these stores have also offered new pricing systems allowing users to purchase both single tracks and entire albums, plus some additional services, such as music sampling and so on. Secondly, music labels (in particular the *big four*) have partially lost control of music retailing. This has certainly involved some losses, since file sharing has displaced some CD sales. However, it is also true that another channel for music distribution has also been opened, which has very quickly increased in importance, with the proportion of record companies' global revenues derived from digital channels reaching 29% in 2011 (IFPI, 2011). Thirdly, independent music labels, or even single artists may have benefited from this new paradigm. The Internet and file sharing could in fact represent for them a very powerful instrument of promotions and direct sales, which would have otherwise been impossible. Finally, this new channel for legal music has allowed more companies to enter into music retailing. This is the case for Apple, and for many other online stores that have both contributed to *legalising* a market in which consumers were originally not allowed to purchase legal music without buying a physical CD, while also allowing these companies to obtain profits from it.

3.4. Conclusions

This chapter has explored the history of DAPs. The starting point was the early stages of the music recording sector. This initial part of the chapter focussed on how technical changes have accompanied the evolution of music recording from analogue media to digital and then compressed digital, with particular emphasis on the introduction of portable music players. This part also focussed on the role of some companies, such as media and music player manufacturers and music labels, and on the benefits that the consumer side has obtained by adopting the new recording technologies offered in the market. The history of the sector directly related to the context of the thesis, the DAP market, was then investigated. Several issues have been presented, such as the role of music compression (in particular MP3s) and the significant technical improvements that have characterised the sector, as well as the role of different players, with particular attention to the market leader (Apple). Finally, this chapter has concentrated on two correlated phenomena that took place in parallel with the diffusion of DAPs. These phenomena are file sharing, and, more broadly, the advent of a new paradigm in music consumption and distribution, with Internet channels gaining particular importance over more traditional ones.

This chapter suggests three further considerations for the recording music industry and in particular for the DAP market. First of all, the DAP sector evolved significantly over the last decade, both from a technological and a non-technological perspective. The storage capacity increased significantly, both for HD players and flash players. In parallel, the average size of the devices gradually decreased, as well as the average price. Many new features and functions have been added, such as colour screens and podcasts as well as additional services such as online music stores. The latest DAPs are more than just audio players; they are portable multimedia devices, able to record and reproduce photos, audio and videos, with an increasing number of players capable of connecting to the Internet via Wi-FI or 3G mobile broadband. At the same time, many players have contended for the DAP sector, including companies such as Sony, which led the market for some DAPs' precursors. However, Apple, despite being a company without direct experience in the sector, emerged as the market leader, with incumbents and other diversifying entrants lagging behind. In summary, the DAP sector is very successful, innovative and competitive. Chapter 7 will attempt to explain the innovative and competitive activity in the sector by considering the evolution of the product's technical characteristics.

The second consideration is that the launch of such devices and the continuous innovation processes around these products have significantly changed the patterns of mobile music listening. These products are able to offer new capabilities inconceivable with previous portable players, such as the possibility of storing very large music collections on a very small device, and a whole new set of additional functions and services, such as access to podcasts, storing photos and videos, purchase of songs and so on. However, at the same time, the usage of DAPs is not as immediate as it was with previous portable players, such as cassette or CD players. The need for a computer and specific software to load the music onto the player raises questions about which kinds of users were able to use these products from the very beginning of their history. This issue, more related to the demand-side, will be mainly addressed in Chapter 6, analysing which characteristics early adopters of these kinds of products had, compared to the late adopters.

One last consideration regards the future of mobile music listening, which is still unclear. However, at least two, not mutually exclusive, scenarios could be foreseen. The first is already taking place, and it is a process of convergence. In fact, devices such as digital audio players, audio recorders, photo cameras, video cameras and mobile phones are rapidly merging into a single device, the so-called *smart phone*. These evolved phones could embed all the functions of the now-available DAPs, and could gradually substitute them. The second scenario regards the new ways in which music is distributed and consumed. The launch of devices constantly connected to the Internet could possibly make the use of any local storage memory superfluous. With sufficient communication bandwidth, personal music libraries could be stored on online servers and accessed anywhere, without the necessity of carrying the actual audio files on the devices themselves. Moreover, services could be offered, for instance unlimited access to large music collections in exchange for a subscription fee. These technological developments have the potential to eliminate the DAP as a distinct device in the future.

PART II - METHODOLOGICAL ISSUES

CHAPTER 4. METHODOLOGY

The review of the literature on the diffusion of innovations summarised in Chapter 2 highlighted the existence of three aspects that deserve some further investigation. These aspects were articulated in detail in Section 2.5.

The first aspect is about the demand-side. One of the most often studied aspects of the diffusion process regards the existence of differences among potential adopters. This has been one of the most interesting themes of the literature, as several models of diffusion have tried to overcome the initial assumption of homogeneous adopters typical of the epidemic models. For instance, in the so-called rank models, potential users differ in some measurable variable. However, in many cases all the differences are summarised by a single variable, such as firm size (in the case of process innovations) or household/individual income (in the case of consumer products). In other models, notably those coming from the sociological and marketing traditions, adopters have been classified on the basis of the time of adoption (early *vs.* late adopters). With respect to this issue, the first empirical chapter of the thesis (Chapter 6) will be an attempt to provide a classification of the adopters, trying to develop a classification based on multiple characteristics, such as demographic and economic variables, user innovativeness, responsiveness to social factors and so on. Furthermore, it proves that it is possible to test if these differences affect the adoption decision and its timing.

The second gap in the literature is related to the role of the supply-side. While the literature on innovation has often been accused of paying too much attention to the supply-side, a common criticism of the models of innovation diffusion is the lack of a supply-side. In some models, especially those coming from the Rogers' tradition, diffusion depends on characteristics of the product, such as trialability, observability, and so on. Other models introduced some dynamic elements, recognising that product characteristics and price are not static, but rather change over time. Moreover, adoption may be modelled as depending on the *perception* of these characteristics, or on the *formation of expectations* about their evolution over time. In other words, these supply-side effects are always considered from the perspective of the demand-side. For this reason, the second empirical chapter (Chapter 7) will be an effort in this direction, first trying to measure the technological change in the DAP sector and then attempting to match the evolution of the technical characteristics of the product with their perception over time by potential adopters.

The third, and perhaps the most evident aspect that deserves some further attention is that there does not exist a comprehensive and shared model or framework for the diffusion of innovations, especially with regard to new consumer products. Models have considered the adoption and diffusion of innovations from many different perspectives. However, each of these approaches is limited to a specific set of influences, usually ones derived from a specific theory, when in fact several theories may be simultaneously relevant and active. The third empirical chapter will be an attempt to study empirically the diffusion of a consumer technology embedding several factors coming from different models (Chapter 8). Collecting sufficient data at the individual level regarding the adoption and diffusion of a specific consumer product allows for a test of the assumptions underlying various models of diffusion in the case of digital audio players.

The present chapter (Chapter 4) will be organised as follows. The first section will present the research questions and the aim of the thesis. The second section will describe the two original datasets collected for the purpose of the thesis. Finally, the third section will present the methods of data analysis used in each empirical chapter.

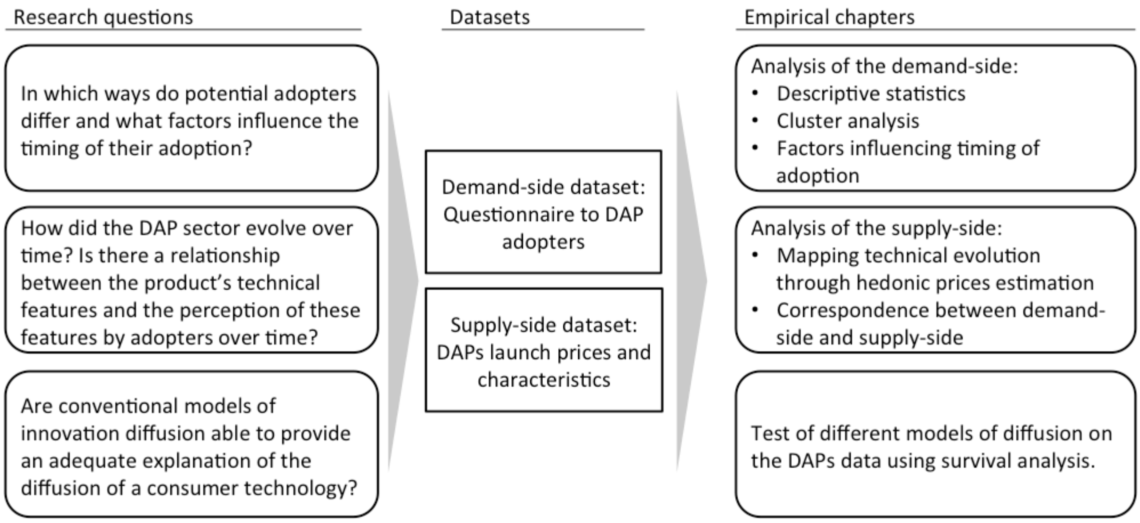
4.1. Research questions and aim of the thesis

The objective of the thesis is to study the adoption and diffusion of a consumer technology by analysing the case of the portable digital audio player (DAP) sector in Europe and Japan. In particular, the thesis aims to answer three research questions that arise from the above-mentioned gaps in the literature on the diffusion of consumer products:

- In which ways do potential adopters differ, and what factors influence the timing of their adoption?
- How has the DAP sector evolved over time? Is there a relationship between the product's technical features and the perception of these features by adopters over time?
- Are conventional models of innovation diffusion able to provide an adequate explanation of the diffusion of a consumer technology?

The methodology of the thesis consists of collecting two original datasets and providing a coherent framework of analysis in order to answer the three research questions using different kinds of quantitative statistical techniques. The first dataset will examine the demand-side based on a survey of potential and actual adopters of DAPs. The second dataset will be about the supply-side, including the technical characteristics and prices of a number of DAPs launched in the period 2001-2009. The analysis of these two sets of data is considered in three empirical chapters. These chapters will match with each of the above-mentioned gaps in the literature and the related research question. In particular, the first empirical chapter will concentrate on the demand-side, the second on the supply-side and the last will embrace both supply- and demand-sides in order to assess the factors affecting the adoption of DAPs. The structure of the thesis (research questions, datasets and empirical chapters) is expressed in Figure 4.1.

Figure 4.1 Structure of the thesis



Before explaining the two sources of data, a few clarifications on the definition of DAPs are needed. For the purposes of the thesis, a digital audio player is a portable device able to load and reproduce MP3s and other audio compressed files using non-removable erasable digital media (Holmes, 2006: p.75), such as flash memories or hard drives. For this reason, devices such as MP3-CD and Minidisc players, although they are compatible with some kinds of audio compressed files and may be considered precursors of DAPs, will be excluded from the analysis. On the other side, Chapter 3, in exploring the history of DAPs, indicated that some recently-launched mobile phones can be used as portable music players. Mobile phones able to play digital music will be considered as successors to DAPs, and they will also be excluded from the analysis. The main reason behind this choice is that the adoption decision with regard to a mobile phone is likely to be quite different from that of a DAP. Mobile phones are often sold in bundle with the services offered by a phone company. In many cases, the price of the phone is included in a monthly fee paid by the user, making it very difficult to distinguish between the price of the phone and the price of the service. In some other cases, the decision to upgrade a mobile phone is not even directly taken by the consumer, but is part of a predetermined upgrading plan offered by a service provider. In addition, these patterns of phone sales are very different between countries. For these reasons, both CD players and mobile phones able to read digital audio files are excluded from the analysis.

4.2. Sources of data

Given the nature of the research questions to which the thesis aims to respond, two original datasets have been collected, the first on potential adopters (demand-side) and the other on the products launched in the market (supply-side).

4.2.1. Demand-side dataset: questionnaire to potential adopters

The diffusion of an innovation can be analytically studied based on two types of data. On one side, one can make use of a general series of data on the number of adopters over time or the sales of a specific product, and test whether their distribution over time fits a predetermined (usually s-shaped) diffusion curve (Sarkar, 1998: p.155-6; Lissoni and Metcalfe, 1994: p.111-2). On the other side, collecting specific data on the adoption history of an innovation by a sample of individuals would make it possible to test (usually using a duration technique) what are the factors that are most likely to have influenced the probability of adoption over time (Lissoni and Metcalfe, 1994: p.111-2). For the purpose of this thesis, the second approach has been followed. The main reasons for this choice are two. The first has to do with the lack of available and detailed data on the diffusion of DAPs. The second regards more specifically the purpose of the thesis, which is about comparing different models of diffusion rather than testing the goodness of fit to a particular diffusion curve.

For these reasons, the main source of data regarding the diffusion of DAPs is based on the behaviour of a sample of potential and actual adopters. This kind of data has been collected through the submission of a questionnaire to a sample of university students from different countries. The original idea was to include several European countries in order to avoid country specificities. During the research, it also became possible to submit the questionnaire to two Japanese universities. The survey was distributed to

1562 young potential and actual DAP adopters from eight European countries (France, Germany, Italy, Portugal, the Netherlands, Spain, Switzerland and the UK) and Japan.

The use of this sampling strategy is subject to different sorts of reservations regarding its degree of representativeness. First of all, the use of students may be called into question, based on claims that students may present characteristics that differ from those of non-students, and hence could present only a partial picture of the population of DAP adopters. Secondly, since the sample is not randomly selected and not stratified, it could be claimed that it is not representative of the European and Japanese population of adopters. This would make it impossible to generalise the results of the analysis.

Three arguments can be made in response to these concerns, in defence of the use of a student survey as a main source of data for this thesis. First of all, students have been extensively used as subjects for social science research, in particular regarding consumer research (Peterson, 2001: p.451). In particular, Peterson estimates that the percentage of empirical studies based on university students published in the *Journal of Consumer Research* increased from 23% to 89% from 1975 to 2000 (Peterson, 2001: p.451). Secondly, while college students have specific characteristics, they also represent a fairly broad cross-section of the middle class population, due to modern levels of participation in higher education in European countries and Japan. There are no particular reasons suggesting that their behaviour should fundamentally differ from that of other groups within society. Thus, even though we cannot claim full generalisation of the results, future research would have a standard against which to compare results from other population groups, ensuring that the results of the thesis will represent a contribution to knowledge. In addition to that, the main objective of one relevant part of the thesis, that regarding the empirical relevance of different diffusion models, is to empirically test theories of diffusion, rather than to generalise the results. This does not strictly require a representative sample (Calder *et al.*, 1981). Furthermore, the possibility of developing a stratified sample has been taken into consideration. However, this would have implied developing a hypothesis on the distribution of the population of potential users of DAPs, which is quite problematic. Moreover, it is not clear what could have been an adequate sampling frame on which potential respondents could have been randomly selected. Finally, the whole operation would have been too costly.

Considering the specificities of this kind of product and the kind of research conducted, choosing students as respondents may also have some benefits. First of all, the research is based on a questionnaire that allows data to be matched with different diffusion theories, and this led to the development of a survey instrument in which there are a large number of questions. It would have been very difficult to collect such a rich dataset using other channels (such as a phone interviews). Moreover, because DAPs have been adopted widely by the youth market, submitting the questionnaire to university students led to a large number of observations of respondents who had actually adopted and used the product.

4.2.2. Supply-side dataset: digital audio players and their features

The second dataset regards the supply-side and involves the collection of data on a sample of 585 models of DAPs sold from 2001 to 2009. The dataset includes the launch date and launch price, as well as several technical characteristics of the DAPs (size, storage space, functions, etc.). The main source of data has been the website CNET.com, which offers reviews of these products. Other additional sources have been PCMagazine.com, Wikipedia and the producers' websites. Chapter 5 contains a more complete description of the dataset and of the data collection procedures.

The use of this dataset may raise questions concerning the degree of representativeness of the sample. CNET is a US-based website. This means that the products reviewed on the website are mostly DAPs commercialised in the US. Moreover, the launch prices are expressed in US dollars, meaning that the price recorded will never be the actual, exact price paid by the respondents to the questionnaire. In response to these issues, one should consider that it is practically impossible to track down all the DAPs commercialised over the last ten years. For this reason, the products have been selected by including the ten DAP brands with the highest numbers of products, according to CNET's classification. Considering that the DAP sector is a very concentrated market with the market leader accounting for a very high market share,[78] including the ten top brands will ensure that the dataset includes most of the products actually available. Moreover, regarding the prices in US dollars, they will never be used directly in the analysis, but rather price trends and indices will be used. The main use of this variable will be to test if prices are systematically related to the technical characteristics of DAPs, making the currency irrelevant.

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[78] In September 2009 Apple's iPod had a 73.8% share of the MP3 players market (source: http://www.wired.com/gadgetlab/2009/09/apple-liveblog-999/; last accessed 12/09/2011).

The rationale behind the collection of this kind of data is that this information is necessary in order to answer the last two research questions of the thesis. First, collecting data on the characteristics of the DAPs launched onto the market is the only way to study the technical evolution of the sector and to try to match it with potential adopters' perceptions over time (research question 2). Second, as indicated in Chapter 2, some diffusion models take into consideration users' expectations regarding the evolution of the supply-side (e.g. product improvements in the future). Collecting data on product prices and characteristics makes it possible to include these models in the list of diffusion models tested on the DAP data (research question 3).

4.3. Methods of data analysis

The analysis of the two datasets will be carried out using different kinds of quantitative statistical techniques and will produce three empirical chapters, each dedicated to one specific research question.

4.3.1. Focus on demand-side

The first empirical chapter (Chapter 6) focuses on the demand-side and is exclusively based on the data collected through the questionnaire. The objectives of the chapter will be three. The first is to provide a descriptive analysis of the data, and this will highlight some of the trends that will be the basis for further analyses. In particular, questions from each section of the questionnaire will be analysed. The main focus of the analysis will be on the adopters; however, the cases of non-adopters and multi-adopters will also be taken into consideration. The main methods used in this part of the chapter will be descriptive statistics, correlations, differences in means and factor analysis.

The second objective of the chapter is the most important one, and will be an attempt to provide a classification of the adopters going beyond the usual categorisation into early and late adopters. The method chosen to classify the adopters in homogenous groups and to compare the characteristics and performances of these groups is cluster analysis. The procedure will follow a two-step clustering process that will help to make a decision on how many groups of adopters should be created and then to aggregate the adopters into these groups. In addition, the results of the clustering process will be analysed, in order to test whether the method has produced a sound classification of adopters, and whether this classification is still compatible with a categorisation based on the timing of adoption.

The last objective of the chapter will be to use ordered logistic regression in order to investigate which factors have predominantly influenced the timing of adoption of DAPs. The presence of differences among clusters of adopters will also be tested. The factors influencing the timing of adoption will be more deeply addressed in Chapter 9 using survival analysis. For this reason, the ordered logistic regression in Chapter 6 can be considered as exploratory, in the sense that it is meant to provide some useful insights for the further analysis that will follow.

4.3.2. Focus on supply-side

The second empirical chapter (Chapter 7) is focussed on the supply-side and on the interactions between demand and supply. The main rationale behind the empirical analysis carried out in this chapter is based on the theoretical framework of products as bundles of characteristics (Lancaster 1966, 1971; Saviotti and Metcalfe, 1984). Following this view, consumers perceive goods as a bundle of characteristics, and it is on the basis of these attributes that they form their preferences. The objective of Chapter 7 is twofold. The first objective is to study the evolution of the DAP sector in terms of the changes in DAPs' characteristics over time. The second objective is to match these characteristics with the preferences on the demand-side and evaluate their impact on the diffusion of DAPs. In light of these observations, the dataset on product characteristics appears particularly appropriate in order to study the technical changes in the DAP sector in terms of the evolution of product characteristics. Moreover, one section of the questionnaire has been specifically designed to match with some of the product characteristics included in the products dataset. For these reasons, the analysis will be based on both datasets. This empirical chapter will be divided into three parts.

The first part will concentrate exclusively on the supply-side and will deal with the technical evolution of the sector. Products' evolution over time will be mapped by analysing both vertical innovation (improvements in some core characteristics) and horizontal innovation (launch of new features or functions). The use of the dataset about product characteristics will allow the testing of whether DAPs have gradually evolved towards a common design. The distinction between vertical and horizontal product differentiation and the study of their relationship has been taken into consideration by other works, such as Gabszwicz and Thisse (1986), Koski and Kretschmer (2007) and Corrocher and Guerzoni (2009).

The second part will be an attempt to map technological changes in the DAP sector. The tool chosen for this analysis is hedonic price analysis, which is a method to estimate the relationship between quality change and the price of a product over time. The main hypothesis of this approach is that any product can be considered as a set of characteristics and that a (hedonic) function can explain the price of a product in terms of its characteristics. In other words, there is a systematic relationship between the price of a product and its objectively measurable characteristics (Triplett, 2004: p.41). When these characteristics change over time, the perceived quality of the product also changes; this influences consumers' willingness to pay, and therefore the price. The data will be analysed using regression analysis. In particular, the characteristics of the products will be regressed on the prices, and the analysis of the coefficients can be read as the importance of a particular characteristic in determining the price of the product (leaving the other characteristics fixed).

The supply-side dataset appears particularly suitable for this kind of analysis. Hedonic price analysis is a well-accepted technique for examining technical and/or quality changes (Griliches, 1971; Rosen, 1974). The kind of data collected will enable the use of so-called *direct* methods of hedonic price estimation, in which all the information comes from the hedonic function (both characteristics and prices). Other *indirect* methods merge two different sources of information, for example data on product characteristics with already existing price indexes (such as those computed by statistical agencies). The lack of a specific price index regarding DAPs (similar indexes might regard consumer products or consumer electronics) makes it impossible to use any kind of indirect technique (Triplett, 2004: p.47-48).

This method has been often used for two purposes. The first is to produce quality-adjusted price indexes (Griliches, 1971; Rosen, 1974). The second is to study price formation and to map technological changes in specific sectors, such as computers (Triplett, 1989; Pakes, 2003), semiconductors (Flamm, 1993), laptop computers (Chwelos, 2003), PDAs (Chwelos *et al.*, 2004), LAN equipment (Fontana, 2007) or the automotive industry (Feenstra and Levinsohn, 1989). In a parallel way, this part of the chapter has two purposes. The first is to estimate the quality change in the sector, testing which characteristics have had an impact on the price over time. The second is to construct a price index that takes into consideration the technical changes that have occurred in the sector (hedonic price index).

In the third part of the chapter the results emerging from the supply-side dataset will be combined with the data on the demand-side, trying to test whether the technical evolution in the sector matches the evolution of preferences over time. The datasets will be merged by corresponding the semester of first adoption with the semester of the first launch of a DAP. This will allow, on one hand, the identification of the characteristics of the products that the demand-side were facing while adopting, while on the other hand it will allow an analysis of the stage of the diffusion process DAP producers were facing when they were launching one of their new products. The objectives of this part of the chapter are two. The first is to analyse how important product characteristics have been for the demand-side. This section will build upon a specific question in the questionnaire in which adopters were asked to rate the importance of several product characteristics in evaluating a DAP. These results regarding demand-side preferences will be merged with the actual technical changes in the sector. This will allow the testing of whether there is a correspondence between technical progress and consumer preferences over time in the DAP sector. The second objective will be to test whether product innovation on the supply-side has influenced adoption by the demand-side. This will be performed by including the hedonic price index in an ordered logit regression estimating the timing of adoption.

4.3.3. Alternative models of diffusion

The last empirical chapter (Chapter 9) will be more general, and will be based on both datasets. The main objective of this chapter is to compare the assumptions underlying the most common models of diffusion, providing an adequate explanation of the pattern of diffusion of DAPs.

The first step will be to select which models of diffusion to test. The literature review presented in Chapter 2 was organised using the epidemic model of diffusion as a starting point and then by presenting the other models of diffusion divided into three groups depending on their main focus (the adopter, the innovation or the diffusion process). The list of models tested will employ the classification used in the literature review chapter. In particular, the first approach to be tested will be the epidemic model. The second approach will regard the models focusing on the adopter, which will be tested by considering the existence of rank effects. The third approach will be about the models of diffusion focusing on the innovation. In this case, the effects of users' expectations about the evolution of the supply-side on DAP diffusion will be considered. Finally, regarding the models focusing on the diffusion process, two approaches will be considered. The first will be about the stock and bandwagon effects, and the second about the order effect.

The second step will be to develop and validate specific indicators that will match with the main hypothesis of the previously selected list of diffusion models. These variables will be built based on data from both datasets. Some of these indicators will be developed through principal component and confirmatory factor analysis using specific sets of questions contained in the questionnaire that were designed to construct latent variables influencing the timing of adoption. The construction and validation of these variables will be described in Chapter 5.

The third step will consist of using these indicators as explanatory variables in an econometric analysis. In particular, survival analysis (duration) will be carried out in order to test the relevance and the impact of different determinants coming from different models of diffusion. There are two reasons for applying duration analysis to the diffusion of DAPs. The first reason is the lack of aggregated data on the diffusion of such technology, which makes necessary the use of a type of analysis at a more disaggregate level (Sarkar, 1998: p.155-6; Lissoni and Metcalfe, 1994: p.111-2). The second is that this type of methodology seems to be particularly appropriate for studying the effects of different factors in explaining the timing of adoption of a technology (Karhsenas and Stoneman, 1995: p.283). This methodology consists of a set of statistical tools for studying the effects of a series of exogenous variables on time elapsing before the occurrence of a determined event, usually the death of the subject, which explains the name 'survival analysis' (Allison, 1995). Survival analysis, borrowed from the biological sciences, has encountered increasing success as a method in the social sciences, especially when applied to the diffusion of innovations (Karhsenas and Stoneman, 1995: p.283; Sarkar, 1998: p.155-6).

In the case of innovation diffusion, the final event is the adoption of the technology. Survival analysis allows the estimation of a hazard function, which is the conditional probability that a user adopts a DAP at time t, given that he or she has not adopted at $t-1$. Since the mid-1980s, this methodology has been applied to study the adoption of several technologies, such as optical scanners (Levin *et al.*, 1987), agricultural technologies (Abdulai and Huffman, 2005), financial innovations (Akhavein *et al.*, 2005; Bofondi and Lotti, 2006), Internet by banking institutions (Corrocher, 2006), home computers (Goolsbee and Klenow, 2002), digital mobile technology (Kauffman and Techatassanasoontorn, 2005), ATMs (Hannan and McDowell, 1984; Sinha and

Chandrashekaran, 1992) and multiple technologies (Stoneman and Toivanen, 1997). In general, these studies use survival analysis in order to test which factors are most significantly associated with a higher hazard (and hence with a higher probability of adoption). The purpose of the last empirical chapter is similar, but slightly different. The intention of the empirical analysis is to match these factors with a certain number of diffusion models. Therefore, testing their effect on the hazard rate would mean indirectly testing the validity of the underlying diffusion models. Other works have attempted a similar exercise (see for instance Karshenas and Stoneman, 1993; Zettelmeyer and Stoneman, 1993; Stoneman and Kwon, 1994; Fusaro, 2009). However, to our knowledge, a similar exercise, at least using disaggregated adoption data, has never been attempted for consumer products.

Survival analysis encompasses several techniques, especially regarding which kind of hazard function is estimated, including both *semi-parametric* and *parametric* functions. In the first case, behaviour is not assumed to follow any specific function of time, i.e. the hazard remains proportional and constant over time (the hazard of one individual is proportional to the hazard of any other individual regardless of the time considered; hence, the hazard rate is constant over time). The semi-parametric case is usually tested through the Cox proportional hazard model. In the second case, behaviour is assumed to follow a specific distribution in time (Kleinbaum and Klein, 2005). A related issue concerns the way in which time is considered. In one case, behaviour in time could be represented by a continuous variable, with the event occurring at any particular instant in time. The other possibility is for behaviour over time to be expressed as a discrete function. This could happen because the underlying process is *intrinsically discrete*, or because data have been grouped into discrete intervals of time (e.g. number of years, semesters, or months) (Jenkins, 2005a). Having a continuous or discrete time elapsing variable implies a different hedonic function estimation technique. In any case, the robustness of the model estimated in the empirical chapter will be tested by using both semi-parametric and parametric models, and both continuous and discrete types of analysis.

CHAPTER 5. DATA COLLECTION AND VALIDATION

Chapter 4 presented the research questions and the analytical methods used in the thesis, indicating that the methodology involves the collection of two original datasets, one on the demand-side (a questionnaire submitted to a sample of DAP adopters) and another on the supply-side (launch dates, prices and characteristics of a sample of DAPs sold on the market). This chapter focuses on the data collection and validation procedures.

The chapter is divided into three parts. The first is dedicated to the demand-side and explains how the questionnaire was designed, piloted and submitted. The second part of the chapter also regards the demand-side, and explains the process of validating the three sets of variables that the questionnaire is meant to build through factor analysis. The third and last part of the chapter is about the supply-side, and reviews the data collection process for building the product characteristics dataset.

5.1. Demand-side dataset: questionnaire on the adoption of DAPs

The main purpose of the questionnaire is to retrieve data about the most important factors that might have influenced the timing of adoption of a DAP among respondents. The choice of which factors to consider is based on the literature on innovation diffusion. This means that almost every question included in the questionnaire refers to a specific theoretical and empirical body of literature. In addition to this main purpose, and in light of the observations made in Chapter 4, the questionnaire is also meant to accomplish four tasks.

The first is to provide a sufficient range of characteristics about DAP adopters, in order to be able to characterise them and divide them into clusters. The second is to provide a sufficiently reliable timing of adoption. This variable is essential to convert a cross-sectional dataset (such as the one collected through the questionnaire) into a sort of time-series based on the timing of adoption. The third task is to develop a series of variables matching some of the characteristics listed in the supply-side dataset. This is needed in order to test whether there is a relationship between the evolution of product characteristics over time and their perception by actual and potential adopters. The last task is to develop variables matching the main assumptions of various different types of diffusion model. This allows the building of a series of indicators and the testing of the validity of those models in order to explain the diffusion of DAPs. In addition to these tasks, which are necessary in order to provide an answer to the research questions, it was seen as potentially interesting to include two other optional series of questions. Consequently the questionnaire includes two short sections dedicated to non-adopters and multi-adopters (those adopters who have purchased more than one DAP). The questionnaire was developed in English and then translated into six languages (French, German, Italian, Japanese, Portuguese and Spanish). The English language version of the questionnaire is included at Appendix A.

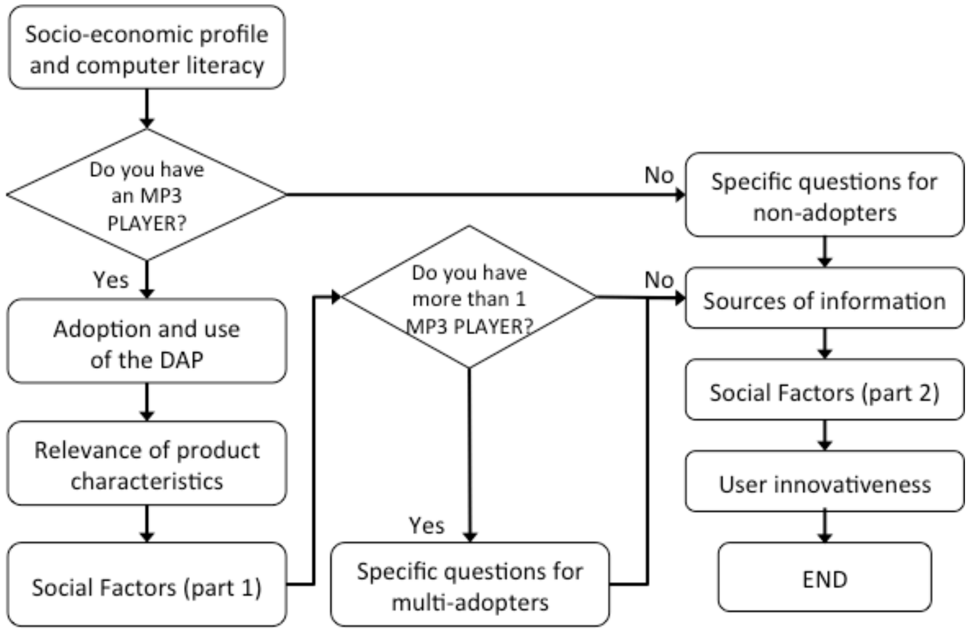
5.1.1. Designing the questionnaire

The review of the literature on innovation diffusion presented in Chapter 2 divided the models of diffusion into three main categories depending on the main focus of the models (the adopter, the innovation and the diffusion process). Similarly, the questionnaire on DAP adoption reflects this structure, including questions regarding each of these themes. In addition, two additional sections are included.

- Questions regarding the adopters:
    - Socio-economic profile of respondents (questions 1-6);
    - Computer literacy and use of the Internet (questions 7-15);
    - User innovativeness (questions 48-49).
- Questions regarding the innovation:
    - Adoption and use of a DAP (questions 16-29, 31);
    - Importance of product characteristics (question 30);
    - Relevance of Rogers' product characteristics (questions 32-35, 37).
- Questions regarding the underlying diffusion process:
    - Social factors (questions 36, 38, 45-47);
    - Sources of information (question 44).
- Questions regarding non-adopters (questions 42-43).
- Questions regarding multi-adopters (questions 39-41).

The structure of the questionnaire (shown in Figure 5.1) takes into account the presence of three kinds of respondents: non-adopters, adopters and multi-adopters. Two questions are specifically designed to discriminate between these three groups of respondents and to indicate to them which sections of the questionnaire they should complete. The questionnaire includes quite a large number of questions; the only respondents that should answer all of them (with the exception of questions 42 and 43, which are dedicated to non-adopters) are multi-adopters. Adopters skip the brief section specifically designed for multi-adopters. In contrast, non-adopters skip a significant part of the questionnaire, avoiding all the questions directly or indirectly related to the adoption of a DAP.

Figure 5.1 Structure of the questionnaire



<u>Questions about the adopter</u>

The first set of factors influencing the diffusion of a DAP is about the characteristics of the adopters. This set is divided in three sub-groups. We refer to Chapter 2 and Table 5.1 for the relevant literature behind each of these groups. The first set of questions regards users' socio-economic profile and includes sections about age, gender, nationality, city of residence, student status (undergraduate or postgraduate) and personal income (questions 1-6). The question on personal income deserves particular attention. The questionnaire includes three questions regarding income (5, 5a, 5b). The first asks if the respondents are financially independent. Secondly, in the case of financially independent students, there is a question about how many people they financially support, while in the case of financially dependent students, there is a question about how many people depend on the household income. The last question asks the respondent to choose between 22 classes of income, from less than €5000 to more than €200,000 (for the UK, the income classes are expressed in Pounds Sterling, while for Switzerland they are expressed both in Euro and Swiss Francs). The variable income is calculated by dividing the central value of each income category by the number of people in the household as a means of making the responses comparable on a per person basis.

The second group of questions regarding adopters' characteristics is about users' computer literacy. Considering the fact that DAPs need a computer in order to be operated, these questions are particularly important. This sub-section (questions 7-15) includes some questions on the use of a computer, such as which kind of computer is mainly used by respondents (Apple Macintosh, Windows PC or open source OS PC), how long the computer is used during a typical day, levels of computer skills and predominant use of the computer (leisure or work). In addition, respondents' activities on the Internet are investigated, through questions asking whether they have a broadband connection at home or at the university, and which activities are more often carried out while they are on the Internet (e.g. chatting, making phone calls, using peer-to-peer software etc.).

Table 5.1 Questionnaire topics and relevant literature 1/3

TOPIC	RELEVANT LITERATURE	
PERSONAL CHARACTERISTICS AND COMPUTER LITERACY		
Personal characteristics (Age, gender, nationality, job, education, computer literacy)	Rogers, 2003; Gatignon and Robertson, 1985; Im *et al.*, 2003; Dickerson and Gentry, 1983	
Adopter segmentation by their time of adoption	Rogers, 2003; Bass, 1969; Mahajan, Muller and Bass, 1990	
Related knowledge and previous experience are associated with a faster rate of adoption	Bettman and Park, 1980; Oh *et al.*, 2003; Dickerson and Gentry, 1983; Eastin, 2002; Sujan, 1985; Park and Lessig 1981	
ECONOMIC FACTORS		
Product price	Stoneman and Toivanen, 1997	Karshenas and Stoneman, 1992; Zettelmeyer and Stoneman, 1993; Stoneman, 2002
Income	Bonus, 1973	
USER INNOVATIVENESS		
Innovative consumers adopt innovations more often and earlier than others	Rogers and Shoemaker, 1971; Midgley and Downling, 1978; Hirschman, 1980; Gatignon and Robertson, 1985; Roehrich, 2004	
Global innovativeness	Goldsmith and Hofacker, 1991; Clark and Goldsmith, 2006; Hirunyawipada and Paswan, 2006; Venkatraman, 1991; Citrin *et al.*, 2000	
Domain-specific Innovativeness (within a specific domain of interest)		

The last questions in this section are about other consumer electronics, first asking which DAP precursors the users have had (Walkman, Discman or Minidisc players), then inquiring about which modern consumer electronic products have been purchased by respondents (such as blue-ray disc players, camcorders, digital cameras, Global Positioning Systems, High-Definition Televisions, Personal Digital Assistants and Smart Phones).

Table 5.2 Examples of questions on user innovativeness

Global Innovativeness
I must see other people using new innovations before I will consider them. (48d)
I am generally cautious about accepting new ideas. (48e)
Domain-specific innovativeness
In general, I am the last in my circle of friends to know about the latest new consumer electronics products. (49a)
I would not buy a new item of consumer electronics if I had only a little experience with it. (49e)

Note: answers given on a five-point Likert scale from 1=Strongly disagree to 5=Strongly agree.

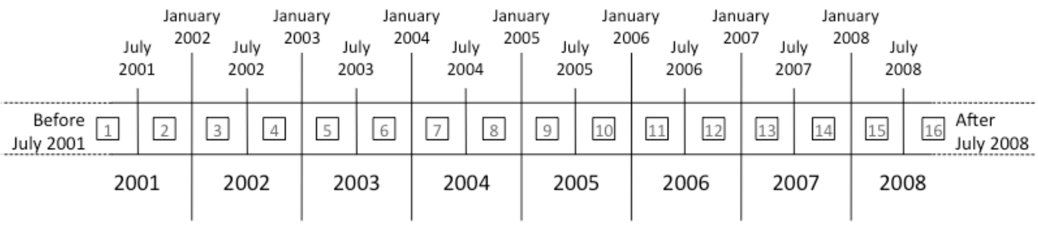
The final group of questions regards consumers' innovativeness (questions 48-49), defined by Hirschman (1980: p.283) as 'the propensities of the consumer to adopt novel products, whether they are ideas, goods or services'. In particular, consumer innovativeness can be decomposed into two aspects. The first is that innovativeness is 'the degree to which an individual is relatively earlier in adopting an innovation than other members of his social system' (Rogers and Shoemaker, 1971: p.27). The second aspect regards 'the degree to which an individual is receptive to new ideas and makes innovation decisions independently of the communicated experience of others' (Midgley and Dowling, 1978: p.236). In this respect, the definition of innovativeness can be further refined by referring to the distinction between *global innovativeness* and *domain-specific innovativeness* (Goldsmith and Hofacker, 1991; Midgley and Dowling, 1993; Goldsmith *et al.*, 1995; Roehrich, 2004; Hirunyawipada and Paswan, 2006). Global innovativeness refers to a personality-like construct, a sort of innate personal characteristic, regarding the propensity to adopt new ideas and new ways of doing things on a general level. On the other side, domain-specific innovativeness captures consumers' innovativeness related to a specific domain of knowledge, for instance consumer electronic products. We started this research with a self-developed set of items meant to build two latent variables (global and domain-specific innovativeness). However, since the confirmatory factor analysis on the results of the pilot questionnaire (see Section 5.1.2) failed to validate these scales, an adaptation of Goldsmith *et al.*'s (1995) set of items has been used for the final version of the questionnaire. Table 5.2 reports some examples of questions on global and domain-specific innovativeness.

<u>Questions about the innovation</u>

The second set of factors regards the characteristics of the innovative product and the demand-side's perception of them. This section of the questionnaire includes three sub-sections. The first is about the adoption and use of MP3 players by respondents. The second is about the importance of some product characteristics in the adoption of a DAP. The last sub-question regards the relevance of Rogers' product characteristics.

The first sub-section regards the adoption and use of a DAP (questions 16-29, 31). The most important question of this section regards the timing of the adoption. This is a crucial question for the entire research design, as most of the analysis carried out in the empirical chapters will be based on the answers to this question. The question on the timing of adoption (question 18, reported in Figure 5.2) asks respondents to choose one period of time from 16 semesters between ‘before July 2001’ and ‘after July 2008’ representing the period in which they adopted their first DAP. Asking respondents for a more precise timing, e.g. the month or the quarter in which they purchased their first DAP, might have created recall problems. For this reason, we eventually opted for time periods based on semesters.

Figure 5.2 Question on timing of adoption



Other questions in this section are: ‘How did you get your first MP3 player?’ (purchased, received as a gift, etc.), and ‘Did you try a DAP before adopting one? Which product did you adopt?’ (brand, type, features, storage capacity, etc.). Moreover, other questions regard the use of the DAP: ‘How frequently do you use it, which features are used the most, how did you learn how to use it?’ Finally, the last two sections regard Internet file sharing, asking: ‘How many GB of music do you have? And, how did you get these music files?’

The second part of the section regarding the innovation asks respondents to rate the importance of a list of product characteristics (such as storage space, weight, battery life, price, etc.) in evaluating a DAP (question 30). The importance of these characteristics is measured by a five-point Likert scale, ranging from ‘unimportant’ to ‘very important’. Most of these characteristics match exactly with the product features included in the supply-side dataset.

Table 5.3 Questionnaire topics and relevant literature 2/3

TOPIC	RELEVANT LITERATURE	
PRODUCT CHARACTERISTICS		
Perceived benefits	Davis, 1989 (perceived usefulness); Cooper and Kleinschmidt, 1987	Rogers, 2003; Hall, 2005; Gatignon and Robertson, 1985; Moore and Benbasat, 1991; Tornatzky and Klein, 1982; Oh *et al.*, 2003
Complexity	Davis, 1989 (perceived ease-of-use); Cooper and Zmud, 1990	
Observability		
Trialability		
Compatibility	Cooper and Zmud, 1990; Ramiller, 1994	

The last questions in this section (questions 32-35, 37) are a set of items aiming at constructing five variables measuring the importance of the five product characteristics defined by Rogers (Table 5.3). Some examples of these questions are reported in Table 5.4.

Table 5.4 Examples of questions on Rogers' product characteristics

Perceived benefits *
I have an MP3 player because:
It allows me to gather all my MP3 in only one device. (33a)
I can bring it with me and listen to music anywhere I want. (33b)
Complexity *
Learning how to use an MP3 player was easy for me. (34b)
Learning how to load my MP3 files into the MP3 player was easy for me. (34d)
Observability *
It was easy to identify which was the best MP3 player for me. (37a)
It was easy to compare the performance of the different MP3 players available. (37c)
Trialability *
After trying an MP3 player it is easier to appreciate its quality. (32a)
Before deciding whether or not to buy an MP3 player I would like to try it. (32c)
Compatibility **
Compatibility with the music file stored in my computer. (35a)
Availability of a dedicated software that connects the player to a computer (e.g. iTunes, Zune software). (35b)

*Note: * answers given on a five-point Likert scale from 1=Strongly disagree to 5=Strongly agree. ** answers given on a five-point Likert scale from 1=Unimportant to 5=Very important.*

Questions about the underlying diffusion process

The third section of the questionnaire takes into consideration the underlying DAPs diffusion process as potential factor influencing the timing of adoption. This section considers two sets of factors; the first one regards three different bandwagon theories, while the second is about the sources of information.

The first sub-section (questions 36, 38, 45-47) regards the three bandwagon theories presented in Chapter 2 and outlined in Table 5.5. The first concentrates on the fact that previous adopters can represent a significant source of information about the innovation, creating a sort of information externality able to foster the adoption process. The exchange of information between previous and potential adopters is usually through personal contact or word-of-mouth. The second theory claims that the bandwagon pressure comes from direct or indirect network externalities, which make the profitability of the innovation increase with an increase in the number of previous adopters.

Table 5.5 Questionnaire topics and relevant literature 3/3

TOPIC	RELEVANT LITERATURE
SOCIAL FACTORS	
Role of information	
Learning theories of bandwagon	Abrahmson and Rosenkopf, 1997; Chatterjee and Eliashberg, 1990
Word-of-mouth	Bass, 1969; Mahajan, Muller and Bass, 1990; Geroski, 2000
Role of network effects (Increasing return theories of bandwagon: the value of the innovation increases with the number of adopters)	Saloner and Shepard, 1985; Katz and Shapiro, 1986; Golsbee and Klenow, 2002; Abrahmson and Rosenkopf, 1997
Role of Interpersonal influence (Fads theories of bandwagon)	
Herd behaviour	Banerjee, 1992; Abrahmson and Rosenkopf, 1997
Informational cascades	Bikhchandani *et al.*, 1992, 1998; Geroski, 2000; Walden and Browne, 2002
SOURCES OF INFORMATION	
Some kinds of sources are associated with an earlier adoption, other sources with a later adoption	Bass, 1969; Mahajan, Muller and Bass, 1990; Lekvall and Wahlbin, 1973; Tonks, 1986; Geroski, 2000

The last type of bandwagon considers the role of herd behaviour and fads in influencing the adoption of innovations. In some cases, potential adopters may find it optimal to dismiss their private signals and imitate the previous adopters' decisions. A series of questions are specifically designed to obtain three latent variables representing the above-mentioned bandwagon effects. Some examples of questions employed to perform this task are reported in Table 5.6.

Table 5.6 Examples of questions on bandwagon theories

Information bandwagon

If I want to know more about a product, I would ask my friends about it. (45a)

I seek out the opinion of those who have tried new products or brands before I try them. (45d)

Network effects

A consumer electronics product is more beneficial if many people use it. (46a)

I would not buy a consumer electronics product if I thought that many other people will not buy it in the future. (46b)

Imitative behaviour

Having an MP3 player makes me feel part of a group. (38c)

Having an MP3 player makes me gain prestige among my friends. (38d)

Note: answers given on a five-point Likert scale from 1=Strongly disagree to 5=Strongly agree.

The second sub-section is about the sources of information (question 44). Potential adopters may get in touch with the innovation or obtain further information about it in several ways. The literature on diffusion usually considers two types of information sources: internal sources (word-of-mouth) and external sources (advertising). However, in the questionnaire a larger list of potential information sources is considered. In particular, one question asks respondents to rate on a Likert scale from 'unimportant' to 'very important' a list of twelve sources of information on DAPs: advertisements, celebrity endorsers, MP3 player producers' websites, family or relatives, friends, previous experience with the same brand, previous experience with similar products, online forums, online shops, traditional shops and other people.

Other questions

The questionnaire also contains two brief sections exclusively dedicated to multi-adopters and non-adopters. The first section regards those adopters who have had more than one DAP. This section (questions 39-41) asks how many MP3 players have been bought by respondents, and when the subsequent DAPs were adopted after the first. Moreover, this section investigates the reasons for purchasing more than one DAP, for instance because the old one got broken or lost, or because users needed a smaller model or more storage space.

The section on non-adopters (questions 42-43) first investigates the reasons for not having adopted a DAP yet, for instance because they are too expensive, users are afraid of not using them (or not being able to use them), they are already using another device to listen to music (such as mobile phones), etc. In addition, another question attempts to discriminate between non-adopters who are inclined to adopt a DAP soon (*interested*) and those who are not (*not interested).* Finally, for those who are interested, the questionnaire also asks what price they are willing to pay for a DAP.

5.1.2. Piloting the questionnaire

Once finalised, the questionnaire was piloted on a sample of 173 students:

- 26 PhD students and masters student at SPRU (University of Sussex, UK);
- 92 undergraduate students in economics and management at Bocconi University (Milan, Italy);
- 55 undergraduate students in engineering at Pavia University (Italy).

Of a total of 173 questionnaires administered:

- 18 were eliminated (obtaining a response rate of 89.6%);
- 155 could be used, of which:
    - 125 respondents are adopters (80.6%):
        - 81 of them are multi-adopters (64.8%);
        - 44 have only one DAP (35.2%).
    - 30 are non-adopters (19.4%):
        - 16 of them are interested in adopting a DAP soon (53.3%);
        - 14 are not interested in having a DAP (46.7%).

Considering the 30 non-adopters:

- 16 of them do not have any portable device able to read MP3 files (53.4%);
- Four have a CD player able to read MP3 files (13.3%);
- Ten use their phone to listen to MP3 files (33.3%).

Regarding the response rate, 18 questionnaires were eliminated at the beginning because they were submitted empty or because they included too many missing values to be considered valid, obtaining a response rate of 89.6%.

The questionnaire had been developed in English and then translated into Italian for the students from Milan and Pavia. The submission of such a long and complex questionnaire could involve a number of potential issues. The pilot of the questionnaire on a sufficiently large sample of students had the main purpose of making sure that these potential issues were kept under control, ensuring the feasibility of the data collection process.

The first issue that the pilot attempted to evaluate regards the adequacy of sampling for its purposes. In particular, the choice of an opportunistic sampling strategy was taken, primarily in order to gather a sufficient number of DAP adopters, not easily retrievable with other sampling methods. In this respect, students represented a good option, since they are considered to be some of the users most likely to be interested in these electronic products. The results of the pilot regarding this issue were excellent. More than 80% of the respondents are adopters of a DAP, with almost 65% of them even being adopters of more than one MP3 player (multi-adopters). This should ensure that submitting the final questionnaire to a much larger number of students would provide a sufficient number of adopters for the purposes of the thesis.

In addition, the pilot was a good opportunity to test whether the structure of the questionnaire, its layout and the redirections to different sections were working well and were not confusing the respondents. The main problem is that the questionnaire is very long, with specific sections for three different groups of respondents. The first result regards the time for completion of the questionnaire. The questionnaire worked quite well, since, despite the large number of questions, students took on average between 15 and 20 minutes to complete the questionnaire. The only respondents who took more than 20 minutes were those students who do not speak the language in which the questionnaire is written as a first language. This is for instance the case for foreign students who can speak English or Italian but who are not as fluent as native speakers. This result is very good, since 20 minutes appears to be an acceptable and feasible timing for the completion of the questionnaire. Moreover, the issue regarding the foreign students suggests that even though most of the students in the main sample would be able to answer in English, the questionnaire should be translated into the language spoken in the country where the respondents are located. Another interesting result regards the structure of the questionnaire and the redirections. In most of the cases, the redirections worked well; only a very small number of respondents answered questions not designed for them, and in all cases, they did not fail to answer required questions, but rather responded to those of other groups.

Other issues are about certain specific questions. Two very critical questions regarded the timing of adoption and the income of respondents. These questions deserved particular attention in the design phase, with positive results coming from the pilot. In particular, the results of the question on the timing of adoption were surprisingly good. First of all, only two students out of 125 were not able to remember when they adopted their first DAP. Moreover, the variable timing of adoption looks normally distributed.[79] By plotting the cumulative frequency against time, it is possible to see that the adoption rate over time draws a clear s-shaped curve. This preliminary result not only reflects most of the theories about diffusion (Geroski, 2000), but also indicates that the timing of this empirical research has been particularly favourable, as not too much time has passed since the first adoption of DAPs, allowing respondents to remember that period easily. The issue of income has been slightly more problematic. Specifically, 45 respondents did not answer this question. Some of them decided not to disclose their income. However, it is possible that a number of respondents, especially those students who depend on their family, did not know their family's income. In addition, the pilot contributed to the inclusion of some new questions that had not been considered in the first version of the questionnaire. Besides age, nationality and university degree, all the questions included in the final questionnaire are multiple-choice. However, the pilot questionnaire had some open answers, such as: 'Other, please specify'. Some of these new options expressed by respondents have been embedded in the final version of the questionnaire. Finally, the wording of some questions were improved by taking into account the useful comments made by some few respondents who spontaneously decided to share some of their concerns about the questionnaire.

The last purpose of the pilot was to attempt a preliminary validation of the scales that the questionnaire was designed to build (user innovativeness, Rogers' product

[79] Although the Kolmogorov-Smirnov test of normality is negative, two other tests based on the excess of skewness and the excess of kurtosis suggest that the distribution of the timing of adoption resembles normal distribution.

characteristics and social factors). The preliminary validation was carried out through exploratory factor analysis. Considering the limited sample size, the validation gave sufficiently good results and helped to refine some of the items constituting those latent variables. The only items not able to construct the scale they were meant to were those related to user innovativeness. For this reason, a new set of items adapted from Goldsmith *et al.* (1995) replaced the one used for the pilot.

5.1.3. Questionnaire submission[80]

The original questionnaire was developed in English, and was then translated into the language(s) spoken in each country in which it was submitted. The exception was the Netherlands, in which the good level of English of the students and the fact that the university courses were taught in English ensured a good comprehension of the questions. The final questionnaire has been translated into six languages (French, German, Italian, Japanese, Portuguese and Spanish). In every case, the questionnaire was translated by a PhD student or another individual who is researching themes somehow related to research in innovation management and policy.

The strategy of submission chosen was to enter the class with the lecturer, briefly present the purpose of the project, distribute the questionnaire and wait until the students had finished completing it. The submission was always pre-arranged with the lecturer, and took place either at the beginning or at the end of the class. This submission strategy had some benefits. First of all, the presence of the lecturer should encourage the students to be diligent in answering the questionnaire. In addition, this strategy reduced the risk of loss of data, missing questionnaires, etc. In a few cases, for various reasons, it was impossible to submit the questionnaire and wait until the students completed it. In those cases, the questionnaires were distributed and the students were asked to return them completed the next day or week. As expected, in this case the response rate dropped, as many students did not return the questionnaire.

[80] We acknowledge that this survey has been carried out within the European project entitled CID (Culture and Innovation Dynamics), funded by the VI Framework Programme of the European Commission and led by KITeS (Knowledge, International and Technology Studies), Bocconi University, Milan, Italy. While the objectives of this thesis and those of the European project diverge, we shared the collection of the data on the adoption of DAPs. The project funded the expenses related to the survey of adopters (such as travel costs, translation, etc.), and also assisted in getting in contact with the lecturers who allowed the submission of the questionnaire to their students. My responsibilities in the project have been mostly related to the design, pilot submission of the questionnaire and conducting the subsequent analysis of the results for other purposes than pursued in this thesis.

Table 5.7 Timetable of questionnaire submission

Country	*Date*	*Place*	*University*	*Sample size and language*
France	25/11/08	Ivry sur Seine	Paris Sud 11	22 French
	25/11/08	Paris	Paris 2	21 French
	25/11/08		Paris 1 Sorbonne	34 French
	28/11/08		Paris 3	27 French
	29/11/08		Paris 1 Sorbonne	36 French
Germany	08/10/08	Vallendar	Otto Beisheim School of Management	41 German, 3 English
	09/10/08			30 German, 16 English
	10/10/08			21 German, 2 English
	18/11/08	Jena	Friedrich-Schiller-University	91 German
Italy	24/11/08	Bergamo	Università di Bergamo	68 Italian
	02/12/08	Milano	Università Bocconi	132 Italian
Japan	15/01/09	Tokyo	Hitotsubashi University	102 Japanese
	15/01/09	Suwa	Tokyo University of Science	166 Japanese
Netherlands	03/11/08	Eindhoven	ECIS	21 English
	14/11/08	Utrecht	Universiteit Utrecht	71 English
Portugal	24/11/08	Lisbona	ISCTE	109 Portuguese
Spain	11/11/08	Sevilla	Universidad Pablo de Olavide	20 Spanish
	12/11/08			76 Spanish
	13/11/08			22 Spanish
	03/12/08	Valencia	Universidad Politécnica	21 Spanish
	26/02/09	Valencia	Universidad Politécnica	48 Spanish
Switzerland	05/11/08	Zurich	ETH	37 German, 1 Italian, 28 English, 5 French
	07/11/08	Lugano	Franklin College	95 English
UK	23/10/08	Bristol	University of Bristol, Dep. of Historical Studies	28 English
	30/10/08	Brighton	SPRU	112 English
	20/11/08	Manchester	University of Manchester	46 English

The questionnaire was submitted in nine countries: France, Germany, Italy, Portugal, the Netherlands, Spain, Switzerland, the UK and Japan. Two different universities were chosen for each country, with the exception of Portugal, in which it was distributed in only one place, and the UK and France, where the universities were respectively three and four in number. Choosing different universities in different cities is a way to compensate for the fact that the effects of interpersonal influence might be very strong within groups of students from only one university campus. For this reason, having respondents from several different places can avoid overly strong imitation phenomena or local specificities. Table 5.7 shows the timetable of the submission process, which started in October 2008 and finished in February 2009. Efforts have been put into polling students from different areas of study. Most of the respondents are students in economics or business and management degrees. However, in many cases the students surveyed were attending a lecture in a subject somehow related to science and innovation policy and management. These kinds of courses are often interdisciplinary and therefore they are followed by students from different fields. For this reason, a significant number of students who responded to the questionnaire belong to different disciplines, such as engineering, history, computer science, marketing, physics, biology, European studies and so on.

Table 5.8 Results of questionnaire submission

Country	*University*	*City*	*Questionnaires*		
			Total	*Not Valid*	*Valid*
France	Paris1Sorbonne	Paris	70	5	65
	Paris2	Paris	21	1	20
	Paris3	Paris	27	1	26
	Paris Sud11	Ivry sur Seine	22	3	19
Germany	Friedrich-Schiller-University	Jena	91	8	83
	Otto Beisheim School of Management	Vallendar	113	11	102
Italy	Unviersità di Bergamo	Bergamo	68	1	67
	Università Bocconi	Milano	132	6	126
Japan	Hitotsubashi University	Tokyo	102	39	63
	Tokyo University of Science, Suwa	Suwa	166	11	155
Netherlands	ECIS	Eindhoven	21	0	21
	Universiteit Utrecht	Utrecht	71	3	68
Portugal	ISCTE	Lisbon	109	6	103
Spain	Universidad Pablo de Olavide	Sevilla	118	2	116
	Universidad Politécnica de Valencia	Valencia	69	4	65
Switzerland	Franklin College	Lugano	95	6	89
	ETH	Zurich	81	9	72
UK	University of Bristol	Bristol	28	3	25
	University of Manchester	Manchester	46	3	43
	SPRU	Brighton	112	7	105
Total			1562	129	1433

The data entry (done manually) and cleaning took around seven weeks, while the validation process took around one month. The results of the questionnaire submission were very good (Table 5.8). The number of questionnaires submitted was 1562; 129 of them were empty or contained too many missing values to be considered valid. The number of valid questionnaires is 1433, representing a response rate of 91.7%.

Of a total of 1433 valid questionnaires:
- 1102 are adopters (76.9%):
    - 627 are multi-adopters (56.9%);
    - 475 have only one DAP (43.1%).
- 331 are non-adopters (23.1%):
    - 127 are interested in adopting a DAP soon (38.4%);
    - 204 are not interested in having a DAP (61.6%).

Considering the 331 non-adopters:
- 181 of them do not have any portable device able to read MP3 files (54.7);
- 10 have a CD player able to read MP3 files (3.0);
- 140 use their phone to listen to MP3 files (42.3).

5.2. Validation of the scales

The questionnaire is meant to obtain several variables affecting the time of adoption. In particular, 41 questions (items) are meant to measure ten latent variables that could possibly influence the time of adoption. These variables are divided into three sub-scales:

- User innovativeness:
  - Global innovativeness (five items: INNOV1-5);
  - Domain-specific innovativeness (five items: IN_DOM1-5).
- Social influences:
  - Info cascades or word-of-mouth (five items: WORD1-5);
  - Imitation (five items: IMIT1-5);
  - Network effects (four items: NETW1-4).
- Product characteristics:
  - Perceived benefits (four items: BENEF1-4);
  - Trialability (three items: TRIAL1-3);
  - Observability (three items: OBSER1-3);
  - Complexity (four items: COMPL1-4);
  - Compatibility (three items: COMPA1-3).

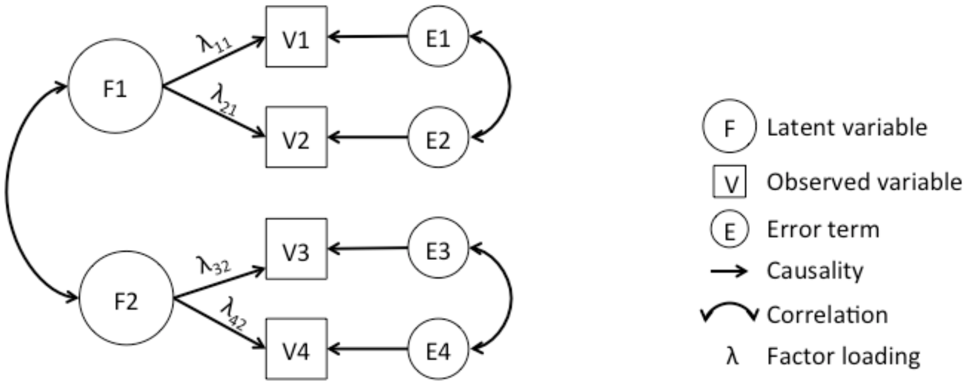
The validation of the scales is meant to verify whether the scales are valid, i.e. if each latent variable constructed by a set of items is the one they are supposed to measure, and reliable, i.e. if the variable obtained gives consistent results under the same conditions (Field, 2009: ch.17).

The methods chosen in order to test the validity of the scales are exploratory factor analysis (EFA) and confirmatory factor analysis (CFA), while the test for reliability chosen is Cronbach's alpha. EFA and Cronbach's alpha computation are performed with the statistical software SPSS, while CFA is carried out with EQS 6.1.

Both exploratory and confirmatory factor analysis use the same input (the correlation among the items); however, they are used for different purposes. Exploratory factor analysis considers the correlations among the observed items: in particular, how they cluster, and if the information provided by these items can be reduced to a smaller number of variables (factors). The structure of the extracted factors is then used for two purposes. First of all, it is compared with the hypothesised structure, in order to see if the observed items have a significant impact (*factor loading*) on the variable they are supposed to build, and whether the factor structure resembles that postulated at the beginning (Field, 2009: p.660-64). Secondly, this method also makes it possible to derive scales (the latent variables) that will be used in the further analysis of the data. In particular, the variables are created as linear combinations of the observed items using the factor loading (refined using a procedure called rotation[81]) as weights (Field, 2009: p.660-64).

On the other side, confirmatory factor analysis, using as an input the covariance matrix of the observed items, tests whether the factor structure of the observed items resembles the hypothesised one (Byrne, 2006). In particular, CFA is an application of structural equation modelling technique (SEM).

Figure 5.3 A general CFA structural equation model



Source: adapted from Byrne, 2006: p.15.

Figure 5.3 presents a general CFA structural equation model in which four items are meant to build two latent variables. In particular, the variables denoted with (*V*) are the items actually measured (questions included in the questionnaire), those denoted with (*F*) are the unobserved latent variables, and the variables expressed by (*E*) are the error terms. The single-headed arrows represent the impact of one variable on another, measured by the parameters λ; and the double-headed arrows represent covariances or correlations. Confirmatory factor analysis consists of the estimation of the following constrained model:

$$V1 = \lambda_{11}F1 + E1$$
$$V2 = \lambda_{21}F1 + E2$$
$$V3 = \lambda_{32}F2 + E3$$
$$V4 = \lambda_{42}F2 + E4$$

[81] The rotation method used in the analysis is an oblique rotation method (*direct oblimin*). This is because with this method the factors extracted are allowed to be correlated. Other orthogonal methods (e.g. *varimax*) would give uncorrelated factors. However, while a hypothesised factor structure exists, there are no clear indications from the literature whether these factors should be correlated or not. For this reason, in all the exploratory factor analysis performed on the data, an oblique rotation method is used (Field, 2009: p.664-8).

In matrix form:

$$\begin{bmatrix} V1 \\ V2 \\ V3 \\ V4 \end{bmatrix} = \begin{bmatrix} \lambda_{11} & 0 \\ \lambda_{21} & 0 \\ 0 & \lambda_{32} \\ 0 & \lambda_{42} \end{bmatrix} \begin{bmatrix} F1 \\ F2 \end{bmatrix} + \begin{bmatrix} E1 \\ E2 \\ E3 \\ E4 \end{bmatrix}$$

The model is constrained in the sense that not all the parameters are free to range. For instance, the parameter λ_{31} is set to be equal to 0, i.e. there is no causality between V3 and F1, since V3 is meant to build only F2. Let S represent the sample covariance matrix (scores of observed items), Σ (sigma) the population covariance matrix and θ a vector including model parameters. As a consequence, $\Sigma(\theta)$ is the restricted covariance matrix implied by the model. Specifically, CFA consists of obtaining the covariance matrices of observed values, estimating the parameters of the model and assessing the model fit by testing whether the population covariance matrix resembles the restricted one.

The software EQS provides several ways to test model fit and also to detect those items that are causing misfit, which should therefore be deleted. Model fit can be evaluated in three ways. The first way regards the individual parameters, which should be in order (having the correct sign and size) and statistically significant (different from 0). The second regards the residuals, the elements of the matrix $\Sigma(\theta) - S$. EQS lists them both individually and on average; they should be low and their distribution should be symmetrical and concentrated around 0. Finally, the last, and perhaps most important test is the goodness of fit of the whole model. Assessing model fit means testing the hypothesis that $\Sigma = \Sigma(\theta)$ (Byrne, 2006: p.80). EQS provides several instruments with which to test this hypothesis. The first one is a chi-square statistic, which, however, tends not to give satisfactory results if the sample size is large (Jöreskog, and Sörbom, 1993, cited by Byrne, 2006: p.96), such as in the case of the present thesis. For this reason, a full set of fit indices and misfit indices is provided.

EFA and CFA are used to test the validity of the scales. In particular, by validity we mean *construct validity*, i.e. whether the measure correlates with the theorised construct. Finally, on the validated factors a reliability analysis is carried out. In particular, the most common measure of scale reliability will be used, Cronbach's alpha, in order to assess whether the questionnaire gives the same results under the same conditions (Field, 2009: p.673). Which value of Cronbach's alpha constitutes an acceptable level is not generally agreed, and the threshold level may vary according to disciplines and the purpose of analysis. An index over .80 usually indicates an excellent level of reliability. However, in general, in the social sciences, .70 is considered the lower limit for Cronbach's alpha, although this threshold may decrease to .60 in exploratory research (Hair, 2010: p.125). Regarding the set of measures collected in this thesis, the only scales that have already been developed and validated by the literature are those about user innovativeness. In this case, the threshold level of Cronbach's alpha will be .70. The other measures have been specifically developed for the purpose of this thesis, and, in this case, a Cronbach's alpha over .60 will be considered acceptable.

5.2.1. Validation of user innovativeness scales

Regarding user innovativeness, ten items are meant to obtain two variables (global innovativeness and domain-specific innovativeness).

The first operation carried out is the production of the correlation matrix. Table 5.9 shows that two items appear to be the most problematic: IN_DOM4 and IN_DOM5. IN_DOM4 appears to have quite a low correlation with the other items (IN_DOM1, IN_DOM2, IN_DOM3). Furthermore, IN_DOM4 is not even significantly correlated with any other IN_DOM items.

Table 5.9 Results of preliminary EFA: correlation matrix

	INNOV1	***INNOV2***	***INNOV3***	***INNOV4***	***INNOV5***	***IN_DOM1***	***IN_DOM2***	***IN_DOM3***	***IN_DOM4***	***IN_DOM5***
INNOV1	1	.618***	.379***	.531***	.420***					
INNOV2		1	.451***	.561***	.450***					
INNOV3			1	.537***	.497***					
INNOV4				1	.533***					
INNOV5					1					
IN_DOM1						1	.622***	.672***	-.118	.211***
IN_DOM2							1	.643***	-.145	.298***
IN_DOM3								1	-.117	.255***
IN_DOM4									1	.013
IN_DOM5										1

*Note: *** p<0.01, ** p<0.05, * p<0.1*

In addition, a preliminary EFA is carried out. By looking at the factor structure (Table 5.10) one can realise that two factors are extracted; the first is global innovativeness and the other is domain-specific innovativeness, with all the items loading on the proper factor. Regarding global innovativeness, all the loadings are quite high, with the exception of INNOV3 which has a slightly lower level. The loadings of domain-specific innovativeness look a bit more problematic.

Table 5.10 Results of preliminary EFA: factor structure

	Component	
	1	2
INNOV1	.822	
INNOV2	.828	
INNOV3	.620	
INNOV4	.807	
INNOV5	.687	
IN_DOM1		-.774
IN_DOM2		-.800
IN_DOM3		-.788
IN_DOM4		.446
IN_DOM5		

Note: factor loadings below .400 are not reported.

The variable IN_DOM4 appears to have a very low loading on factor 2 (.446) and IN_DOM5 does not even appear in the factor list (its factor loading is smaller than .400). In light of these results, the two items IN_DOM4 and IN_DOM5 will not be included in the analysis.

Figure 5.4 Results of preliminary CFA: standardised residuals

```
                    AVERAGE ABSOLUTE STANDARDIZED RESIDUALS     =         .0411
         AVERAGE OFF-DIAGONAL ABSOLUTE STANDARDIZED RESIDUALS     =         .0529

 LARGEST STANDARDIZED RESIDUALS:

     NO.    PARAMETER   ESTIMATE      NO.    PARAMETER   ESTIMATE
     ---    ---------   --------      ---    ---------   --------
      1     V6,  V3         .198      11     V6,  V5         .064
      2     V2,  V1         .124      12     V5,  V3         .044
      3     V8,  V3         .114      13     V6,  V2        -.043
      4     V7,  V3         .114      14     V3,  V2        -.042
      5     V7,  V1        -.109      15     V5,  V2        -.037
      6     V7,  V2        -.084      16     V5,  V1        -.034
      7     V6,  V1        -.081      17     V7,  V5         .034
      8     V3,  V1        -.079      18     V7,  V4        -.029
      9     V8,  V1        -.076      19     V8,  V5         .028
     10     V8,  V2        -.066      20     V8,  V4        -.023
```

The same structure is then tested through a preliminary confirmatory factor analysis. The first result regards the residual matrix, which should indicate that the residuals are low. As indicated by Figure 5.4, both the average standardised residuals and the off-diagonal average residuals are low (.0411 and .0529 respectively). However, by looking at the 20 largest standardised residuals, it is possible to realise that on the five largest residuals, variable V3 (INNOV3) is included three times. This result, together with the low factor loading reported in Table 5.10, could suggest that the item INNOV3 should be excluded in order to obtain a better fit.

Figure 5.5 Results of preliminary CFA: goodness of fit statistics

```
CHI-SQUARE =      301.023 BASED ON      19 DEGREES OF FREEDOM
PROBABILITY VALUE FOR THE CHI-SQUARE STATISTIC IS       .00000

FIT INDICES
-----------
BENTLER-BONETT     NORMED FIT INDEX =      .937
BENTLER-BONETT NON-NORMED FIT INDEX =      .913
COMPARATIVE FIT INDEX (CFI)         =      .941
BOLLEN   (IFI) FIT INDEX            =      .941
LISREL    GFI  FIT INDEX            =      .945
LISREL   AGFI  FIT INDEX            =      .896
ROOT MEAN-SQUARE RESIDUAL (RMR)     =      .065
STANDARDIZED RMR                    =      .062
ROOT MEAN-SQUARE ERROR OF APPROXIMATION (RMSEA)     =      .102
90% CONFIDENCE INTERVAL OF RMSEA  (        .092,        .112)
```

Finally, the goodness of fit summary (reported in Figure 5.5) gives a series of indexes that test the fit of the model as a whole. The chi-square test indicates a misfit (p=.000); however, this might be due to the above-mentioned known problems of chi-square tests with large samples. The vast majority of the other goodness of fit indexes show a good fit of the data to the model (being in all cases higher than .900). However, the measures of absolute misfit (RMR, SRMR, RMSEA) are still too high (since RMR and SRMR are >.05 and RMSEA is >.08).

Figure 5.6 Results of final EFA: tests and factor extraction

KMO and Bartlett's Test

Kaiser-Meyer-Olkin		.807
Bartlett's Test of Sphericity	Approx. Chi-Square	3960.198
	df	21
	Sig.	.000

Factor extraction

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadingsa
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	3.312	47.317	47.317	3.312	47.317	47.317	2.829
2	1.574	22.493	69.810	1.574	22.493	69.810	2.636
3	.603	8.612	78.422				
4	.430	6.139	84.561				
5	.382	5.453	90.014				
6	.379	5.409	95.422				
7	.320	4.578	100.000				

These results suggest that by eliminating one variable (INNOV3) it would be possible to get better results. For this reason, the final validation process (both EFA and CFA) will be repeated, eliminating INNOV3.

The first results of the final EFA are reported in Figure 5.6, which shows some preliminary tests and the factor extraction. The KMO test of sample adequacy indicates that the sample size of 1433 cases is more than enough. Finally, Bartlett's test indicates that the correlation matrix shows that all the correlation coefficients off the diagonal are not equal to zero (sig.<.001). The next table reports the results of the factor extraction process. Using the Kaiser method (eigenvalue >1), two factors (as expected) are extracted. These factors account for 69.81% of the total variance. Table 5.11 shows the factor structure after performing principal component analysis with direct oblimin oblique rotation.

Table 5.11 Results of final EFA: factor structure

	Component	
	1	2
INNOV1	.863	
INNOV2	.856	
INNOV4	.786	
INNOV5	.660	
IN_DOM1		-.855
IN_DOM2		-.877
IN_DOM3		-.874

Note: factor loadings below .400 are not reported.

Table 5.11 indicates that all the items load in the appropriate factor, with quite high factor loadings, and none of the items load in more than one factor. This suggests that, allowing the items to freely load in any factor, the resulting factor structure is strongly similar to the hypothesised one. The next step is to perform CFA on the same scales. In this case, the items will be constrained to load only in the specific factor that they are supposed to build. An analysis of the goodness of fit and of the residuals of this kind of analysis will then indicate whether the data fits the hypothesised factor structure. In other words, it will indicate if the scales are valid or not.

Figure 5.7 shows the residuals of the CFA. Both the average standardised residuals and the average off-diagonal residuals are quite low. Moreover, the distribution of standardised residuals is reasonably symmetrical and centered around 0 (more than 95% of the residuals are between -0.1 and +0.1). Regarding the individual parameters (Figure 5.8), they appear to be in order, and they are all statistically significant.[82]

[82] EQS automatically performs a t-test marking the coefficients statistically different from 0 at the .05 level with the symbol @.

Figure 5.7 Results of final CFA: standardised residuals

```
                     AVERAGE ABSOLUTE STANDARDIZED RESIDUALS     =         .0335
        AVERAGE OFF-DIAGONAL ABSOLUTE STANDARDIZED RESIDUALS     =         .0447

 DISTRIBUTION OF STANDARDIZED RESIDUALS
      ----------------------------------------
      !                                      !          RANGE      FREQ PERCENT
    15-                    *                 -
      !                    *                 !    1   -0.5  -  --       0    .00%
      !                    *                 !    2   -0.4  -  -0.5     0    .00%
      !                 *  *                 !    3   -0.3  -  -0.4     0    .00%
      !                 *  *                 !    4   -0.2  -  -0.3     0    .00%
    10-                 *  *                 -    5   -0.1  -  -0.2     0    .00%
      !                 *  *                 !    6    0.0  -  -0.1    12  42.86%
      !                 *  *                 !    7    0.1  -   0.0    15  53.57%
      !                 *  *                 !    8    0.2  -   0.1     1   3.57%
      !                 *  *                 !    9    0.3  -   0.2     0    .00%
     5-                 *  *                 -    A    0.4  -   0.3     0    .00%
      !                 *  *                 !    B    0.5  -   0.4     0    .00%
      !                 *  *                 !    C     ++  -   0.5     0    .00%
      !                 *  *                 !    -------------------------------
      !                 *  *  *              !          TOTAL        28 100.00%
      ----------------------------------------
         1  2  3  4  5  6  7  8  9  A  B  C      EACH "*" REPRESENTS  1 RESIDUALS
```

Figure 5.8 Results of final CFA: individual parameters

```
  MEASUREMENT EQUATIONS WITH STANDARD ERRORS AND TEST STATISTICS
  STATISTICS SIGNIFICANT AT THE 5% LEVEL ARE MARKED WITH @.

 INNOV1  =V1  =   1.000 F1    + 1.000 E1
 INNOV2  =V2  =   1.003*F1    + 1.000 E2
                   .040
                 24.809@
 INNOV4  =V4  =   1.069*F1    + 1.000 E4
                   .043
                 24.736@
 INNOV5  =V5  =    .906*F1    + 1.000 E5
                   .042
                 21.331@

 IN_DOM1 =V6  =   1.000 F2    + 1.000 E6
 IN_DOM2 =V7  =    .989*F2    + 1.000 E7
                   .034
                 28.892@
 IN_DOM3 =V8  =   1.064*F2    + 1.000 E8
                   .035
                 30.281@
```

Figure 5.9 Results of final CFA: goodness of fit statistics

```
  CHI-SQUARE =      129.784 BASED ON      13 DEGREES OF FREEDOM
  PROBABILITY VALUE FOR THE CHI-SQUARE STATISTIC IS       .00000

  FIT INDICES
  -----------
  BENTLER-BONETT     NORMED FIT INDEX =      .967
  BENTLER-BONETT NON-NORMED FIT INDEX =      .952
  COMPARATIVE FIT INDEX (CFI)         =      .970
  BOLLEN   (IFI) FIT INDEX            =      .970
  MCDONALD (MFI) FIT INDEX            =      .960
  LISREL    GFI  FIT INDEX            =      .972
  LISREL   AGFI  FIT INDEX            =      .940
  ROOT MEAN-SQUARE RESIDUAL (RMR)     =      .050
  STANDARDIZED RMR                    =      .046
  ROOT MEAN-SQUARE ERROR OF APPROXIMATION (RMSEA)     =      .079
  90% CONFIDENCE INTERVAL OF RMSEA  (        .067,        .092)
```

Finally, the goodness of fit summary provides a series of indexes that test the fit of the model as a whole. The chi-square test indicates a misfit ($p=.000$); however, this might be due to the well-known problems of chi-square tests with large samples. All the other fit indexes show an excellent fit of the data to the model. In particular, the comparative fit indexes (NFI, NNFI, CFI and IFI) are higher than .950, and the absolute fit indexes (MFI, GFI and AGFI) are above .900. In addition, the measures of misfit (RMR, SRMR, RMSEA) are low enough.

The results of both the EFA and the CFA indicate that the scales can be considered valid. The last measure regards the scales' reliability (Table 5.12). Cronbach's alpha calculated for the two factors indicates a very high reliability (>.080). In addition, when deleting any of the items in each scale, the Cronbach's alpha never increases.

Table 5.12 Cronbach's alpha for user innovativeness scales

	Cronbach's alpha	***N of Items***
Global innovativeness	.811	4
Domain-specific innov.	.845	3

In conclusion, the two scales regarding user innovativeness could be considered valid and reliable.

5.2.2. Validation of Rogers' product characteristics scales

In order to obtain five latent variables regarding Rogers' product characteristics (perceived benefits, complexity, compatibility, observability and trialability), 17 items have been developed.

In this case the sample size is 1102 cases, because only adopters answered these questions. Table 5.13 shows the correlation matrix of the items composing each factor. The main issue regards the perceived benefits items. In particular, BENEF1 and BENEF2 show a very low correlation (in one case even a negative correlation) with the other two items. This indicates that it would be useful to drop these two items. The other two items with a lower level of correlation are COMPL1 and COMPA1.

Table 5.13 Results of preliminary EFA: correlation matrix

	BENEF1	***BENEF2***	***BENEF3***	***BENEF4***	***TRIAL1***	***TRIAL2***	***TRIAL3***	***COMPL1***	***COMPL2***	***COMPL3***	***COMPL4***	***COMPA1***	***COMPA2***	***COMPA3***	***OBSER1***	***OBSER2***	***OBSER3***
BENEF1	1	.274***	.195***	.128***													
BENEF2		1	.034	-.106***													
BENEF3			1	.353***													
BENEF4				1													
TRIAL1					1	.35***	.391***										
TRIAL2						1	.294***										
TRIAL3							1										
COMPL1								1	.427***	.309***	.297***						
COMPL2									1	.507***	.575***						
COMPL3										1	.586***						
COMPL4											1						
COMPA1												1	.32***	.173***			
COMPA2													1	.408***			
COMPA3														1			
OBSER1															1	.472***	.331***
OBSER2																1	.312***
OBSER3																	1

*Note: *** p<0.01, ** p<0.05, * p<0.1*

Table 5.14 Results of preliminary EFA: factor structure

	Component				
	1	2	3	4	5
BENEF1					-.587
BENEF2					-.820
TRIAL1			.768		
TRIAL2			.711		
TRIAL3			.756		
COMPL1	.609				
COMPL2	.816				
COMPL3	.788				
COMPL4	.807				
COMPA1		.487			-.418
COMPA2		.819			
COMPA3		.792			
OBSER1				-.789	
OBSER2				-.834	
OBSER3				-.512	-.418

Note: factor loadings below .400 are not reported.

A preliminary exploratory factor analysis using all the items besides BENEF1 and BENEF2 is performed. Table 5.14 reports the factor structure. The expected number of factors extracted is five. The only items that appear to be problematic are COMPA1 and OBSER3, which load in more than one factor. This would suggest dropping them from the list. Moreover, another item that has a lower factor loading is COMLP1. This item also had quite a low correlation with the other items. For these reasons, COMPL1 will also be excluded.

Figure 5.10 Results of final EFA: tests and factor extraction

KMO and Bartlett's Test

Kaiser-Meyer-Olkin		.715
Bartlett's Test of Sphericity	Approx. Chi-Square	2505.490
	df	66
	Sig.	.000

Factor extraction

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadingsa
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	2.902	24.183	24.183	2.902	24.183	24.183	2.394
2	1.682	14.014	38.197	1.682	14.014	38.197	1.547
3	1.463	12.193	50.390	1.463	12.193	50.390	1.838
4	1.073	8.942	59.332	1.073	8.942	59.332	1.793
5	1.051	8.759	68.090	1.051	8.759	68.090	1.467
6	.732	6.097	74.188				
7	.645	5.378	79.566				
8	.575	4.795	84.361				
9	.560	4.668	89.029				
10	.496	4.132	93.161				
11	.443	3.688	96.849				
12	.378	3.151	100.000				

The validity of the five scales with the 12 remaining items will now be tested again with EFA and CFA. Figure 5.10 reports the results of the final EFA, first of all indicating that the KMO test for sample adequacy and the Bartlett test give good results. Moreover, the number of factors extracted is (as expected) five, representing 68.09% of the total variance. Table 5.15 shows the factor structure after performing principal component analysis with direct oblimin rotation. All the items load into their respective factors with significantly high loadings, and none of them load into more than one.

Since the exploratory factor analysis extracted the expected factor structure, confirmatory factor analysis will be now performed in order to test whether this structure fits with the data and the scales can be considered valid. The first results of

CFA are reported in Figure 5.11 and regard the residuals of the analysis. First, the average residuals and the off-diagonal average residuals are quite low (.0339 and .0400). Moreover, the residuals are reasonably symmetrically distributed around 0.

Table 5.15 Results of final EFA: factor structure

	Component				
	1	2	3	4	5
BENEF1					-.678
BENEF2					-.821
TRIAL1			-.749		
TRIAL2			-.709		
TRIAL3			-.764		
COMPL2	.795				
COMPL3	.844				
COMPL4	.865				
COMPA2		.801			
COMPA3		.850			
OBSER1				-.775	
OBSER2				-.855	

Note: factor loadings below .400 are not reported.

Figure 5.11 Results of preliminary CFA: standardised residuals

```
                   AVERAGE ABSOLUTE STANDARDIZED RESIDUALS     =         .0339
      AVERAGE OFF-DIAGONAL ABSOLUTE STANDARDIZED RESIDUALS     =         .0400

DISTRIBUTION OF STANDARDIZED RESIDUALS
   ----------------------------------------
   !                                      !
 40-                    *                 -
   !                    *                 !
   !                    *                 !
   !                 *  *                 !
   !                 *  *                 !            RANGE      FREQ PERCENT
 30-                 *  *                 -
   !                 *  *                 !    1   -0.5  -  --       0    .00%
   !                 *  *                 !    2   -0.4  -  -0.5     0    .00%
   !                 *  *                 !    3   -0.3  -  -0.4     0    .00%
   !                 *  *                 !    4   -0.2  -  -0.3     0    .00%
20-                  *  *                 -    5   -0.1  -  -0.2     3   3.85%
   !                 *  *                 !    6    0.0  -  -0.1    34  43.59%
   !                 *  *                 !    7    0.1  -   0.0    39  50.00%
   !                 *  *                 !    8    0.2  -   0.1     2   2.56%
   !                 *  *                 !    9    0.3  -   0.2     0    .00%
 10-                 *  *                 -    A    0.4  -   0.3     0    .00%
   !                 *  *                 !    B    0.5  -   0.4     0    .00%
   !                 *  *                 !    C     ++  -   0.5     0    .00%
   !              *  *  *                 !    -------------------------------
   !              *  *  *  *              !            TOTAL        78 100.00%
   ----------------------------------------
      1  2  3  4  5  6  7  8  9  A  B  C      EACH "*" REPRESENTS  2 RESIDUALS
```

The second result of CFA is about the individual parameters, and is reported in Figure 5.12. In all the cases the parameters appear in order and the t-test indicates that they are significantly different from 0. The last result regards the overall goodness of fit, and it is reported in Figure 5.13. In this case the chi-square statistic is also not significant; however, this may be due to the large sample used in the analysis. All the other fit indices (with the sole exclusion of the non-normed fit index) give satisfactory results, indicating that the five scales can be considered valid, meaning that they are currently measuring what they are intended to measure.

Figure 5.12 Results of final CFA: individual parameters

```
 MEASUREMENT EQUATIONS WITH STANDARD ERRORS AND TEST STATISTICS
 STATISTICS SIGNIFICANT AT THE 5% LEVEL ARE MARKED WITH @.

BENEF1  =V1  =   1.000 F5    + 1.000 E1
BENEF2  =V2  =    .543*F5    + 1.000 E2
                  .069
                 7.897@

TRIAL1  =V5  =   1.000 F1    + 1.000 E5
TRIAL2  =V6  =    .819*F1    + 1.000 E6
                  .079
                10.415@
TRIAL3  =V7  =    .863*F1    + 1.000 E7
                  .082
                10.531@

COMPL2  =V9  =   1.000 F2    + 1.000 E9
COMPL3  =V10 =   1.455*F2    + 1.000 E10
                  .073
                19.853@
COMPL4  =V11 =   1.329*F2    + 1.000 E11
                  .065
                20.429@

COMPA2  =V13 =   1.000 F3    + 1.000 E13
COMPA3  =V14 =    .799*F3    + 1.000 E14
                  .127
                 6.305@

OBSER1  =V15 =   1.000 F4    + 1.000 E15
OBSER2  =V16 =    .852*F4    + 1.000 E16
                  .081
                10.497@
```

Figure 5.13 Results of final CFA: goodness of fit statistics

```
 CHI-SQUARE =      250.635 BASED ON      44 DEGREES OF FREEDOM
 PROBABILITY VALUE FOR THE CHI-SQUARE STATISTIC IS       .00000

 FIT INDICES
 -----------
 BENTLER-BONETT     NORMED FIT INDEX =      .900
 BENTLER-BONETT NON-NORMED FIT INDEX =      .874
 COMPARATIVE FIT INDEX (CFI)         =      .916
 BOLLEN   (IFI) FIT INDEX            =      .916
 MCDONALD (MFI) FIT INDEX            =      .911
 LISREL    GFI  FIT INDEX            =      .964
 LISREL   AGFI  FIT INDEX            =      .936
 ROOT MEAN-SQUARE RESIDUAL (RMR)     =      .043
 STANDARDIZED RMR                    =      .049
 ROOT MEAN-SQUARE ERROR OF APPROXIMATION (RMSEA)    =      .065
 90% CONFIDENCE INTERVAL OF RMSEA  (        .057,        .073)
```

The final task about the product characteristics scales regards the reliability statistics, which unfortunately do not give a completely satisfactory result. Table 5.16 reports the Cronbach's alpha for each scale, showing that in two cases the index is too low to consider the scale reliable. These are the cases of perceived benefits and compatibility. In particular, the variable 'perceived benefits' has a very low Cronbach's alpha. This means that particular attention should be paid to interpreting the results of any analysis involving the use of these two variables.

Table 5.16 Cronbach's alpha for Rogers' product characteristics scales

	Cronbach's alpha	***N of Items***
Perceived benefits	.381	2
Trialability	.610	3
Complexity	.777	3
Compatibility	.579	2
Observability	.640	2

5.2.3. Validation of social factors scales

Similar to the other two groups of variables, the scales regarding social factors will now be validated. Specifically, 14 items are supposed to build three latent variables regarding the effects of social factors on the timing of adoption (network effects, word-of-mouth/info cascades and imitation). In this case the sample size is also represented by 1102 respondents, since only adopters answered these questions.

Table 5.17 Results of preliminary EFA: correlation matrix

	NETW1	***NETW2***	***NETW3***	***NETW4***	***WORD1***	***WORD2***	***WORD3***	***WORD4***	***WORD5***	***IMIT1***	***IMIT2***	***IMIT3***	***IMIT4***	***IMIT5***
NETW1	1	.485***	.267***	.323***										
NETW2		1	.211***	.227***										
NETW3			1	.464***										
NETW4				1										
WORD1					1	.208***	.378***	.270***	.240***					
WORD2						1	.398***	.505***	.365***					
WORD3							1	.441***	.340***					
WORD4								1	.548***					
WORD5									1					
IMIT1										1	.628***	.395***	.531***	.418***
IMIT2											1	.473***	.565***	.451***
IMIT3												1	.552***	.515***
IMIT4													1	.538***
IMIT5														1

*Note: *** p<0.01, ** p<0.05, * p<0.1*

First of all, Table 5.17 reports the correlation matrix. All the items seem to be adequately correlated with the other items composing the same factor. The most problematic item seems to be WORD1, which is poorly correlated with all the other items. This suggests dropping this item in order to avoid problems in creating the three latent variables.

A preliminary EFA (Table 5.18) performed on the social effects items, excluding WORD1, extracts the correct number of factors (three), without any particularly evident problems regarding the factor structure. The only item with a relatively lower loading is WORD3.

Table 5.18 Results of preliminary EFA: factor structure

	Component		
	1	2	3
NETW1			.720
NETW2			.625
NETW3			.687
NETW4			.721
WORD2		.753	
WORD3		.531	
WORD4		.852	
WORD5		.775	
IMIT1	.720		
IMIT2	.755		
IMIT3	.766		
IMIT4	.808		
IMIT5	.791		

Figure 5.14 Results of preliminary CFA: goodness of fit statistics

```
CHI-SQUARE =      798.073 BASED ON      62 DEGREES OF FREEDOM
PROBABILITY VALUE FOR THE CHI-SQUARE STATISTIC IS       .00000

FIT INDICES
-----------
BENTLER-BONETT     NORMED FIT INDEX =      .822
BENTLER-BONETT NON-NORMED FIT INDEX =      .789
COMPARATIVE FIT INDEX (CFI)         =      .833
BOLLEN   (IFI) FIT INDEX            =      .833
MCDONALD (MFI) FIT INDEX            =      .716
LISREL    GFI  FIT INDEX            =      .898
LISREL   AGFI  FIT INDEX            =      .850
ROOT MEAN-SQUARE RESIDUAL (RMR)     =      .088
STANDARDIZED RMR                    =      .081
ROOT MEAN-SQUARE ERROR OF APPROXIMATION (RMSEA)    =      .104
90% CONFIDENCE INTERVAL OF RMSEA  (        .097,        .110)
```

The second step before the final validation of the scales is to perform a preliminary CFA. Figure 5.14 reports the goodness of fit statistics, indicating a poor fit of the data to the hypothesised model, since none of the fit or misfit indices are within the acceptable level. A way to detect which items are the most problematic is to list the largest standardised residuals (reported in Figure 5.15). The items that appear most often are V13 (IMIT4), V14 (IMIT5) and V7 (WORD3). For this reason, these items will be excluded, and the final EFA and CFA will be performed on the remaining ten items.

Figure 5.15 Results of preliminary CFA: largest standardised residuals

```
LARGEST STANDARDIZED RESIDUALS:

    NO.     PARAMETER   ESTIMATE       NO.     PARAMETER   ESTIMATE
    ---     ---------   --------       ---     ---------   --------
     1      V14, V13        .346       11      V14, V1         .109
     2      V14, V7         .270       12      V13, V4         .107
     3      V10, V7         .202       13      V7,  V2         .107
     4      V14, V4         .188       14      V12, V8        -.104
     5      V13, V7         .174       15      V4,  V2        -.098
     6      V4,  V3         .161       16      V7,  V4         .096
     7      V11, V7         .151       17      V7,  V3         .093
     8      V7,  V1         .151       18      V13, V9         .087
     9      V2,  V1         .128       19      V6,  V4        -.082
    10      V12, V7         .124       20      V3,  V2        -.080
```

Figure 5.16 reports the results of the EFA. First of all, the KMO and Bartlett tests indicate that the data fulfils the preconditions necessary in order to proceed with the analysis. The number of factors extracted following Kaiser's method (eigenvalue >1) is three, explaining 59.9% of the variance.

Figure 5.16 Results of final EFA: tests and factor extraction

KMO and Bartlett's Test

Kaiser-Meyer-Olkin		.738
Bartlett's Test of Sphericity	Approx. Chi-Square	2635.729
	df	45
	Sig.	.000

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadingsa
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	3.134	31.339	31.339	3.134	31.339	31.339	2.289
2	1.582	15.818	47.158	1.582	15.818	47.158	2.198
3	1.276	12.764	59.922	1.276	12.764	59.922	2.365
4	.952	9.520	69.442				
5	.674	6.739	76.181				
6	.606	6.063	82.244				
7	.537	5.373	87.617				
8	.491	4.913	92.530				
9	.391	3.909	96.439				
10	.356	3.561	100.000				

The three factors can be easily interpreted by looking at the factor structure reported in Table 5.19. All the items have significantly high loadings only on the scale they are expected to build. For this reason, the three scales regarding social influences can be considered valid for what concerns exploratory factor analysis.

Table 5.19 Results of final EFA: factor structure

	Component		
	1	2	3
NETW1			.746
NETW2			.687
NETW3			.670
NETW4			.686
WORD2		.752	
WORD4		.846	
WORD5		.788	
IMIT1	.812		
IMIT2	.838		
IMIT3	.749		

Note: factor loadings below .400 are not reported.

The next step is to perform CFA, constraining the data to have a hypothesised structure and then evaluating the goodness of fit of the data to this structure. The initial results are reported in Figure 5.17 and regard the individual parameters, which are all in order and significantly different from 0.

Figure 5.17 Results of final CFA: individual parameters

```
 MEASUREMENT EQUATIONS WITH STANDARD ERRORS AND TEST STATISTICS
 STATISTICS SIGNIFICANT AT THE 5% LEVEL ARE MARKED WITH @.

NETW1   =V1  =   1.000 F1    + 1.000 E1
NETW2   =V2  =    .955*F1    + 1.000 E2
                  .071
                13.369@
NETW3   =V3  =    .768*F1    + 1.000 E3
                  .061
                12.597@
NETW4   =V4  =    .865*F1    + 1.000 E4
                  .064
                13.505@

WORD2   =V6  =   1.000 F2    + 1.000 E6
WORD4   =V8  =   1.570*F2    + 1.000 E8
                  .103
                15.186@
WORD5   =V9  =   1.083*F2    + 1.000 E9
                  .069
                15.658@

IMIT1   =V10 =   1.000 F3    + 1.000 E10
IMIT2   =V11 =   1.419*F3    + 1.000 E11
                  .081
                17.431@
IMIT3   =V12 =   1.300*F3    + 1.000 E12
                  .073
                17.738@
```

The second result (Figure 5.18) regards the residuals, which are on average quite low and significantly centred around 0. Finally, Figure 5.19 reports the goodness of fit statistics. Besides the usual issue with the chi-square statistic, all the fit indexes are higher than .90 and misfit indices have values low enough to conclude that the data fits with the hypothesised model, and hence that the three scales can be considered valid.

Figure 5.18 Results of final CFA: standardised residuals

```
                      AVERAGE ABSOLUTE STANDARDIZED RESIDUALS     =         .0306
         AVERAGE OFF-DIAGONAL ABSOLUTE STANDARDIZED RESIDUALS     =         .0374

 DISTRIBUTION OF STANDARDIZED RESIDUALS
    ----------------------------------------
    !                                      !
    !                    *                 !          RANGE      FREQ PERCENT
 30-                     *                 -
    !                    *                 !   1   -0.5  -  --        0    .00%
    !                    *                 !   2   -0.4  -  -0.5      0    .00%
    !                    *                 !   3   -0.3  -  -0.4      0    .00%
    !                 *  *                 !   4   -0.2  -  -0.3      0    .00%
 20-                  *  *                 -   5   -0.1  -  -0.2      0    .00%
    !                 *  *                 !   6    0.0  -  -0.1     22  40.00%
    !                 *  *                 !   7    0.1  -   0.0     31  56.36%
    !                 *  *                 !   8    0.2  -   0.1      2   3.64%
    !                 *  *                 !   9    0.3  -   0.2      0    .00%
 10-                  *  *                 -   A    0.4  -   0.3      0    .00%
    !                 *  *                 !   B    0.5  -   0.4      0    .00%
    !                 *  *                 !   C     ++  -   0.5      0    .00%
    !                 *  *                 !   -------------------------------
    !                 *  *  *              !          TOTAL        55 100.00%
    ----------------------------------------
       1  2  3  4  5  6  7  8  9  A  B  C      EACH "*" REPRESENTS  2 RESIDUALS
```

Figure 5.19 Results of final CFA: goodness of fit statistics

```
 CHI-SQUARE =      220.012 BASED ON      32 DEGREES OF FREEDOM
 PROBABILITY VALUE FOR THE CHI-SQUARE STATISTIC IS       .00000

 FIT INDICES
 -----------
 BENTLER-BONETT     NORMED FIT INDEX =      .928
 BENTLER-BONETT NON-NORMED FIT INDEX =      .912
 COMPARATIVE FIT INDEX (CFI)         =      .938
 BOLLEN   (IFI) FIT INDEX            =      .938
 MCDONALD (MFI) FIT INDEX            =      .918
 LISREL    GFI  FIT INDEX            =      .960
 LISREL   AGFI  FIT INDEX            =      .932
 ROOT MEAN-SQUARE RESIDUAL (RMR)     =      .051
 STANDARDIZED RMR                    =      .046
 ROOT MEAN-SQUARE ERROR OF APPROXIMATION (RMSEA)    =      .073
 90% CONFIDENCE INTERVAL OF RMSEA  (        .064,        .082)
```

The last step of the validation process is represented by the reliability statistics. Table 5.20 reports the Cronbach's alpha for the three scales. The Cronbach's alpha is higher than .7 for word-of-mouth and imitation, while it is a bit lower for network effects. In any case, the three scales can be considered reliable for the purposes of the thesis.

Table 5.20 Cronbach's alpha social influences scales

	Cronbach's alpha	***N of Items***
Network effects	.661	4
Word-of-mouth	.706	3
Imitation	.778	3

5.3. Supply-side dataset: product characteristics

The second dataset regards the supply-side and involves the collection of data on a sample of DAPs, complete with launch date, price and product characteristics. Different kinds of potential sources of data have been taken into consideration, including magazines, consumer guides and online websites. The lack of a consumer magazine specialising in DAPs made it necessary to retrieve the data from some online sources. The main source of data has been CNET.com, a website offering buyers' guides for several kinds of electronic products. In particular, CNET has a specific section dedicated to DAPs, offering a review of the newest DAPs launched onto the market. These reviews contain several types of information, including (in most cases) launch price, launch date and several technical characteristics. In addition, the website includes comments from the reviewers and allows users to give a rating to the product, reporting the average value given to the product.

CNET lists a large number of DAPs and DAPs producers; however, the fact that this list is complete cannot be taken for granted, since it is possible that some products are not listed, or even that some producers are not considered. In addition, CNET (during the data collection period) included products sold by 80 companies. However, 41% of these companies had only one product reviewed, and 66% no more than five. For these reasons, we opted to collect data about a sample of DAPs.

Table 5.21 Number of products included in the dataset by brand

Brand	*Number of products*
Creative	88
Sony	88
Samsung	70
iRiver	65
Philips	63
Cowon	60
Apple	58
Archos	51
Sandisk	34
Microsoft	8
TOTAL	585

The selection criterion was to include the ten producers with the highest number of products launched in the period 2001-2009, according to CNET's list, and excluding two producers that are not well-known in Europe and Japan (RCA and Coby[83]). Only a small number of DAPs had been reviewed by CNET before 2001. These few products

[83] The decision to exclude these two brands was based on the fact that we did not find any support websites and no mention of resellers of these products outside the US. This means that it can be considered very unlikely that a significant number of respondents from Europe and Japan could have got in touch with the MP3 players produced by these two companies. In addition, in the light of the history of the sector presented in Chapter 3, none of the key players in the market has been excluded from the dataset, and therefore we can consider the sample of products representative of the DAP sector.

have been included in the dataset. However, they will be added to the first time category. In this way, the supply-side dataset will match the demand-side one, in which the first adopting time period is 'before July 2001'. The data collection took around seven weeks and finished in November 2009, resulting in a dataset of 585 DAPs. Table 5.21 shows the number of products included in the dataset by brand.

CNET offers a tool that allows the comparison of the characteristics of several DAPs and the reporting of this comparison on the same webpage. However, this tool suffers from some issues that do not allow the extraction of these data in an automatic way. For this reason, data entry was carried out manually. Moreover, the CNET dataset is not complete, meaning that some characteristics of the product may be missing (for instance launch date or price). For this reason, other sources of data were integrated with the CNET data. These sources have been PCMagazine.com (another buyers' guide website, similar to CNET), Wikipedia, and, more importantly, the official websites of DAP producers. In particular, by looking at the support pages of the official websites of the producers, it has been possible to download the user manuals of the products containing all the technical details. Moreover, by performing some searches among press releases, most of the missing launch dates and prices have been retrieved.

The dataset contains the following variables:

- Brand name and product name;
- Launch date (or review date if missing);
- Launch price (in US dollars);
- Memory type (hard disk, flash, Microdrive);
- Storage space (in GB);
- Display (no screen, monochromatic screen, colour screen);
- Screen size (in number of pixels, e.g. 128x64);
- Size (width, depth, height in inches);
- Weight (in ounces);
- Type of battery (AAA, lithium; rechargeable or not);
- Estimated battery life (in hours);
- Radio FM (yes/no);
- Voice recorder (yes/no);
- Video recorder (yes/no);
- Radio FM recorder (yes/no);
- Photo display (yes/no);
- Video playback (yes/no);
- Built-in speakers (yes/no);
- Touch screen (yes/no).

The dataset includes only measurable and verifiable characteristics. The reviewers' comments and the users' ratings have not been included in the dataset. The only variable with some missing cases is launch price (14.8% of cases missing). All the other variables are complete.

5.4. Summary and conclusions

This chapter has focussed on the data collection process. The three research questions postulated in the previous chapter (Chapter 4) and based on the conclusions of the review of the literature on the diffusion of innovations (Chapter 2) required the collection of two original datasets.

The first one, regarding the demand-side, has been collected through a survey of actual and potential adopters of DAPs. A questionnaire was developed by taking into consideration a series of potential factors influencing adoption that are closely related to the theoretical and empirical literature on diffusion. The questionnaire included a set of questions covering a broad range of factors, such as respondents' socio-economic profile, computer literacy, use and adoption of the DAP, degree of innovativeness, preferences about product characteristics, sources of information, and other social and external factors. The questionnaire also included specific sections for non-adopters and multi-adopters. An initial version of the questionnaire was piloted on a sample of 173 students from Italy and the UK. The results of the pilot provided very relevant insights, and contributed to significantly improving the final questionnaire, which was submitted to a sample of 1562 university students from eight European countries and Japan. The main conclusion of this section is that the submission of the questionnaire gave very good results, both in terms of the response rate (91.7% response rate, with a limited number of questions with several missing values) and sampling strategy (76.9% of the respondents owned at least one DAP, and 56.9% had more than one).

Another issue regarding the survey on the demand-side is that the questionnaire was meant to construct some variables affecting the timing of adoption. In particular, 41 questions (items) were meant to measure ten latent variables. The second part of this chapter has been dedicated to the validation of these scales, through exploratory factor analysis, confirmatory factor analysis and reliability analysis. In this case, we can also conclude that the data collection process has been successful; in fact, aside from two constructs that have been validated with some reservations (perceived benefits and compatibility, which have overly low reliability scores), all the other scales have been validated, giving very satisfactory results.

Finally, the last section of this chapter has been dedicated to the database regarding the supply-side. A dataset of 585 DAPs launched in the period 2001-2009 has been collected. The dataset includes the product name, launch date, launch price and a list of measurable technical characteristics of the product, such as size, weight, storage space and so on. The main source of this data has been a website reviewing the latest DAPs launched, integrated with other online sources. This dataset will allow the technical progress in the DAP sector to be traced, testing whether the supply-side has influenced the diffusion of DAPs. In addition, the two datasets collected will be combined in order to test whether there is a relationship between supply- and demand-sides in explaining the diffusion of DAPs.

These two datasets will be used to answer the research questions, using a series of statistical quantitative techniques. The third part of this thesis will explore the empirical analysis, and will be divided into three chapters, each dedicated to one specific research question. Specifically, Chapter 6 will examine the questions on the demand-side, Chapter 7 will be about the supply-side, and finally Chapter 8 will be more general and will provide a comparison of different models of diffusion.

PART III – EMPIRICAL ANALYSIS

CHAPTER 6. DIFFUSION OF DAPS AND CHARACTERISTICS OF THE ADOPTERS

This first empirical chapter focuses on the demand-side and is based on the data collected through the questionnaire. The objectives of this chapter are three. The first is to present the data collected through the questionnaire (Section 6.1). The main task here is to provide a descriptive analysis of the data, but also to highlight some of the trends that will be the basis of further analysis of the data. The second objective is to provide a classification of the adopters that goes beyond the usual classification into early and late adopters (Section 6.2). This section will use a cluster analysis technique in order to categorise the adopters. The third section (6.3) will use ordered logistic regression in order to examine which factors have influenced the timing of adoption.

6.1. Descriptive analysis of the results of the questionnaire

The main objective of this section is to present a detailed descriptive analysis of the results of the questionnaire. The questionnaire was submitted to 1562 students from eight European countries and Japan. The number of valid completed questionnaires obtained was 1433 (91.7% of the total). Table 6.1 reports the total number of questionnaires submitted in each country and the number of valid completed questionnaires obtained, as well as the number of adopters and non-adopters.

Table 6.1 Questionnaires submitted and number of adopters by country

Country	*Questionnaire submitted*	*Valid questionnaires*	*Adopters*	*Non-adopters*
France	140	130	119	11
Germany	204	185	127	58
Italy	200	193	178	15
Japan	268	218	107	111
Netherlands	92	89	62	27
Portugal	109	103	93	10
Spain	187	181	151	30
Switzerland	176	161	126	35
UK	186	173	139	34
Total	1562	1433	1102	331

The descriptive analysis will follow the structure of the questionnaire. Chapter 5 offers more detailed information about the design and submission of the questionnaire. A copy of the questionnaire is included at Appendix A. The first section focuses on the socioeconomic profile of respondents, while the second section concentrates on the use of computers, other electronic gadgets and the Internet. The third section is based on the variables regarding the adoption and use of a DAP. The fourth section examines the sources of information used in order to evaluate DAPs. Finally, the last two sections are about the non-adopters and the multi-adopters respectively.

6.1.1. Socioeconomic profile of respondents

The first section of the questionnaire (questions 1-6) deals with the socioeconomic status of the adopters.

Table 6.2 Age of respondents: descriptive statistics

Age	
Mean	21.43
Median	21.00
Std. Deviation	2.923

The average age of respondents is 21.4 years (Table 6.2). The dataset is quite homogeneous with regard to the age of respondents (Table 6.3). Most of the respondents (78.9%) are undergraduate students and this explains the young age.

Table 6.3 Average age by country

	Average age
France	21.02
Germany	21.89
Italy	22.39
Japan	21.08
Netherlands	21.59
Portugal	19.04
Spain	20.73
Switzerland	23.31
UK	20.93

On average, the dataset is quite balanced regarding the distribution by gender (Table 6.4), although there is a little disparity in favour of male respondents. However, the data show relevant differences between countries. The countries with the highest percentages of males are Japan and the Netherlands, followed by Switzerland and Portugal, while the countries with the highest percentages of female respondents are Italy, France, Spain and the UK.

Table 6.4 Distribution by gender, on average and by country

	Male	*Female*
Average	56.8%	43.2%
France	41.5%	58.5%
Germany	54.6%	45.4%
Italy	39.9%	60.1%
Japan	83.9%	16.1%
Netherlands	82.0%	18.0%
Portugal	60.2%	39.8%
Spain	45.9%	54.1%
Switzerland	62.1%	37.9%
UK	46.8%	53.2%

Another socioeconomic question concerns the nationality of respondents. This variable is not taken into consideration in the analysis, since the variation by country considers the survey country (i.e. the country in which the respondents are living) and not the country of origin. However, it is interesting to point out that while the number of surveyed countries is only nine, the respondents have 69 different nationalities. The nationalities most highly represented (besides those of the nine surveyed countries) are the US (3.6% of the total number of respondents), followed by Russia, Sweden and China (each representing 0.8% of the respondents).

Table 6.5 Variable income: descriptive statistics

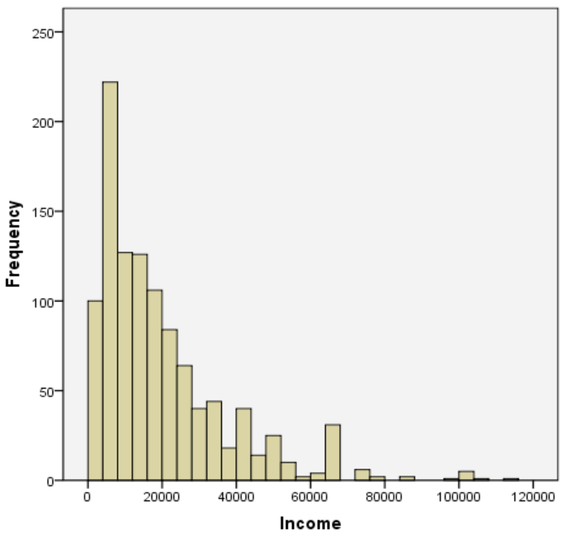
Income (€)

N	Valid	1075
	Missing	358
Mean		20,080
Median		15,000
Mode		7500
Std. Deviation		17,684
Percentiles	25	7,500
	50	15,000
	75	26,250

Some of the most critical questions are those regarding the income of the respondents. For this reason, particular attention has been paid to defining these questions. The questionnaire included three questions regarding income. The first question asks if the respondents are financially independent. The second question, in the case of financially independent students, asks how many people they financially support, while in the case of financially dependent students the question is how many people depend on the household income. The last question asks respondents to choose between 22 classes of income, from less than €5000 to more than €200,000 (for the UK the income classes were expressed in Pounds Sterling, while for Switzerland they were expressed both in Euros and Swiss Francs). The variable income has been calculated by dividing the central value of each income category by the number of people in the household.

The first information stemming from Table 6.5 is that income has been the least answered question. Of a total of 1433 valid questionnaires, 358 respondents (24.9%) decided not to answer this question. This was expected, since in most surveys questions regarding personal income are some of the most problematic, and the DAP questionnaire was not an exception. In addition, in the case of the present questionnaire, some more difficulties derived from the relatively young age of the respondents. It is possible that some respondents willing to answer this question left it blank simply because they did not know their family income (this is confirmed by the fact that several respondents wrote on the questionnaire comments such as: 'Sorry, I don't know').

Figure 6.1 Income distribution



Considering the 1075 respondents who answered this question, the average income is slightly more than €20,000. However, a standard deviation of more than €17,000, the distribution in percentiles, and the median (€15,000) and mode (€7,500) values indicate that the variable income is, as expected, not evenly distributed among the respondents. The long right tail in the frequency distribution histogram (pictured in Figure 6.1) confirms that the distribution of income among the respondents is skewed to the right.

Table 6.6 reports the average income by country and by university. The average income is calculated by dividing the total income of all respondents in a country by the number of respondents in that country. The country with the highest average income is Switzerland, followed by the UK. Considering the differences between universities, the universities with higher-income students are not only those from Switzerland and the UK, but also the private universities: Vallendar (Germany) and Bocconi (Italy).

Table 6.6 Average income by country and by university

Country	*Average income (€)*	*University*	*Average income (€)*
France	13,681	Paris 1 Sorbonne	14,958
		Paris 2	20,505
		Paris 3	10,797
		Paris 11 Sud	4,505
Germany	18,813	Jena	13,106
		Vallendar	25,662
Italy	20,952	Bergamo	18,355
		Bocconi	22,391
Japan	20,774	Hitotsubashi	25,102
		Suwa	19,063
Netherlands	13,777	Eindhoven	11,562
		Utrecht	14,857
Portugal	12,868	Lisbon	12,868
Spain	12,826	Sevilla	13,454
		Valencia	12,017
Switzerland	35,363	Lugano	38,693
		Zurich	31,811
UK	23,574	Bristol	27,734
		Manchester	25,377
		SPRU	21,959

The last question (number 6) regarding the socioeconomic profile is about student status. The question asks whether the respondent is an undergraduate, a postgraduate, or sitting in the class without being a student.

Table 6.7 Distribution of respondents by type of student

	Percentage
Undergraduate	78.90%
Postgraduate	20.60%
Non students	0.40%
Missing	0.10%
	100.00%

Table 6.7 reports that the majority of the respondents are currently taking undergraduate university courses, and that in only a very few cases the respondents are not students. The same question asked in which kind of degree the respondents were currently enrolled (e.g. economics, engineering, etc.). This question created some interpretation problems, mostly due to the different languages used by the students and the different higher education systems in the surveyed countries. These issues made it difficult to create a meaningful and homogeneous variable based on the answers to this question. For this reason, although there was a very high response rate,

the answers to this particular question will not be taken into consideration in any further analysis. In any case, the range of different areas of study reported by the students confirms that the efforts to have an interdisciplinary sample of students succeeded (see Section 5.1.3 for a more detailed explanation of the data collection procedures).

6.1.2. Computer literacy and use of the Internet

Another section of the questionnaire (questions 7-15) regards the use of a computer, of the Internet and of other electronic gadgets. The first four questions of this section regard the use of a computer. In particular, question 7 asks what kind of computer is owned by the respondents (reported in Table 6.8). Most of the respondents are PC users with a Microsoft Windows operating system (XP, Vista, 7, etc.) On average, 9% of the respondents own an Apple MAC, 1.5% own a computer with an open-source operating system (such as Linux), and only a very small percentage use another system (those who responded *other* are in general those who combine more than one operating system in a dual-boot modality). It is interesting to point out the very high penetration of Apple in Switzerland (36%), followed by the UK and Germany, and the very low use of MAC computers in Japan, Portugal and Spain.

Table 6.8 Kind of computer owned, on average and by country

	Apple	***PC***	***Open-source***	***Other***	
Average	9.1%	88.7%	1.5%	0.7%	100.0%
France	6.2%	90.0%	0.8%	3.1%	100.0%
Germany	10.3%	87.6%	1.6%	0.5%	100.0%
Italy	7.8%	91.2%	1.0%	0.0%	100.0%
Japan	0.5%	98.6%	0.5%	0.5%	100.0%
Netherlands	2.2%	95.5%	2.2%	0.0%	100.0%
Portugal	1.0%	99.0%	0.0%	0.0%	100.0%
Spain	1.7%	95.6%	1.7%	1.1%	100.0%
Switzerland	36.0%	59.6%	4.3%	0.0%	100.0%
UK	13.3%	83.8%	1.7%	1.2%	100.0%

Questions 8, 9 and 10 regard the use of the computer both in quantitative and qualitative terms. In particular, question 8 (reported in Table 6.9) indicates that respondents are generally very frequent computer users. On average only 12.2% of respondents reported using a computer for less than one hour per day, and more than 16% reported using it for more than five hours. There are not significant differences in terms of computer usage by gender. The only difference is in regard to the heaviest users (those who answered ‘more than 5 hours’), who are more frequently men than women. Regarding the differences by type of computer, the data indicate that the users of Apple computers and the users of other open-source systems are on average more frequent users than PC owners.

Table 6.9 Computer use on average, by type of computer, and by gender

	Never	*Less than 1/2 hour*	*1/2 to 1 hour*	*1-3 hours*	*3-5 hours*	*More than 5 hours*	
Average	0.30%	2.00%	10.20%	45.60%	25.80%	16.10%	100%
Apple	0.00%	0.00%	3.80%	39.20%	33.80%	23.10%	100%
PC	0.40%	2.20%	10.90%	45.90%	25.30%	15.30%	100%
Open-source	0.00%	0.00%	4.50%	50.00%	18.20%	27.30%	100%
Other	0.00%	0.00%	10.00%	80.00%	0.00%	10.00%	100%
Male	0.49%	1.84%	8.60%	44.59%	26.66%	17.81%	100%
Female	0.16%	2.10%	12.28%	46.85%	24.72%	13.89%	100%

Question 10 is about computer skills. Computer users, regardless of the time they spend using a computer, can show very different levels of skills or expertise, which can be correlated with the use of a broad range of other electronic products, including DAPs. Question 10 asked: 'Relative to the average computer user, how would you describe your skills in using a computer?', with answers organised in a five-point Likert scale, ranging from 'much below the average' to 'much above the average'.

Table 6.10 Average computer skills, by country, type of computer, and gender

	Much below the average	*Moderately below the average*	*On the average*	*Moderately above the average*	*Much above the average*	
Average	1.8%	7.8%	54.2%	31.7%	4.5%	100%
France	3.8%	9.2%	63.1%	22.3%	1.5%	100%
Germany	1.1%	4.3%	42.2%	42.7%	9.7%	100%
Italy	0.5%	5.2%	66.3%	25.9%	2.1%	100%
Japan	6.0%	25.7%	56.0%	10.6%	1.8%	100%
Netherlands	0.0%	3.4%	42.7%	44.9%	9.0%	100%
Portugal	0.0%	2.9%	53.4%	43.7%	0.0%	100%
Spain	1.7%	6.1%	69.1%	21.0%	2.2%	100%
Switzerland	0.0%	3.7%	34.8%	50.9%	10.6%	100%
UK	1.2%	1.7%	53.2%	39.3%	4.6%	100%
Apple	0.8%	3.1%	38.5%	51.5%	6.2%	100%
PC	1.9%	8.4%	55.9%	29.7%	4.1%	100%
Open-source	0.0%	0.0%	36.4%	40.9%	22.7%	100%
Other	10.0%	10.0%	70.0%	10.0%	0.0%	100%
Male	2.1%	8.0%	43.0%	39.8%	7.1%	100%
Female	1.5%	7.6%	68.8%	21.0%	1.1%	100%

Table 6.10 reports the results of question 10. On average, more than half the respondents consider themselves average computer users (54.2%), with a considerable percentage of respondents (36.2%) indicating themselves to be (moderately or much) above the average computer user. The data indicate relevant differences by country,

type of computer and gender. In particular, the respondents from Switzerland, Germany and the Netherlands are those who report to have the highest levels of computer skills. Moreover, Apple users and, much more frequently, open-source users are those who report that they are more skilled. Finally, males self-identify as being more skilled users more often than females, who, in general, consider themselves average users (68.8%).

Question 9 investigates which kind of activity is carried out most frequently when using a computer. The range of potential computer activities is so broad that we opted for a general division between work or study activities and leisure activities. Question 9 asked what percentage of the time spent using a computer is devoted to accomplish any kind of work task versus what share of time is devoted to leisure activities. Table 6.11 reports the results. Respondents reported spending on average 49% of the time using a computer to work or study. The differences by country indicate that German, Swiss and Italian students are more inclined towards work activities than the average, as with female respondents in comparison to males. Not very relevant differences are associated with computer skills, with the exception of the two extreme categories, 'much below the average' and 'much above the average', which show, respectively, a lower and higher percentage of time spent working or studying than the average.

Table 6.11 Percentage of time spent working while using a computer

		Percentage of time spent working
Average		49.0%
Country	France	43.4%
	Germany	57.9%
	Italy	56.1%
	Japan	44.3%
	Netherlands	46.6%
	Portugal	45.4%
	Spain	44.8%
	Switzerland	53.5%
	UK	45.3%
Gender	Male	46.7%
	Female	52.0%
Computer skills	Much below the average	35.0%
	Moderately below the average	45.1%
	On the average	49.0%
	Moderately above the average	49.8%
	Much above the average	55.0%

The next two questions (11 and 12) regard the use of the Internet. In particular, question 11 is about access to a broadband connection. Table 6.12 shows that the majority of the students have access to a broadband Internet connection, both from home and from the university. In principle, all the universities included in the survey should provide broadband Internet access to students. However, some respondents (more frequently those from France, Italy and Portugal) answered that the university does not provide such a service. This kind of answer can be interpreted as the existence of some kind of limitation or impediment that *de facto* discourage the use of the Internet from university facilities.

Table 6.12 Access to a broadband Internet connection

	Home and University	***Only home***	***Only University***	***No***	
Average	76.4%	15.1%	6.6%	2.0%	100%
France	55.4%	40.8%	1.5%	2.3%	100%
Germany	80.0%	7.6%	9.7%	2.7%	100%
Italy	65.8%	24.9%	5.7%	3.6%	100%
Japan	72.0%	12.8%	13.3%	1.8%	100%
Netherlands	83.1%	9.0%	6.7%	1.1%	100%
Portugal	76.7%	22.3%	1.0%	0.0%	100%
Spain	85.6%	9.4%	3.3%	1.7%	100%
Switzerland	85.7%	6.8%	5.6%	1.9%	100%
UK	83.8%	8.1%	6.9%	1.2%	100%

Question 12 is about what kinds of activities are carried out while on the Internet, and asks about the frequency of use of nine Internet services. Table 6.13 indicates that the most frequent activities are sending emails or chatting, watching videos (such as on YouTube) and updating personal pages (such as MySpace or Facebook). Besides these very basic activities, the most frequent activity is the use of peer-to-peer (P2P) software in order to download or exchange files (most often music or video files) over the Internet. In other words, the most frequent activity carried out on the Internet, besides emailing, chatting and social networking, is related to so-called file sharing. This is an interesting result, since it may indicate that a large number of respondents could have carried out copyright infringement. It is true that this question does not provide any indication of the type of files exchanged through P2P networks. However, the literature cited in Section 3.3.1 seems to suggest that scrupulous observance of copyright is not a recognised characteristic of P2P users, especially in the case of university students. Moreover, the results of other questions that will be analysed in the following sections also seem to suggest that a significant share of the files exchanged through P2P networks are copyright protected. For these reasons, we can infer that our respondents have probably downloaded a certain amount of audio and video files without respecting copyright.

This result was to some extent expected; however, it provides at least two very interesting insights for the purpose of this work. The first insight is that, since the benefits of adopting a DAP strictly depend on the availability of songs in digital format to be loaded onto the player, one of the variables associated with the diffusion of DAPs may be related to the accumulation of this type of file. For this reason, this variable will be used in many further analyses, both in order to cluster potential adopters, and in order to explain the timing of adoption. The second insight is that, besides a very few cases of music being offered for free over the Internet, one of the potential factors that might have affected the dramatic success of the portable DAP market over recent years is the very frequent activity of file sharing of copyright-protected music, which may expose those who do it to civil legal penalties (see Section 3.3.1)

Table 6.13 Frequency of use of some Internet activities

	Mean	*Std. Deviation*
Buy products	2.47	1.053
Buy songs	1.52	.940
Phone calls	2.09	1.258
Personal page	3.35	1.406
Email/chat	4.25	.944
Watch videos	3.75	1.025
Upload videos	1.88	1.176
Peer-to-Peer	2.49	1.438
Internet Radios	2.33	1.236

Note: answers given on a five-point Likert scale from 1=Never to 5=Very often.

Returning to Table 6.13, the activities that are carried out on the Internet less frequently are Internet shopping, phone calls, listening to Internet radio and uploading videos. The least frequent activity is buying songs, which also confirms the relevance of file sharing. Regarding Internet use by country, a few differences can be retrieved. The respondents more engaged in e-commerce activities are from the UK, Germany and Switzerland. However, only the UK and Switzerland also show an intense level of Internet shopping regarding music and songs. Regarding the use of peer-to-peer software, the most frequent users of this type of service are respondents from the south of Europe (Italy, Portugal and Spain), from the Netherlands and from France, while the users with less intense use are from Japan and Germany. Another interesting result is that adopters of Apple's iPod show a higher propensity to buy songs in digital format, which might indicate the success of iTunes as provider of songs in digital format, which are compliant with laws on copyright (see Section 3.3.2 for a more detailed explanation of the role of online music stores in the recent history of the music industry).

Figure 6.2 Internet activities by computer skills

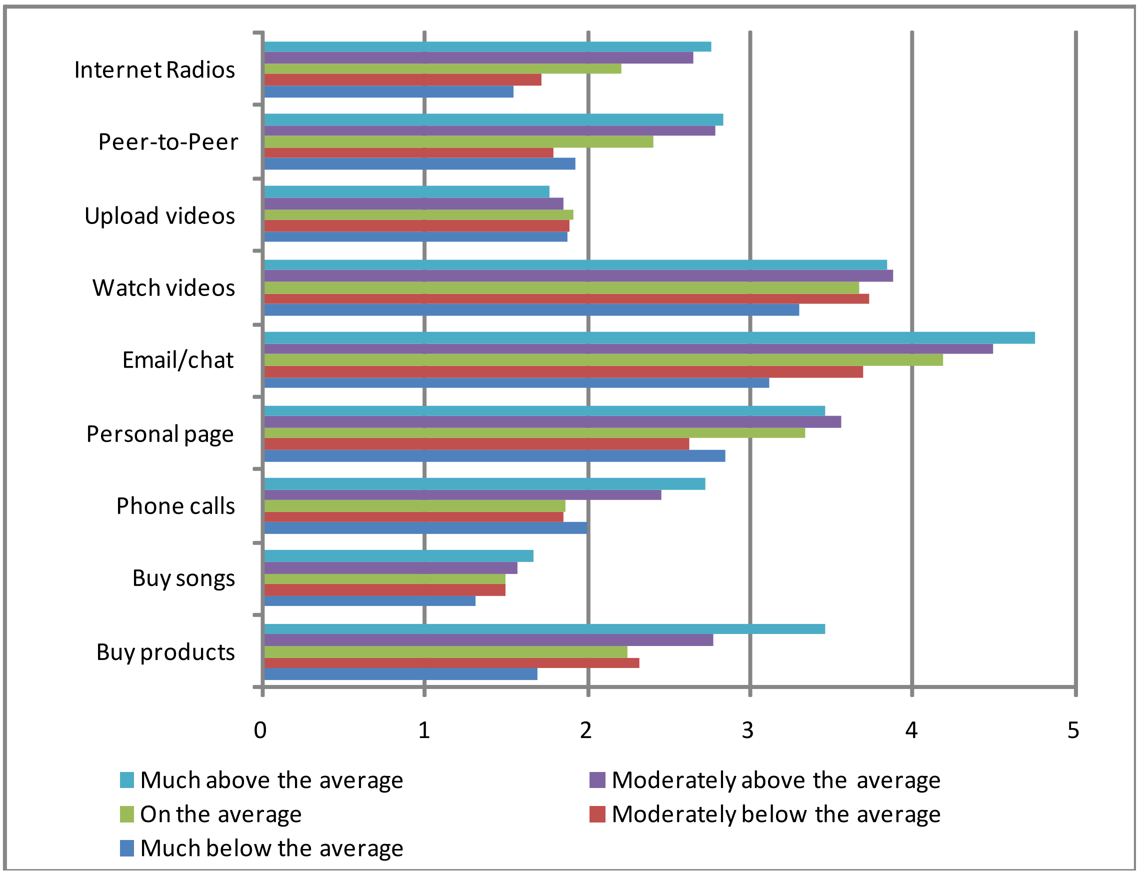


Figure 6.2 indicates that there is a correlation between the use of most Internet services and computer skills, since more skilled users use Internet services more intensively than others. This is particularly evident for those kinds of services that are somewhat more sophisticated than simply chatting or social networking and which, for this reason, need more skills to be carried out, such as e-commerce, phone calls, peer-to-peer software and Internet radios. This can serve as a confirmation of the validity of question 10 regarding computer skills. The problem is that asking respondents to self-judge their computer skills may give biased results, indicating that respondents may simply have a very high opinion of themselves, or a low opinion of the average computer user. A way to prove the validity of the question on computer skills is to compare it with a behavioural question, such as the question about Internet activities, in which respondents are not asked to provide any opinion of themselves, but rather a description of their behaviour. This consideration is also confirmed by the results shown in Table 6.10, which indicate that open-source users consider themselves as skilled users much more frequently than other users. In particular, 40.9% of them report being moderately above average and 22.7% report being much above average. This is taken as another confirmation of the validity of the question on computer skills, because the use of an open-source operating system implies a more conscious and

savvy use of a computer than the average PC or MAC user. The main reason for dedicating so much attention to this question is that this measure is trying to capture a potentially very important factor, which can be correlated with many potential dependent variables, such as, for instance, the timing of adoption of a DAP.

Question 13 regards the most listened-to music genres. The main result is that respondents regularly listen to a wide range of types of music. All of the genres in the list are listened to by at least 10% of the respondents. Moreover, almost 90% of the respondents declared that they listen to at least two genres of music. The most listened-to genres are pop music and rock music, followed by dance and hip-hop/rap music. This question will not be used in any particular analysis. However, it has been included as a sort of robustness check on the overall validity of the questionnaire. Since DAPs are mostly used to listen to music, we would expect that users who listen to different music genres are more inclined towards the use of those kinds of products. This speculation seems to be true, since on average DAP adopters listen to more music genres than non-adopters (confirmed by an independent sample t-test). In addition, the number of music genres listened-to is positively correlated with the amount of music owned by the respondents, a question that will be discussed in the following sections (correlation: .218 significant at .01 level).

Table 6.14 Earlier portable music players owned on average, and by country

	Walkman	***Discman***	***Minidisc***	***No previous players***
Average	74.1%	75.3%	26.2%	9.4%
France	73.1%	75.4%	17.7%	13.1%
Germany	78.4%	82.2%	22.7%	5.4%
Italy	94.8%	90.7%	11.9%	1.6%
Japan	52.8%	41.3%	54.6%	12.8%
Netherlands	79.8%	74.2%	24.7%	6.7%
Portugal	25.2%	48.5%	14.6%	41.7%
Spain	90.6%	90.1%	8.3%	4.4%
Switzerland	78.3%	86.3%	29.8%	5.0%
UK	79.2%	84.4%	39.9%	6.4%

The last two questions of this section regard the use of electronic products. These products have been divided into two groups. The first one (question 14) is about earlier portable music players (Walkman, Discman, Minidisc[84]). The second one (question 15) regards other sophisticated electronic products: blue-ray disc players, camcorders,

[84] We acknowledge that the terms Walkman, Discman and Minidisc do not indicate a generic type of product but rather names of three portable music players produced by Sony. However, they are often used to represent the whole product category. For this reason, the phrasing of the question was as follows: 'I owned a Walkman or another portable cassette player'.

digital cameras, GPS, HD televisions, PDAs and smart phones.

Table 6.14 reports the adoption of earlier portable music players. On average, more than 90% of respondents had at least one portable player. Around 74% had a cassette player, and around 75% a CD player. Considering those users who owned more than one portable player, 51.2% of respondents had two players, and 16.9% had a cassette, a CD and a Minidisc player. These results confirm the role of DAP's precursors (highlighted in Section 3.1) indicating that the success of DAPs built upon the success of the previous kinds of portable music playes. Regarding the differences among countries, Italy and Spain present a very high penetration of both cassette and CD players (more than 90%). Minidisc generally present a much lower adoption rate by respondents, since only 26.2% of respondents have had a Minidisc player. However, the data confirm the fact that the Minidisc player encountered a much greater success rate in Japan than in Europe, with the adoption rate in Japan more than double the average (54.6%).

Table 6.15 Electronic gadget ownership, on average, by country and gender

	Blue- ray	*Camcorder*	*Digital Camera*	*GPS*	*HD*	*PDA*	*Smart Phone*
Average	11.0%	22.8%	82.3%	25.5%	32.9%	12.4%	16.7%
France	32.3%	33.8%	84.6%	24.6%	34.6%	2.3%	20.0%
Germany	3.8%	12.4%	82.7%	17.3%	13.0%	8.6%	17.8%
Italy	10.4%	39.4%	95.3%	35.8%	45.1%	10.9%	16.1%
Japan	14.2%	2.3%	63.8%	19.7%	27.1%	31.2%	3.2%
Netherlands	5.6%	11.2%	61.8%	19.1%	15.7%	4.5%	15.7%
Portugal	6.8%	21.4%	71.8%	21.4%	32.0%	3.9%	2.9%
Spain	5.0%	44.2%	92.8%	34.3%	53.0%	15.5%	13.3%
Switzerland	13.0%	18.6%	90.7%	30.4%	39.8%	15.5%	42.9%
UK	9.2%	21.4%	86.7%	23.1%	28.3%	5.2%	18.5%
Male	12.4%	20.8%	76.3%	28.0%	33.9%	16.3%	19.7%
Female	9.2%	25.5%	90.1%	22.3%	31.5%	7.3%	12.8%

The results of question 15 (about the use of electronic gadgets) confirm that the students in the sample are usually adopters of electronic products. Table 6.15 shows that, on average, all electronic gadgets have been adopted by an appreciable number of respondents, ranging from digital cameras, which have been purchased by more than 80% of respondents, to blue-ray players, which are owned by only 11% of respondents. In general, all electronic gadgets have been adopted more frequently by males than by females, with the exception of camcorders and digital cameras. Regarding the differences among countries, it is difficult to highlight general trends. Even countries with a higher than average income, such as Switzerland and the UK, do not show a systematically higher penetration rate in all technologies. The number of electronic gadagets is still positively and significantly correlated with both personal income and computer skills, although with quite low coefficients (.188 and .147 respectively).

6.1.3. Adoption and use of a DAP

The third section of the questionnaire (questions 16-31) is dedicated to the adopters of DAPs. The question discriminating between adopters and non-adopters is number 16. A respondent is considered an adopter of a DAP or a MP3 player if he or she owns a portable device able to load and play music in digital format (MP3, MP4, WMA, AAC, etc.). The owners of CD players able to play MP3 files and the owners of mobile phones with that feature are considered non-adopters.[85] Adopters are then classified as *single adopters* if they have adopted only one DAP, or *multi-adopters* if they adopted more than one DAP. On the other side, non-adopters are divided into *interested*, if they declare that they are willing to buy a DAP soon, and *not interested*, in the case that they are not disposed to buy any kind of DAP.

Table 6.16 reports the classification of adopters and non-adopters. First of all, the majority of respondents (76.9%) have owned at least one MP3 player. This indicates, using a sample of students represented, a good choice in order to study the adoption of this kind of product. More than half of the adopters (56.9%) are also multi-adopters, in the sense that they have owned more than one DAP. Non-adopters represent a smaller percentage of respondents, and most of them (61.6%) are not even interested in buying a MP3 player in the future.

Table 6.16 Classification of adopters and non-adopters

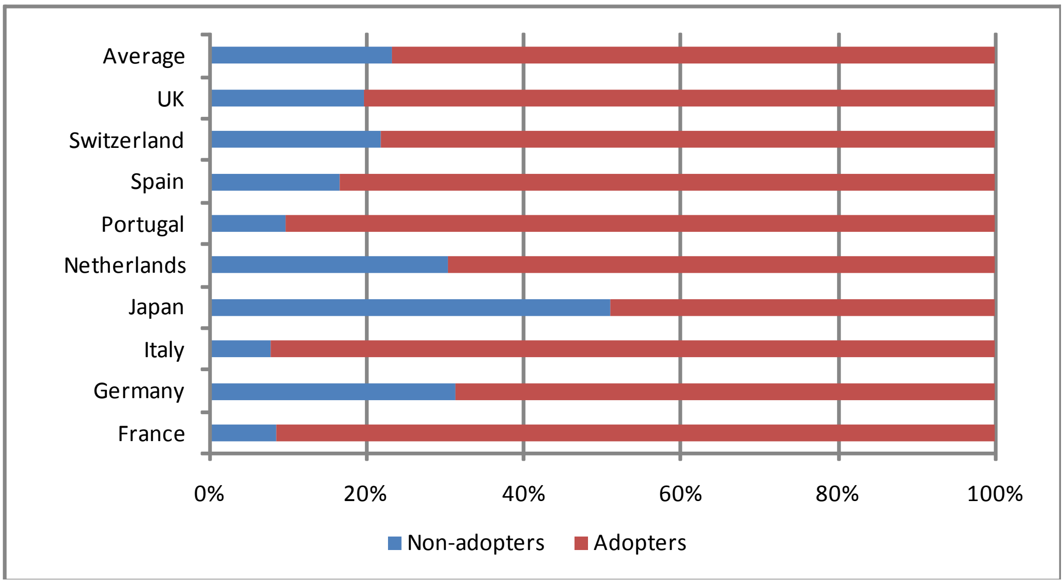
	Freq.	***Perc.***		***Freq.***	***Perc.***
Adopters	1102	76.9%	**Single adopter**	475	43.1%
			Multi-adopter	627	56.9%
Non-adopters	331	23.1%	**Not interested in buying a DAP**	204	61.6%
			Interested in buying a DAP	127	38.4%
Total	1433	100%		1433	

The country with the highest percentage of adopters is France, followed by Portugal and Italy. Japan is the country with the lowest percentage of DAP adopters in the sample, which might be related to the fact that most of them had already adopted a

[85] Recalling Chapters 3 and 4, for the purpose of this thesis, a DAP is defined as a portable device able to load and reproduce MP3 and other audio compressed files using non-removable erasable digital media, such as flash memories or hard drives. In addition, even if we recognise the existence of a difference between the terms digital audio player and MP3 players, for simplicity they will be used as synonyms.

Minidisc player.

Figure 6.3 Adopters and non-adopters by country



All the following questions in this section have been answered only by adopters, restricting the sample to 1102 people. Table 6.17 shows how the adopters got their first MP3 player. Almost half of the sample purchased the player on their own, while another 27.2% of them asked for a DAP as a gift (some of them requesting a specific model, others requesting a generic gift). A considerable percentage of adopters received a DAP as an unexpected gift (21.8%) and only 1.5% of them won or *found* one.

Table 6.17 How did you get your first DAP?

	Percentage
Purchased	49.50%
Requested a specific model	15.20%
Requested a generic gift	12.00%
Unexpected gift	21.80%
Won/found	1.50%
	100%

The next question (number 18) is one of the most important questions of the questionnaire, and asks when the first DAP was adopted by the respondent. The timing of adoption is a very relevant variable in this work, for several reasons. First of all, the timing of adoption will be used as a dependent variable in several kinds of regressions. Moreover, it is the variable that will be used to match the data collected through the questionnaire with the data regarding the supply-side. Finally, it is the variable that gives a time attribute to the data collected through the questionnaire, which is a cross-section set of data, transforming it into a sort of time-series set of data. This will make it possible, for instance, to draw a diffusion curve by using the results of the questionnaire. Question 18 asked respondents to choose one period of time among 16 semesters between 'before July 2001' and 'after July 2008'. The response rate to this delicate question was quite successful. Only 14 respondents (out of 1102 adopters) were not able to remember the semester in which they adopted their first DAP (98.7% response rate). Figure 6.4 shows the number of adopters over time. It is possible to notice that the number of adopters grows over time; it reaches a peak in the period between 2004 and 2006 and then declines over time.

Figure 6.4 Number of adopters over time

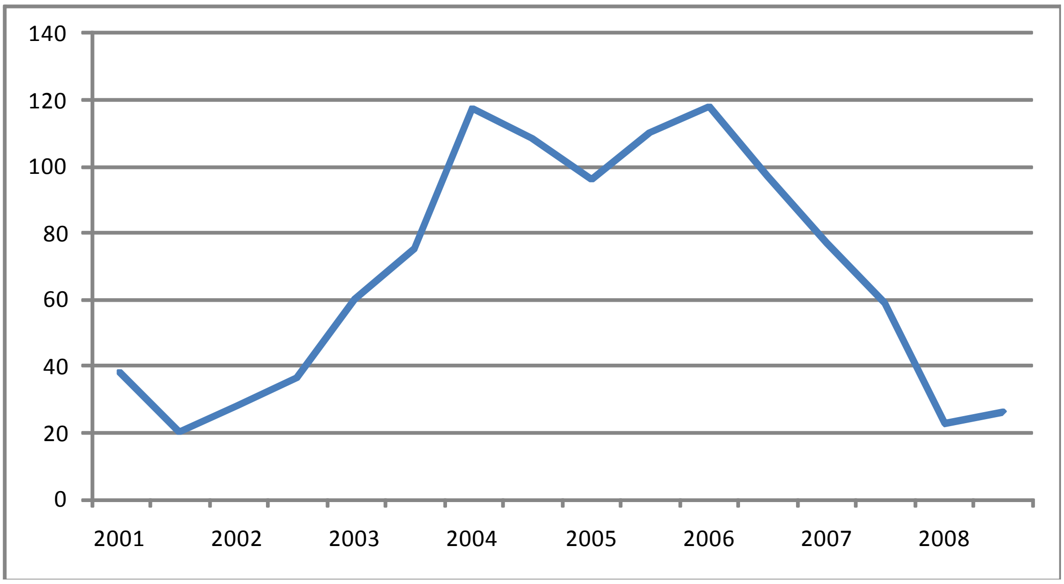
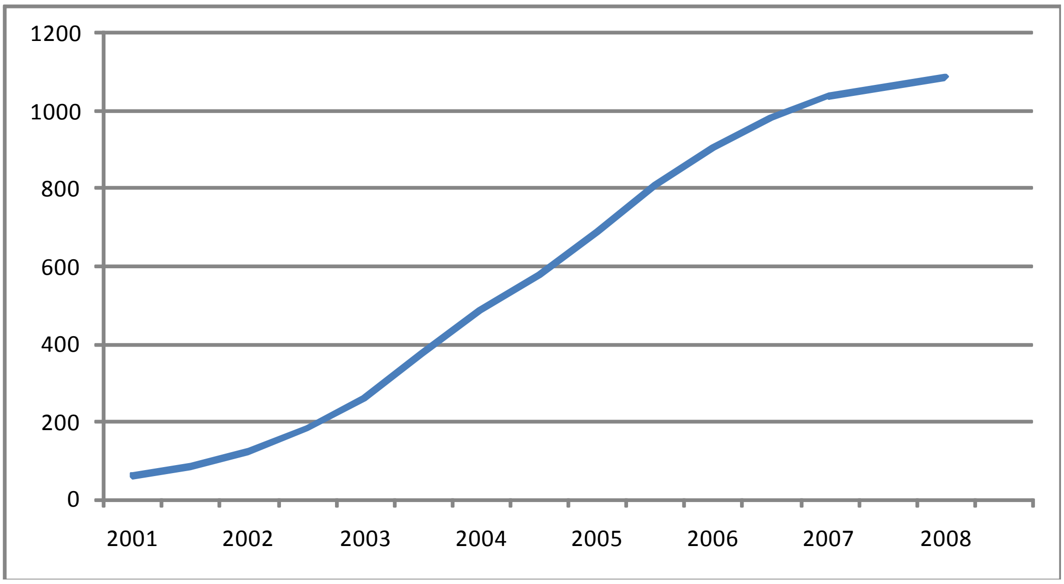


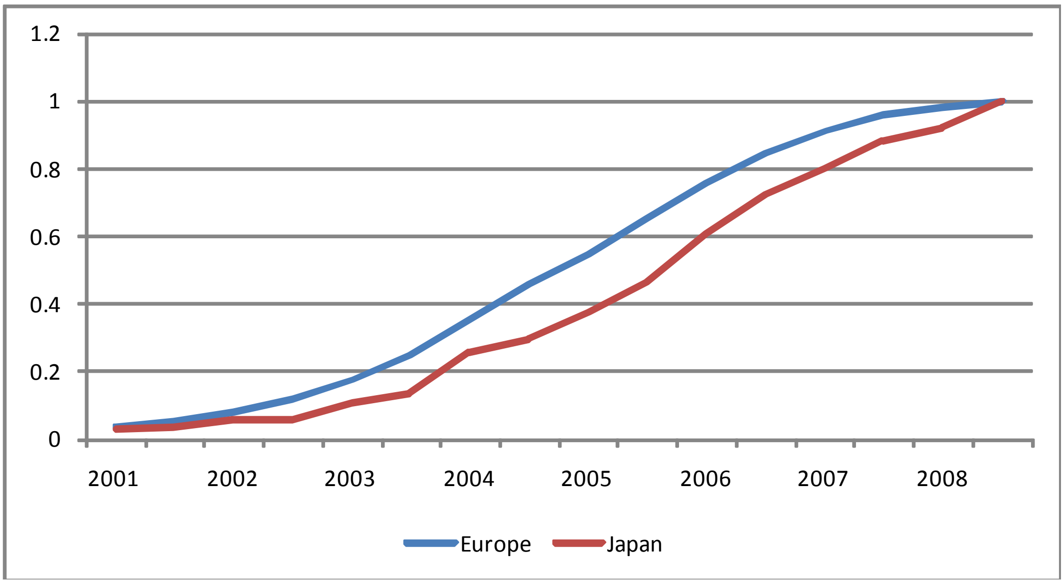
Figure 6.5 shows the cumulative number of adopters over time, highlighting that it follows quite a clear s-shaped trend. This is an interesting result, since it is in line with most of the diffusion studies reviewed in Chapter 2, confirming that the diffusion of an innovation follows a sigmoid curve. It is true that this result is not too surprising, because, since the sample is quite large (more than 1000 observations), the frequency distribution will tend to have a bell shape, and hence the cumulative distribution will necessarily be s-shaped. However, considering that the sampling strategy did not pretend to be representative of the population of potential DAP adopters in the countries surveyed, the fact that the main dependent variable of the analysis is distributed as predicted by most of the empirical and theoretical literature on diffusion is helpful.

Figure 6.5 Cumulative number of adopters over time



Moreover, Figure 6.5 shows that the adoption rate starts to decrease after 2006. This indicates that the timing with which this study has been carried out has been quite convenient, since the data collected seem to capture the maturity phase of the DAP diffusion process. Drawing diffusion curves for each country will give too erratic results; however, the differences between the adoption curves of Europe and Japan can provide some interesting insights, such as those shown in Figure 6.6, indicating that Japanese respondents adopted a DAP systematically later than European respondents. In any case, the diffusion curves for both groups of adopters follow a similar s-shaped curve.

Figure 6.6 Cumulative percentage of adopters in Europe and Japan



The next set of questions (19-23) had the specific purpose of identifying which DAP player had been adopted and which characteristics that specific player had. All these questions will specifically refer to the first DAP player owned by the adopters.

Figure 6.7 Ranking of most commonly adopted DAP brands

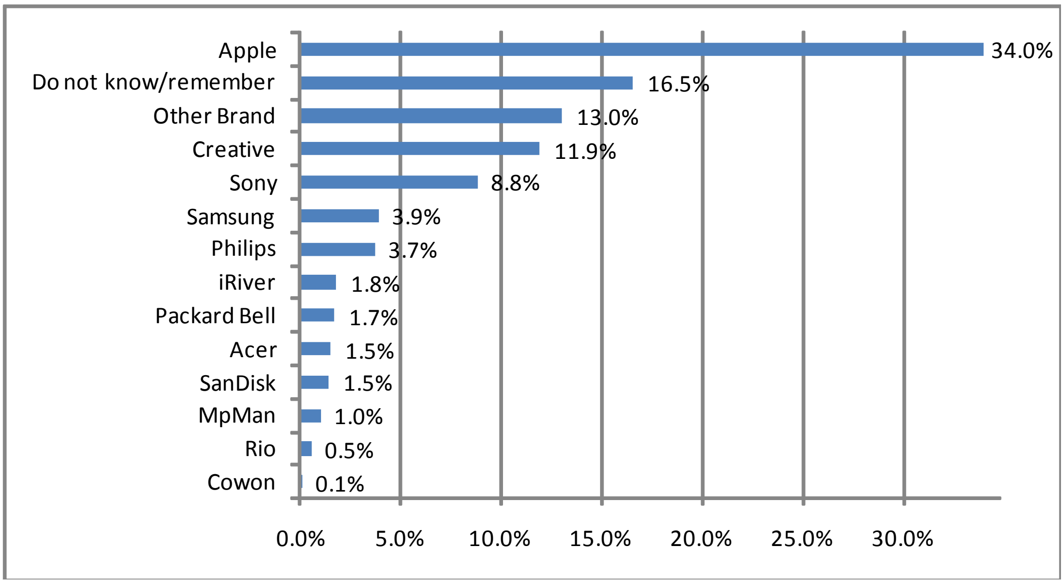


Figure 6.7 shows the ranking of the brands most commonly adopted by respondents. As expected, Apple is the most frequent brand, representing 34% of the total,[86] followed by Creative, Sony and Samsung. It is interesting to point out that none of the respondents declared having adopted a Microsoft DAP as their first MP3 player; however, almost one-third of adopters did not remember the name of their first player, or declared that was manufactured by another producer. Regarding the differences among countries, aside from in Portugal, Apple is the most commonly adopted brand in every country. In Japan, Apple is also the most often chosen DAP as a first MP3 player (48.6%), followed by Sony (24.3%).

DAPs can be divided into two groups, flash and hard drive (HD) players, depending on the type of memory used to store music. Figure 6.8 shows the cumulative number of adopters over time for each type of player, both in absolute terms and in percentages. On average, flash player adopters represent 74.7% of the respondents, while HD players only 25.3%. Flash player adopters outnumber HD adopters over all time periods. However, by looking at the cumulative adoption expressed in percentages of those having adopted by the time of the survey, the two diffusion paths almost overlap, and

[86] The figures on Apple's iPod sales indicate a much larger market share than in the data collected. However, this data refers only to the first adoption; they are not meant to reflect the market structure of the sector.

follow an s-shaped path.

Figure 6.8 Cumulative adopters by type of player (in absolute terms and percentage)

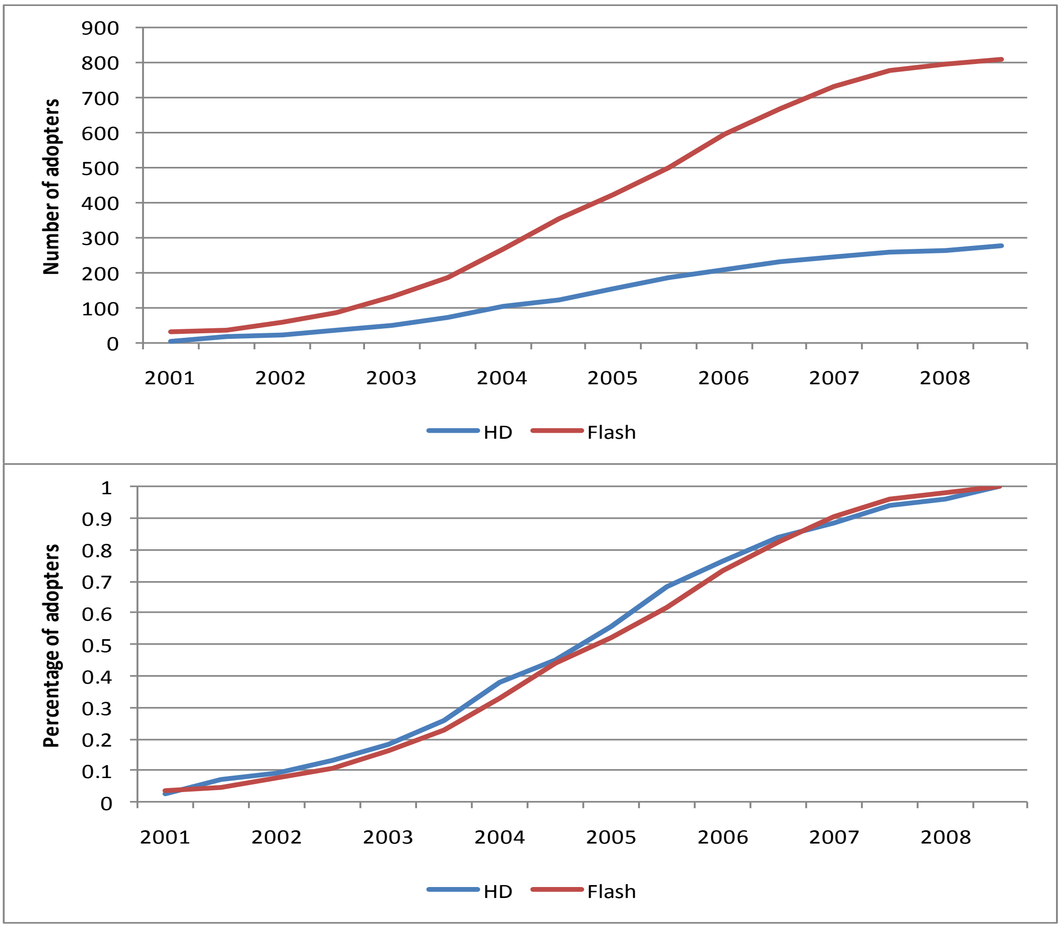
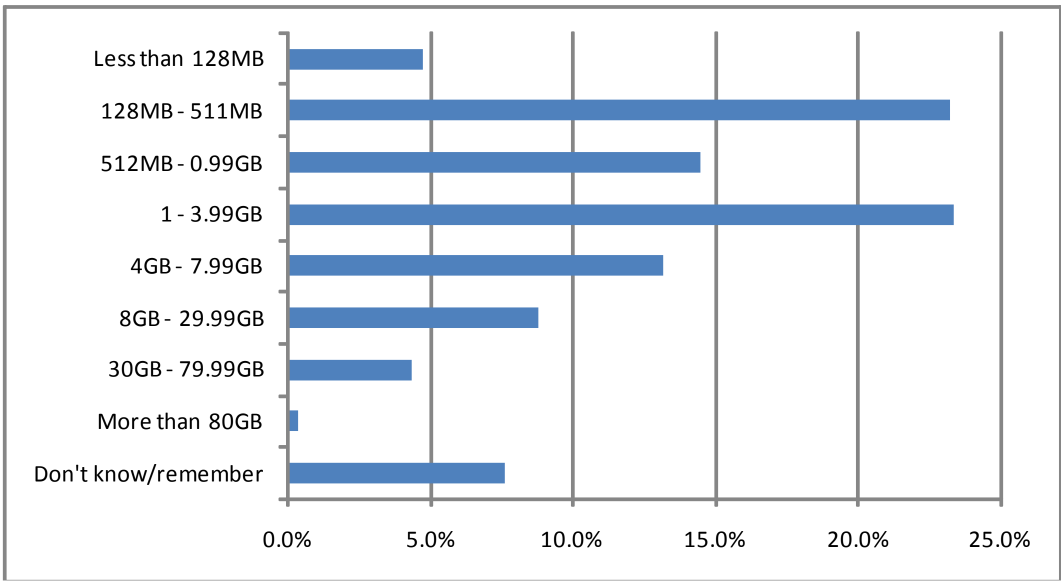


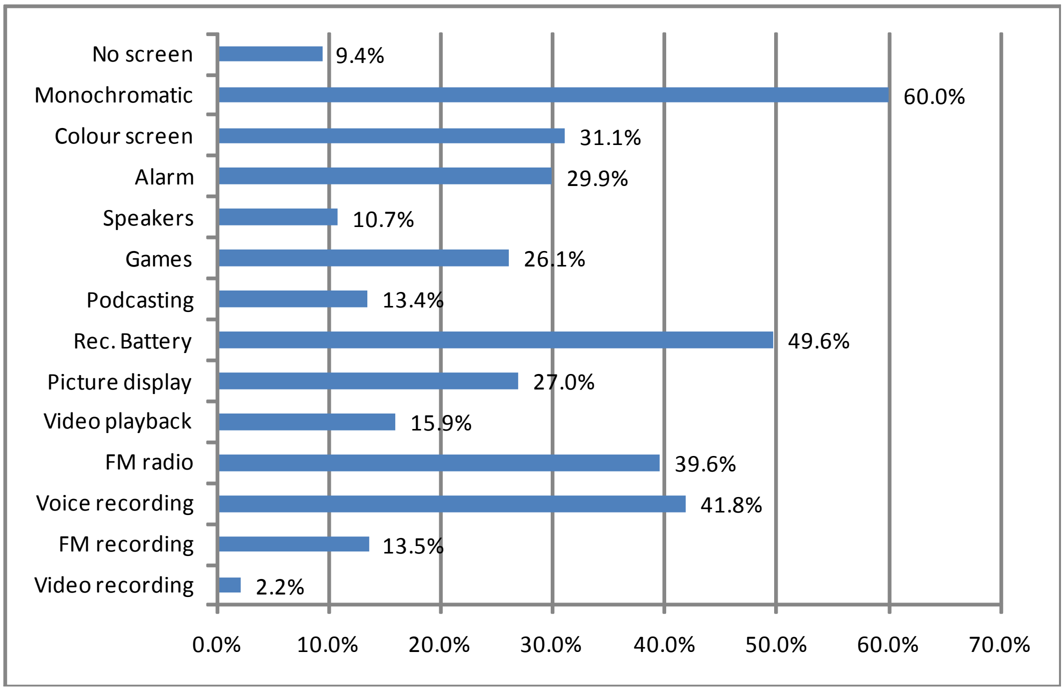
Figure 6.9 Storage space of first adopted DAP



On average, as shown by Figure 6.9, most of the first adopted players have less than 4GB of storage space. This reflects the fact that at the beginning of the period, the storage space of the MP3 players was quite limited, with most of the flash players having a very little memory (32, 64 or 128MB), while HD players were equipped with 4 or 5GB hard drives. The players' available storage space has increased exponentially over time, and this represents one of the most relevant reasons for buying a new DAP after the first adoption (see Section 6.1.6).

The last questions regarding the characteristics of the first MP3 player adopted are shown in Figure 6.10 and Figure 6.11.

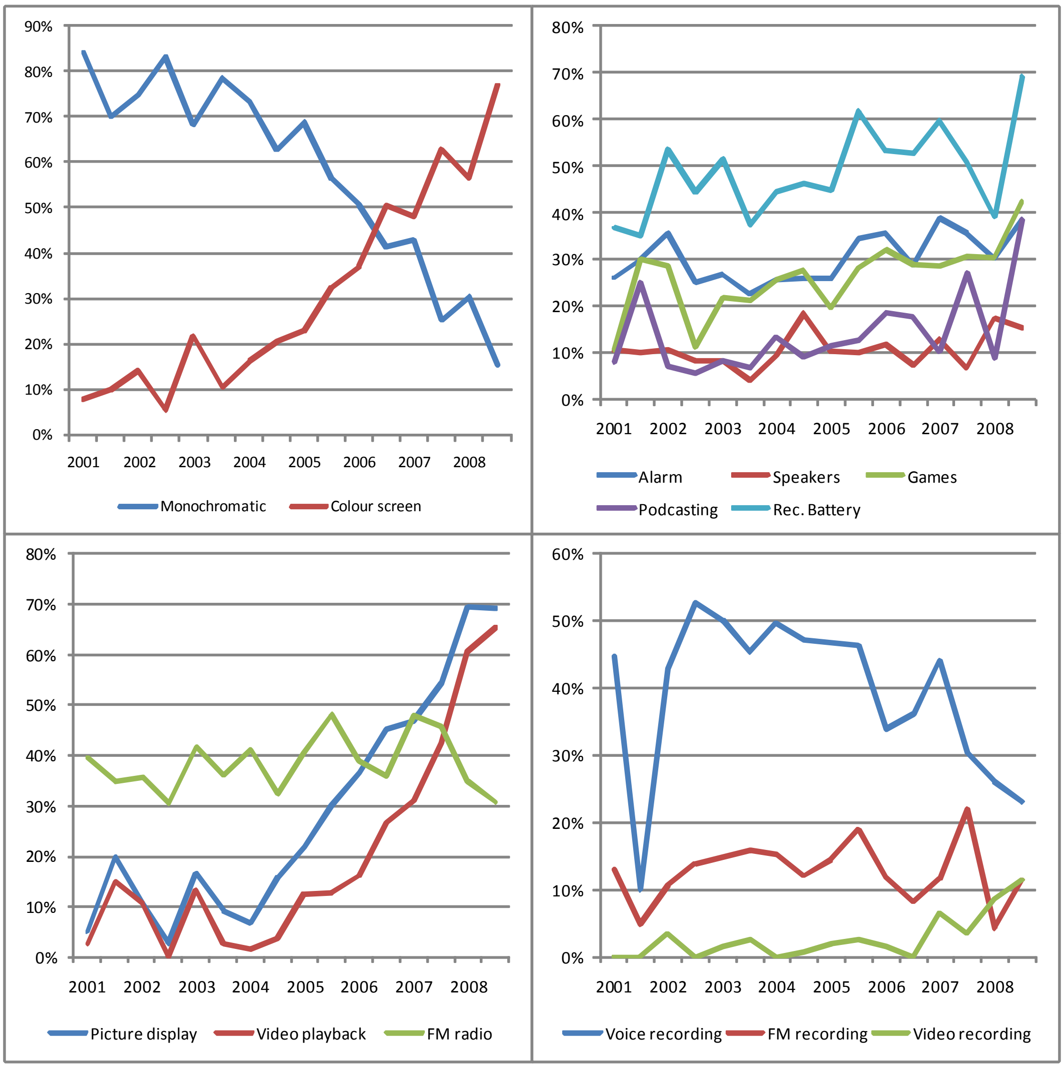
Figure 6.10 Average characteristics of adopted DAPs



On average, less than 10% of players did not have a screen. The majority of the players are equipped with a monochromatic screen; however, in the period 2006-2007 the number of adopted players with colour screens outnumber the number of players with monochromatic screens.

Regarding the extra features of DAPs, the most common ones are radio FM and voice recording. These features, as well as others, such as alarms, games and podcasting, have also been quite stable over time. On the contrary, graphical features such as picture display and video playback have increased a lot over time. This trend has coincided with the development of colour displays.

Figure 6.11 Characteristics of adopted DAPs over time



Regarding the question about the use of the player, more than one-half of the adopters use their DAP for less than one hour a day (Table 6.18). The country in which respondents reported using their DAP the longest is Japan, followed by Portugal and France.

Table 6.18 Use of DAP on average and by country

	Percentage
Never	9.3%
Less than 1/2 hour	23.2%
1/2 hour to 1 hour	32.3%
1-3 hours	27.6%
3-5 hours	6.2%
More than 5 hours	1.5%
	100.0%

Regarding the most commonly used features of the DAPs (besides listening to music),

Table 6.19 shows that none of the extra functions receive particular attention. However, the features that are used the most are photo display and FM radio.

Table 6.19 Use of DAP features (when available)

	Mean	***Std. Deviation***
Alarm/calendar	1.08	1.214
Speakers	0.79	1.246
Games	1.18	1.261
Photo	1.46	1.358
Podcasting	1.07	1.284
FM	1.31	1.423
FM recording	0.64	.890
Video	1.15	1.338
Voice recording	0.93	1.054
Video recording	0.52	.914

Note: answers given on a five-point Likert scale from 1=Never to 5=Very often.

In conclusion, adopters quite often use their DAP, at least on a daily basis; however, despite the proliferation of several extra functions over time, the most used function remains the core purpose of listening to music. Finally, question 29 investigates the most used ways of listening to music (shuffle songs, play playlists or search every time for a specific song), with the result that all these ways are used by respondents, and none of them predominates over the others.

The next questions in this section concentrate on the adopter's profile, without specifically referring to the adoption of the first DAP.

Table 6.20 Most important source of knowledge for learning how to use a DAP

	Percentage
Myself	70.1%
Friends or relatives	15.0%
Product manual	11.1%
Online forum	1.7%
Online support	1.4%
Employees in the store	.8%
	100%

In particular, question 26 is about which sources of knowledge have been the most important in order to learn how to use a DAP. Table 6.20 shows that learning how to use a DAP did not seem to be a difficult task for respondents, since a large majority of users learned to use their DAP by themselves, while 15% of the adopters asked a friend or a relative, and 11.1% used the product manual.

Table 6.21 Share of users having tried a DAP before adoption

	Percentage
Tried friend's one	46.10%
Tried in a generic store	11.20%
Tried in a brand store	5.60%
No	44.50%

Question 31 examines what share of users had tried a DAP before deciding to adopt one. Table 6.21 shows that most of the users tried a DAP (55.5%), and most of them used one belonging to a friend, indicating a sort of epidemic-style of adoption.

The last questions of this section are about how much music the adopters have access to and what sources they use to acquire music files. Considering the fact that adopters seem mostly to use their DAP to listen to music, disregarding the extra features, measuring how much music in digital format (hence loadable onto their MP3 player) they possess could be very relevant in order to explain the timing of their adoption. In particular, Table 6.22 highlights the fact that users have accumulated over time a great quantity of music in digital format.

Table 6.22 GB of music owned by adopters (not necessarily stored in the DAP)

	Less than 1GB	***1GB - 4.99GB***	***5GB - 9.99GB***	***10GB - 29.9GB***	***More than 30GB***	***Don't know/ remember***	
Average	7.2%	19.2%	19.2%	24.6%	16.0%	13.8%	100%
France	9.2%	16.8%	19.3%	21.8%	18.5%	14.3%	100%
Germany	7.1%	16.5%	21.3%	29.9%	15.7%	9.4%	100%
Italy	8.4%	26.4%	24.2%	17.4%	12.4%	11.2%	100%
Japan	9.3%	33.6%	14.0%	26.2%	6.5%	10.3%	100%
Netherlands	12.9%	9.7%	14.5%	30.6%	25.8%	6.5%	100%
Portugal	3.2%	28.0%	17.2%	24.7%	17.2%	9.7%	100%
Spain	5.3%	16.6%	15.9%	21.2%	9.9%	31.1%	100%
Switzerland	5.6%	7.9%	24.6%	24.6%	25.4%	11.9%	100%
UK	5.8%	15.1%	17.3%	30.9%	18.7%	12.2%	100%

More than 40% of users have more than 10GB of music.[87] Respondents from more or less all the countries declared themselves to have a significant amount of music in digital format. Table 6.23 investigates what are the sources of this amount of music. In particular, respondents are asked to rank four sources of MP3s: Internet with payment (e.g. iTunes store), Internet without payment, personal collection of CDs and friends. The music source ranked first most frequently is Internet without payment, followed by collection of CDs. The most important result of this question is that 70.3% of the MP3s

[87] 10GB of music is equivalent to about 2000 songs (depending on the compression codec and bitrate).

owned by respondents have been obtained primarily through sources that presumably do not respect copyright (Internet file sharing or file sharing with friends). This result seems to confirm the above-mentioned speculation about the relevant role played by Internet file sharing in fostering the diffusion of DAPs, which was introduced in Chapter 3.

Table 6.23 Most important source of music in digital format

	Internet without payment	***Friends***	***Collection of CDs***	***Internet with payment***	
Average	54.1%	16.2%	23.3%	6.4%	100%
France	63.2%	15.1%	20.8%	0.9%	100%
Germany	31.2%	31.2%	31.2%	6.5%	100%
Italy	69.9%	13.5%	13.5%	3.1%	100%
Japan	29.2%	4.2%	56.3%	10.4%	100%
Netherlands	78.0%	11.9%	8.5%	1.7%	100%
Portugal	68.4%	20.3%	10.1%	1.3%	100%
Spain	69.0%	16.2%	12.7%	2.1%	100%
Switzerland	38.1%	18.6%	27.4%	15.9%	100%
UK	39.0%	16.3%	30.9%	13.8%	100%

Based upon the sample, the country that relies the most on illegal sources is the Netherlands, followed by the Southern European countries (Italy, Spain and Portugal) and France. In contrast, Germany and Japan are the countries in which legal sources are more relevant, although Germany has the highest percentage of users obtaining music primarily from friends, and in Japan almost 30% of respondents still use Internet sources without payment as their first source.

6.1.4. Sources of information

The relevance and variety of sources of information are often considered as factors influencing the diffusion of an innovation. Question 44 takes this issue into consideration by asking respondents to rate the importance of a list of twelve potential sources of information:

- Advertisements;
- Celebrity endorsers;
- MP3 player producers' websites;
- My family or relatives;
- My friends;
- My previous experience with products of the same brand;
- My previous experience with similar products;
- Online forum or communities;
- Online shops/retailers;
- Traditional shops/retailers;

- Other people around me;
- Specialised magazines.

The importance was measured by a five-point Likert scale, ranging from ‘unimportant’ to ‘very important’. Before analysing the sources of information it would be useful to reduce the list of sources to a more manageable number of variables. The list of items was not prepared with the idea of testing a particular *a priori* hypothesis, and deliberately mixed the order of choices with regard to proximity. To see whether the responses reveal a structure, a factor analysis seems to be an appropriate tool (Hair *et al.*, 2010: p.94). First of all, the KMO and Bartlett tests ensure that the factor analysis can be carried out. In particular, the Kaiser-Meyer-Olkin measure of sampling adequacy is equal to .745, indicating that the items are able to be grouped into a smaller set of factors. Moreover, the Bartlett test (sig. .000) indicates that all correlation coefficients off the diagonal are not equal to zero. The method used is principal component analysis, while the rule for deciding the number of factors extracted is the Kaiser method (eigenvalue >1). Additionally, in order to strengthen the relationship between the items composing each factor and to improve the interpretation of the factor structure, a rotation procedure is applied. We opted for an oblique rotation, in order to leave the factors free to be correlated among themselves (an orthogonal rotation would have forced the factors to be uncorrelated). Finally, the factor scores have been used to create a variable representing each factor using the Anderson-Rubin method (Hair *et al.*, 2010: ch.3; Field, 2009: ch.17).

The literature on the diffusion of innovation has generally considered two types of information sources. The first one is represented by word-of-mouth, usually called *internal sources*, while the second one considers other sources, such as advertising, which are usually labelled *external sources*. The list of sources used in the factor analysis is much richer; for this reason, we might expect to retrieve more than two factors.

This proves to be the case; the factor analysis procedure extracts four factors. Table 6.24 shows the factor loadings of each item into each factor. On first impressions, the matrix appears to highlight a clear factor structure. None of the items load significantly (low factor loadings are reported as blanks) into more than one factor. Moreover, the list of items contributing to building each of the factors appears to be coherent and meaningful. In particular, Factor 1 represents *internal sources* (INFO_INT), since it considers items such as friends, family and other people. Factor 2 can be interpreted as *external sources* (INFO_EXT), since it contains advertisements, celebrity endorsers and the producers' websites. These two factors confirm the classification of information sources often put forward by the literature on innovation diffusion. Of the others factors, Factor 3 includes *previous experience* (INFO_EXP) with similar brands or similar products. Finally, Factor 4 includes external sources that are both online (online shops and online forums) and offline (specialised magazines and shops), which may be associated with a more active role of users in seeking out the information they need in order to evaluate a DAP. This factor has been labelled *active sources* (INFO_ACT). Finally, Cronbach's alpha indicates sufficient scale reliability (above .6) for each variable: INFO_INT=.624; INFO_EXT=.764; INFO EXP=.841; and INFO_ACT=.654.

Table 6.24 Factor loadings matrix after oblique rotation

	Component			
	1	2	3	4
Friends	.851			
Family	.829			
People around me	.680			
Online shops				.779
Online forums				.768
Specialised magazine				.658
Traditional shops				.494
Experience with brand			-.915	
Experience with products			-.888	
Advertisement		.824		
Celebrities		.785		
Producers' websites		.493		

Note: factor loadings below .400 are not reported.

In conclusion, the factor analysis on information sources is consistent with the classification offered in part of the literature on the diffusion of innovation. Moreover, it contributes to a better understanding of the sources of information by adding two new potential information sources. Moreover, it identifies the separate existence of an external information source through which potential adopters are not passive recipients of exogenous information, but also active seekers of relevant pieces of information.

6.1.5. Non-adopters

Although the questionnaire mainly concentrates on DAP adopters, a short section is still dedicated to non-adopters. Recalling Table 6.16, the questionnaire surveyed 331 non-adopters, representing 23.1% of the total number of respondents. Non-adopters have been divided into *interested* and *not interested* in buying a DAP, thanks to a specific question. The majority of non-adopters (61.6%) are not interested in buying a DAP, while only 38.4% declared that they will buy a DAP soon.

Table 6.25 Reasons for not having a DAP

	Non-adopters+	***Not interested***	***Interested***	***T-test***
	Mean	Mean	Mean	Sig. (2 tailed)
Waiting for price to decline	2.67	2.36	3.17	**.000*****
Waiting for new functions	2.08	1.92	2.34	**.001*****
I think I will not use it	3.21	3.52	2.72	**.000*****
Afraid of not being able to use it	1.56	1.57	1.54	.721
Using another player	2.32	2.30	2.35	.788
Using a mobile phone as DAP	3.11	3.29	2.82	**.002*****

*Note: answers given on a five-points Likert scale from 1=Strongly disagree to 5=Strongly Agree. + Includes the average of all non-adopters, including both not interested and interested. *** p<0.01, ** p<0.05, * p<0.1*

Table 6.25 shows the answers to a question about the reasons for not having adopted yet. The first column reports the average for all non-adopters. The second and third columns report the average scores for not interested and interested non-adopters separately. Finally, the last column indicates the probability of an independent t-test on the differences between the scores of the two groups of non-adopters. Concentrating on the first column, the most relevant reason is in regard to the benefits from adoption, i.e. thinking they would not use the product after purchase. The second most important reason is that non-adopters are currently using a mobile phone as a portable MP3 player. The third reason for non-adoption is that users think that DAPs cost too much and they are waiting for the price to decline. Only limited importance is given to the other answers: waiting for new functions, afraid of not being able to use it and using another player (e.g. cassette, CD or Minidisc player).

However, the profile of non-adopters looks different if we consider those who are still interested in adopting a DAP and those who are not (last three columns of the table). An independent sample t-test indicates that besides the two potential reasons for not having a DAP (being afraid of not being able to use it and using another player), there are significant differences between these two groups of non-adopters. In particular, those who are still interested are more likely to be waiting for the price to decline or for new functions. On the other hand, those who are not interested in DAPs declared more frequently that they are using a phone to listen to digital music or that they would not use a DAP if they adopted one.

Table 6.26 Price limit for the purchase of a DAP

	Percentage
Less than €30	12.0%
€30 - €59.99	31.2%
€60 - €124.99	36.8%
€125 - €189.99	12.0%
More than €190	8.0%

Note: only non-adopters willing to buy a DAP answered to this question.

The next question, answered only by those who are interested in DAPs, and demonstrated in Table 6.26, indicates that the price limit for this group of non-adopters is quite low (only 20% declared themselves to be willing to pay more than €125 for a DAP). However, this limited willingness to pay does not seem to be related with the respondents' income. A Chi-square test does not indicate any significant relationship between respondents' income and the price they are willing to pay for a DAP.[88]

6.1.6. Multi-adopters

Multi-adoption or multi-purchase of DAPs is an important phenomenon, since 56.9% of the adopters have purchased more than one MP3 player. The questionnaire surveyed 1102 adopters who have purchased a total number of 1861 DAPs. The first question regarding this group of adopters (sample=637 respondents) is how many MP3 players they have bought. Table 6.27 shows that respondents have adopted up to six MP3 players. The majority of them (81.5%) had two players, 12.4% had three players and almost 5% of respondents had four players. Only 1.2% of respondents had more than five players.

Table 6.27 Number of DAPs purchased by multi-adopters

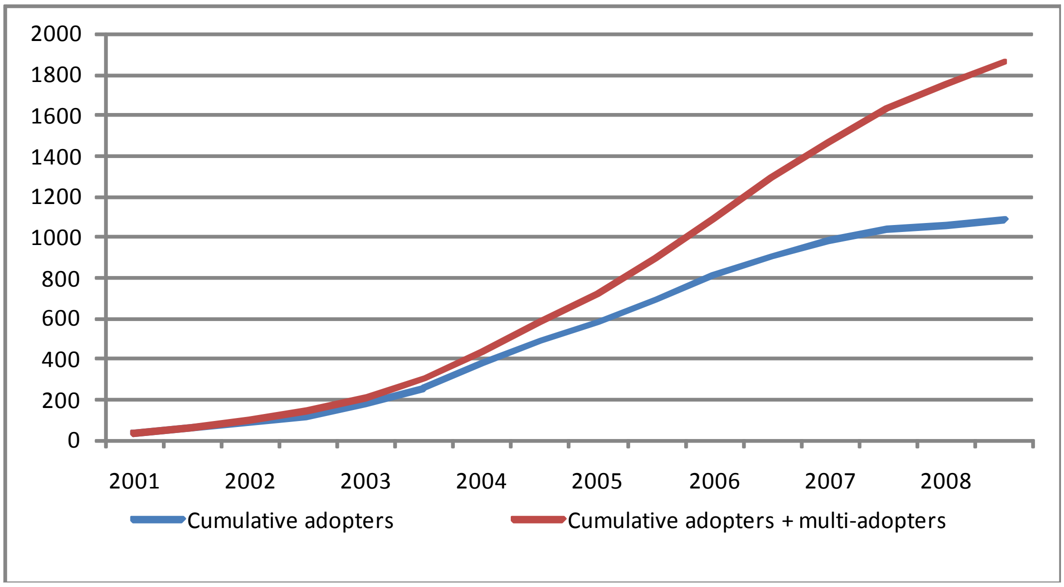
	Percentage
2 players	81.5%
3 players	12.4%
4 players	4.9%
5 players	1.0%
6 players	0.2%
	100.0%

Figure 6.12 compares the trend of two curves. The first one is the cumulative adopters curve (already pictured in Figure 6.5), while the other one represents the cumulative sum of adopters and multi-adopters. Cumulative adoption has an s-shaped curve,

[88] The test is performed on the average willingness to pay by non-adopters belonging to different income groups (four quartiles).

which means that the adoption rate after 2006 started to slow down, since a high percentage of potential adopters had already adopted. Quite interestingly, the deceleration in multi-adoption is much less pronounced, suggesting that substantial further growth opportunity remains in the market.

Figure 6.12 Cumulative adopters and multi-adopters over time



This result raises questions about the supply-side. MP3 players should still be competing in the market, even if most of the potential adopters have already adopted. Firms may be engaged in two sorts of competitive activities: competing for users adopting a new innovative product that they did not have before, and competing to encourage adopters to dismiss their current product in favour of buying another one. Finally, given that multi-adoption is a very frequent and relevant phenomenon, Table 6.28 summarises the reasons for purchasing another DAP after the first one.

Table 6.28 Reasons for purchasing another DAP after the first one

	Percentage
The old one broke down	55.5%
The old one got lost or stolen	12.1%
I wanted to use the new function of a novel product	26.2%
I needed a smaller model	13.2%
I needed more storage space	38.3%
All my friends have a new one	1.3%
I got it as a gift	24.4%

Note: yes/no question with the possibility of giving multiple answers.

The most frequent reason for adopting another DAP is that the old one broke down or did not work properly anymore. Other reasons relate to the loss or theft of the previous one (12.1%) or a gift (24.4%). Only a very small percentage of respondents declared that they bought a new MP3 player in order to imitate their friends. A last group of reasons regards the evolution of the DAP sector from the supply-side, either because adopters wanted a smaller model (13.2%), one with more storage space (38.3%) or one with some additional function (26.2%). This might indicate that multi-adopters formulate expectations of some product improvements, and decide to buy another product depending on the fulfilment of these expectations. The last consideration is the fact that more than 38% of respondents declared that they needed more storage space. This is another suggestion of the contribution of illegal downloads of music in digital format to the growth of the DAP market. The accumulation of such music files may be important for both the first adoption of a DAP and also for its repeated purchase.

6.2. Classification of the adopters through cluster analysis

The objective of this section is to provide a classification of the adopters. The reasons for classifying the adopters are twofold. First of all, the results of the questionnaire indicate that, besides their age, respondents are differentiated in terms of socio-economic indicators, digital literacy, adoption and use of DAPs. All these distinctions might make it difficult to provide a homogeneous adopter profile. Providing a classification of the adopters can help to test whether all these differences can be grouped into homogenous clusters and, at the limit, whether apparent differentiation is illusory. Having concluded that adopters are not quite homogeneous, the second aim is to consider how a classification of adopters that does capture their heterogeneity impacts on the timing of adoption. Considering that many of the diffusion models (especially those belonging to Rogers' tradition) classify adopters according to the timing of their adoption, one of the tasks of this section will be to test whether the classification of DAP adopters is compatible with the usual classification into early and late adopters, where each has distinguishable characteristics.

6.2.1. Two-step clustering procedure

The most suitable method to classify the adopters in homogenous groups and to compare characteristics and performances of these groups seems to be cluster analysis. First of all, this method offers some help in deciding the most appropriate number of clusters describing the variability in the population.[89] Moreover, it will aggregate

[89] It is important to note that cluster analysis does not *determine* the number of such groups, but rather provides criteria for assessing the degree of variability that is captured by different groupings. Moreover, it provides a more definitive solution to the problem of assessing the

adopters into these groups in a way that the variance within clusters is robustly lower than between clusters.

Clustering variables

The first step of cluster analysis is to choose the variables used to measure the differences between objects and clusters. This list of characteristics should be able to characterise the adopters without favouring any preconceived class of adopters. In particular, the list will necessarily exclude any variable referring to the timing of adoption as this would immediately favour this variable entering directly into the clustering process. This does not mean that these characteristics should not somehow be correlated with the time of adoption. However, no *a priori* hypothesis has been made about the relationship between the clusters and the timing of adoption.

The choice of the variables to be used to measure the distance between adopters is based on the results of the descriptive analysis, also following a parsimony criterion (in order to avoid multicollinearity), designating a list of five variables. The first variable is income and regards the socioeconomic profile of respondents. The next three variables regard computer use, computer literacy and use of electronic gadgets. The last variable is GB_MUSIC, a measure of the volume of music downloaded or otherwise accumulated in digital format. This issue emerged so frequently in the descriptive analysis that it would have been a mistake not to consider it in the clustering process.

- *Income* (INCOME): built as explained in Section 6.1.1.
- *Computer use* (COMP_USE): 1 to 6 variable from ‘never’ to ‘more than 5 hours’.
- *Computer skills* (SKILLS): 1 to 5 variable from ‘much below the average’ to ‘much above the average’.
- *Number of electronic gadgets* (GADGETS): variable ranging from 1 to 7, indicating how many electronic gadgets are owned by the respondents from the list: blue-ray player, camcorder, digital camera, GPS, HD TV, PDA and smart phone.
- *GB of music* stored in the computer (GB_MUSIC): 1 to 5 variable from ‘less than 1GB’ to ‘more than 30GB’.

As mentioned above, these variables are chosen in such a way that no *a priori* hypothesis on the timing of adoption of a DAP is made. However, one may speculate that the variable GADGETS could be at least indirectly related with the timing of adoption, being, for instance, correlated with the variable domain-specific innovativeness. However, there is no indication of how early the respondents with a lot of gadgets had acquired them, and therefore no *a priori* reason to believe that these

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‘relatedness’ of characteristics that may comprise a cluster.

respondents would necessarily be from the very early adopter group.

Another variable that might have been included in the list is respondent's gender. However, the use of binary variables such as gender is not allowed in one of the clustering methods used (K-means). For this reason, gender will not be included in the clustering variables list. In order to avoid problems related to different units of measurement, all the variables have been standardised, subtracting their mean and dividing by their standard deviation (Hair *et al.*, 2010: p524).

Clustering methods

Two kinds of clustering methods will be applied. The first one is the *hierarchical agglomerative method*. This method is called *agglomerative* because it starts from the complete list of objects (having then N observations), arranging them into groups, depending on their similarity, until only one cluster remains. Moreover, this method is also *hierarchical* because the clustering structure can be graphically represented by a treelike structure called a *dendrogram* (Hair *et al.*, 2010: p.529-34). This method is particularly useful since it can provide some indications of what is the most appropriate number of clusters (*stopping rule*), which is the most subjective decision in cluster analysis. The second method is *non-hierarchical*, and it is a procedure used to assign each object to a cluster, once the number of clusters is already specified. This method starts by selecting an initial cluster centre (*seed*) for each cluster, which represents the average characteristics of each of the clusters that should be formed. These seeds can be randomly selected or assigned according to some prior assumptions or previous research. The clustering process starts from these seeds, and then each further observation is assigned to a cluster, based on the distance from the cluster centres. Moreover, a new cluster centre is recalculated at each iteration, using the mean values of all the cases in each cluster. These steps are repeated following an iterative process until any reassignment of cases would make the clusters more internally variable or externally similar (Hair *et al.*, 2010: p.529-34).

The clustering procedure used in this research will use a combination of both kinds of clustering methods, by applying a two-step procedure. As the first step, a hierarchical method will be used. The main objective of this step, rather than creating the definitive cluster membership, is to determine the number of clusters and the average characteristics of the members of each cluster. These two outputs of the hierarchical clustering will be the basis for the second step of the clustering process.[90]

Two issues should be taken into consideration in employing this method: how to measure similarity, and the clustering method. The first issue regards the measure of similarity, and this is quite a relevant issue, since the clustering procedure should maximise the similarity within clusters, while minimising the similarity between clusters. Some of the most commonly used measures of similarity are based on the distance between the observations. Two of the most commonly used measures are the Euclidean distance (the length of the straight line between the observations) and the Squared Euclidean distance (which more strongly emphasises the separation between observations). The second issue is the clustering method, which is how to use the measure of similarity to aggregate the objects into groups. Several methods are available. Most of these methods aggregate clusters by minimising the distance between two clusters. The distance can be measured between single observations within each cluster (e.g. the closest or the farthest ones) or between the whole clusters (e.g. the average of all observations or centroids). In this case, Ward's method will be employed. This method is one of the most popular hierarchical clustering techniques (Milligan, 1980; Hair *et al.*, 2010: p.534). Ward's method does not use similarity as a single measure, but rather the sum of squares within the clusters summed over all variables. In other words, clusters are combined by minimising the within-cluster sum of squares, considering all variables (Hair *et al.*, 2010: p.532). Since the main objectives of this step of the clustering process are to decide the number of clusters and to create the seeds for the next step of the clustering process, this method seems particularly suitable, for two reasons. The first is that Ward's method tends to create clusters of approximately the same number of observations, usually combining small clusters, avoiding the creation of clusters with only one or few elements, which are very difficult to interpret (Hair *et al.*, 2010: p.532). Secondly, this method creates clusters by minimising the within-clusters distance, and seems to be the most appropriate method to determine the cluster seeds which will be the starting points for the creation of the definitive clusters (Milligan and Cooper, 1987; Peña *et al.* 1999: p.1029). However, this method is strongly affected by outliers (Milligan 1980: p.331), suggesting that procedures should be carried out in order to detect them and exclude them from the analysis. The last issue regards the stopping rule; in other words, the number of

[90] This two-step is mentioned by statistics textbooks such as Hair *et al.* (2010: p.546), and applied in several empirical analyses to cluster different kinds of objects. Some examples of two-step clustering used in studies in the field of science and innovation policy and management are: Clarysse and Muldur (2001) for regions, Kakati (2003) for high-tech new ventures, and Okazaki (2006) for the case of adopters of innovations.

clusters that should be formed. Most of the time, the stopping rule is based on visual analysis of the dendrogram, which involves the discretion of the investigator.

The second step involves the use of a non-hierarchical method. The method used here will be the K-means (provided by the statistical software SPSS) procedure, which is an optimising procedure. This means that using this method will not only create a cluster solution, but it will also produce a classification that minimises the variance within each cluster (Punj and Stewart, 1983: p.139). In other words, this method is very efficient; however, it also presents several drawbacks. First of all, it requires the pre-specification of the number of clusters. Secondly, the clustering procedure depends on the appropriateness of the first seeds, and can lead to ambiguous results in case the first seeds are selected randomly (Punj and Stewart, 1983: p.138). This is because an *unsuitable* combination of elements at an early stage of the process can provoke an *inappropriate* clustering that persists throughout the clustering procedure. This means that sorting the dataset according to different variables can create very different results (Hair *et al.* 2010: p.533-4). However, these issues should be solved by using the results of the first step of the analysis, i.e. the number of clusters, and the cluster seeds, as a basis for the K-means clustering.

No outliers and no multicollinearity assumptions

Before performing the clustering process, two further issues should be addressed. The first is about the presence of outliers, since they can bias the results of the clustering method used (Ward's method). The second is about one of the assumptions of cluster analysis: that there should be no multicollinearity among the variables on which the clustering is performed. This is because if the distance between observations is measured by a Squared Euclidean distance, having overly correlated variables may result in an overestimated distance between observations.

The identification of outliers will be carried out at both univariate and multivariate levels. The first kind of outlier detection is based on the distribution of single variables (univariate), and is performed by examining the distribution of each of the five variables used in the cluster analysis, and by identifying the most extreme observations in the distribution. The threshold value will be +/- four standard deviations[91] (Hair *et al.*, 2010: p.67). The only variable that has cases over this threshold is INCOME. In particular, five observations have z-scores over four. These observations are thus

[91] The interval of +/- 4 standard deviations is based on Chebychev's theorem, which ensures that at least 94% of cases fall within four standard deviations (Greene, 2003: p.848).

considered outliers and not taken into consideration for the purpose of the cluster analysis. The second kind of detection is performed at multivariate level, and it involves the use of the Mahalanobis D^2 measure[92] (Hair *et al.*, 2010: p.67). The number of observations that have an overly high Mahalanobis distance is six. This list contains the five observations already considered outliers using the univariate detection method. In conclusion, six observations have been identified as outliers, and they will not be used in the cluster analysis.

The no multicollinearity assumption will be checked by providing the correlation between the variables on which the distance between observations is based.

Table 6.29 Correlation matrix

	INCOME	*COMP_USE*	*SKILLS*	*GB_MUSIC*	*GADGETS*
INCOME	1	.127***	.102***	.043	.188***
COMP_USE		1	.307***	.143***	.053**
SKILLS			1	.238***	.147***
GB_MUSIC				1	.118***
GADGETS					1

*Note: *** p<0.01, ** p<0.05, * p<0.1*

Table 6.29 shows the correlation matrix between the five clustering variables. The main indication of the table is that the correlations between the variables are quite limited. The variables with the highest correlation are SKILLS and COMP_USE (.307), followed by SKILL and GB_MUSIC (.238). This should ensure that the multicollinearity problem is under control.

Results of clustering

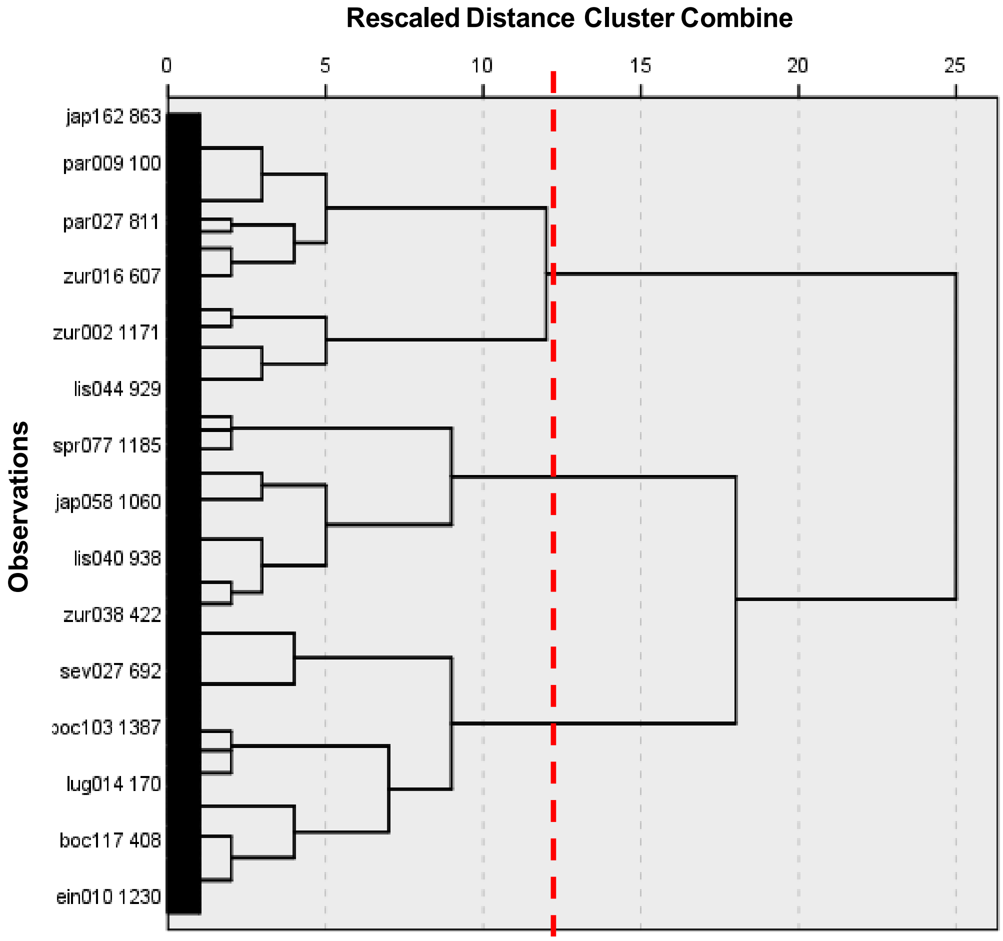
In brief, a hierarchical agglomerative procedure using Ward's clustering method and Squared Euclidean distance (the appropriate kind of distance measure for this type of method) will be used to select the number of clusters. Secondly, a non-hierarchical procedure using the K-means approach will be employed to assign each object to a cluster, once the number of clusters is specified, using the average characteristics of the clusters determined within the first step as initial seeds.

Figure 6.13 shows the dendrogram resulting from the first step of the clustering

[92] Mahalanobis D^2 is a measure that assesses the distance of each observation from the mean centre of all observations. This distance can be interpreted thanks to some of its statistical properties: by dividing it by the number of variables involved (D^2/df) the Mahalanobis distance approximately follows a Student's *t* distribution. For this reason, for large samples, observations having D^2/df larger than four can be considered outliers (Hair *et al.*, 2010: p.66-7).

method. The vertical axis of the dendrogram reports all the observations (the respondents), and on the horizontal axis the degree of similarity of the cluster solution (calculated by a distance measure rescaled to a number between 0 and 25). Connected vertical lines represent the combination of two clusters in order to create a new one.

Figure 6.13 Dendrogram



Note: the dendrogram represents a hierarchical agglomerative clustering using Ward's method and a Squared Euclidean distance.

Visual analysis of the dendrogram suggests choosing a three-cluster solution. Accepting a smaller number of clusters (to the right of the dashed line) would make the new clusters contain overly distant objects. On the other side, choosing more than three clusters would mean splitting the cluster on the top of the dendrogram into two groups, and this would produce two clusters of relatively small size, without gaining much in terms of lower distance regarding similarity (from 12 to 9). As noted above, the choice of the number of clusters involves a certain degree of discretion on behalf of the researcher. For this reason, the visual results provided by the dendrogram will be supported by a more analytical tool: the agglomeration schedule (reported in Table

6.30).

Table 6.30 Agglomeration schedule

Stage	*Number of clusters*	*Heterogeneity Coefficient*	*Percentage increase in heterogeneity*
.	.	.	.
.	.	.	.
701	8	1735.66	5.6%
702	7	1832.10	5.6%
703	6	1966.80	7.4%
704	5	2143.46	9.0%
705	4	2320.60	8.3%
706	3	2545.70	9.7%
707	2	2904.75	14.1%
708	1	3414.52	17.5%

The agglomeration schedule is one of the outputs of the statistical software SPSS and shows the stages of the hierarchical clustering process. At each stage two clusters are joined to form one new cluster. The table reports the number of clusters after each combination, as well as the heterogeneity coefficient and the percentage increase in heterogeneity after each step. The last row represents the case of only one cluster, the second to last row the case of two clusters and so on (only the final stages of the agglomeration schedule are reported). This table is useful in deciding how many clusters should be chosen. The rationale behind the stopping rule is based on the fact that aggregating two different clusters will reduce the within-cluster similarity (heterogeneity coefficient). When combining two clusters involves a large increase in cluster heterogeneity, this indicates that the clustering process should stop.

In particular, a cluster solution with more than six groups will be unmanageable for the purposes of the analysis; for this reason, stages 701 and 702 will not be considered. Following those steps, the percentage increase is quite stable until stage 706 (three clusters), ranging from 7.4% to 9.7%. However, having less than three clusters would significantly raise the increase in heterogeneity (14.1%). This seems to confirm the visual results of the dendrogram, suggesting that a three-cluster solution seems to be the most suitable.

The second step of the clustering process (non-hierarchical) uses the K-means method provided by the software SPSS. As previously explained, this process is very efficient in aggregating observations into clusters; however, it can give unstable results if the seeds are randomly selected, or depending on the particular order of the observations. For this reason, the average values of the clusters generated with the hierarchical method are used as initial seeds for the clustering, and, in order to avoid problems with the ordering of observations, the dataset has been sorted according to a randomly generated series of numbers. In addition, a further check has been carried out. Once the final results of the K-means clustering were obtained, the procedure has been replicated after having sorted the dataset according to other variables (e.g. INCOME or GADGETS), and according to other randomly generated series of numbers. Since the results of these other attempts are almost identical to the original result, we can conclude that the results of the clustering are very stable and not affected by the variable ordering.

Table 6.31 Cluster structure

	Frequency	***Percentage***
CLUSTER 1	265	37.4%
CLUSTER 2	183	25.8%
CLUSTER 3	261	36.8%
TOTAL	709	100.0%

The results of the second step (K-means) are presented by Table 6.31, which represents the final cluster structure. The first impression is that none of the clusters contain a small number of adopters. The second impression is that, unfortunately, the sample size has dropped from 1102 to 709 respondents. This is due to the inclusion in the clustering variables of the variable INCOME, which was the one with the lowest response rate (290 missing values among the adopters). Moreover, the question GB_MUSIC gave the possibility of answering 'I do not know / I do not remember'. Since around 13% of the adopters gave that answer, the sample size for the cluster analysis drops to 715 cases.[93] Finally, another six cases have been excluded as they have been identified as outliers, giving a final number of 709 cases, still representing a very large set of data for this kind of analysis.

6.2.2. Validation and discussion of clustering results

One of the characteristics of cluster analysis is that the procedure necessarily produces a cluster solution, while one of the most difficult tasks is to interpret and validate this structure. This section will show the differences between the three clusters of adopters regarding a series of variables, including the timing of adoption and the latent variables

[93] This might raise questions on how appropriate is the choice of two variables with such a high number of missing cases. The inclusion of these two variables is necessary because income is one of the variables most widely used in the literature in order to explain the adoption of innovations. Moreover, in the descriptive analysis of the questionnaire, the amount of music in digital format owned by potential adopters emerged as an important factor in order to explain the adoption of a product such as a DAP.

constructed through factor analysis in Chapter 5.

Table 6.32 Differences between clusters regarding socioeconomic variables, computer skills and use of the Internet

	Cluster 1	***Cluster 2***	***Cluster 3***	***Chi-square***	***ANOVA F-test***
Socio-economic					
Gender (males)	63.4%	69.9%	49.4%	**.000*****	
Income	€14,418	€26,479	€21,538		**.000*****
Computer skills					
Computer use+	0.48	0.00	-0.31		**.000*****
Computer skills+	0.54	0.36	-0.48		**.000*****
GB music+	0.51	0.49	-0.86		**.000*****
Gadgets+	-0.46	1.35	-0.26		**.000*****
DAP use+	0.14	0.19	-0.20		**.000*****
Use of the Internet					
Buy products	2.8	2.7	2.3	**.000*****	
Buy songs	1.6	1.8	1.5	**.000*****	
Phone calls	2.4	2.4	1.8	**.000*****	
Personal page	3.6	3.7	3.3	**.001*****	
Email/chat	4.5	4.4	4.1	**.000*****	
Watch videos	3.9	4.0	3.6	**.000*****	
Upload videos	2.0	2.2	1.9	**.062****	
Peer-to-Peer	2.7	3.1	2.3	**.000*****	
Internet Radios	2.7	2.5	2.1	**.000*****	

*Note: += standardized values; *** p<0.01, ** p<0.05, * p<0.1*

Table 6.32 presents the differences between clusters regarding socioeconomic variables, computer skills and the use of the Internet. Regarding socioeconomic variables, clusters 1 and 2 show a predominance of males (63.4% and 69.9%). In contrast, cluster 3 has a higher number of females: 50.6%, which is higher than the average share of females in the questionnaire (43.2%). In addition, the three clusters are quite differentiated in terms of average income (as shown also by Figure 6.14). Cluster 2 contains the adopters with the highest average income (around €26,500), followed by cluster 3 (around €21,500), while cluster 1 has a lower average income (around €14,400). All these differences are statistically significant as indicated by the Chi-square or F-test.[94]

[94] The Chi-square statistics are calculated for categorical variables, while the ANOVA F-test is computed for continuous variables.

Figure 6.14 Income differences among clusters

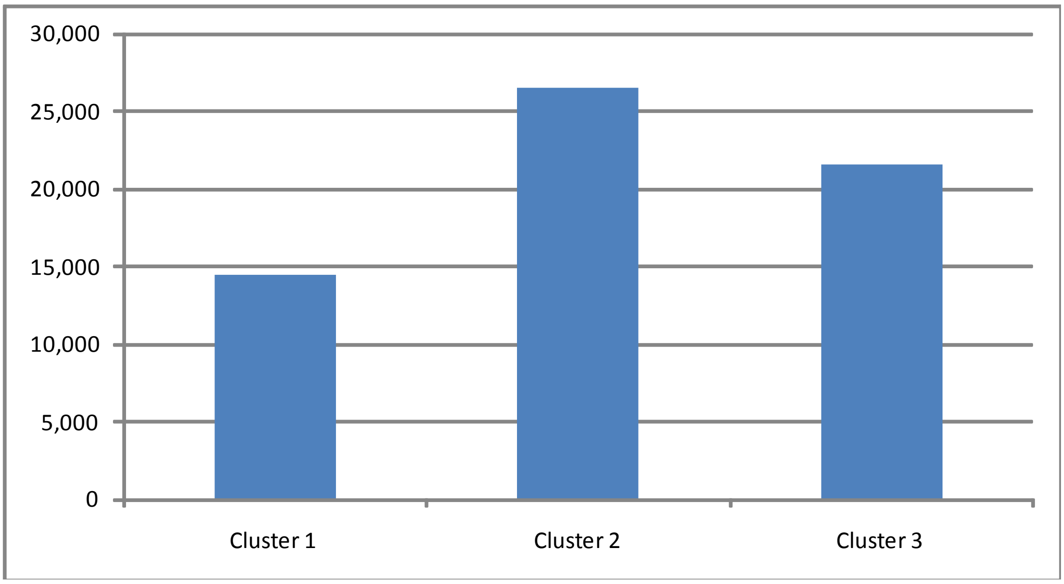
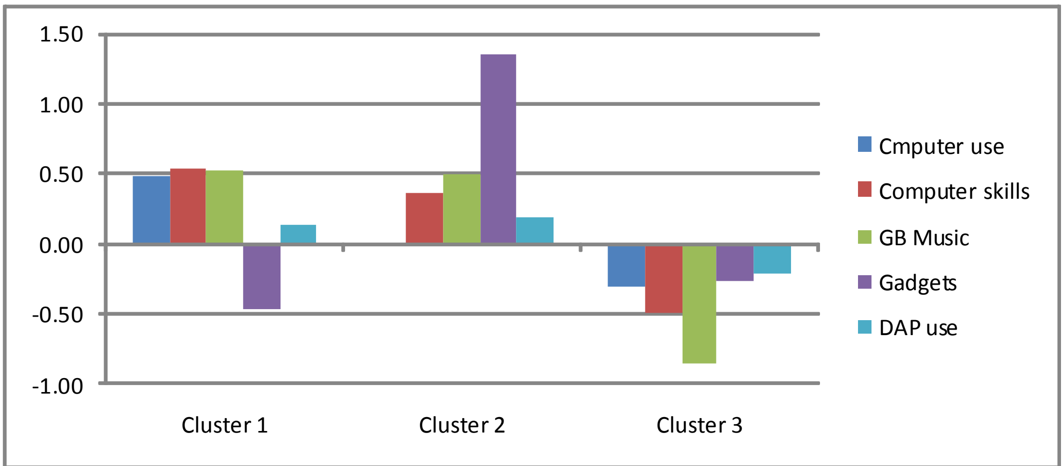
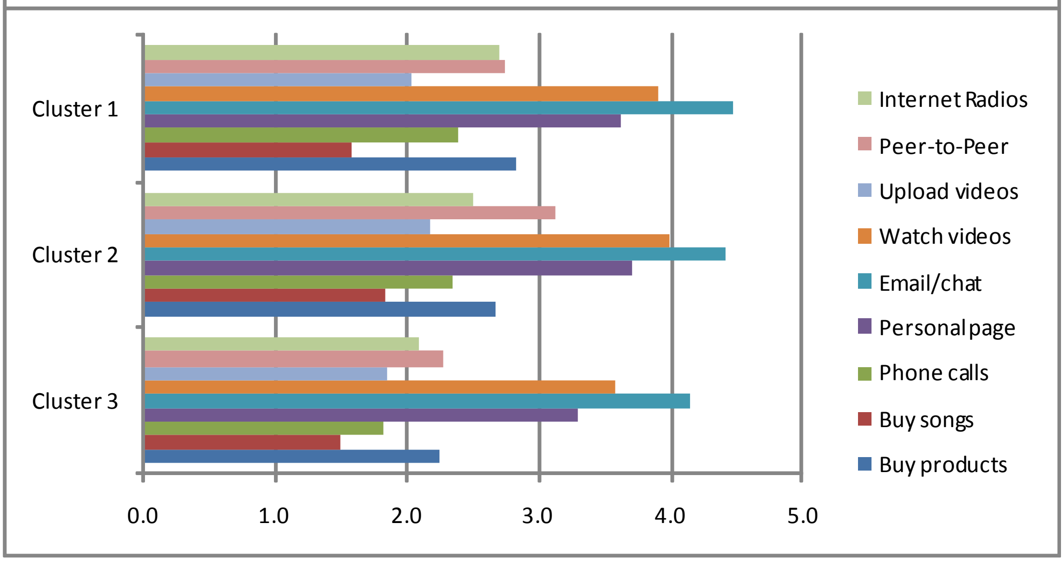


Figure 6.15 Cluster differences regarding computer literacy and use of the Internet





The three clusters are also different with regard to their digital literacy profiles. In particular, as shown by Figure 6.15, cluster 3 is the cluster that scores lower than average on all the indicators. However, clusters 1 and 2 also have different profiles, with members of cluster 1 appearing to be more skilled and more frequent users of computers than members of cluster 2. On the other side, members of cluster 2 are characterised by owning a much higher number of electronic gadgets than any other cluster. Regarding the amount of of music stored in the DAP or computer in GB, clusters 1 and 2 seem to have around the same amount of music, with cluster 3 much below the average (with the variable DAP use which shows very similar results). Again, these differences are corroborated by the ANOVA F-test, which show that they are statistically significant.

The last difference presented in Table 6.32 and Figure 6.15 regards use of the Internet. Again, cluster 3 is the group with the lowest intensity of use of any Internet service. Clusters 1 and 2 show quite similar scores in all the services.

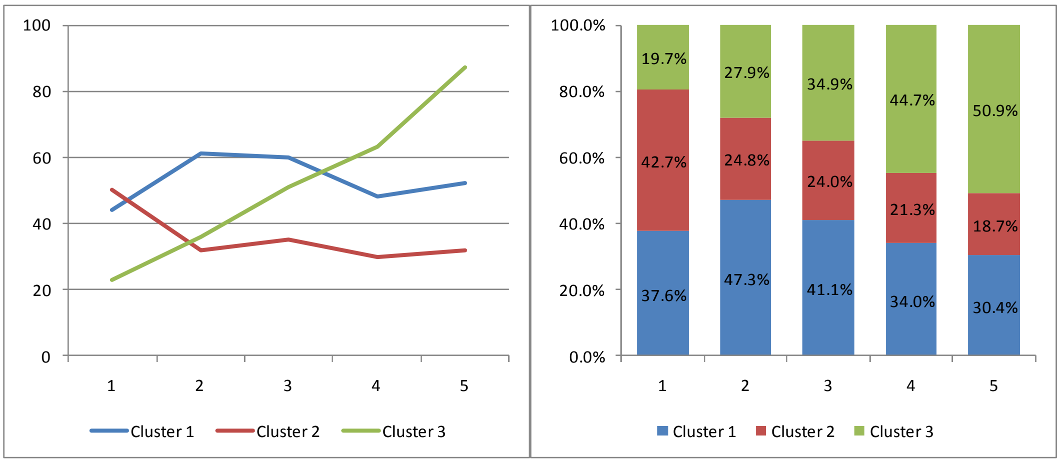
Table 6.33 Cluster differences regarding the adoption of the first DAP

		Cluster 1	*Cluster 2*	*Cluster 3*	*Chi-square*	*ANOVA F-test*
DAP adoption						
Previous player		90.6%	93.4%	93.1%	.432	
Tried		55.8%	60.1%	52.5%	.282	
Self learning		74.3%	74.3%	61.3%	**.001*****	
Number of DAPs		1.76	2.07	1.54	**.000*****	
Most adopted brands	Apple	30.2%	40.4%	34.1%	-	
	Creative	15.8%	13.1%	7.7%	-	
	Sony	13.6%	10.4%	15.3%	-	
Type of player (flash)		73.6%	61.2%	78.9%	**.000*****	
Early adopters		39.6%	45.8%	22.7%	**.000*****	
Average adopting time		8.5	7.8	9.9		**.000*****

**** $p<0.01$, ** $p<0.05$, * $p<0.1$*

Table 6.33 shows the differences between clusters regarding the adoption of a DAP. The first three variables are: having previously had a portable player, having tried a DAP before adopting, and having learnt to use the DAP by themselves. The first two variables do not show statistically significant differences among clusters, while the variable regarding self-learning has significantly higher scores for clusters 1 and 2 compared with cluster 3. In addition, the ranking of the most commonly adopted brands shows some differences. Apple's products (the market leader) have the highest penetration in cluster 2 and the lowest penetration in cluster 1. Moreover, Creative products have been first adopted by just a small percentage of members of cluster 3. The most important differences regarding the adoption of a DAP are about the number of DAPs adopted and, even more importantly, the timing of adoption. Respondents who are in cluster 2 bought more DAPs than any other cluster (showing similar behaviour regarding electronic gadgets in general), followed by cluster 1 and cluster 3. The differences regarding the timing of adoption are measured in three ways. Firstly, the percentage of early adopters is reported; in this case, an early adopter is calculated as including the first 40% of the cases in the frequency distribution. Cluster 2 has the highest percentage of early adopters (45.8%), followed by cluster 1 (39.6%). On the other side, cluster 3 shows a percentage of early adopters which is almost one-half of those of the other clusters. The second measure is the average time of adoption,[95] which confirms the same result, indicating that cluster 2 contains the earliest adopters, followed by cluster 1, and that, on average, respondents in cluster 3 adopted later than the other two clusters. Both the percentage of early adopters and the average timing of adoption show statistically significant differences.

Figure 6.16 Visual representation of cluster differences in the timing of adoption



The last measure regarding the timing of adoption is visual, and it is shown in Figure 6.16. In this case, the distribution in quintiles of adopters is shown. In particular, both graphs show the same set of data; however, the first graph shows the trend over time of the percentage of adopters from different clusters, while the second graph shows the breakdown by cluster in the number of adopters in each time quintile. By looking at the figures it is possible to conclude that the number of adopters in cluster 3 starts with a low percentage in the earlier periods, then grows, becoming the largest group in the last period (more than 50% of the adopters). Clusters 1 and 2 adopt much earlier than cluster 3. The cluster with the highest percentage of very first adopters is cluster 2, with

[95] We recall that the timing of adoption is measured by a variable ranging from one to 16 indicating the semester in which the first DAP was adopted, from 'before July 2001' to 'after July 2008'.

42.7% of the adopters in the first quintile being members of cluster 2. However, this is true only in the very first period, since the percentage of adopters in cluster 2 gradually drops over time, with cluster 1 already overtaking cluster 2 in the second period of time. Again, these differences are statistically relevant, having a Chi-square test with a .000 probability (i.e. significant at the .01 level).

The final differences between clusters taken into consideration regard three sets of factors – user innovativeness, external factors and product features – and sources of information.[96] These differences are reported in Table 6.31 and visually represented by Figure 6.17. Regarding user innovativeness, both measures (innovativeness and domain-specific innovativeness regarding electronic products) show significant differences. In particular, clusters 1 and 2 seem to be more innovative regarding the specific domain of electronic products. This confirms the previous results about digital literacy. Considering the previous results about the timing of adoption, number of DAPs and number of electronic gadgets, it is not surprising that cluster 2 shows a higher domain-specific innovativeness than cluster 1. In contrast, cluster 3 appears to be more innovative regarding new ideas and new ways of doing things (user innovativeness), and much less innovative regarding the specific domain of electronic products.

Table 6.34 Cluster differences regarding four sets of variables

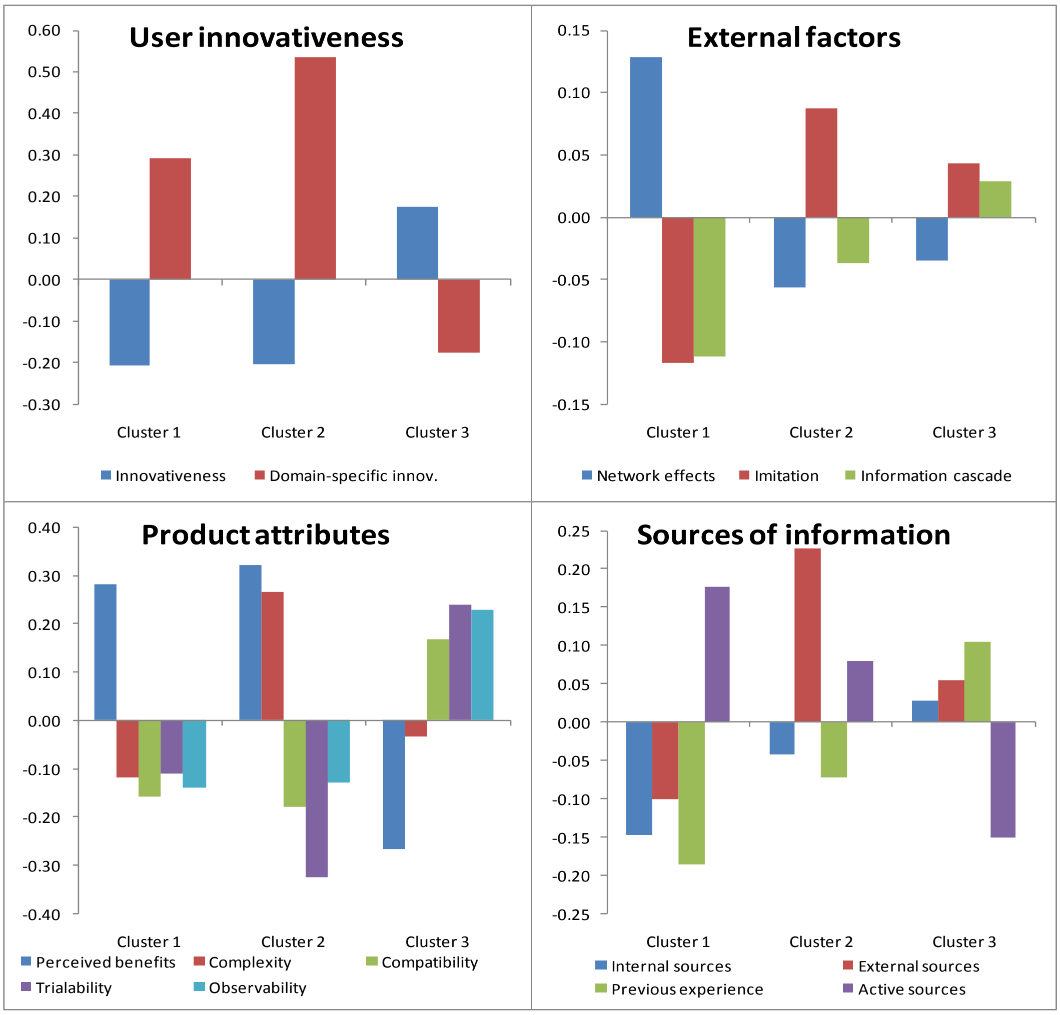
	Cluster 1	***Cluster 2***	***Cluster 3***	***ANOVA F-test***
User innovativeness				
Innovativeness	-0.21	-0.20	0.17	**.000*****
Domain-specific innov.	0.29	0.54	-0.18	**.000*****
External factors				
Network effects	0.13	-0.06	-0.03	**.068****
Imitation	-0.12	0.09	0.04	**.054****
Informational cascade	-0.11	-0.04	0.03	.277
Product attributes				
Perceived benefits	0.28	0.32	-0.27	**.000*****
Complexity	-0.12	0.26	-0.03	**.000*****
Compatibility	-0.16	-0.18	0.17	**.000*****
Trialability	-0.11	-0.32	0.24	**.000*****
Observability	-0.14	-0.13	0.23	**.000*****
Information sources				
Internal sources	-0.15	-0.04	0.03	.125
External sources	-0.10	0.23	0.05	**.003*****
Previous experience	-0.19	-0.07	0.10	**.002*****
Active sources	0.18	0.08	-0.15	**.001*****

*Note: all the variables are standardized; *** p<0.01, ** p<0.05, * p<0.1*

[96] We refer to Chapter 5 for a more detailed description of the theoretical and empirical literature behind the three sets of factors, and for the way the variables have been created and validated. We refer to Section 6.1.4 for a description of the sources of information.

The second set of factors considered regards the external factors. It is interesting to point out that the first two clusters show a greater emphasis on only one of the external factors. In particular, for cluster 1, network effects are the most relevant factor, while for cluster 2 it is imitative behaviour. In contrast, both informational cascade and imitation seem to be more important than average for cluster 3. However, not all these differences are statistically significant, since the ANOVA test on informational cascades does not show any significant differences between the three clusters. It is interesting to point out that the group that takes into consideration the behaviour of the others the most is cluster 2. Despite the fact that imitative behaviour has usually been seen as a prerogative of late adopters, cluster 2 shows the highest percentage of early adopters of the whole sample. This consideration will be particularly helpful later on, when a discussion of the three adopter profiles will be attempted.

Figure 6.17 Visual representation of cluster differences regarding 4 sets of variables



The third set of variables is about the perception of the product features by adopters. Both clusters 1 and 2 take into consideration the perceived benefits of the product. However, the analysis of this particular variable may be biased, since the validation process (see Chapter 5 for a more detailed explanation) did not reach a satisfactory conclusion over the reliability of this measure. Product complexity is considered only by cluster 2 and not by cluster 1. This might be related to the fact that users who belong to the latter cluster have the highest level of computer skills of the sample, and that the use of a DAP does not represent a particularly difficult task for them. On the other side, members of cluster 3 appear to be more concerned about other tangible and visible aspects of the product by taking into consideration the compatibility, observability and the trialability of the DAP. The differences regarding the five product attributes are also statistically significant.

The last set of variables is about the sources of information used by adopters to obtain information and evaluate a DAP. Members of cluster 1 are active seekers of information; the only sources of information they take into consideration are active sources. This kind of source is also relevant for cluster 2, but less so. In any case, cluster 2 shows that they are also affected by external sources of information (such as advertising). Cluster 3 is affected by internal and external sources; however, the most important source is their previous and personal experience. These differences regarding the sources of information (aside from internal sources) are statistically significant.

Having checked the numerous differences between the three groups of adopters, it is possible to give an interpretation of these clusters. Cluster 3 includes the late adopters. These people are in general quite open to adopting innovations (in the sense of new ideas, new ways of doing things, etc.), but not with regard to new electronic products. This is not the group with the lowest level of income, but it is the one with the lowest rate of adoption of other electronic gadgets and the lowest level of computer skills. It seems that the reasons for not adopting electronic products and DAPs (or for adopting later than the others) are more closely related to personal characteristics rather than economic reasons. Members of cluster 3 take the decision to adopt a DAP very seriously. Since they are sceptical about new technologies, they want to be able to observe and evaluate the real characteristics of the product before adopting it, as well as trying it, if possible. They rely on several sources of information, such as advertising or word-of-mouth. However, their main source of information is their previous personal experience. On average, they adopt a DAP later than others, only when the majority of potential adopters have already taken the decision to adopt.

Clusters 1 and 2 are more similar, in the sense that both clusters broadly contain many early adopters. However, they also show some interesting differences. People in cluster 1 are very skilled and frequent computer users. Their average income is the lowest of the sample, but this does not prevent them from adopting a DAP, although their consumption of electronic products is much lower than cluster 2. Regarding the timing of adoption, they adopt earlier than the others, but they are not the very earliest adopters. Their decision process regarding the adoption of a DAP seems to be quite conscious and deliberate. For this kind of people, the value of the innovation mostly resides in its characteristics. They do not rely on other people and advertising. On the contrary, they are active seekers of relevant information about the right product to adopt. They are the most innovative group of adopters; however, at the same time they also look more introverted than cluster 2.

Finally, people in cluster 2 are those with the highest average income. They have adopted many different kinds of electronic gadgets and they have also accumulated a high volume of MP3 files. They are the very first adopters of DAPs in the sample, and might be characterised as *experimental users*. At the same time, they are quite strongly affected by the behaviour of the other people. This group of adopters is less skilled than cluster 1, but they seem more extroverted and outward-looking. They are information seekers, but they mostly rely upon advertising in order to choose a DAP. Moreover, cluster 2 is the group that is most affected by imitation or herd behaviour. This is quite unusual for early adopters. It seems that for them, the value of the innovation is also determined by their capacity to display and share it. As a result, one reason for being early adopters might be to gain a sort of first-mover advantage; in other words, to gain the possibility to exhibit their new electronic gadgets to others. These clusters can be labelled with more concise and evocative names: cluster 1: *innovators*; cluster 2: *early imitators*; and cluster 3: *followers*.

In conclusion, the categorisation of the adopters has given very meaningful results. A two-step clustering procedure led to the creation of three groups of adopters. These clusters show very different profiles, both regarding socio-economic variables, computer and Internet use, and the adoption of a DAP, as well as regarding the variables related to user innovativeness, external factors, product features and sources of information. These results, on one hand, confirm the very common classification into early and late adopters. However, at the same time, they suggest a refinement of the concept of early adopters. First of all, high available income is not the only variable able to explain the timing of adoption, since one category of early adopters includes the least affluent respondents of the sample (cluster 1). Secondly, early adopters may be classified into two different categories: one more inward-looking, and the other more extroverted. This seems to contrast with some classifications of early and late adopters, in which the former are seen as more willing to follow their own beliefs, while the latter are seem to be influenced by the behaviour of other people. The results of the cluster analysis indicate that the group that is more susceptible to imitative behaviour is mostly made up of early adopters. This interesting result will be further considered in the next section and in Chapter 8.

Comparison with Rogers' classification

Before testing for factors which influenced the timing of adoption, it is useful to compare the results obtained in the cluster analysis with another classification of adopters known as the Rogers' classification. As explained before, Rogers' categorization of adopters is solely based on the timing of adoption. Adopters are classified according to the distance (measured in standard deviations) from the average time of adoption. Adopters are divided in to five groups (innovators, early adopters, early majority, late majority, and laggards), and then each group is characterized by certain specific features. Rogers' classification is explained in more detail in section 2.2.2.

In parallel with the clustering carried out in this thesis, the data collected using the questionnaire allows for a replication of Rogers' categorization. There are two purposes for this replication: the first is to test whether the five Rogers' clusters of adopters actually represent five distinct groups of adopters; the second is to compare Rogers' classification with the classification carried out in this thesis, which was obtained through cluster analysis, and to try to assess which one provides a better understanding of the patters of adoption of a DAP.

Figure 6.18 shows the differences among Rogers' categories in terms of income and computer literacy. The upper part of the figure indicates that there is clear a relationship between time of adoption and income, with early adopters having higher incomes than late adopters. However, the difference between two of the groups (early majority and late majority) seems to be small. The second part of the figure shows indicators of computer literacy and use of the DAP (all the variables are standardized).

In general, innovators and early adopters score higher in each indicator than the other groups. However, it is also the case that little can be said about consistent differences between the different groups of adopters. For instance innovators own a much higher number of electronic gadgets, but they are less skilled than early adopters.

Figure 6.18 Differences among Rogers' groups of adopters regarding average income and computer literacy

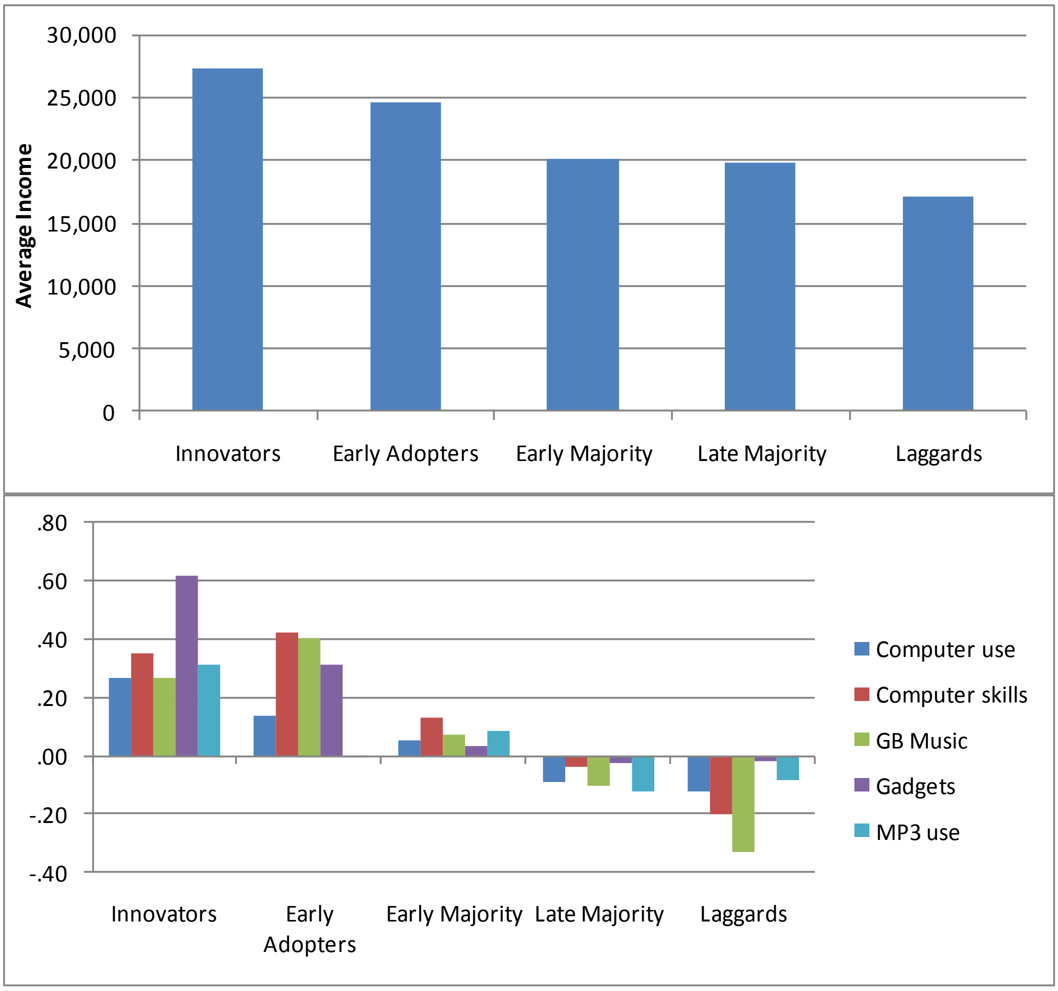
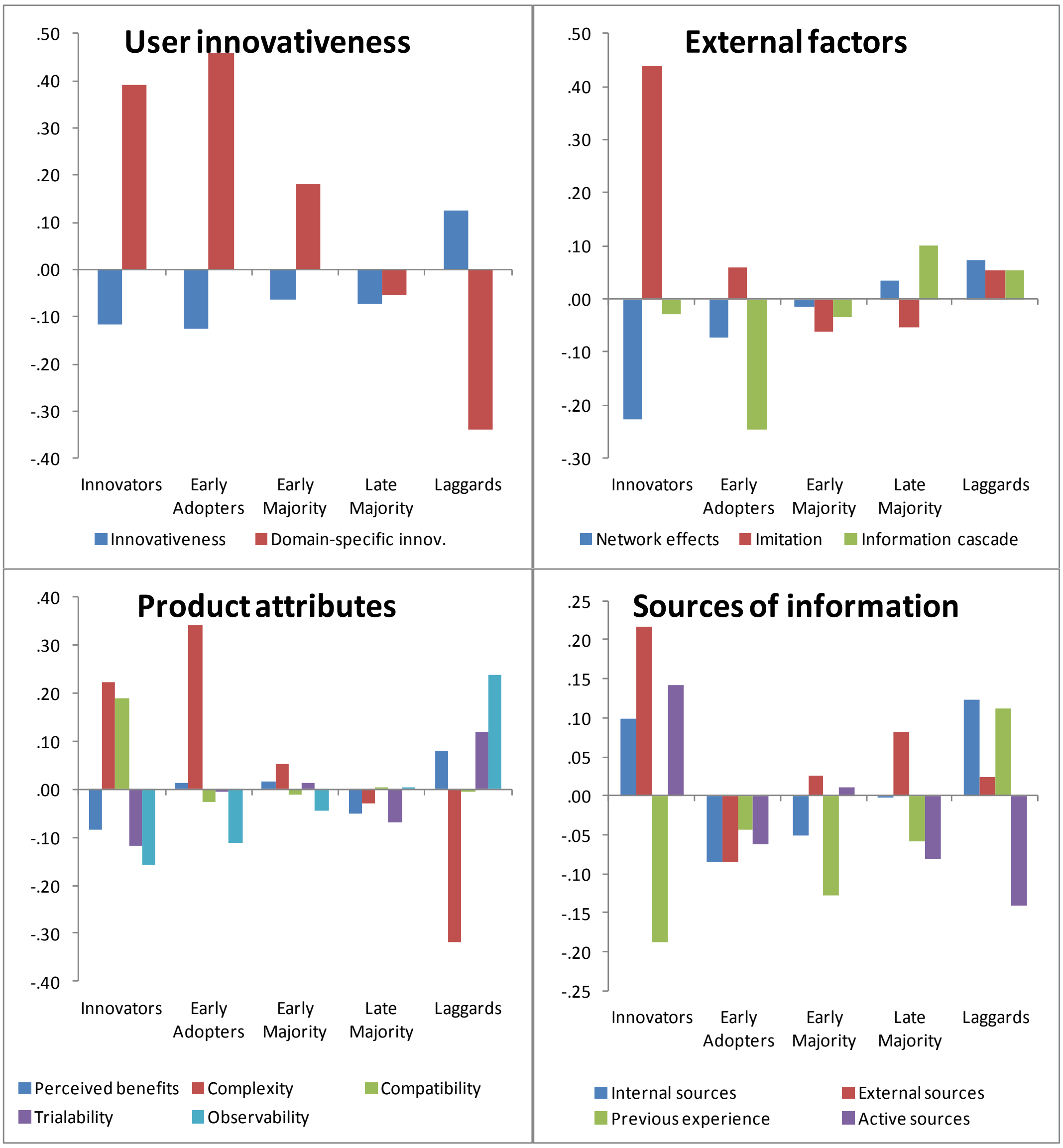


Figure 6.19 shows the differences among Rogers' groups of adopters regarding the four above-mentioned sets of variables identified as potentially affecting the adoption of a DAP. First of all, regarding user innovativeness, the picture does not provide any clear understanding of the differences among clusters. Regarding external factors, the figure shows a classification clearly in contrast with Rogers' tradition. The most evident issue is the fact that late adopters (late majority and laggards) that are supposed to be followers and to imitate the early adopters have a much lower score in the variable about imitation than the first group, who, in turn, according to Rogers' tradition, should not be affected by this kind of factor. Finally, regarding both product attributes

and sources of information, the classifications appear confused, without any clear pattern, suggesting that the five groups of adopters are not really differentiated among each other.

Figure 6.19 Visual representation of the differences among Rogers' groups of adopters regarding 4 sets of variables



In the light of these considerations it is possible to conclude that, according to the data collected in this thesis, the five groups of adopters classified by timing of adoption do not represent five distinct groups of DAPs' adopters with consistent characteristics. Moreover, in terms of comparing Rogers' classification with the classification obtained through cluster analysis, it is possible to say that some of the results of Rogers' grouping can only be understood only in light of the cluster analysis. For example in Rogers' framework, innovators should be more experimental and more skilled than the average user, more able to take independent decisions. However, they score lower in computer skills than early adopters, and they are the group affected the most by imitative behaviour. The cluster analysis carried out in this chapter offers an interpretation to this inconsistency. In particular, the so-called early imitators group obtained using the cluster analysis seem to fit this description well. Moreover, the last three groups of Rogers' classification (early and late majority, and laggards) are not well differentiated, and they could be easily grouped together. Finally, in Rogers' classification there is no indication of the existence of a group of early adopters with a lower level of income, the cluster that is referred to in this thesis as innovators.

In conclusion, the results of the comparison between Rogers' classification (based on the timing of adoption) and the classification obtained through the cluster analysis (not based on timing of adoption) seem to reinforce the conclusions expressed in the previous section, which is that the classification of DAPs' adopters obtained in this thesis both confirms and expands some of the most commonly used classifications of adopters put forward in the literature.

6.3. Factors influencing the timing of adoption

This section will use several variables presented in the previous sections as well as the results of the cluster analysis in order to answer two questions: (1) what are the factors that influenced an earlier adoption of a DAP? And (2) what factors are associated with the adoption of more than one DAP? Regarding the factors affecting the timing of adoption, an ordered logistic regression will be carried out using as a dependent variable the quartiles of adopters. The analysis will be of an explorative nature; the explanatory variables taken into consideration are:

- *Income* (LN_INCOME): natural logarithm of income.
- *Computer use* (COMP_USE): 1 to 6 variable from 'never' to 'more than 5 hours'.
- *Computer skills* (SKILLS): 1 to 5 variable from 'much below the average' to 'much above the average'.
- *GB of music* stored in the computer (GB_MUSIC): 1 to 5 variable from 'less than 1GB' to 'more than 30GB'.
- *User innovativeness:* (INNOV: innovativeness); (IN_DOM_INNOV: domain-specific innovativeness).
- *External factors*: (NETWORK: network effects); (INCO_CASC: informational cascade); (IMITATION: imitation behaviour).
- *Information sources*: (INFO_INT: internal sources); (INFO_EXT: external sources); (INFO_EXP: previous experience); (INFO_ACT: active sources).

Table 6.35 presents the correlation matrix.

Table 6.35 Correlation matrix

	LN_INCOME	*COMP_USE*	*COMP_SKILLS*	*GB_MUSIC*	*GADGETS*	*INNOV*	*IN_DOM_INNOV*	*NETWORK*	*INFO_CASC*	*IMITATION*	*INFO_INT*	*INFO_EXT*	*INFO_EXP*	*INFO_ACT*
LN_INCOME	1	.096***	.085***	.048	.189***	.032	.115***	-.128***	.018	.200***	.012	.027	.018	-.007
COMP_USE		1	.307***	.143***	.053**	-.068***	.148***	.006	-.047	-.007	-.073***	-.063**	-.073***	.099***
COMP_SKILLS			1	.238***	.147***	-.227***	.321***	.058	-.115***	-.061**	-.082***	-.100***	-.140***	.105***
GB_MUSIC				1	.118***	-.116***	.249***	.022	-.058	.008	-.042	-.011	-.101***	.091***
GADGETS					1	-.101***	.273***	-.086***	.026	.049	.001	.135***	-.082***	.067**
INNOV						1	-.335***	-.332***	.227***	.378***	.240***	.204***	.061**	.072***
IN_DOM_INNOV							1	.021	-.159***	-.051	-.164***	-.023	-.107***	.114***
NETWORK								1	-.280***	-.393***	-.334***	-.332***	.076**	-.188***
INFO_CASC									1	.139***	.406***	.211***	-.228***	.129***
IMITATION										1	.319***	.302***	.026	.129***
INFO_INT											1	.257***	-.241***	.212***
INFO_EXT												1	-.149***	.260***
INFO_EXP													1	-.234***
INFO_ACT														1

*Note: *** p<0.01, ** p<0.05, *<0.1*

The dependent variable is a variable that ranges from one to four, representing the quartiles of adopters based on their timing of adoption. Since one represents an early adoption and four a late adoption, the coefficients with a negative sign will represent factors influencing early adoption, and *vice versa*. Table 6.36 shows the results of the ordered logistic regression. First of all, the test of parallel lines indicates that the coefficients can be assumed to be the same across all levels. The first column regards all adopters. The factors that positively influence an early adoption are income, computer skills, GB of music and domain-specific innovativeness. In general, richer and more skilled users are those who adopted earlier than others. Moreover, the speculation regarding the download and accumulation of music seems to be confirmed by the regression. However, these factors do not have the same importance for all the clusters of adopters. In order to consider the differences between clusters, three other regressions have been performed, one for each group of adopters. However, performing different regressions on each subsample reduced the sample size, and this affected the test of parallel lines. For this reason, the four levels taken by the dependent variables have been collapsed to form three levels. Specifically, the adjacent quartiles 2 and 3 have been combined. This procedure allowed for passing the test of parallel lines not affecting the inferences drawn from the regression[97] (Tarling, 2009: p.103).

Table 6.36 Results of ordered logistic regression on timing of adoption

	All adopters		***Cluster 1+***		***Cluster 2+***		***Cluster 3+***	
LN_INCOME	**-0.201****	[0.0788]	**-0.341****	[0.0788]	-0.327	[0.0788]	-0.193	[0.0788]
COMP_USE	0.0245	[0.0799]	0.0927	[0.0799]	0.226	[0.0799]	-0.0168	[0.0799]
COMP_SKILLS	**-0.200***	[0.104]	-0.0219	[0.104]	-0.371	[0.104]	-0.132	[0.104]
GB_MUSIC	**-0.258*****	[0.0596]	-0.135	[0.0596]	**-0.301***	[0.0596]	**-0.348****	[0.0596]
GADGETS	-0.0399	[0.0521]	-0.0112	[0.0521]	0.0146	[0.0521]	-0.130	[0.0521]
INNOV	0.0185	[0.0822]	0.0634	[0.0822]	0.140	[0.0822]	0.0769	[0.0822]
DOM_SP_INN	**-0.377*****	[0.0846]	**-0.442*****	[0.0846]	**-0.616*****	[0.0846]	**-0.268***	[0.0846]
NETWORK	0.000648	[0.0820]	0.0653	[0.0820]	-0.207	[0.0820]	0.197	[0.0820]
INFO_CASC	0.0371	[0.0781]	0.0910	[0.0781]	0.0852	[0.0781]	-0.156	[0.0781]
IMITATION	-0.0752	[0.0833]	-0.0627	[0.0833]	**-0.449****	[0.0833]	0.128	[0.0833]
INFO_INT	0.0245	[0.0837]	-0.131	[0.0837]	-0.139	[0.0837]	**0.351****	[0.0837]
INFO_EXT	-0.0358	[0.0784]	0.0690	[0.0784]	0.00312	[0.0784]	**-0.263***	[0.0784]
INFO_EXP	0.0188	[0.0781]	-0.130	[0.0781]	0.00793	[0.0781]	**0.250***	[0.0781]
INFO_ACT	-0.0879	[0.0763]	-0.0377	[0.0763]	-0.118	[0.0763]	-0.0777	[0.0763]
cut1	-4.779***	[0.851]	-4.569***	[0.851]	-5.885***	[0.851]	-5.197***	[0.851]
cut2	-3.693***	[0.843]	-1.955	[0.843]	-3.285	[0.843]	-2.476	[0.843]
cut3	-2.272***	[0.837]						
Observations	710		265		179		260	
log likelihood	-932.7		-254.3		-163.4		-239.5	
Chi-square	95.05		23.52		41.46		31.99	
Prob Chi2	0		0.0523		0.000151		0.00402	
Test of parallel lines	.354		.482		.481		.127	

Note: +for clusters, the quartiles have been collapsed to form 3 adjacent levels.
*Standard errors in brackets; *** p<0.01, ** p<0.05, * p<0.1*

The only variable that is significant for all the clusters is domain-specific innovativeness. The timing of adoption in cluster 1 is also affected by income, which is probably related to the fact that they represent the lowest income group, while the timing of adoption for cluster 2 is significantly affected by GB of music and imitation. The variable 'imitation' needs some further attention. First of all, it is significant, indicating that members of cluster 2 seriously take into consideration the behaviour of others, and confirming that the label of *early imitators* seems appropriate. Moreover, the coefficient is negative (indicating a positive influence on early adoption). Making reference to Chapter 5, the variable IMITATION indicates the influence of other

[97] An alternative procedure could have been to include two dummies in the main regression and using the other cluster as a reference group. However, the previous section demonstrated that the clusters are significantly different regarding almost all the variables used in the regression. Therefore, including the dummy variables would have resulted only in an increase of multicollinearity.

people's behaviour in adopting a new technology. This means that since the users of cluster 2 have a preference for being first adopters, the imitative behaviour in this type of users can be considered as a sort of pressure to adopt before the others.

On the other hand, cluster 3, representing the group of late adopters, aside from GB of music, seems to be affected only by information sources (with the exception of active sources). Moreover, it is interesting to point out that only external sources have a positive impact on the timing of adoption (negative coefficient), while both internal sources (word-of-mouth) and previous experience have a negative impact on the timing of adoption (positive coefficient). This seems to confirm the idea that these users are quite reserved or even suspicious regarding the adoption of new electronic gadgets, or perhaps the existence of a sort of snob effect, which makes them avoid the adoption of a product that has already been purchased by a large number of people.

The second explorative analysis performed regards multi-adoption, which emerged as a very relevant phenomenon and which deserves some further attention. For this reason, another ordered logistic regression has been carried out. In this case, the dependent variable is the number of DAPs adopted. In particular, this variable takes values from one to four (1: one player; 2: two players; 3 three players; 4: more than three players). In this case, a positive coefficient indicates a positive effect on the number of MP3 players adopted. The independent variables will be the same as the previous regression, excluding sources of information. In addition, in this case four regressions are carried out, one for the entire sample and one for each cluster. In all the cases, the test of parallel lines indicates that the coefficients are comparable across all levels. Table 6.37 reports the results of the regressions. For what concerns the entire dataset, several variables positively affect the number of DAPs. These variables are: computer skills, GB of music, ownership of several other electronic gadgets and domain-specific innovativeness. The heavy use of computers (COMP_USE) negatively affects the number of DAPs adopted. These factors only partially overlap with the factors influencing the timing of first adoption.

Regarding the differences between clusters, three different regressions have been performed, one for each cluster. First of all, it is interesting to point out that available income does not have an impact on the number of DAPs owned by respondents. On the contrary, the only variable that is significant for all the clusters is GB of music, indicating that the accumulation of MP3 files, regardless of the source (legal or illegal), is definitely a relevant factor in explaining both adoption and sales of MP3 players. In addition, the coefficients of domain-specific innovativeness are positive, but they are significant only for clusters 1 and 3. The last difference regards the variable INFO_CASC, which seems to influence only members of cluster 3.

Table 6.37 Results of ordered logistic regression on number of DAPs

	All adopters		*Cluster 1*		*Cluster 2*		*Cluster 3*	
LN_INCOME	0.0972	[0.0840]	0.0218	[0.149]	0.0377	[0.194]	0.159	[0.141]
COMP_USE	**-0.181****	[0.0848]	-0.108	[0.147]	-0.0813	[0.172]	-0.269*	[0.161]
COMP_SKILLS	**0.234****	[0.115]	0.248	[0.200]	0.348	[0.242]	0.192	[0.254]
GB_MUSIC	**0.380*****	[0.0636]	**0.280****	[0.137]	**0.445*****	[0.149]	**0.544*****	[0.159]
GADGETS	**0.154*****	[0.0554]	0.0252	[0.147]	0.0815	[0.129]	0.154	[0.139]
INNOV	-0.0703	[0.0877]	-0.0198	[0.148]	-0.225	[0.182]	-0.0430	[0.148]
DOM_SP_INN	**0.301*****	[0.0882]	**0.410*****	[0.136]	0.116	[0.188]	**0.283***	[0.156]
NETWORK	-0.0447	[0.0845]	-0.0974	[0.149]	0.232	[0.161]	-0.234	[0.146]
INFO_CASC	0.121	[0.0780]	-0.0165	[0.127]	0.0788	[0.153]	**0.339****	[0.144]
IMITATION	-0.117	[0.0819]	-0.199	[0.134]	-0.173	[0.158]	0.0724	[0.155]
cut1	2.124**	[0.885]	1.429	[1.703]	2.186	[1.939]	2.541	[1.625]
cut2	4.701***	[0.901]	3.852**	[1.720]	4.925**	[1.972]	5.339***	[1.661]
cut3	5.995***	[0.917]	5.320***	[1.746]	5.939***	[1.986]	7.086***	[1.743]
Observations	709		265		183		261	
log likelihood	-702.9		-270.5		-197.1		-218.7	
Chi-square	104.5		20.66		19.28		32.91	
Prob Chi2	0		0.0236		0.0368		0.000282	
Test of parallel lines	.062		.925		.375		.998	

*Note: standard errors in brackets; *** p<0.01, ** p<0.05, * p<0.1*

The analyses carried out in this section have had an exploratory nature, and the results indicate that several factors seem to influence the timing of adoption of a DAP or the ownership of more than one player. In particular, some of these factors are adopters' characteristics, such as income, computer skills and user innovativeness. In other cases, the effect derives from a particular behaviour of the adopters, e.g. the download and accumulation of music. Although many effects influencing the timing of first adoption and multi-adoption are quite similar, these two phenomena are not completely explained by the same set of factors. In addition, some external factors can also play an important role, such as imitation. However, imitation, usually considered typical of late adopters, seems to be relevant only for the cluster of early imitators. Finally, in none of the cases have these factors been associated with a specific model of adoption; this type of analysis will be carried out in Chapter 8.

6.4. Conclusions

This empirical chapter has considered the diffusion of DAPs purely from the demand-side. It has used the results of the questionnaire as the main source of data and has carried out three types of analysis. The first one was an extensive descriptive analysis, which provided several interesting insights. First of all, the population of students represented a good sampling frame in order to study the adoption of DAPs, since a very high percentage of the respondents have at least one MP3 player. Moreover, one of the most critical tasks of the questionnaire has been accomplished. This task was to retrieve information on the timing of adoption of the first DAP. This variable provided a time element to a cross-section questionnaire and will also be used to trace time effects on the supply-side. Moreover, this information will be used as a dependent variable in several types of analysis. Another interesting result regards the sources of information. A factor analysis on several potential sources of information has indicated the existence of four distinct groups of sources. Two of these sources reflect the classifications offered by the literature on the diffusion of innovation (word-of-mouth and advertising), while a third one is still quite plausible (previous experience). However, the most interesting source of information is represented by active sources of information, which can be considered an advance on the existing literature. In addition, among the several variables collected through the questionnaire, some of them, for example those regarding file sharing on the Internet, emerged as quite relevant, as it seems that the respondents had accumulated a large volume of music files on their computers over recent years. This is a factor that influenced not only the first adoption of a DAP, but also the multi-adoption of other MP3 players. Finally, multi-adoption emerged as a very relevant issue, as the majority of adopters who purchased more than one DAP had done so in a quite short time span. Moreover, the factors influencing first and following adoptions only partially overlap.

The second part of this chapter has concentrated on the differences between adopters, and has involved the use of cluster analysis on the sample of respondents. The clustering process has led to the creation of three clusters, with quite clear and distinctive profiles. The first one is composed of innovative people, early adopters, with high computer skills, but also quite inward-looking and with low incomes. The second cluster is composed of technology enthusiasts who take the behaviour of others into consideration; for this reason they adopt more often and more quickly most of the electronic gadgets with which come into contact. In contrast, the third cluster is made up of late adopters, people who are reserved about or look suspiciously on the adoption of hi-tech electronic products and who wait to be fully convinced before adopting an innovative product. This classification is still comparable with the usual classification into early and late adopters. However, since it splits the group of early adopters in two clusters with very distinct profiles, it can also be seen as an advance on the literature.

The last section has provided an exploratory analysis on the factors influencing the timing of adoption and the ownership of more than one DAP. The main results are that several factors are able to influence these issues, but not necessarily the same ones for both phenomena. Moreover, the explanatory variables impact in different ways depending on the cluster of adopters. It is important to point out that this analysis did not try to associate any factor influencing the timing of adoption to any specific diffusion model, since this task will be carried out in Chapter 8. However, it has provided some interesting insights into which are the factors that could explain why some users decided to adopt earlier than others.

The main conclusions of this chapter are four. First of all, the questionnaire has been quite a successful instrument in order to retrieve data about the adoption of DAPs. Secondly, the adopters are not homogenous, and their differences can be associated to form three groups of adopters. We believe that the clustering process has led to a reasonably sound classification of adopters, which both confirms some adopter classifications put forward by the literature (such as Rogers' classification) and also goes beyond them. Thirdly, multi-adoption is a relevant phenomenon, which can only be partially explained using the same factors explaining first adoption. This result seems to question some of those studies of diffusion that do not consider only the first adoption, but rather the entire sales of the product, since first and following adoptions are not completely overlapping phenomena. Fourthly, the download of digital music from the Internet has been a very relevant phenomenon, which appears to be closely entangled with the diffusion of DAPs.

CHAPTER 7. TECHNICAL CHANGE IN THE DAP SECTOR AND INTERACTIONS WITH DEMAND

The second empirical chapter is focussed on the supply-side and on the interactions between demand and supply. For this reason, the analysis will be based on both the results of the questionnaire and on the products' datasets. The objectives of this chapter are three. The first is to present the dataset on the launch of new DAPs and to analyse how technical innovation in the sector occurred in the period 2001-2009 (Section 7.1). The second objective is to measure technological change in the sector by using hedonic price estimation (Section 7.2). This section will also create a price index that takes into consideration the technical change occurring in the sector. The last objective is to study whether there is a relationship between the patterns of adoption of a DAP over time and the evolution of the technical characteristics within the sector (Section 7.3).

7.1. Innovation in the DAP sector

The DAP sector has been subject to very rapid technical change over the last decade. In order to capture the technical evolution of the sector, an original set of data on DAPs launched between 2001 and 2009 has been collected.[98] The data collection resulted in a dataset of 585 products, including the following variables:

- Brand and product name;
- Launch date;
- Launch price;
- Memory type (hard disk, flash, minidrive);
- Storage Space (in GB);
- Display (no screen, monochromatic screen, colour screen);
- Screen size (number of pixels, e.g. 128x64);
- Size (width, depth, high in inches);
- Weight (in ounces);
- Estimated battery life (in hours);
- Rechargeable battery (yes/no);
- Radio FM (yes/no);
- Voice recorder (yes/no);
- Video recorder (yes/no);
- Radio FM recorder (yes/no);
- Photo display (yes/no);

[98] We refer to Chapter 3 for the history of the sector and to Chapter 5 for the data collection procedure.

- Video playback (yes/no);
- Built-in speakers (yes/no);
- Touch screen (yes/no).

The dataset contains only verifiable variables. For this reason, although the sources of data also provided some users' opinions on product aesthetics or usability, this type of information has not been taken into consideration. The only variable with some missing cases is launch price (14.8% of cases missing). All the other variables are complete.

DAP players can be divided into three product families, depending on the type of memory used to store music files: flash, hard disk (HD) and Microdrive players. In some cases, these types of players will be analysed separately, in order to test whether these groups of products evolved in a different way. Most of the DAPs in the dataset are flash players (436); HD players are 122, while Microdrive players are only 27. The number of Microdrive players is too small to be analysed separately. A Microdrive is a miniaturised hard drive used in some DAP models in order to achieve a storage space comparable to that of HD players but with the size of a flash player. They were used only for a short period of time, as they were discontinued when flash memories overtook Microdrives' storage capacity, making their use pointless. For these reasons, Microdrive players will be grouped together with flash players.

Figure 7.1 Frequency and cumulative distribution of DAPs launched in each year

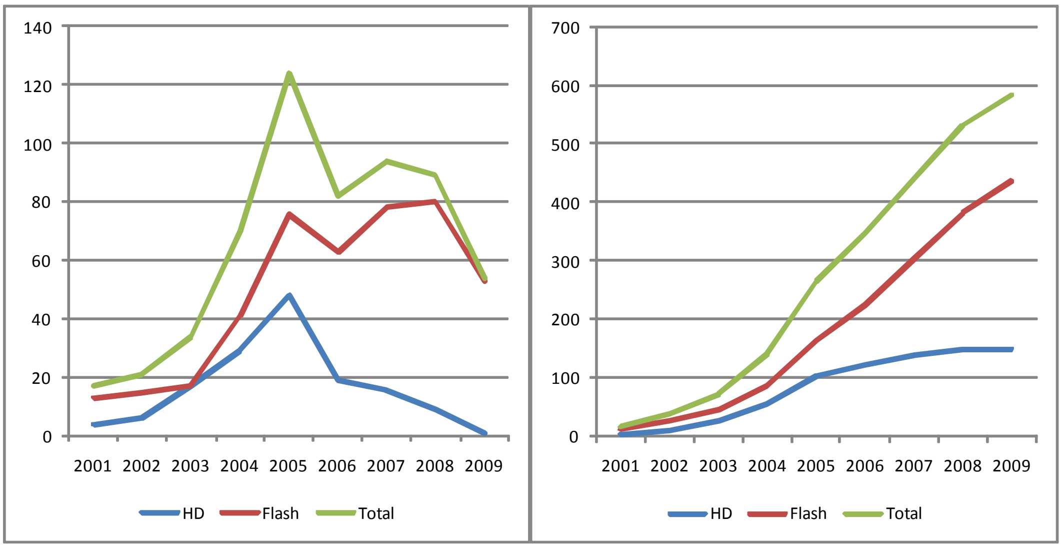


Figure 7.1 shows the number of players launched in each year, and also the cumulative number of players. The first impression is that the number of new players by year has a

similar trend to the adoption of players over time. The number of players launched rises over time, reaching a peak in the period 2004-2005, and then declines. This makes the cumulative trend follow a sort of s-shaped curve, similar to a diffusion curve. The graphs also show that flash players have always outnumbered HD players, and also that the decline in the launch of HD players in the most recent periods is much sharper than in the case of flash players.

DAPs improved in several ways during this period. In general, they became smaller, with larger storage memories and equipped with new functions. Since the main objective of this section is to study the technical innovation in the sector, the first step will be to present the definition of innovation that will be used in the analysis. Product innovation can occur in two ways. First of all, DAP producers can improve any of the product's technical characteristics (e.g. storage space, size, etc.). This kind of innovation will be defined (for the purposes of this thesis) as *vertical innovation*. On the other hand, innovation can also occur by offering new products with new additional features (e.g. picture display, video playback, touch screen, etc.). This kind of innovation will be defined as *horizontal innovation*. The variables in the dataset have been divided into vertical and horizontal innovation as follows:

- Vertical innovation:
  - Storage space in GB (STORAGE)
  - Screen size in number of pixels (PIXELS)
  - Size in cubic inches (VOLUME)
  - Weight in ounces (WEIGHT)
  - Battery life in hours (BATT_LIFE)
- Horizontal innovation:
  - Colour screen (SCR_COL)
  - Picture display (PICS)
  - Video playback (VIDEO)
  - Rechargeable battery (BATT_REC)
  - Radio FM (FM)
  - Voice recording (REC_VOICE)
  - Radio FM recording (REC_FM)
  - Video recording (REC_VIDEO)
  - Built-in speakers (SPEAKERS)
  - Touch screen (TOUCH_SCR)

The evolution of the products following this list of measures will be used to map technical change in the sector. Moreover, another dimension that will be taken into consideration is the degree of similarity among products. This will be explored by measuring the average differences between products in each period, and will allow analysis of whether the sector is converging towards a common dominant design or is continuing to differentiate over time. The similarity or differentiation among products will be measured by coefficients of variation calculated for each characteristic in each period of time. In particular, the coefficient of variation is calculated by dividing the standard deviation of a certain characteristic by its mean in each year. Therefore, a coefficient approaching zero will indicate that the products are converging towards a dominant design, at least regarding that particular characteristic.

Figure 7.2 DAPs' average and maximum storage space by year

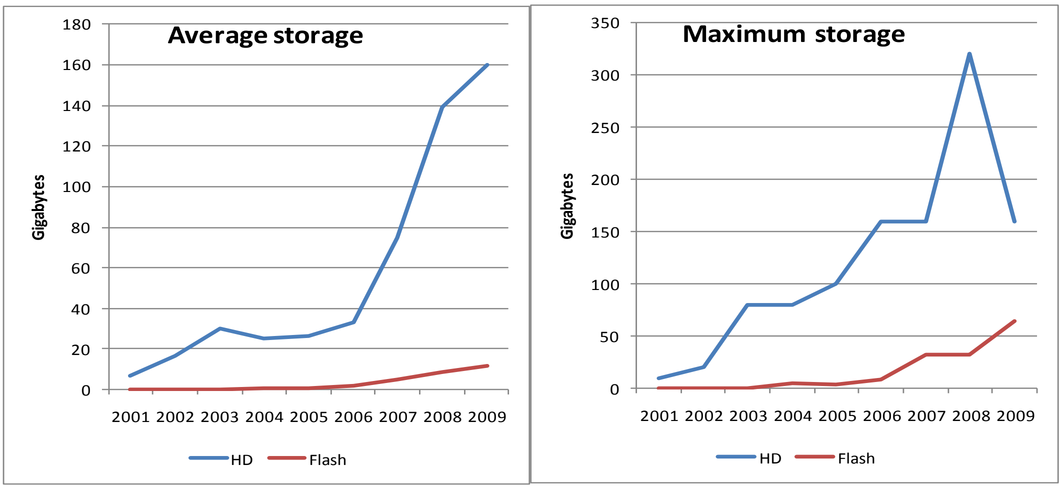


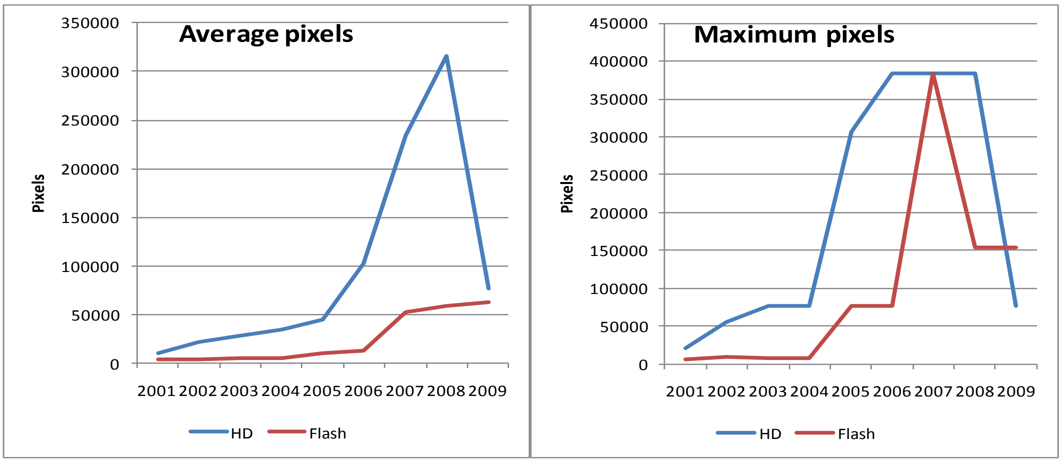
Figure 7.2 shows technical change in the DAP sector regarding one of DAPs' most important characteristics, storage space. The values observed in the graph on the left represent the mean of storage space (in GB) offered by the models launched in that year, while the observations on the graph on the right display the maximum storage space offered by at least one of the models launched in that year.[99] Figure 7.2 indicates that storage space increased significantly over time both for HD players and flash players. HD players started from a 5GB hard drive, reaching a maximum of 320GB in 2008. Flash players have a much smaller storage space than HD players; however, they showed a much greater increase, passing from 32MB to a maximum of 64GB.

Figure 7.3 regards the evolution of the number of pixels. This variable measures the screen resolution; however, it can be used as a proxy for screen size.[100] The average number of pixels has also increased over time. The period of highest growth in screen size is 2005-2006. This is also the period in which an increasing number of players started to be equipped with colour screens, offering the possibility of showing pictures

[99] Figure 7.3, Figure 7.4 and Figure 7.5 will display the same kind of information for the other vertical innovation characteristics (pixels, volume, weight and battery life).
[100] The pixels of the screen measure the resolution, and not necessarily the size of the screen. However, considering the small size of the DAP screen (not more than 4"), the screen resolution can also be used as a measure of the screen size.

and videos. These new functions also required a bigger screen in order to provide a better user experience. The drop during the last period may be due to the declining number of players introduced annually combined with the fact that the data collection was carried out in the period October-November 2009, and hence the products launched after that period have not been considered, resulting in a right truncation of the last year.

Figure 7.3 DAPs' average and maximum number of pixels by year



On average, hard disk players have much bigger screens than flash players. However, in 2007 flash players reached their maximum number of pixels, which is equivalent to the maximum that HD players reached one year before. In any case, the screen size cannot grow without limit, given the size of the device. Some touch screen DAPs have a display that already covers the entire surface of the device. In addition, another limit to the growth of screen resolution is that a further increase in pixel density in a handheld device might not even be discernable by human eyes. Even if a full high definition screen (1920x1080 pixels) were technically possible, the definition would be so high that it would require a magnifying lens to see the detail displayed.

The next product feature taken into consideration by Figure 7.4 is the size of the player. In particular, two measures are considered: the volume in cubic inches and the weight in ounces. As expected, flash players are considerably smaller and lighter than HD players. Moreover, the average and minimum sizes of players declined considerably over time. However, this trend is not monotonic for HD players, since this type of player experienced an increase in both the average size and weight in the period 2006-2007. This seems to be linked with the emergence of colour screens, since in that period a number of HD players with new functions, bigger batteries and screens were launched, and this came at the expense of the size of the devices, which were larger than their predecessors.

Figure 7.4 DAPs' average and minimum size (volume and weight) by year

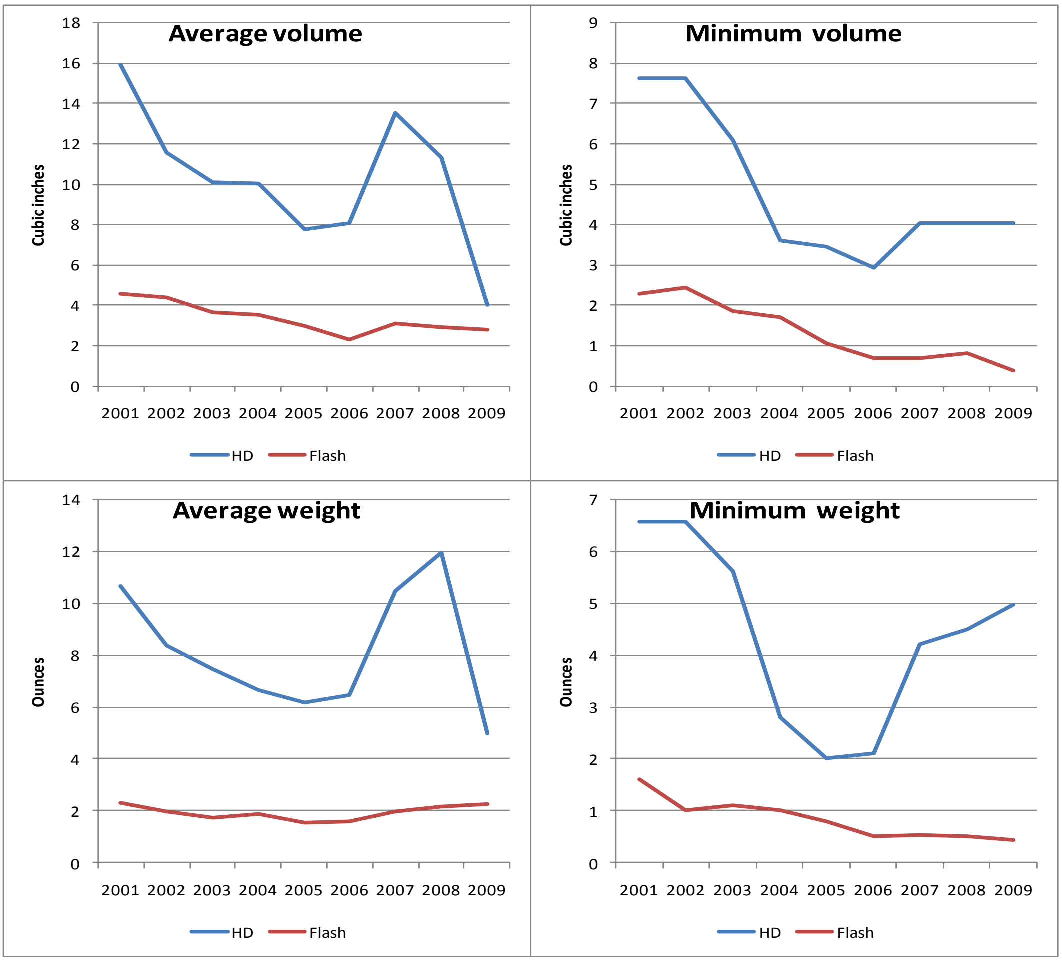
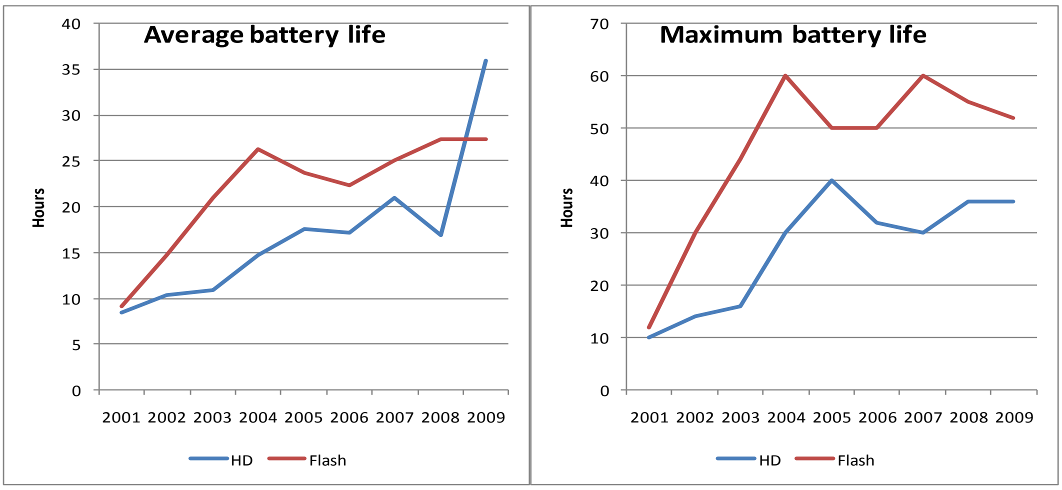


Figure 7.5 DAPs' average and maximum battery life by year



The last vertical innovation characteristic considered is shown in Figure 7.5 and regards battery life. HD players, with their bigger size, allow the installation of much greater capacity batteries than those employed in flash devices. However, these more powerful batteries add to the costs and hence to the price of the product. On the other hand, flash memories are smaller devices, less demanding in terms of power consumption. Therefore, the average battery life of flash players is longer than that of HD players in every period except for the last. In particular, the average battery life of players started at around ten hours of audio playing, reaching a maximum of 60 hours for HD players and 40 for flash players.

The next figures regard horizontal innovation. This type of innovation is carried out by equipping the product with new functions. These functions have been divided into three groups: graphic features (colour screen, picture display and video playback), audio and multimedia features (radio FM, voice recording, radio FM recording and video recording) and extra features (rechargeable battery, built-in speakers and touch screen). Figure 7.6 regards the graphic features. Since the variables considered by this kind of graph are all dichotomous, the vertical axis represents the percentage of players in a specific period of time that were equipped with that particular function. First of all, colour displays were launched for the first time in 2003 for HD players and in 2004 for flash players. This kind of feature has been adopted by an increasing number of players, and it has been followed by the implementation of both picture and video display. Video playback was also possible before colour screens; however, only a limited number of monochromatic players were equipped with this kind of feature.

Figure 7.6 DAPs' graphic features by year

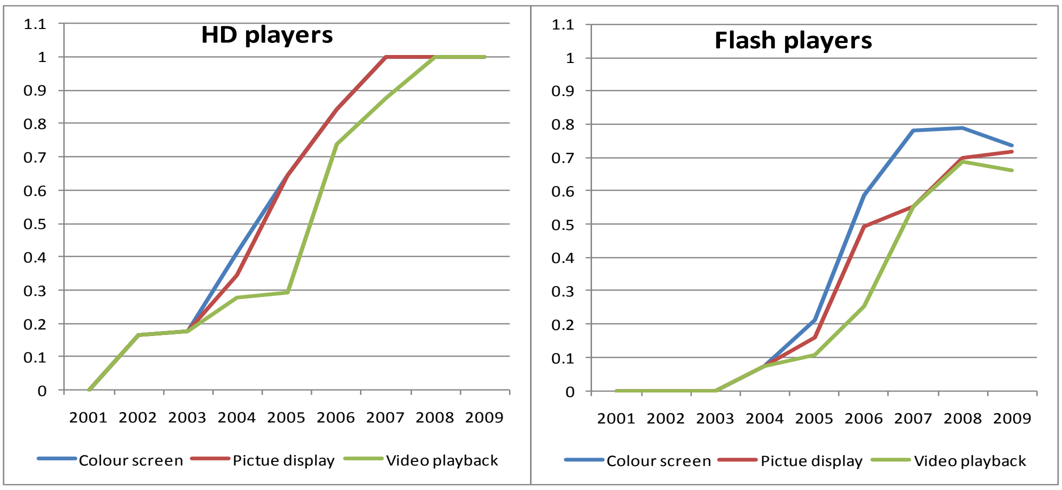
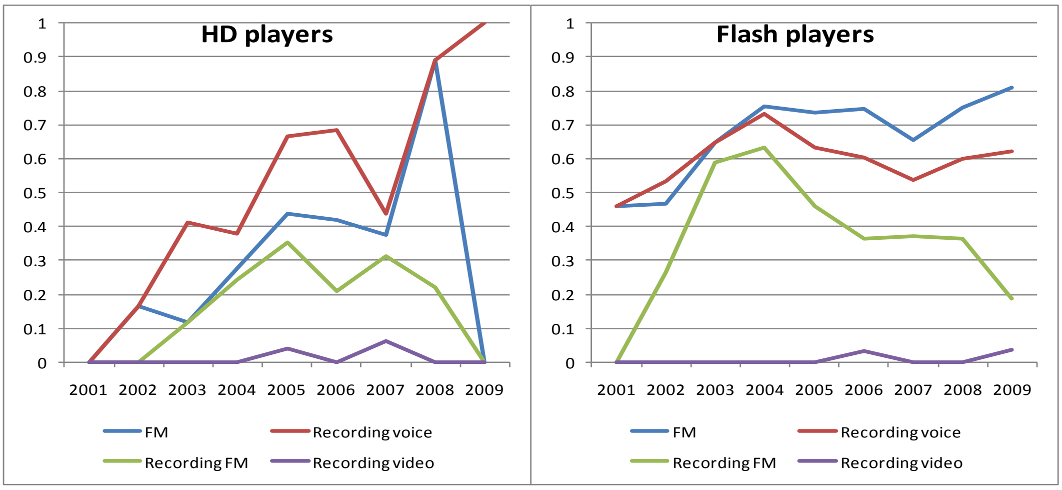


Figure 7.7 shows the trend for audio and multimedia features. First of all, radio FM and voice recording are the most common features. Moreover, both radio FM and voice recorders have been installed more frequently in flash players than in HD players. This

issue needs some further consideration. Even in the first periods, almost 50% of the flash players were already also radio players and voice recorders. Since in the same period most of these players also had a very limited storage space (e.g. 32MB), it is possible to say that a certain group of flash players, at least in the first years, were *mainly* radio players and voice recorders.

The players belonging to this particular market niche were still digital audio players; however, their main task was to record voices. The existence of this kind of DAP does not have any influence on the demand-side, since the questionnaire specifically asked about players, not recorders. However, it may have some impact on the hedonic price regression performed in the next section. FM recording is a feature much more commonly used by flash players, which however became less common after 2004.[101] Finally, video recording is still a feature used by only a limited number of products.

Figure 7.7 DAPs' audio and multimedia features by year

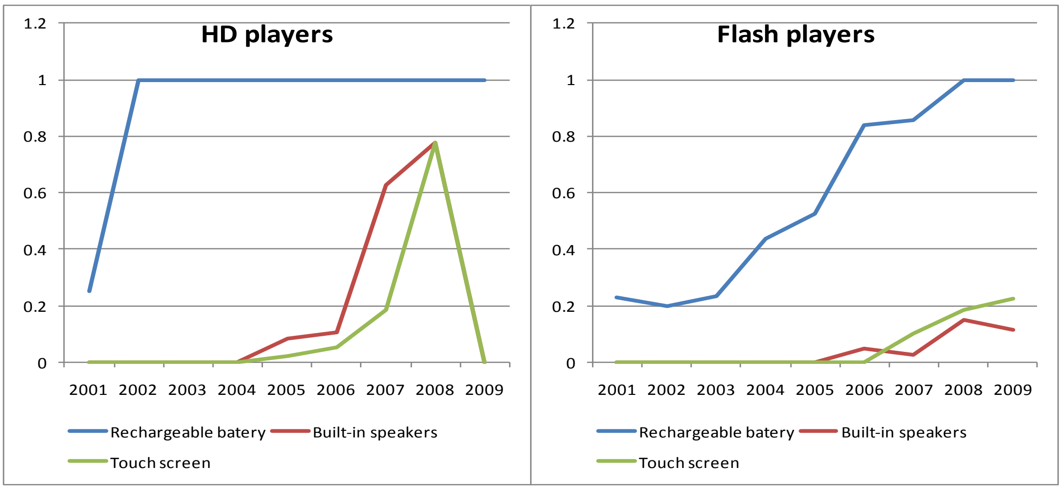


The last group of features are reported in Figure 7.8. One of these features is quite relevant: rechargeable battery. Since users do not have to purchase and provide the player with new batteries each time (or remove and recharge batteries in a separate charger), the usability and the value of a player with a rechargeable battery is higher than a product without one. This feature has been equipped on all HD players since 2002, perhaps because the costs of replacing batteries for these devices would be much higher, since HD players need more energy as they have to power a hard drive. However, flash players show a much slower trend towards the adoption of rechargeable

[101] This seems to coincide with the popularity gained by podcasting in the same period. An increasing number of radio stations started offering the possibility to regularly download some of their radio programmes (or part of them) through podcasting, making the possibility of recording FM radio less useful.

batteries. Regarding the other features, built-in speakers were increasingly installed in HD players after 2004. On the other side, touch screens were launched for the first time in 2005 for HD players and 2006 for flash players, and encountered increasing application, especially in the case of HD players.

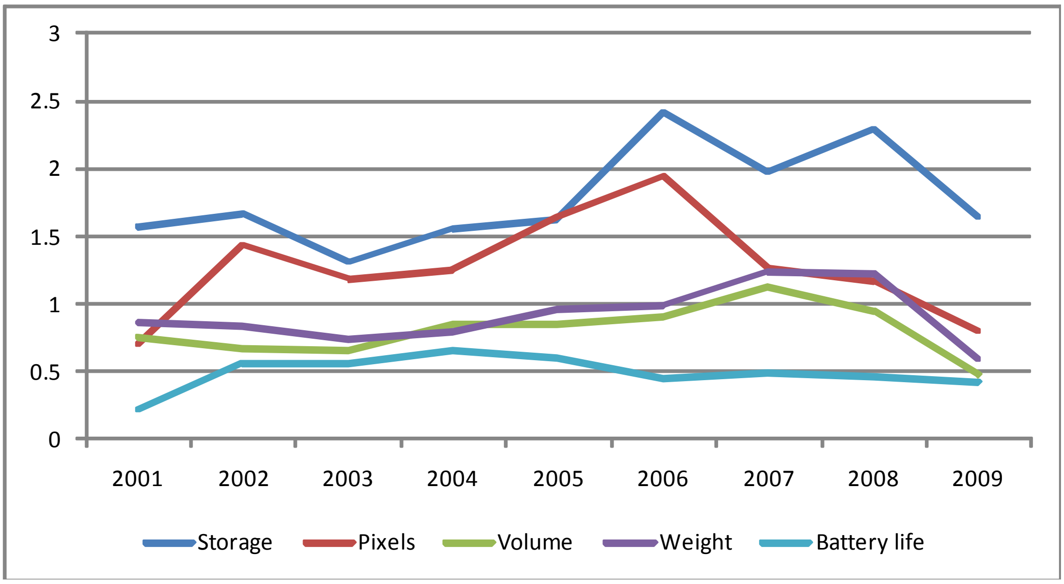
Figure 7.8 DAPs' extra features by year



The trends of vertical and horizontal characteristics over time are useful to give an idea of which kinds of technical innovation occurred in the DAP sector. However, it does not ensure that all the products followed the same pattern, or that a sort of dominant design is emerging. The next step in the analysis will consider the evolution of the sector in terms of product differentiation. The coefficients of variation have been calculated both for all players and separately for the two categories of player. Since the results were quite similar, for simplicity, only the measures regarding the entire sample will be reported. The analysis of the coefficients of variation will be visual. In particular, a decreasing coefficient approaching zero will highlight that the market is reaching a dominant design, at least regarding that specific feature. In contrast, if the coefficient remains stable or increases, it will mean that the DAP producers are still launching differentiated products.

Figure 7.9 shows the coefficients of variation regarding vertical innovation features. First of all, storage space is the feature with the highest degree of differentiation among products. The coefficient of variation for this characteristic seems also to increase over time, even though the trend over the most recent periods is rather ambiguous. The number of pixels is another variable that highly differentiate DAPs. The degree of differentiation regarding this feature grew until 2006 and then declined. Volume and weight show a very similar trend with a non-decreasing coefficient (aside from in the last period[102]). This seems to indicate that the miniaturisation process that occurred did not involve all the DAPs launched, but rather that products of different sizes have been produced and launched over the same periods. Finally, battery life is the least differentiated horizontal feature, also remaining quite stable over time. The main conclusion reagarding vertical features is that DAPs are still quite differentiated products and have not shown any marked convergence towards a dominant design. On the contrary, different designs of DAPs still coexist, at least regarding vertical characteristics.

Figure 7.9 Coefficients of variation on vertical innovation features



Regarding the horizontal features, the picture changes significantly. Figure 7.10 reports the coefficients of variation for graphical horizontal innovation features. In all the cases, the lines show a sharp and decreasing trend, indicating that DAPs are actually converging towards a design in which the average player is equipped with a colour screen and is able to show pictures and play videos. Figure 7.11 shows the coefficients of variation for audio and multimedia features. Video recording is omitted because of the overly small number of players equipped with this kind of capability. The main indication coming from this figure is that radio FM and voice recording have a declining coefficient of variation, while FM recording has not.

[102] We believe that the results of the last period of time may be affected by the right truncation of the data. However, by looking at the percentage of products launched in these two months over prior years, it does not seem that these periods present any particular difference in the number of products launched with respect to the other parts of the year.

Figure 7.10 Coefficients of variation on horizontal innovation features (1)

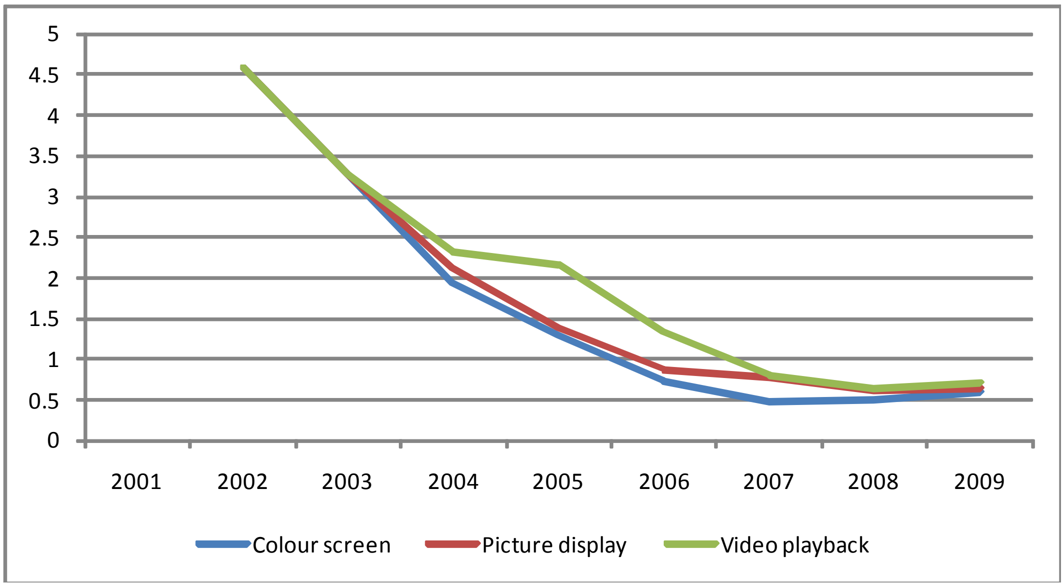
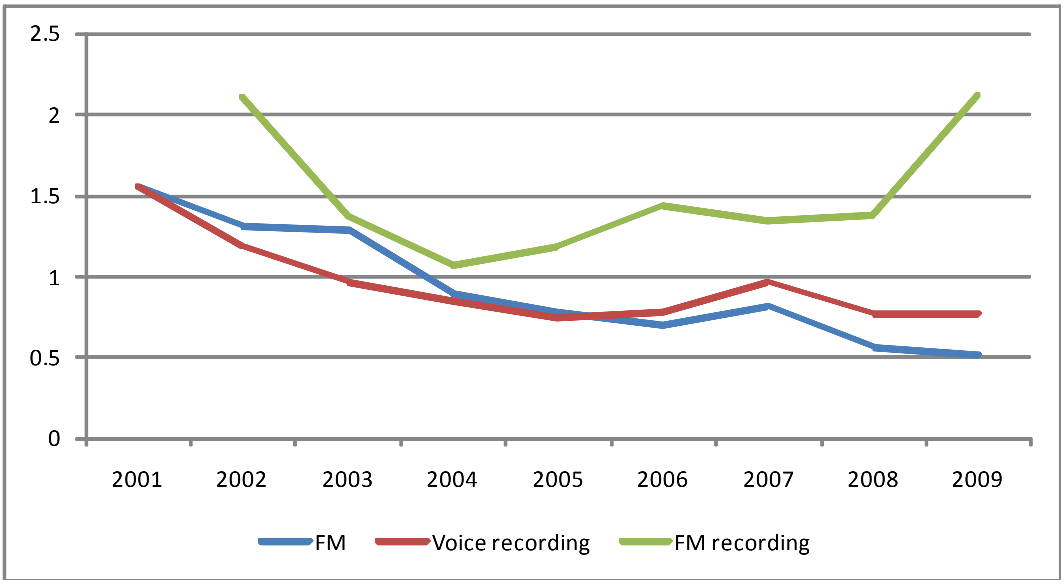
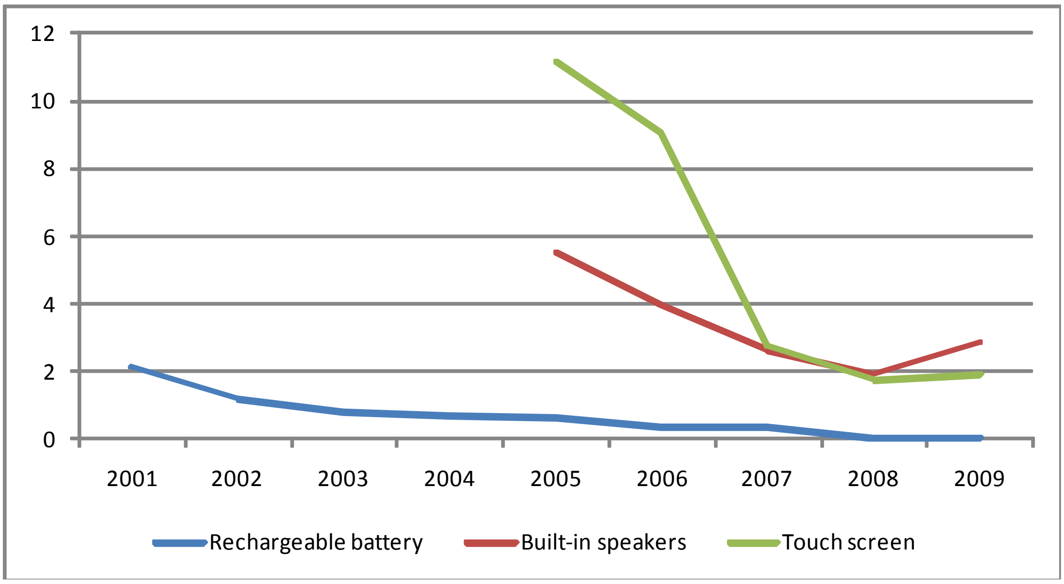


Figure 7.11 Coefficients of variation on horizontal innovation features (2)



Finally, Figure 7.12 reports the coefficient of variation regarding the extra features. As expected, the coefficient for rechargeable batteries is declining over time, reaching zero over the last two periods. Built-in speakers and touch screens also show a declining trend. However, the level of the coefficients in the most recent period are still around two, meaning that the standard deviation is still twice the mean and indicating that the products are still far from being very similar regarding those characteristics.

Figure 7.12 Coefficients of variation on horizontal innovation features (3)



In summary, with respect to innovation in the technical characteristics of DAPs, a vertical type of innovation has occurred. Both flash and HD players are becoming smaller, lighter, with larger screens and equipped with more capable storage memories and more powerful batteries. At the same time, a horizontal type of innovation has also taken place, with both types of models having been progressively equipped with rechargeable batteries. Other horizontal features have characterised only particular types of player. In particular, radio FM and voice recorders have more often been installed on flash players, while touch screens and speakers have more frequently been used by HD players. If we also consider the analysis of product differentiation, two conclusions can be drawn. First of all, vertical innovation features have not converged towards a dominant design. On the contrary, products are still differentiated in terms of storage, size, battery life and screen size. In contrast, some of the features associated with horizontal innovation have converged to a dominant design. This is the case of colour screen picture display, video players, rechargeable batteries, radio FM and voice recording. Table 7.1 provides a summary of the patterns of technical innovation in the DAP sector analysed so far.

Table 7.1 Emergence of a dominant design vs. differentiation in the DAP sector

	DOMINANT DESIGN	***DIFFERENTIATION***
HORIZONTAL INNOVATION	COLOUR SCREEN, PICS, VIDEO, RECHARGEABLE BATTERY, FM, VOICE RECORDING	VIDEO RECORDING, FM RECORDING, SPEAKERS, TOUCH SCREEN
VERTICAL INNOVATION		STORAGE SPACE, SCREEN SIZE, VOLUME, WEIGHT, BATTERY LIFE

In conclusion, DAPs are becoming multimedia devices, able to reproduce different types of media, thanks to improved screens and batteries. This is particularly true for HD players, which can count on very high storage memory, large screens and, in some cases, speakers and touch screens. On the other side, flash players have evolved a lot over the last ten years. The first models were very simple products using non-rechargeable AA or AAA batteries, with a very limited storage capacity (sometimes even less than one CD of songs), which, in some cases, were mostly used as voice recorders or radio FM players. On the contrary, the flash players that followed the early models have become very sophisticated products, having almost all the characteristics of the bigger HD players, but with a much more miniaturised size.

This analysis has not taken into consideration any variable related to investments in or extending of marketing or communications; however, the data analysed so far has drawn a picture of a very competitive market. Producers are engaged in a continuous process of innovation regarding both the core features of the players and the extra features. Some of these extra functions have become common in most DAPs, e.g. rechargeable batteries and colour screens. However, this kind of convergence seems to be more closely related with the fact that this type of component has become very cheap and readily available for integration into the product, rather than with the emergence of a dominant design. On the contrary, the competition in the DAP market seems to be more closely related to product differentiation. The first MP3 players satisfied the basic need to listen to music in any place, giving the opportunity of having smaller devices with very similar audio quality but a much higher storage capacity than a CD player. Since then, DAP producers have made an effort to offer the right product to different niches of customers. For this reason, many different types of DAPs have emerged. These products are very widely differentiated, sometimes having in common only the basic feature of enabling listening to music. These new kinds of products include, for instance, physically large and/or high-volume storage HD players that are authentic multimedia devices, able to play movies, or very tiny flash players without screens or with very limited displays, or other flash players with larger colour displays and with as many functions as the bigger HD players. Another market niche is represented by very sophisticated touch screen devices (equipped with flash memories or HDs), offering many other services besides listening to music, such as gaming and Internet browsing. In all these types of products, the main characteristics are tailored to offer different users an experience that will fulfil their preferences. The question that is still unanswered is whether this hedonic competition is accompanied by price competition.

The next section will answer this question by testing whether there is a systematic relationship between prices and characteristics of DAPs over time.

7.2. Measuring technological change in the DAP sector

The previous section has analysed how technical innovation has occurred in the DAP sector by looking at the evolution of product characteristics over time. However, the method used was essentially exploratory and based mainly on a visual analysis of the technical improvements over time. This section will provide a quantitative measure of technical change in the DAP sector, based upon products' objectively-measurable characteristics. More particularly, a hedonic price estimation technique will be used in order to test if there is a relationship between prices and DAP characteristics. This analysis will be used in order to achieve two objectives. The first is to estimate the quality change in the sector, testing which characteristics have had an impact on prices over time. The second is to construct a price index that takes into consideration the technical changes that have occurred in the sector (hedonic price index).

The first hedonic regression will be a *time dummy hedonic estimation*. The dependent variable will be the natural logarithm of the price. The estimation will be carried out using OLS, employing two sets of independent variables. The first group of variables comprises the characteristics of the product, both vertical innovation characteristics (continuous variables) and horizontal innovation characteristics (dichotomous variables). Furthermore, for continuous independent variables, natural logarithms will be used in the regression. The second group of variables will include a dummy variable for each year, using the first period as reference group. A second regression using dummies by semester will also be carried out, encompassing 18 periods from the first semester in 2001 to the last semester in 2009.

Before carrying out the hedonic estimation, the choice of the vertical innovation characteristics needs some further consideration. At least two issues arise in considering the list of vertical innovation variables. First, players' size is captured by two variables: weight and volume. These two variables are very highly correlated (.880). For this reason, we decided to drop one of them (LN_VOLUME) and to include only LN_WEIGHT in the regression. Another issue is that the size and weight of the player directly depends on the size of the screen and the battery life. The same consideration does not hold for storage space, since flash memories are very small and light, regardless of the size, and the same is the case for hard disks.[103] For this reason, the interaction between battery life and weight (WEIGHT*LIFE) and between screen size and weight (WEIGHT*PIXELS) will be included in the regression. The same regression has been carried out using the interactions with VOLUME instead of WEIGHT, giving very similar results. The regressions will include two other variables. The first is TYPE of player (flash or HD), in order to test if flash players are more expensive than HD players. The second variable is APPLE. This variable is included in order to test whether the fact of being such a strong market leader in the sector might confer a sort of market power to Apple products. A positive and significant coefficient of APPLE would demonstrate the presence of a sort of *Apple effect* on prices. In summary, the variables used in the time dummy hedonic estimation will be:

- Vertical innovation (continuous) variables:
  - LN_STORAGE: natural log of GBs of storage space;
  - LN_PIXELS: natural log of number of pixels;
  - LN_LIFE: natural log of hours of battery life;
  - LN_WEIGHT: natural log of weight in ounces;
  - WEIGHT*PIXELS: interaction effect between LN_WEIGHT and LN_PIXELS;
  - WEIGHT*LIFE: interaction effect between LN_WEIGHT and LN_LIFE.
- Horizontal innovation (dichotomous) variables:
  - BATT_REC: rechargeable battery (1/0);
  - FM: radio FM (1/0);
  - REC_VOICE: voice recording (1/0);
  - REC_FM: radio FM recording (1/0);
  - REC_VIDEO: video recording (1/0);
  - COL_SCR: colour screen (1/0);
  - PICS: picture display (1/0);
  - VIDEO: video playback (1/0);
  - SPEAKERS: built-in speakers (1/0);
  - TOUCH_SCR: touch screen (1/0).
- Other variables:
  - TYPE: 1=flash player; 0=HD player;
  - APPLE: 1=Apple player; 0=other brand.
- Time dummies:
  - (Y2002-Y2009): dummies by year;
  - (S2-S18): dummies by semester.

Table 7.2 shows the results of the hedonic regression using time dummies by year. The estimation has been carried out for all the players in the sample, and separate regressions have also been performed for HD players and flash players.

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103 Although a certain difference exists between the two most frequent types of hard drives installed in DAPs (2.5" and 1.8"), we consider it insignificant for the purposes of the analysis. Moreover, adding WEIGHT*STORAGE does not make any changes to the results of the hedonic regression.

Table 7.2 Results of hedonic prices regression with time dummies by year

	ALL PLAYERS		***HD PLAYERS***		***FLASH PLAYERS***	
CONSTANT	**5.035*****	(0.277)	**5.316*****	(1.027)	**5.690*****	(0.342)
LN_STORAGE	**0.210*****	(0.0191)	**0.123*****	(0.0311)	**0.320*****	(0.0242)
LN_PIXELS	**0.111*****	(0.0286)	-0.0678	(0.0862)	**0.119*****	(0.0357)
LN_LIFE	-0.0235	(0.0463)	**0.364***	(0.197)	-0.0294	(0.0548)
LN_WEIGHT	**-0.783*****	(0.192)	-0.413	(0.487)	**-0.853****	(0.365)
WEIGHT*PIXELS	**0.0417*****	(0.0151)	**0.0873****	(0.0394)	**0.0660****	(0.0335)
WEIGHT*LIFE	**0.143*****	(0.0428)	-0.124	(0.106)	0.0927	(0.0770)
BATT_REC	**0.115*****	(0.0443)	-0.109	(0.242)	**0.163*****	(0.0474)
FM	0.0220	(0.0415)	-0.0449	(0.0636)	0.0359	(0.0508)
REC_VOICE	**-0.104*****	(0.0384)	0.0678	(0.0516)	**-0.151*****	(0.0475)
REC_FM	0.0227	(0.0362)	0.0883	(0.0635)	0.00913	(0.0410)
REC_VIDEO	**0.519*****	(0.110)	**0.321****	(0.128)	**0.602*****	(0.146)
COL_SCR	0.00942	(0.0590)	-0.105	(0.147)	0.0385	(0.0653)
PICS	0.000659	(0.0613)	0.202	(0.145)	**-0.142****	(0.0688)
VIDEO	0.0373	(0.0546)	0.0195	(0.0729)	0.0245	(0.0655)
SPEAKERS	**0.133****	(0.0557)	-0.0165	(0.0837)	**0.164****	(0.0691)
TOUCH_SCR	**0.185*****	(0.0577)	0.125	(0.0981)	0.101	(0.0752)
TYPE	**0.334*****	(0.0727)				
APPLE	-0.0208	(0.0510)	**0.101***	(0.0559)	-0.0532	(0.0804)
Y2002	**-0.421*****	(0.105)	-0.108	(0.197)	**-0.427*****	(0.123)
Y2003	**-0.727*****	(0.109)	-0.177	(0.194)	**-0.843*****	(0.143)
Y2004	**-0.814*****	(0.103)	-0.286	(0.193)	**-0.950*****	(0.121)
Y2005	**-1.164*****	(0.107)	**-0.513****	(0.200)	**-1.493*****	(0.125)
Y2006	**-1.553*****	(0.119)	**-0.707*****	(0.208)	**-2.007*****	(0.141)
Y2007	**-2.029*****	(0.129)	**-0.996*****	(0.221)	**-2.542*****	(0.151)
Y2008	**-2.170*****	(0.136)	**-1.140*****	(0.240)	**-2.718*****	(0.159)
Y2009	**-2.439*****	(0.145)	**-1.343*****	(0.296)	**-3.016*****	(0.169)
Observations	479		138		341	
R-squared	0.809		0.763		0.751	
Prob F test	.000		.000		.000	

*Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1*

The coefficients should be interpreted as the impact of an increase of a specific characteristic (or the presence of that feature for dichotomous variables) on the price of the product. Since both dependent and independent variables are in natural logarithms the coefficients can be interpreted as elasticities. For instance, the coefficient of LN_STORAGE in the first column indicates that a 10% increase in the storage space would result, *ceteris paribus*, in a 2.1% increase in the price of the product. The coefficients of the dummies by year indicate whether the average price increased or decreased with respect to the reference period without taking into consideration price fluctuations due to an improvement in the product's characteristics. The first indication coming from Table 7.2 is that all the dummies by year are negative and significant. This means that the average price of DAPs decreased over time, even when the product qualities remain constant. Moreover, the coefficients always increase over time, indicating that the decline in prices has occurred at an increasing rate.

Regarding the vertical innovation variables, all continuous variables have an impact on the price. First of all, LN_STORAGE is positive and significant; LN_PIXELS and WEIGHT*PIXELS also have a positive impact on the price. LN_LIFE is not significant; however, its interaction with weight (WEIGHT*LIFE) is positive and significant. On the other side, LN_WEIGHT has a negative impact on price. The interpretation of the coefficients regarding battery life, screen size and weight and their interaction effects is as follows. An increase in the size or weight of a DAP can depend on two opposite forces. On one side, a bigger screen or a more powerful battery may have been installed in that player. On the other side, a bigger player means that it may have been built with less sophisticated or miniaturised equipment or materials. The effects of both interactions are positive (WEIGHT*PIXELS and WEIGHT*LIFE). This means that if a larger size/heavier weight of a player is associated with a more powerful battery or with a bigger screen, their effect on the price is positive. On the other hand, an increase in size or weight not associated with an increase in the other characteristics (LN_WEIGHT) has a negative effect on the price. In other words, a player which is bigger and heavier than the others not because it is equipped with a larger screen and a higher capacity battery should have a lower price than other players.

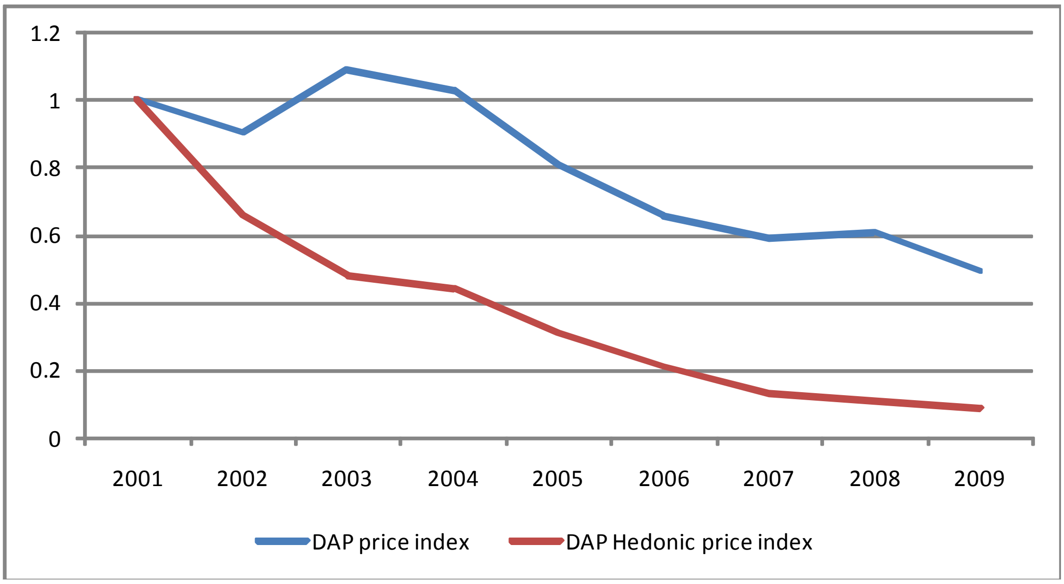
The next group of variables regard horizontal innovation features. The extra features that have a significant and positive impact on price are: rechargeable batteries, video recording, built-in speakers and touch screens. On the other side, the presence of a voice recorder is associated with a negative impact on prices. This might be related to the presence of the above-mentioned voice recorders which also have the capability of playing music. These players are cheaper than the others and, considering their very limited storage capacity, are almost only used for their voice recording feature. This might be the reason why the variable REC_VOICE has a negative coefficient. In any case, the results regarding the coefficient of horizontal innovation variables indicate that most of the features that seemed to be related to the emergence of a dominant design do not have any significant impact on the price. This is the case of colour screens, picture display, video playback and radio FM. This seems to confirm the previous speculation that these features have been installed only because they are economically accessible, and that no convergence towards a dominant design has taken place. The last variables in the sample are TYPE, which has a positive impact on price, suggesting that flash players are, on average, more expensive than HD players, and APPLE, which is not significant, indicating the absence of an effect due to Apple's products. This seems to suggest that regardless of its potential market power, Apple's market pricing is competitive in the DAP market.

The same table also presents the results of two separate regressions, one for HD players and one for flash players, suggesting the existence of some interesting differences between the two lines of product. Some of these differences seem to be related to the specific technical characteristics of the two families of products. LN_STORAGE is significant and positive for both types of players, while screen size and weight have a positive impact only on flash players. This might indicate that, since HD players are normally bigger than flash players, miniaturisation appears to be an issue only for the second type of products, while HD players' customers are less concerned with the players' size. On the other side, battery life has an impact only on HD players' prices, which may be related with the higher energy consumption of HD-based players. Regarding extra functions, rechargeable batteries are significant only for flash players, which is not unexpected, since all HD players in the sample have been equipped with rechargeable batteries since 2002. REC_VOICE has a negative impact only on flash players' prices, as does PICS. On the contrary, SPEAKERS have a positive impact on flash players. Finally, HD players do show a positive Apple effect; however, it is significant only at 10%, indicating that Apple may have realised a small amount of market power for this segment of the market, perhaps by initially setting the ceiling price for HD players below that at which competitors make their offerings. The last consideration must be done on the year dummies. Flash players show the same decline in hedonic prices over time as the average, while for HD players this reduction is significant only from 2005. This seems consistent with the previous speculation about Apple's market power. Until 2004 Apple was active only in the HD player market segment, apparently having the power of imposing a sort of reference price for the whole sector. Moreover, it seems that Apple lost this advantage when it started offering other kinds of players that competed against their own HD-based iPod (the iPod Mini was launched in 2004, and the iPod Shuffle and iPod Nano in 2005).

Table B.1 in the appendices provides the results of the same regressions using semester dummies instead of year dummies. These results confirm the results so far obtained with the year dummies. The reasons for replicating the hedonic estimation are two. The first is a robustness check. The second is because the time periods in semesters will be used in order to merge the results of the hedonic price regression with the data collected through the questionnaire, in which the timing of adoption is expressed in semesters.

The second hedonic estimation will be an *adjacent period dummy variable hedonic estimation*. In this case, a separate regression for each pair of adjacent years has been carried out, adding a year dummy for the second period. For instance, the first regression considers the years 2001 and 2002 and includes a dummy for the year 2002; the second regression puts together the years 2002 and 2003, using a dummy for year 2003, and so on. In this way, it will be possible to test whether the decline in the hedonic prices holds on a year-by-year basis, rather than considering the whole sample. However, splitting the dataset into eight groups makes the sample for each regression too small, at least in the early periods, creating some problems of interpretation of results. For these reasons, this analysis will be used only as a confirmation of the previous results, and the only variables that will be considered are the year dummies. Table B.2 in the appendices shows the results of the eight hedonic regressions using the adjacent years technique. The main result is that the coefficients for the year dummies, aside from the periods 2001/2 and 2003/4, are always significant and with a negative sign. This provides a confirmation of the previous result that even with the quality changes in the sector holding constant, the prices have declined over time.

Figure 7.13 DAP price index and Hedonic price index



One of the most interesting outcomes of the hedonic estimation is the possibility of using the coefficients of the dummies by year (or semester) in order to construct a price index that does not consider quality improvements in the product (hedonic price index). Figure 7.13 reports the DAP price index and the hedonic price index (calculated using the year dummies). The DAP price index is simply the average DAP price normalised by using 2001's average price as a point of reference. The comparison between the two trends suggests that both indexes indicate a price reduction over time. However, the hedonic price index shows that the reduction has been much more significant. The gap between the two lines can be interpreted as the price of the quality improvements occurring year by year.

The results of the hedonic estimation suggest at least two sorts of considerations. The first one is that the price of a DAP can be broken up into several components. Part of the price is due to vertical innovation characteristics. A bigger storage memory, a bigger screen, a more powerful battery and a smaller size (without considering its interaction with screen size and battery life) are factors associated with an increase in price. Another portion of the price depends on the extra functions installed. In particular, rechargeable batteries, video recording, built-in speakers and touch screens have a significant impact on the price. In addition, the results of the hedonic price estimation seem to confirm the idea that the sector has not converged to a dominant design. This is because the functions that show a declining coefficient of variation (with the exception of rechargeable batteries) do not show any impact on the price of the final product. This indicates that the installation of these types of features seems to be more closely related to their economic accessibility than to a deliberate design choice.

The second consideration is about the competitive activity in the sector. The previous section of the chapter described the DAP sector as a very competitive market. In less than ten years, DAPs have evolved a lot. On one side, their quality has significantly improved in terms of storage space, battery life, size, extra functions, etc. On the other side, different product designs or configurations have been launched in order to satisfy the needs of every customer niche. In other words, DAP producers have competed both through product improvements and product differentiation. The results of the hedonic estimation indicate that even when the quality improvements of MP3 players hold constant, the average price of DAPs has steadily decreased over time. This demonstrates that firms have also been engaged in price competition. In conclusion, the competition in the sector can be considered twofold. The first type is a hedonic competition, which regards product quality and functions; the second is price competition. These results can then be taken forward to examine how this competition has impacted on the demand-side. The next section will merge the dataset on the supply-side with the dataset obtained from the questionnaire. The main tasks will be to test whether the competition for quality and prices has influenced the adoption and diffusion of DAPs, and *vice versa*.

7.3. Interaction between supply and demand in the DAP sector

The two previous sections have concentrated on the supply-side of the DAP sector. This section will consider both demand and supply by merging the dataset obtained through the questionnaire with the products' dataset. The datasets will be merged by corresponding the semester of first adoption with the semester in which a DAP was launched. This will enable, on one hand, exploration of the characteristics of the products that were offered to meet the demand for adoption, while, on the other hand, it will also show which stage of the diffusion process DAP producers faced when they were launching one of their new products. The demand-side dataset includes 16 semesters from the beginning of 2001 until the end of 2008, while the supply-side also covers the year 2009. For this reason, the last two semesters of the supply-side dataset will be dropped.

This section has two main objectives. The first is to analyse how important product characteristics have been for the demand-side. This section will build upon a specific question in the questionnaire in which adopters were asked to rate the importance of several product characteristics in evaluating a DAP. These results regarding demand-side preferences will then be merged with the actual technical change in the sector. This will allow testing of whether there is a correspondence between technical progress and consumer preferences over time in the DAP sector. The second objective is to test whether the product innovation on the supply-side has influenced the adoption on the demand-side. This will be performed by including the hedonic price index in the ordered logit regression on the timing of adoption.

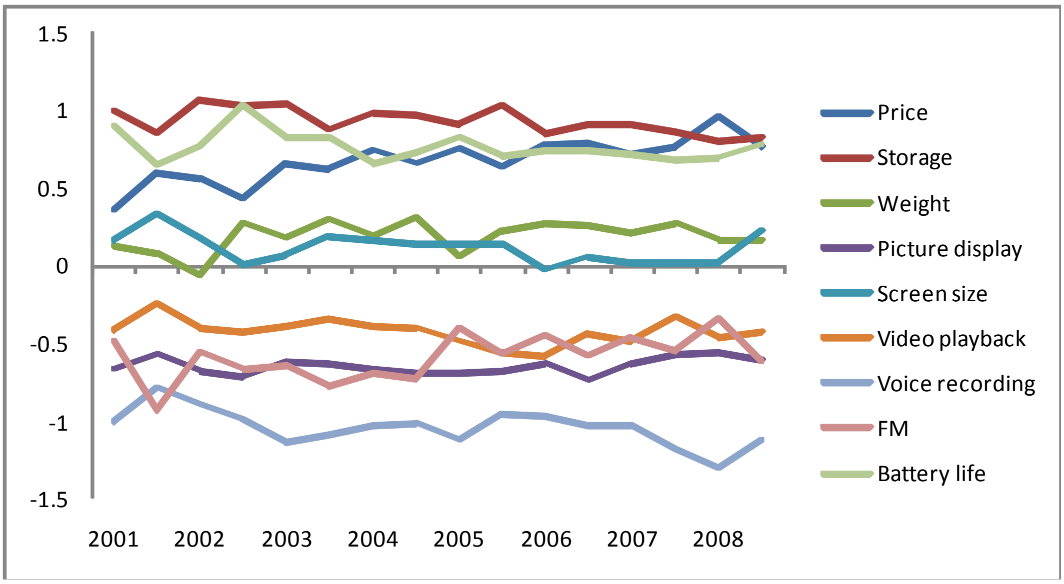
7.1.1. Perception of product characteristics by demand

The perception of product characteristics by demand will be investigated in two steps. A first stage of the analysis will focus on a specific question of the questionnaire in which respondents were asked to rate the importance of a set of product characteristics (including the price) in evaluating a DAP. These perceptions will be analysed and their relative importance will be ranked. Moreover, it will be attempted to group these characteristics through factor analysis. Finally, it will be tested whether there are differences between the three clusters of adopters in the perception of product characteristics. The second step will be based on the fact that the list of product characteristics from the demand-side matches some of the features listed in the product dataset. This will allow a comparison of the relevance of some product characteristics as perceived by the demand-side and their actual evolution over time.

The preferences on product characteristics have been investigated by question 30 of the questionnaire. This question asked respondents to rank the importance of a set of product characteristics on a five-point Likert scale from 'unimportant' to 'very important'. The question included a list of eight product characteristics[104] plus the price, specifically:

- Price;
- Battery life;
- Display size;
- Pictures;
- Radio FM;
- Storage;
- Videos;
- Voice Recording;
- Weight.

Figure 7.14 Importance of price and product characteristics for the adopters



The answers to these questions have been normalised among respondents in order to exclude response style effects[105] and to make it possible to rank them. Figure 7.14

[104] *Warranty* and *design/aesthetics* were also included in the questionnaire. However, these two characteristics will not be taken into consideration.
[105] Response styles are systematic patterns of responding to a set of questions (for instance

provides a visual representation of the perceived importance of each characteristic (vertical axis) over the year of adoption (horizontal axis). The most important characteristic is storage space, followed by battery life. However, the relevance of product price increases over time, overtaking, in the most recent period, the relevance of storage and battery.

The other characteristics perceived as more important than average (over the horizontal axis) are weight and screen size. It is relevant to point out that all these characteristics are vertical innovation features. However, the first impression of this particular question is that the average importance of these characteristics remains quite stable over time. The only factor with an increasing importance is product price. This does not seem to coincide with the evolution of the characteristics from the supply-side, because, recalling the figures in Section 7.1, the technical characteristics of DAPs have improved a lot over recent years. This seems to indicate that although the product has technically improved a lot over time, along different dimensions, the perception of these improvements by the demand-side has been quite static. Figures B.1 and B.2 reported in the appendix demonstrate that unfortunately there is not a correspondence between the evolution of product characteristics and their perception over time by potential adopters. In addition, these perceptions do not even seem to be related to the timing of adoption.

Conversely, it is possible to make a comparison between the price indexes calculated in the previous section and the perceived relevance of price by the demand-side. In particular, Figure 7.15 plots the two price indexes and the relevance of price by the demand-side. The fluctuations of these two indexes appear to be different from Figure 7.13 because in this case the indexes have been calculated by semesters and not by years. The first impression is that there is a negative relationship between price (both normal price and hedonic price) and its perception by potential adopters. In other words, the more the average DAP price declines over time, the more price is considered as a relevant factor when evaluating the adoption of a DAP. In brief, while the perception of product characteristics does not coincide with the actual evolution of these characteristics, it is possible to draw a correspondence between product prices and the value given to the price by adopters. This might suggest that potential adopters

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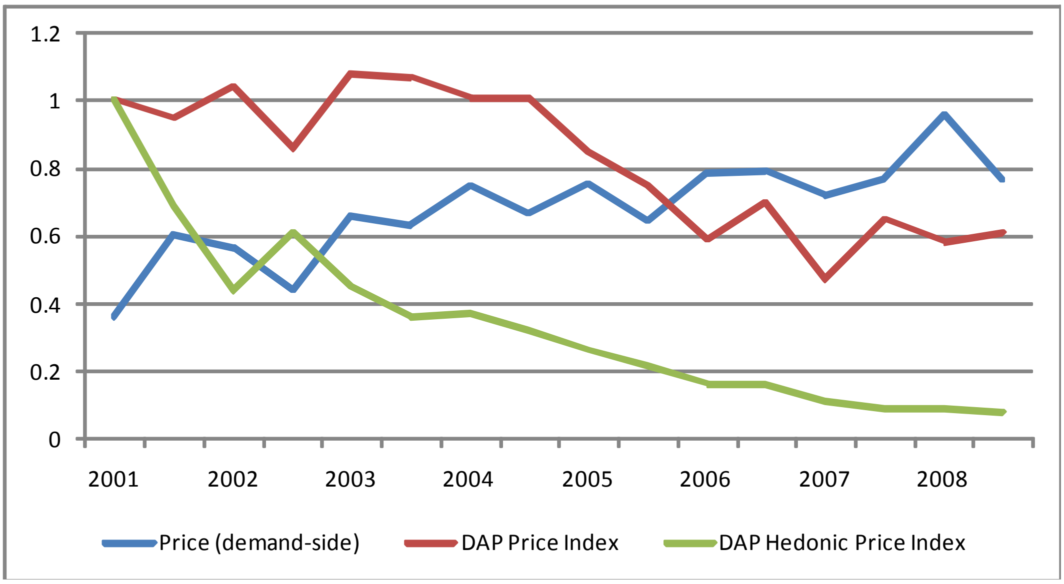
always answering 'yes' or always giving the same rate). Since in this case the main task is to create a ranking of the most-preferred characteristics, these response style effects can bias the results of the analysis. A way to cope with this issue is to normalise the answers by subtracting the mean and dividing by the standard deviation calculated at respondent level (Hair *et al.*, 2010: p.525).

may be formulating expectations about the future trend of prices, and may be willing to postpone adoption in order to wait for a decline in price.

Figure 7.15 DAP price indexes and relevance given to price by demand-side



Another step in the analysis of the perception of product characteristics considers the possibility to group these supply-side characteristics into factors. For this reason a factor analysis has been carried out on the list of perceived characteristics (not considering the price). The methodology used is principal component analysis with oblique rotation. After checking that both KMO and Bartlett's tests give positive results, the factor analysis extracted three factors following Kaiser's method (eigenvalue>1). Table 7.3 reports the factor loading structure.

Table 7.3 Factor loadings matrix after oblique rotation

	Component		
	1	2	3
Battery life	.763		
Storage	.769		
Weight	.523		
Pictures		.861	
Videos		.920	
Display size		.712	
Radio FM			.808
Voice Recording			.784

Note: factor loadings below .400 are not reported.

The interpretation of the factor structure appears quite straightforward. Factor 1 includes storage, weight and battery, and can be considered to be capturing the importance of the core functions of a DAP (CORE). Factor 2 consists of pictures, videos and display size, and indicates the relevance of graphical features (GRAPH). Finally, factor 3 includes other extra functions (EXTRA), such as radio FM and voice recording. Figure 7.16 reports the importance of these three factors over time (where time is measured by five quintiles of adoption). All the curves are u-shaped: the importance of core, graphical and extra features drops and then increases when the final cohorts of users adopt. CORE appears to be the most important factor for the first three cohorts of adopters; however, in the final period the relevance of other factors increases.

Figure 7.16 Importance of core, graphical and extra features over time

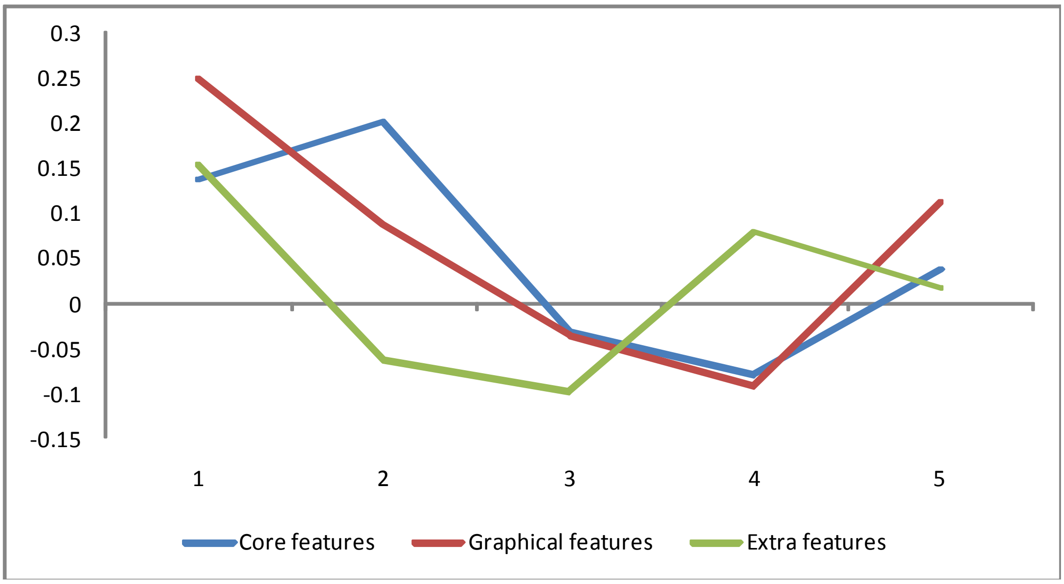
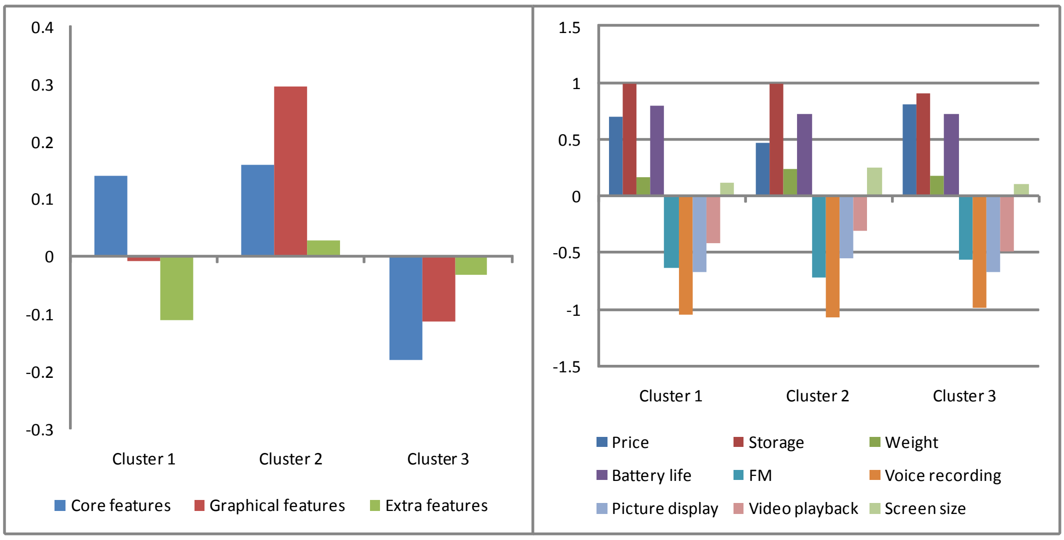


Figure 7.17 Perception of product characteristics by different clusters of adopters



The final exploration of demand-side preferences regards the differences in perceptions of different clusters of adopters. Figure 7.17 reports these differences using a graphical visualisation. The differences appear quite coherent with the cluster profiles outlined in the previous chapter. First of all, cluster 3, representing late adopters scarcely interested in DAPs, does not seem to perceive any of the three factors as relevant. In contrast, cluster 1 appears to be more concerned about the core characteristics, and cluster 2, whose members are those most attracted by consumer electronics, show the highest relevance for all factors. In the case of core and graphical functions, at least, these differences are also statistically significant, as reported by Table 7.4.

Table 7.4 Results of ANOVA F-test on the perception of product features by clusters of adopters

	ANOVA F-test
CORE_O	**.000*** **
GRAPH_O	**.000*** **
EXTRA_O	.345

*Note: *** p<0.01, ** p<0.05, * p<0.1*

In conclusion, adopters of a DAP do not perceive the features of DAPs in the same way. Some features are considered as more important, such as storage space, weight and battery life. Moreover, the price of the DAP is considered an important factor. In addition, these preferences differ depending on the cluster to which the users belong. However, the perception of product characteristics does not coincide with the actual evolution of these characteristics, since these preferences seem to be quite static over time, while the characteristics of DAPs have considerably improved over time. The only factor showing a relationship between supply and demand is product price. However, this lack of correspondence only regards technical changes and user perceptions, and it does not mean that the technical evolution of the product has not influenced the adoption of DAPs and *vice versa*. These possibilities will be tested in the following sections.

The case of multi-adopters

If adopters differ regarding their perceptions of product characteristics, these perceptions do not seem to be related with technical changes or with the timing of adoption. Nevertheless, a different type of conclusion can be drawn if the specific case of multi-adopters is considered.

A specific question in the questionnaire asked respondents about which reasons caused them to decide to buy another DAP. Some of these reasons were linked to the supply-side: the need for more storage space, the need for a smaller model and the need for new functions. The reasons for having a new DAP can be linked with the importance given to some product characteristics. In particular, the need for more space can be linked with the importance of storage space, the need for a smaller product with the relevance of the product's size, and the need for new functions with the importance given to four extra functions: picture display, video playback, radio FM and voice recording. A correspondence between the answers of these three groups of questions could indicate that even if the perception of the product's features did not influence the first adoption, it did influence subsequent purchases.

Table 7.5 Perception of product features by multi-adopters

		Relevance of product characteristics in evaluating a DAP						***T-test sig.***
		Storage space	**Size**	**Picture display**	**Video playback**	**Radio FM**	**Voice recorder**	
Need for more storage space	No	4.31						**.000*****
	Yes	**4.53**						
Need for a smaller model	No		3.39					**.026****
	Yes		**3.67**					
Need for new functions	No			2.21				**.000*****
	Yes			**2.66**				
	No				2.47			**.000*****
	Yes				**3.05**			
	No					**2.39**		.433
	Yes					2.30		
	No						1.84	.722
	Yes						**1.87**	

*Note: *** p<0.01, ** p<0.05, * p<0.1*

Table 7.5 shows the correspondence between responses to the question about the reasons for having another DAP and those responses regarding the perception of product characteristics. The table should be read horizontally. For instance, regarding the question about the need for more storage space as a reason for having another DAP, those who answered *yes* scored higher in the question regarding the importance of storage space (4.53) than those who answered *no* (4.31). This difference is significantly relevant (measured by an independent sample t-test), meaning that those multi-adopters who believed that storage space was a relevant feature are also those who decided to buy another DAP player after the first one, most probably because they needed more storage space.

A similar conclusion can be drawn for product size. The multi-adopters who decided to buy a new DAP in order to have a smaller model are also those who think that size is an important feature. Regarding the need for new functions, this correspondence has been shown to be statistically significant only for picture display and video playback, while for radio FM and voice recording the differences are not significant. This indicates that the users who liked graphical features such as picture and video display have been more willing to change their first DAP in order to have a new product with such capabilities. These results demonstrate again that adoption and multi-adoption can be analysed as two similar but separate phenomena, since the factors influencing them only partially coincide.

7.1.2. Influence of the supply-side in the timing of adoption of a DAP

The previous analysis has demonstrated that there is no correspondence between quality change and perception of product characteristics by the demand-side. The only correspondence regards product price: while users give more importance to price in evaluating a DAP, the average price has declined over time. This sub-section will concentrate on the demand-side and will attempt to test whether changes in product prices and characteristics have an influence on the timing of adoption. This task will be carried out in two ways. First of all, the correlation between different supply-side measures and the timing of adoption will be calculated. Secondly, some supply-side variables will be added to the ordered logit regression presented in the last chapter.

Table 7.6 Correlation between DAP price indexes and adoption over time

	DAP Price Index	***DAP Hedonic Price Index***	***Adopters over time***	***Cumulative adopters***	***Storage space***	***Weight***
DAP Price Index	1	684***	-.825***	-.878***	-.002	.635***
DAP Hedonic Price Index		1	-.918***	-.878***	-.426***	.321***
Adopters over time			1	.987***	.418***	-.420***
Cumulative adopters				1	.342***	-.456***
Storage space					1	.546***
Weight						1

*Note: *** p<0.01, ** p<0.05, * p<0.1*

Table 7.6 shows the correlation matrix between the timing of adoption (adopters over time and cumulative adopters) and some measures coming from the supply-side dataset (price index, hedonic price index, average storage space and weight). The first result is that there is a very strong and negative correlation between both price indexes and the number of adopters over time. It seems that the decline in DAP prices went along with the process of diffusion. Moreover, the evolution of technical characteristics is also correlated with the number of adopters. In particular, an increase of storage space and a weight reduction are positively correlated with adoption. These results might indicate that, although the relative importance of product characteristics, in terms of users' perceptions and preferences, have remained quite stable over time, the quality improvements have actually had an influence on the DAPs' diffusion process. This influence might have taken the form of expectations from the demand-side. In other words, potential adopters might have decided to postpone or anticipate adoption, taking into consideration future technical improvements of the products.

This hypothesis will be tested by using the same ordered logit regression used in the last chapter. The dependent variable will be the same, a variable going from one to four indicating the four quartiles of adoption, from early to late adopters. Therefore, a positive coefficient of an explanatory variable will indicate a negative effect on the timing of adoption, hence an impact pushing towards a late adoption, and *vice versa*.

Table 7.7 Results of ordered logistic regression on the timing of adoption including supply-side variables

	(1)		*(2)*		*(3)*	
LN_INCOME	**-0.188****	[0.0800]	**-0.174****	[0.0801]	**-0.191****	[0.0836]
GENDER	-0.184	[0.152]	-0.167	[0.152]	-0.107	[0.159]
COMP_USE	0.0227	[0.0806]	0.0142	[0.0811]	-0.0170	[0.0835]
COMP_SKILLS	**-0.177***	[0.106]	**-0.209***	[0.107]	-0.157	[0.110]
GB_MUSIC	**-0.241*****	[0.0611]	**-0.250*****	[0.0605]	**-0.268*****	[0.0635]
GADGETS	-0.0327	[0.0526]	-0.0437	[0.0527]	-0.0359	[0.0549]
INNOV	0.0584	[0.0843]	0.0584	[0.0849]	0.00556	[0.0891]
DOM_SP_INNOV	**-0.354*****	[0.0857]	**-0.354*****	[0.0859]	**-0.350*****	[0.0911]
NETWORK	**0.162***	[0.0863]	**0.180****	[0.0868]	0.124	[0.0895]
INFO_CASC	0.0562	[0.0784]	0.0644	[0.0789]	0.0214	[0.0820]
IMITATION	-0.0455	[0.0854]	-0.0293	[0.0856]	-0.0175	[0.0885]
INFO_INT	0.0263	[0.0850]	0.0208	[0.0850]	0.0115	[0.0885]
INFO_EXT	-0.0236	[0.0793]	-0.0330	[0.0790]	-0.0756	[0.0820]
INFO_EXP	0.00435	[0.0805]	0.0746	[0.0795]	0.0905	[0.0825]
INFO_ACT	-0.0510	[0.0786]	-0.0547	[0.0781]	-0.00999	[0.0808]
CORE	-0.0958	[0.0765]				
GRAPH	-0.0192	[0.0761]				
EXTRA	0.0228	[0.0734]				
EXP_HED_PRICES			**-3.300*****	**[0.565]**		
EXP_PRICES					**-2.592*****	[0.465]
EXP_STORAGE					**0.179*****	[0.0183]
EXP_WEIGHT					**-0.789*****	[0.0938]
cut1	-4.624***	[0.863]	-4.221***	[0.864]	-5.737***	[0.907]
cut2	-3.529***	[0.856]	-3.097***	[0.857]	-4.445***	[0.897]
cut3	-2.100**	[0.850]	-1.628*	[0.852]	-2.685***	[0.889]
Observations	710		710		710	
log likelihood	-929.1		-911.9		-822.4	
Chi-square	102.2		136.6		315.7	
Prob Chi2	0		0		0	
Test of parallel lines	.308		.225		.692	

*Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1*

Three different regressions have been performed. The results are reported in Table 7.7. The first includes three variables that do not come from the supply-side dataset, but that nonetheless are related to the perception of the supply-side by potential adopters. These variables are CORE, GRAPH and EXTRA features, representing respectively the importance assigned by adopters to core functions (such as weight and storage), graphic functions (such as display's size, picture display and video playback) and extra functions (such as radio FM and voice recording). These variables are the three factors extracted through exploratory factor analysis from the users' perceptions of product characteristics (section 7.1.1). None of these variables is significant, indicating, again, that users have not changed their preferences over time, and that their preferences did not influence their adoption decision.

The second regression includes the users' expectations of the hedonic price index (EXP_HED_PRICES). This variable has been calculated, in each period of time, by taking the percentage increase in the hedonic price index in the next period.

$$EXP\_HED\_PRICES_t = \frac{hed\_price\_index_{t+1} - hed\_price\_index_t}{hed\_price\_index_t}$$

Since the hedonic price index already takes into account the technical changes in the sector, this variable should be included alone, without any other supply-side measure. The first consideration regarding this regression is that adding the new variable does not change the structure or significance of any other explanatory variable. Moreover, the variable EXP_HED_PRICES is significant and has a negative coefficient. This means that an expectation of a price increment in the future pushes towards an earlier adoption. In contrast, if users expect a decrease in the price they will probably postpone adoption, in order to benefit from the price reduction.

The last regression includes the expectations of the price (not hedonic) and the product technical changes measured by the improvements in storage capacity and weight. The variable EXP_PRICES is measured in the same way as EXP_HED_PRICES. The variables EXP_STORAGE and EXP_WEIGHT at time *t* represent the average storage space and weight of the product launched in the period *t+1*. The three variables are significant at a .01 level. In particular, EXP_PRICES has the same negative sign as EXP_HED_PRICES, indicating that an expectation of an increase in DAP prices should anticipate adoption and *vice versa*. On the other side, EXP_STORAGE has a positive sign, indicating that if adopters expect the launch of new DAPs with more storage space, they will decide to postpone adoption. EXP_WEIGHT has an opposite sign to EXP_STORAGE, but the interpretation is the same. An expectation of a reduction in the size of a DAP will have the effect of postponing adoption.

Although the supply-side does not have any apparent direct effect on consumer preferences, it does influence demand. Potential adopters respond to the continuous efforts concerning both product innovation and differentiation by developing expectations about price trends and future improvements. However, the final effect of these expectations on the adoption rate seems to be negative, since they have the consequence of postponing adoption.

7.4. Conclusions

This chapter has explored the dataset on the supply-side and its combination with the data from the demand-side. The first section attempted to provide an analysis of the innovations occurring in the DAP sector by analysing two kinds of innovative activities. Firstly, vertical innovation concerns improvements in some core features such as storage space, player size, screen size and battery life. Secondly, horizontal innovation means adding new features, such as picture display, voice recording and touch screen. Coefficients of variation for each of these characteristics have also been calculated, in order to analyse whether the sector was converging towards a dominant design. The main result has been that, although very important product improvements have occurred over the last ten years, the DAP sector, instead of reaching a dominant design, has increased its level of differentiation.

The second section of the chapter tried to estimate the effects of technical change. In particular, through hedonic price estimation, it has been possible to study which product characteristics have had an impact on the product price. Moreover, the hedonic estimations have allowed the construction of a price index that does not take into consideration technical changes in the sector. This price index has a much more rapid decline than the simple price index, indicating that DAP producers have also been competing in price, and that the resulting price decline has been partially compensated for by technical improvements or by the introduction of new features.

The third section merged data on the demand-side with data on the supply-side. This merge has allowed an attempt to measure whether the ranking of the most important product characteristics perceived by the demand-side changes depending on the timing of adoption. Moreover, these perceptions have been compared with the actual technical changes occurring in the sector. The main result was that users' preferences remain quite stable over time, with very little correspondence with technical changes. The only user preference that shows an interesting trend relates to product price. The more product price declines, the more its relative importance for the demand-side increases.

Conversely, these preferences do matter if we consider subsequent adoption instead of first adoption. The data on multi-adopters showed a clear correspondence between the preferences for some product characteristics and the reasons for purchasing another DAP after the first. The final piece of analysis carried out in the chapter regarded the impact of supply-side variables on the timing of adoption. This has been carried out by adding some supply-side variables to the ordered logistic regression on the timing of adoption. In particular, expectations of prices and of the storage and weight of future products have been included in the regression. The main result has been that all these expectations have a significant effect on the timing of adoption, particularly by delaying the adoption in order to wait for future improvements or price drops.

The analyses carried out in this chapter suggest three kinds of conclusions. The first is that the DAP market has been subject to a very rapid technical change. The products have changed and improved quite radically over recent years. Firstly, these improvements have related to some core characteristics of DAPs (vertical innovation). Secondly, the products have also been upgraded by adding new functions (horizontal innovation). These two kinds of technical innovations have had an impact on the average DAP price. Another component that has had an impact on product price has been competitiveness. The hedonic estimation indicated that, even holding constant all the technical improvements in the sector, the average price of DAPs has constantly and sharply declined over time; however, this innovative process has not led to a dominant product design. On the contrary, the degree of differentiation has considerably increased over time, and new kinds of DAPs have been launched in order to satisfy every possible market segment.

The second conclusion regards the competition in the DAP sector. Two sorts of competitive forces seem to be present: hedonic competition and price competition. On one side, firms have undertaken a strong innovative effort in order to launch more innovative and differentiated products, meeting the preferences of different kinds of market segments. On the other side, a price competition took place in the DAP sector in the last year. Firms, supported by the remarkable success of DAPs and by an increasing adoption rate, strived to offer cheaper products, even considering all the technical advances implemented.

The last conclusion regards the relationship between supply and demand. The first two conclusions describe a sector subject to rapid technical change, sustained by both product and price competition among firms, but still with a minor role of demand in influencing firms' strategies. However, the results of the last part of this chapter contradict this, indicating that demand can have an impact on the supply-side. In any case, even though users do not change their preferences about product characteristics, they do take them into consideration in their adoption decisions. In particular, users formulate expectations both with regard to prices and improvements in product features. These preferences have an impact on the timing of adoption. In particular, potential adopters are willing to delay adoption in order to wait for product improvements or price declines. Firms need to fulfil these expectations in order not to slow down the ongoing diffusion process. Thus, demand and supply reciprocally influence each other. Firms strategically keep improving their products in order to compete and survive in the DAP market. This competition does not change consumers' preferences, but it does influence their adopting behaviour, through the creation of expectations, which, in turn, create a pressure for firms to sustain technical change.

CHAPTER 8. ALTERNATIVE MODELS OF ADOPTION OF DAPS

One of the conclusions of the review of the literature on the diffusion of innovations presented in Chapter 2 regards the lack of an empirical comparison between different views on diffusion. Although the literature on innovation diffusion is ample and differentiated both at theoretical and empirical levels, each different model of diffusion has focussed on a specific set of factors able to influence the adoption and diffusion of an innovation. However, none of the approaches seems to be suitable to account for the influences coming from different models, and, more importantly, prior work on diffusion has not been able to compare alternative formulations. This makes it difficult for different actors interested in the diffusion of an innovation, e.g. scholars, company executives or policy-makers, to decide which variables may speed up or slow down the diffusion of an innovation.

The main objective of this chapter is to test alternative models of adoption by comparing their performance in explaining the adoption and diffusion of DAPs. A similar exercise has been attempted by Karshenas and Stoneman (1993). The methodology used to achieve this objective is duration analysis, and the datasets used will be both about demand and supply. This chapter is organised as follows. The first section (8.1) will present the models of diffusion that will be tested on the data on DAPs. The second (8.2) will describe the duration models estimated and the hazard functions used in the estimation, as well as the variables used in the regressions. The third section (8.3) illustrates the results of the estimation and the fourth section (8.4) provides a conclusion.

8.1. Models of diffusion and their effect on the adoption of a DAPs

The literature review presented in Chapter 2 was organised using the epidemic model of diffusion as a starting point and then presenting the other models of diffusion, divided into three groups depending on their main focus. In particular, the review considered models mainly focusing on the adopter, on the innovation and on the diffusion process. This chapter, rather than testing specific theories of diffusion, will test the main effects or the main factors on which the above-mentioned approaches to innovation diffusion are based. The list of models tested will respect the classifications used in the literature review chapter. In particular, the first approach to be tested will be the epidemic model. The second approach will examine those models focusing on the adopter, which will be tested by considering the existence of rank effects. The third approach will be about the models of diffusion focusing on the innovation. In this case, the effects of users' expectations about the evolution of the supply-side on DAP diffusion will be considered. Finally, regarding the models focusing on the diffusion process, two approaches will be considered. The first will be about the stock and bandwagon effects, and the second will explore the order effect. A short review of each of these effects will follow; we refer to Chapter 2 for a more detailed outline of the literature behind each category of diffusion model.

The first effect considered is based on the epidemic model of diffusion (see Section 2.1). Following this approach, the innovative product represents a superior choice with respect to all actual options. For this reason, potential adopters will start using the innovation as soon as they are informed about it. Moreover, the way by which adopters are informed about the innovation is personal contact. As a result, the diffusion of an innovation resembles the spread of an infectious disease, in which the probability of adopting increases over time, simply because the number of adopters is growing.

The second effect is the rank effect (see Section 2.2.1). This kind of effect is mostly represented by some of the so-called equilibrium models, which are neoclassical models of diffusion that assume perfect information and rational and maximising behaviour. The main idea of rank models is that adoption is not instantaneous because adopters are heterogeneous. In particular, potential adopters differ in some characteristic x_i, which directly affects the benefits from adoption and consequently the timing of adoption. This characteristic is distributed across the population according to some function, and the diffusion path will directly depend on the distribution of this particular characteristic of potential adopters.

The third influence on adoption is based on the fact that the innovation is not static, but rather evolves over time (see Section 2.3.3). A certain group of diffusion models explicitly assume that innovations change over time, claiming that these changes can influence consumers' willingness to adopt the innovation. Therefore, one of the reasons why the diffusion of an innovation is not instantaneous may be related to the fact that potential adopters could be waiting for changes in the product's price or characteristics. Thus, potential adopters formulate expectations on the technical evolution or price trend of an innovation and may deliberately decide to postpone adoption. In particular, in Chapter 7 it was demonstrated that DAPs changed a lot during the period under analysis. Not only did the average price considerably decline, but also the product characteristics significantly improved. Moreover, these changes are correlated with the timing of adoption. In this case, the task will be to verify whether an expectation of a future change in the supply-side can influence the current likelihood of adoption.

Stock and bandwagon effects are the fourth kind of effect considered, and they are related with the process of diffusion itself (see Section 2.4). This effect depends on the fact that when the adopter is facing the decision whether or not to adopt the innovation, a diffusion process is probably already taking place. This ongoing diffusion process is probably bringing forward an epidemic sort of influence, having the form of an informative effect, making potential adopters aware of the innovation. However, the stock of previous adopters may also influence the adoption decision in other ways. In particular, the literature does not provide a univocal interpretation of this kind of effect. On the one hand, an increase in the number of adopters negatively influences the innovation's profitability in the future, as seen in the case of the so-called game-theoretic models (stock models). In the case of consumer products, the negative influence exerted by the stock of previous adopters can be seen as a *snob effect*, occurring when potential adopters reject the innovation trying to look different from the others. On the other hand, the stock of previous adopters is meant to produce a positive externality (bandwagon effect). This type of externality has often been conceptualised in at least three ways: as a direct or indirect network effect (increasing returns theories of bandwagons), as an imitative effect (fad theories of bandwagons) or as an informational cascade (learning theories of bandwagons).

The fifth and last effect on diffusion taken into account is the order effect (see Section 2.4.1). This type of model belongs to the same category as stock models, since their main focus is on the diffusion process. In particular, these models assume that the returns on the adoption of an innovation for a specific adopter depend on his or her position in the order of adoption. The main assumption is that high-order adopters experience a higher return than low-order adopters. This effect is often considered as a sort of first-mover advantage, by which a firm or an individual, by adopting before others, is able to reap more benefits from the innovation. In the case of firms, a high-order adoption is supposed to ensure returns such as better geographical position, easier searches for skilled labour or the exploitation of a temporary monopolistic position. In the case of consumers, an early move in adopting an innovation can have the advantage of providing the status of an opinion leader, and hence the ability to influence other individuals in their attitudes or behaviour and to induce imitation.

8.2. Description of models and variables

Duration analysis is an econometric method able to describe which factors influence the probability of an event occurring in a specific period of time without having occurred in any previous period (Kleinbaum and Klein, 2005; Jenkins, 2005a, 2005b). Regarding the specific case of DAPs, the conditional probability that an individual adopts a DAP at time *t*, given that he or she has not adopted at *t-1*, is estimated. To this end, we estimate a hazard function, which is defined as the conditional probability of adopting a DAP at time *t*, without having adopted before. The hazard, $h(t \mid X, \beta)$, is a function of time and a series of other variables:

$$h(t \mid X, \beta) = h_0(t) + \exp\{X' \beta\} \tag{1}$$

X is a vector of *k* explanatory variables incorporating the influences on diffusion, β is a vector of parameters and $h_0(t)$ is the baseline hazard, which is the hazard when all the other covariates are equal to *0*. The estimation of the $\hat{\beta}$ is carried out through maximum likelihood maximisation. This methodology will allow a test of whether the assumptions of several diffusion models are applicable to the case of DAPs. In particular, the vector *X* will contain one or more variables matching each of the diffusion models considered.

Before estimating the model, two issues should be taken into consideration. The first issue is which function should be assigned to time. Survival analysis contemplates both *semi-parametric* and *parametric* functions. In the first case, behaviour is not supposed to follow any specific function in time, and hazard (the probability of adoption) is proportional and constant over time (the hazard of one individual is proportional to the hazard of any other individual, i.e. the hazard rate is constant over time). The semi-parametric case is usually tested through the Cox proportional hazard model (Kleinbaum and Klein, 2005: ch.3; Jenkins 2005b: lesson 5). In the second case, behaviour over time is assumed to follow a specific distribution. This is of particular interest when studying the diffusion of innovations since, as mentioned before, there might be some factors related with the diffusion process that increase the probability of adoption over time (Kleinbaum and Klein 2005: ch.7; Jenkins 2005b: lesson 5). The second issue regards the way in which time is considered: continuous or discrete (Jenkins 2005b: lesson 2). In theory, all the above-mentioned hazard functions should be applied only to cases in which time is a continuous variable. However, in this case time is expressed in 16 semesters, from the first semester of 2001 to the last semester of

2008. This means that the time elapsing in this model is discrete rather than continuous. Although in most studies (including Karshenas and Stoneman, 1993) a continuous model is also applied in cases of discrete time variables, in this case both a continuous and a discrete type of hazard function will be tested.

The discrete survival hazard function is based on a manipulation of the data (as suggested in Jenkins 2005b: lesson 6, p.2), which expands the number of observations and in which the dependent variable is a dichotomous variable that is repeated T_i times for each subject (where T_i is the timing of adoption of the individual i), and which has value 0 if $t<T_i$ and 1 when $t=T_i$. The estimation is then carried out through a logistic or complementary log-log hazard function. In order to achieve more robust results, both the cases of discrete and continuous time variables will be considered. Moreover, both the cases of parametric and semi-parametric hazard functions will be included. This means that four different models will be tested.

Table 8.1 Four different hazard functions

	Discrete	***Continuous***
Parametric	(1) Complementary log-log (and logit) regressions including a specific function of behaviour over time	(3) Parametric hazard function using Weibull distribution
Semi-parametric	(2) Complementary log-log regression with time dummies (no specific function given to behaviour over time)	(4) Cox continuous semi-parametric hazard function

Table 8.1 lists all the hazard functions that will be tested using the data on the diffusion of DAPs. The discrete and parametric hazard function number (1) will be used as a reference case. For this hazard function, the effects from different models of diffusion will be tested. This function has been chosen as the point of comparison for two reasons. First of all, since time is expressed in discrete periods in the data, the most correct procedure would be to use a discrete kind of hazard function (Jenkins, 2005a: p.16). The continuous hazard functions will also be estimated, and this will represent a robustness check. However, in the case of the diffusion of innovations, the hazard is supposed to follow a specific trend; specifically, it is supposed to grow over time. Moreover, one of the most important models of diffusion tested on the data is the epidemic model, which claims that, since an increasing number of potential users become adopters, the probability of adoption increases over time, because it represents an encouragement for further users to adopt. This epidemic process is included in the

model by testing whether the hazard (and thus the probability of adopting) increases over time, regardless of all the other covariates. For this reason, the main hazard function should necessarily include a function of time, and the hazard function should be parametric. However, in order to test the robustness of the results, a semi-parametric hazard function will also be estimated. The four kinds of duration models estimated will use the following hazard functions:

1. Complementary log-log (cloglog) discrete parametric hazard function

$$h(t \mid X, \beta) = 1 - \exp[-\exp(z(t)] \qquad (2)$$

   where $z(t) = c(t) + \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_k x_k$. This function includes a function of time, *c(t)* and *k* explanatory variables. This function will be used as a reference case. The validity of this model will be tested by also using a logit regression.

2. Complementary log-log (cloglog) discrete semi-parametric hazard function

$$h(t \mid X, \beta) = 1 - \exp[-\exp(z(t)] \qquad (3)$$

   where $z(t) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_k x_k + \delta_2 t_2 + \delta_3 t_3 + ... + \delta_n t_n$. In this case, time is embedded in the model through *n-1* dummy variables.

3. Weibull continuous parametric hazard function

$$h(t \mid X, \beta) = \lambda p t^{p-1} \qquad (4)$$

   where $\lambda = \exp[\beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_k x_k]$. The shape of the Weibull hazard function depends on the parameter *p*. In particular, if *p=0* the Weibull function resembles an exponential function, if *p>1* the hazard increases as time increases, and if *p<1* the hazard decreases as time increases.

4. Cox continuous semi-parametric hazard function

$$h(t \mid X, \beta) = h_0(t) + \exp[\beta_1 x_1 + \beta_2 x_2 + ... + \beta_k x_k] \qquad (5)$$

8.2.1. The variables

The dependent variable of the analysis is the probability of adopting at time *t* given that adoption had not occurred at time *t-1*. This probability is based upon a specific question from the questionnaire asking whether the respondents had adopted a DAP and, if so, when. Respondents were allowed to choose between 16 semesters from the beginning of 2001 to the end of 2008. A descriptive analysis of this question has been presented in Section 6.1.3.

The epidemic effect is tested by checking whether the hazard increases as time elapses. In the case of a discrete and parametric hazard function, the variable used is the natural logarithm of time (LN_T). In the case of a discrete and semi-parametric hazard function, the epidemic effect is tested by analysing the coefficients of a series of dummy variables (D1-D16), which indicate time elapsing. In the case of the continuous and parametric hazard functions the epidemic effect is tested by analysing the estimation parameter *p* which describes the shape of the hazard curve.

In order to estimate the rank effect, two variables are included. The first one is the natural logarithm of the personal income (LN_INCOME), a measure used quite often in rank models of diffusion regarding consumer products. The second one is GB_MUSIC, the quantity of music files available to the potential adopter, a measure that emerged as one of the most interesting results from several previous analyses. This variable is measured in gigabytes of music, divided into five categories, ranking from less than 1GB to more than 30GB.

The users' expectations regarding the supply-side are measured by three variables. One variable regards expectations of the price (EXP_PRICES), while the other two variables regard the expectations of two technical characteristics: storage space (EXP_STORAGE) and weight (EXP_WEIGHT). The same kinds of variables were used in Section 7.1.2 with interesting results. In particular, users' expectations of the price (EXP_PRICES) are calculated, in each period of time, by taking the percentage increase of the price index in the next period.

$$EXP\_PRICES_t = \frac{price\_index_{t+1} - price\_index_t}{price\_index_t}$$

A similar variable could have been calculated using the hedonic price index. However, the hedonic price index should not be used together with other expectations regarding the product's technical characteristics. This is because the hedonic price index already takes into account the technical change in the sector. The other two variables (EXP_STORAGE and EXP_WEIGHT) regard the expectations of the evolution of two technical characteristics of the product. In particular, EXP_STORAGE and EXP_WEIGHT at time *t* are calculated as the average storage space and weight of the product launched in the period *t+1*.

The stock effect is tested by using four variables. The first is the cumulative number of previous adopters at time *t*, which is calculated at country level. Following Karshenas and Stoneman (1993), in order to avoid endogeneity a two-stage estimation procedure is used. In the first stage, an autoregressive model is estimated by regressing the number of adopters in period *t* on the number of adopters in *t-1*. In the second stage, the predicted values of the previous regression are used to create the variable CUMUL. The other variables are linked to three kinds of bandwagon effects: network effects (NETWORK), imitative effects (IMITATION) and informational cascades (INFO_CASC). To investigate the importance of these effects, respondents were asked to evaluate on a five-point basis the importance of a series of items, which had been put together through factor analysis. A detailed explanation of this process is illustrated in Chapter 5.

Finally, the order effect is calculated as the difference between $CUMUL_{t+1}$ and $CUMUL_t$ (as in Karshenas and Stoneman, 1993), and measured by the variable ORDER. This difference can be interpreted as the expected change in the cumulative number of adopters in the period (*t, t+1*). In particular, a positive effect of this variable on the hazard indicates the presence of a first-mover advantage.

The regressions also take into consideration a list of control variables (we refer to Chapter 6 for further explanation regarding these variables).

- Gender (GENDER): 1= male; 0=female.
- Previous player (PREV_PLAY): 1= the adopter owned a portable music player in the past (Walkman, Discman, Minidisc); 0=otherwise.
- Computer u*se* (COMP_USE): 1 to 6 variable from 'never' to 'more than 5 hours'.
- Computer skills (COMP_SKILLS): 1 to 5 variable from 'much below the average' to 'much above the average'.
- User innovativeness*:* (INNOV: innovativeness); (IN_DOM_INNOV: domain-specific innovativeness).
- Dummies by geographic area: JAPAN, UK, EU_NORTH (France, Switzerland, Germany and the Netherlands), and EU_SOUTH (Italy, Spain and Portugal).

Table 8.2 provides a list of the variables used in the duration analysis, as well as some descriptive statistics, such as the number of observations, mean, and standard deviation, minimum and maximum. First of all, both LN_T and the parameter *p* are not included, since they are obtained only when performing the regressions. Moreover, by examining the table, it is possible to highlight that some variables have been standardised: this is the case of COMP_SKILLS, COMP_USE and GB_MUSIC. In addition, all the variables obtained through factor analysis are standardised (NETWORK, IMITATION, INFO_CASC). However, in this case it is the method used to create the factor using the factor loadings (the Anderson-Rubin method) that creates, by default, standardised variables.

Table 8.2 Variable list and descriptive analysis

	Variable	*N*	*Mean*	*Std. Deviation*	*Min*	*Max*
DEP. VARIABLE	**ADOPTION TIMING**	1088	8.96	3.56	1	16
CONTROL VARIABLES	**GENDER**	1102	.53	.499	0	1
	PREV_PLAY	1102	.92	.270	0	1
	COMP_SKILLS	1102	.0658	.939	-3.05	2.28
	COMP_USE	1102	-.0027	.976	-3.55	1.63
	INNOV	1102	-.0439	.990	-1.85	3.15
	DOM_SP_INNOV	1102	.0638	.988	-2.75	1.95
	UK	1102	.13	.332	0	1
	EU_NORTH	1102	.29	.452	0	1
	EU_SOUTH	1102	.38	.486	0	1
RANK EFFECT	**LN_INCOME**	812	9.5492	.925	6.91	11.65
	GB_MUSIC	950	.0000	1.000	-1.84	1.41
USERS' EXPECTATIONS	**EXP_STORAGE**	1088	11.6568	24.339	.08	164.29
	EXP_WEIGHT	1088	3.2385	2.743	1.07	13.40
	EXP_PRICES	1088	-.08833	.216	-.605	.277
STOCK EFFECT	**CUMUL**	1102	9.1053	4.426	.00	25.05
	NETWORK	1102	.0000	1.000	-3.07	2.26
	IMITATION	1102	.0000	1.000	-1.11	4.14
	INFO_CASC	1102	.0000	1.000	-3.44	2.06
ORDER EFFECT	**ORDER**	1102	.9652	3.386	-10.33	8.72

Note: valid number of observations (listwise): 710.

8.3. Regression results

The estimation will follow a sequential procedure, starting with a basic epidemic model and adding at each step the specific variables of the other models being tested. The basic estimation will be a discrete parametric hedonic function using complementary log-log (cloglog) regression. Moreover, the regressions will be replicated for specific cohorts of adopters (early vs. late) and for adopters belonging to different clusters. The robustness of these results will be checked by performing the estimation using a logit regression. The next steps will be to perform a discrete semi-parametric estimation, and finally to perform continuous estimations (both semi-parametric and parametric).

8.3.1. Discrete parametric hazard function

Table 8.3 reports the coefficients and their significance for the discrete parametric hazard functions using cloglog regression. The first step in the analysis is represented by model (1), a basic model including only control variables and the epidemic effect. Regarding the controls, GENDER, PREV_PLAY and DOM_SP_INNOV show positive and significant coefficients higher than one. This means that being male, having adopted an earlier portable music player and being innovative in the specific domain of consumer electronics have a positive impact on the probability of adopting. Computer skills and level of use, which showed a correspondence with the timing of adoption in previous analysis, are not significant. In addition, the dummies by geographic area are significant.

Table 8.3 Estimation of the discrete parametric hazard functions (cloglog)

	(1)	*(2)*	*(3)*	*(4)*	*(5)*
GENDER	**0.228*****	0.131	**0.181****	**0.181****	**0.176****
	[0.0654]	[0.0837]	[0.0840]	[0.0863]	[0.0851]
PREV_PLAY	**0.230****	0.179	0.179	**0.419*****	**0.388*****
	[0.114]	[0.141]	[0.144]	[0.150]	[0.149]
COMP_SKILLS	0.0429	0.0459	0.0589	0.00807	0.0145
	[0.0386]	[0.0479]	[0.0481]	[0.0508]	[0.0508]
COMP_USE	0.0274	0.00191	-0.0140	-0.0176	-0.0181
	[0.0329]	[0.0424]	[0.0429]	[0.0446]	[0.0447]
INNOV	0.00567	0.0207	0.0326	-0.0364	-0.0367
	[0.0312]	[0.0387]	[0.0401]	[0.0454]	[0.0452]
DOM_SP_INNOV	**0.192*****	**0.211*****	**0.198*****	**0.226*****	**0.214*****
	[0.0345]	[0.0430]	[0.0447]	[0.0478]	[0.0481]
UK	**0.424*****	**0.508*****	**0.639*****	**0.982*****	**0.910*****
	[0.135]	[0.157]	[0.159]	[0.172]	[0.172]
EU_NORTH	**0.491*****	**0.521*****	**0.589*****	**0.650*****	**0.646*****
	[0.114]	[0.132]	[0.135]	[0.136]	[0.135]
EU_SOUTH	**0.283****	**0.402*****	**0.465*****	**0.964*****	**0.882*****
	[0.115]	[0.136]	[0.137]	[0.149]	[0.152]
LN_T	**1.705*****	**1.776*****	**2.041*****	**2.099*****	**2.155*****
	[0.0910]	[0.115]	[0.125]	[0.118]	[0.122]
LN_INCOME		**0.105*****	**0.108****	**0.142*****	**0.129*****
		[0.0404]	[0.0422]	[0.0444]	[0.0446]
GB_MUSIC		**0.123*****	**0.137*****	**0.122*****	**0.106*****
		[0.0383]	[0.0389]	[0.0403]	[0.0405]
EXP_STORAGE			**-0.0206*****	**-0.0212*****	**-0.0197*****
			[0.00648]	[0.00519]	[0.00487]
EXP_WEIGHT			**0.0788****	**0.0922*****	**0.0846*****
			[0.0373]	[0.0307]	[0.0295]
EXP_PRICES			**0.494*****	**0.549*****	**0.593*****
			[0.143]	[0.146]	[0.150]
CUMUL				**-0.114*****	**-0.102*****
				[0.0166]	[0.0167]
NETWORK				**-0.114****	**-0.128*****
				[0.0482]	[0.0483]
IMITATION				0.0502	0.0520
				[0.0507]	[0.0511]
INFO_CASC				-0.0601	-0.0538
				[0.0394]	[0.0393]
ORDER					**0.0510*****
					[0.0150]
CONSTANT	-5.880***	-6.991***	-7.564***	-7.420***	-7.481***
	[0.252]	[0.501]	[0.545]	[0.576]	[0.575]
Observations	9,767	6,282	6,277	6,277	6,277
Pos. outcomes	1102	715	710	710	710
Log likelihood	-2969	-1902	-1832	-1785	-1779
Chi-square	416.2	302.6	341.0	637.7	615.7
Prob Chi2	0	0	0	0	0

*Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1*

The reference group for the analysis is Japan, which is the country in the sample in which the adoption took place slightly later than in the other surveyed countries.

However, the most important variable in this particular specification is time elapsed, expressed as following a logarithmic trend. The coefficient is positive, significant at .01 level and also quite high. This indicates that the hazard increases over time, suggesting the existence of an epidemic effect.

In the next steps it will be checked whether this result holds when other variables and effects are added. The second specification, model (2), includes the two variables regarding rank effects. Both LN_INCOME and GB_MUSIC are significant and positive, indicating that the probability of adopting is affected by how income and quantity of music are distributed among adopters. The results regarding income were expected, since many rank models regarding consumer products have used income as a ranking variable. The findings related to GB_MUSIC are specific to the context of the analysis. The results indicate that those users who have more gigabytes of music have a higher propensity to adopt a DAP. The epidemic effect also holds in the second regression.

Model (3) includes three variables regarding users' expectations on the supply-side. All variables are significant. EXP_STORAGE has a negative impact on the hazard, and this seems to be quite reasonable, meaning that an expected increase in the average storage space of the players launched in the future has the effect of delaying adoption. In contrast, EXP_WEIGHT and EXP_PRICES show positive coefficients. This indicates that an expected future decrease in prices or in the average size of players also have the effect of postponing adoption. Both effects tested in models (1) and (2) are still significant and have similar coefficients.

Model (4) captures stock effects. The first result is that the coefficient of variable CUMUL is negative. This seems to indicate that the negative stock effect pictured in several stock models is in place. In this case, the effect can be interpreted as a snob effect, which leads potential adopters to refuse the adoption of a product that too many people have already adopted.

This specification also includes three other stock variables, NETWORK, IMITATION and INFO_CASC. The variable NETWORK is significant and decreases the hazard. This could be interpreted in a similar way as the users' expectations, as it seems that those adopters who believe that network effects are important are willing to postpone adoption in order to wait until a sufficient number of people have adopted and they are therefore able to benefit from these direct or indirect network effects. Finally, the non-significance of IMITATION and INFO_CASC seem to confirm the snob effect. In addition, in this case the coefficients relative to the previous effects are still significant.

In model (5) order effect is added, summarised by the variable ORDER. The coefficient is significant and higher than one. This means that potential adopters have a first-mover advantage, accelerating their adoption of a DAP if they expect that many other people will adopt in the near future. It is interesting to point out that besides GENDER in regression (2) and PREV_PLAY in regressions (2) and (3), none of the variables lose significance when adding any of the further effects. The regression method used in all the estimations presented is complementary log-log. However, other types of regression, such as logit, could have been used. Table B.3 in the appendices presents the results of the final estimation, model (5), using logit regression, indicating that all the coefficients have the same degree of significance, and are also quite similar to those estimated through cloglog. This is a first test of the robustness of the results.

The analysis carried out so far has given quite successful results, indicating that all the models taken into consideration have a certain effect on the probability of adopting a DAP, both taken singularly or used together in the same estimation. At this point, all models have some measure of truth. However, it would be interesting to prioritise the relative power of these models, providing some insights into how these models perform on specific sub-groups of adopters. In particular, two different analyses will be performed. The first will replicate the estimation, including all the potential effects, by cohorts of adoption, by carrying out two separate regressions for early and late adopters. The second analysis will do the same on the three clusters of users presented in Chapter 6.

The first analysis considers different cohorts of adopters regarding their time of adoption. In particular, for simplicity, only two groups of adopters are considered. Considering the distribution of adopters by timing of adoption, early adopters are defined as those users that are in the first quartile, while late adopters are those users lying in one of the remaining quartiles.

Table 8.4 reports the coefficients of the regressions performed for early and late adopters by using the same variables as in model (5) in the previous table. The first impression is that the factors associated with an early adoption are different from those related to a late adoption. In particular, regarding the rank variables, both LN_INCOME and GB_MUSIC lose significance for early adopters, while only GB_MUSIC becomes significant in the case of late adopters. Another consideration regards the epidemic effect, since the coefficient of the variable LN_T is higher for late adopters than for early adopters. This seems to give support to the basic idea behind epidemic models of diffusion: that the increase in the probability of adoption related to time elapsing is much stronger in the later stages of the diffusion process than at the beginning. Concerning user expectations, only EXP_STORAGE is significant for both groups of adopters, while EXP_PRICES loses significance. EXP_WEIGHT has an impact only on the hazard of early adopters, perhaps because in the second period of time, DAPs were already sufficiently miniaturised.

Table 8.4 Estimation of the discrete parametric hazard functions split by cohorts of adopters

	Early adopters		*Late adopters*	
GENDER	0.180	[0.212]	0.154	[0.100]
PREV_PLAY	0.602	[0.395]	0.109	[0.174]
COMP_SKILLS	0.00534	[0.115]	0.0827	[0.0626]
COMP_USE	0.00121	[0.118]	-0.0434	[0.0525]
INNOV	-0.132	[0.142]	-0.0119	[0.0532]
DOM_SP_INNOV	0.122	[0.107]	**0.222*****	[0.0548]
UK	-0.194	[0.555]	**0.613*****	[0.192]
EU_NORTH	0.595	[0.440]	**0.654*****	[0.153]
EU_SOUTH	0.400	[0.478]	0.231	[0.189]
LN_T	**2.631*****	[0.265]	**4.632*****	[0.165]
LN_INCOME	-0.00609	[0.125]	0.0604	[0.0515]
GB_MUSIC	0.0116	[0.100]	**0.137*****	[0.0455]
EXP_STORAGE	**-0.115*****	[0.0274]	**-0.0153*****	[0.00313]
EXP_WEIGHT	**0.618*****	[0.116]	0.0366	[0.0226]
EXP_PRICES	-0.494	[1.025]	0.133	[0.146]
CUMUL	**-0.432*****	[0.0714]	**0.0539*****	[0.0157]
NETWORK	**-0.245****	[0.103]	**-0.163*****	[0.0563]
IMITATION	0.0874	[0.144]	-0.0435	[0.0619]
INFO_CASC	0.0288	[0.117]	-0.0409	[0.0485]
ORDER	0.0497	[0.0724]	**0.103*****	[0.0150]
CONSTANT	-4.090***	[1.442]	-13.50***	[0.702]
Observations	699		5,578	
Pos. outcomes	171		539	
Log likelihood	-267.9		-1151	
Chi-square	208.3		880.8	
Prob Chi2	0		0	

*Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1*

The results regarding stock effects are quite interesting. The coefficient of the variable CUMUL is significant for both groups of adopters; however, with an opposite sign. In particular, the snob effect seems to be present only during the first phases of the diffusion period. In contrast, the stock of previous adopters has a positive impact in the case of late adopters. This seems to confirm, again, that there is an epidemic type of effect occurring that increases the probability of adopting as time elapses and as more potential adopters adopt the innovation. The last result regards the order effect, which is present only for late adopters. This effect adds and reinforces the positive epidemic and stock effects for late adopters. As a matter of fact, it seems that late adopters try to avoid being the last ones to adopt. For this reason, instead of a first-mover advantage, we can talk about a sort of *last-mover disadvantage*.

The second kind of analysis used in order to prioritise the potential effects influencing the probability of adopting a DAP is performed by splitting the sample by clusters of adopters. The three clusters of adopters were obtained in Chapter 6. In brief, cluster 3 contains a majority of late adopters, quite sceptical about DAPs and consumer electronics in general. Cluster 2 contains the earliest adopters in the sample, a group of adopters characterised by being wealthy and extroverted, and who take into serious consideration other people's opinions on their decisions. Finally, cluster 1 also contains a majority of early adopters; these people are highly skilled and frequent computer users, less influenced by other people and with a lower income than cluster 2.

Table 8.5 shows the results of the hazard function estimated separately for each cluster of adopters. The first result regards the epidemic effect. Cluster 3 has the highest hazard ratio for the variable LN_T, followed by cluster 1 and cluster 2. Now, considering that cluster 3 is mostly made up of late adopters, and cluster 2 by the earliest adopters, it is possible to conclude that the hazard related to time elapsing seems to be much higher for late adopters than for early adopters. Moreover, regarding the rank effects, both income and GB of music are significant only for cluster 1. Other differences regard the users' expectations of the supply-side. Both EXP_STORAGE and EXP_PRICES are significant for all clusters, while EXP_WEIGHT does not have any impact in the case of cluster 3.

A further consideration regards the stock effects. First of all, the variable CUMUL is significant and has a negative sign for all the clusters. However, its effect is much stronger for cluster 2, confirming the fact that these adopters are strongly influenced by others. Moreover, cluster 1 shows a negative effect for NETWORK, and, more interestingly, the variable IMITATION is significant and positive for cluster 2, confirming that the label of *early imitators* given to this cluster in Chapter 6 is appropriate. The variable ORDER gives the same effect presented in Table 8.4, and it is significant for cluster 3, which confirms the last-mover disadvantage for cluster 3 (late adopters). Both the differences by clusters of adopters and early vs. late adopters are corroborated by a Chow-type structural stability test that confirms that the differences between the coefficients of the regressions performed on the sub-samples of adopters are statistically significant at .05 level.

Table 8.5 Estimation of the discrete parametric hazard functions split by cluster of adopters

	Cluster 1		*Cluster 2*		*Cluster 3*	
GENDER	-0.00316	[0.147]	0.0681	[0.193]	**0.328****	[0.142]
PREV_PLAY	0.186	[0.241]	0.262	[0.326]	**0.546****	[0.254]
COMP_SKILLS	0.0422	[0.0937]	0.145	[0.128]	-0.0796	[0.101]
COMP_USE	-0.00335	[0.0810]	0.00525	[0.118]	0.0571	[0.0738]
INNOV	0.0236	[0.0825]	-0.0577	[0.0950]	-0.106	[0.0867]
DOM_SP_INNOV	**0.224*****	[0.0752]	0.137	[0.124]	**0.173***	[0.0966]
UK	**0.589****	[0.293]	**1.495*****	[0.444]	**1.216*****	[0.284]
EU_NORTH	**0.325**	[0.259]	**1.021*****	[0.385]	**0.761*****	[0.211]
EU_SOUTH	**0.538***	[0.280]	**1.441*****	[0.391]	**0.955*****	[0.261]
LN_T	**2.292*****	[0.199]	**1.814*****	[0.195]	**2.928*****	[0.290]
LN_INCOME	**0.151***	[0.0821]	0.0670	[0.124]	0.105	[0.0768]
GB_MUSIC	**0.166***	[0.0974]	0.0168	[0.106]	0.0453	[0.0888]
EXP_STORAGE	**-0.0873*****	[0.0311]	**-0.0209*****	[0.00579]	**-0.0155*****	[0.0054]
EXP_WEIGHT	**0.409*****	[0.135]	**0.0789****	[0.0361]	0.0489	[0.0422]
EXP_PRICES	**0.852*****	[0.267]	**0.933****	[0.435]	**0.565****	[0.242]
CUMUL	**-0.0746*****	[0.0246]	**-0.201*****	[0.0382]	**-0.0657***	[0.0337]
NETWORK	**-0.171***	[0.100]	-0.151	[0.0993]	-0.0176	[0.0862]
IMITATION	-0.0539	[0.0862]	**0.200***	[0.115]	0.0572	[0.0900]
INFO_CASC	-0.0857	[0.0629]	0.0101	[0.0857]	-0.0115	[0.0749]
ORDER	0.0341	[0.0276]	-0.0289	[0.0357]	**0.0844*****	[0.0256]
CONSTANT	-8.034***	[0.997]	-5.167***	[1.474]	-9.623***	[1.206]
Observations	2,251		1,397		2,578	
Pos. outcomes	265		179		260	
Log likelihood	-645.3		-428.3		-643.0	
Chi-square	237.2		180.0		192.2	
Prob Chi2	0		0		0	

*Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1*

So far, the estimations have assumed that time follows a logarithmic function, with the result that the hazard increases over time. However, the use of a parametric function depends on the speculation that an epidemic effect exists and that the diffusion of an innovation generally follows a curve that grows until the market is saturated. The next step in the duration analysis is to consider the case of the semi-parametric hazard function. In other words, in this model no function is given to time; on the contrary, time is considered as a series of dummy variables from D2 to D15 (D16 is automatically dropped due to an overly small number of observations). Table 8.6 shows that most of the time dummies are significant and that the coefficients of these variables increase over time, indicating that the hypothesis of an increasing hazard over time (epidemic effect) is confirmed, even in the case of a semi-parametric hazard function. Moreover, the sign and the significance of the coefficients largely confirm the previous results, indicating a good robustness of the estimations.

Table 8.6 Estimation of the discrete semi-parametric hazard function

	Cloglog with non-parametric baseline				
GENDER	0.205**	[0.0893]	D2	-0.720**	[0.337]
PREV_PLAY	0.472***	[0.160]	D3	-0.199	[0.290]
COMP_SKILLS	0.0342	[0.0525]	D4	0.0431	[0.275]
COMP_USE	-0.0360	[0.0463]	D5	0.704***	[0.241]
INNOV	-0.000926	[0.0488]	D6	1.152***	[0.225]
DOM_SP_INNOV	0.259***	[0.0510]	D7	1.805***	[0.209]
UK	1.023***	[0.183]	D8	2.107***	[0.208]
EU_NORTH	0.774***	[0.145]	D9	2.167***	[0.215]
EU_SOUTH	0.926***	[0.163]	D10	2.584***	[0.213]
LN_INCOME	0.137***	[0.0461]	D11	3.021***	[0.217]
GB_MUSIC	0.142***	[0.0418]	D12	3.373***	[0.231]
EXP_STORAGE	-0.0510***	[0.0129]	D13	3.430***	[0.242]
EXP_WEIGHT	0.227***	[0.0568]	D14	4.284***	[0.274]
EXP_PRICES	0.975***	[0.165]	D15	4.266***	[0.355]
CUMUL	-0.0794***	[0.0164]			
NETWORK	-0.140***	[0.0497]			
IMITATION	0.0228	[0.0532]	Observations	6,257	
INFO_CASC	-0.0562	[0.0410]	Pos. outcomes	690	
ORDER	0.0636***	[0.0159]	Log likelihood	-1658	
			Chi-square	1105	
Constant	-5.746***	[0.558]	Prob Chi2	0	

*Variable D16 has not been included by the system because of the overly small number of observations. Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1*

8.3.2. Continuous (parametric and semi-parametric) hazard functions

The last step in the duration analysis is to carry out the estimations of the hazard ratios by using a continuous type of function. First of all, the estimation of the continuous hazard functions will be a robustness and sensitivity test of the previous results. Moreover, the parametric continuous estimation will allow the trend of the hazard function to be graphically plotted over time.

Table 8.7 reports the coefficients of the semi-parametric estimation using Cox's hazard function, and of the parametric estimation using Weibull's distribution. In both cases the coefficients are expressed in terms of hazard ratios. A hazard ratio higher than one indicates a positive influence on the probability of adoption; in contrast, a hazard ratio lower than one highlight a negative effect. Both models show coefficients very similar to those in Table 8.3, with all the variables having the same significance and sign, indicating a good robustness of the results. In Cox models, the assumption is that the characteristics of the adopter proportionally shift the baseline hazard. However, the increasing or decreasing trend of the Weibull hazard over time depends on the estimation of the parameter *p*.

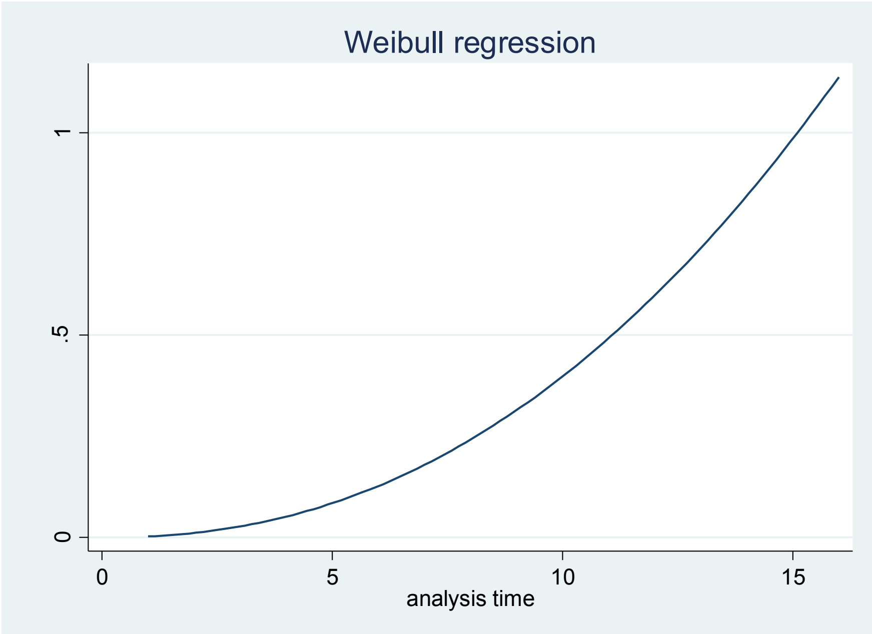
Table 8.7 Estimation of the continuous hazard functions (parametric and semi-parametric)

	Semi-parametric Cox hazard function		***Parametric hazard functions with Weibull distribution***	
PREV_PLAY	**1.216****	[0.0962]	**1.191****	[0.0939]
COMP_SKILLS	**1.426****	[0.208]	**1.471*****	[0.215]
COMP_USE	1.022	[0.0431]	1.014	[0.0435]
INNOV	0.973	[0.0363]	0.982	[0.0367]
DOM_SP_INNOV	0.966	[0.0405]	0.965	[0.0399]
UK	**1.248*****	[0.0541]	**1.238*****	[0.0535]
EU_NORTH	**2.543*****	[0.411]	**2.467*****	[0.397]
EU_SOUTH	**1.961*****	[0.242]	**1.901*****	[0.215]
LN_T	**2.374*****	[0.321]	**2.403*****	[0.314]
LN_INCOME	**1.137*****	[0.0468]	**1.136*****	[0.0475]
GB_MUSIC	**1.127*****	[0.0425]	**1.111*****	[0.0423]
EXP_STORAGE	**0.979*****	[0.00305]	**0.981*****	[0.00367]
EXP_WEIGHT	**1.090*****	[0.0266]	**1.088*****	[0.0300]
EXP_PRICES	**2.158*****	[0.368]	**1.805*****	[0.282]
CUMUL	**0.921*****	[0.0141]	**0.904*****	[0.0156]
NETWORK	**0.881*****	[0.0395]	**0.881*****	[0.0395]
IMITATION	1.034	[0.0506]	1.053	[0.0527]
INFO_CASC	0.951	[0.0376]	0.947	[0.0381]
ORDER	**1.059*****	[0.0130]	**1.052*****	[0.0135]
CONSTANT			0.000182***	[0.000101]
p			3.149	
LN(p)=0 (sig.)			0.000	
Observations	710		710	710
Log likelihood	.		.	.
Chi-square	-3905		-320.6	-320.6
Prob Chi2	278.4		250.0	250.0
	0		0	0

*Note: Hazard ratios are reported. Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1*

Table 8.7 provides an estimation of parameter *p*, which is higher than one, indicating that the hazard increases over time. This estimation is corroborated by a test for *LN(p)=0* (meaning *p=1*) automatically performed by the system. This result can be taken as further evidence in support of the presence of an epidemic effect. This result is also displayed in Figure 8.1, which reports the hazard curve calculated for the Weibull hazard function and shows that the hazard grows at an increasing rate as time elapses.

Figure 8.1 Hazard curve in the case of Weibull distributions



8.4. Conclusions

This chapter has performed duration analysis on the data regarding the diffusion of DAPs. Both datasets on demand and supply have been used, in order to estimate different hazard functions, and hence the conditional probability of adopting at time *t* without having adopted before. Five classes of models of diffusion have been tested. The first one is the epidemic effect, which is represented by the positive coefficient of the variable logarithmic function of time, or by the plot of the Weibull hazard function over time. The second is a rank effect, due to income and to the number of songs in digital format owned by the respondents. Both variables increase the probability of adopting a DAP. The third model regards the expectations formulated by potential adopters, which can be about product improvements or product prices. The results of the regression show that every kind of expectation has an effect on the probability of adoption. In particular, expecting an increase in storage space, a decrease in a player's weight or a price reduction will have the effect of delaying adoption. The fourth model is a stock effect, which has been interpreted as a sort of snob effect, demonstrated by the coefficient of CUMUL, which is negative, and by the non-significance of the variable IMITATION. Moreover, another result linked to the stock of previous adopters regards the presence of network effects, which seems to indicate that those users who perceive this kind of effect as relevant are willing to wait until a sufficient number of people have purchased a DAP before adopting. The last effect is an order effect, represented by the variable ORDER, which has a positive coefficient, indicating that the expectation of a rise in the number of adopters in the future positively influences the adoption decision. Finally, other control variables have a significant impact, for instance country-specific effects are in place. The highest hazard is in the UK, followed by South Europe and Continental Europe. Japanese consumers are the most recent adopters of DAPs in the sample. The results seem to confirm that all the potential effects taken into consideration (epidemic, rank, expectations, stock and order effects) have an impact on the adoption of a DAP. The robustness of the results has been tested by using both a semi-parametric approach and a continuous-type of analysis. These further tests indicate that all the coefficients, using all the possible specifications are very similar regardless of the type of regression, demonstrating an excellent goodness-of-fit of the data to the models of diffusion presented.

At this stage of the analysis, all the models seem to have a certain level of truth. A way to prioritise them has been to restrict the regression to specific periods of time or to certain groups of adopters. The results of this exercise gave a much more differentiated view on the diffusion of DAPs. In synthesis, during the first stages of the diffusion process not all the potential adopters seem to be willing to adopt a DAP. In particular, only two groups of users started to consider this possibility (clusters 1 and 2). However, these two groups were stimulated by two different sorts of motivations. Adopters belonging to cluster 1 were mostly influenced by personal factors such as budget constraints or by the quantity of music owned, while adopters in cluster 2, more extroverted and outward-looking, were mostly influenced by the behaviour of others, with imitation and stock effects taking place. Moreover, an epidemic effect starts to positively influence adoption at an increasing rate. At the same time, these positive influences on the probability of adoption are mitigated by other factors, such as snob effects, or expectations regarding the supply-side, which make users postpone adoption in order to wait for product improvements or price reductions. The situation changes in the later stages of the diffusion process. During this period a critical number of potential users have already adopted a DAP, significantly enhancing the power of the epidemic effect, which becomes predominant. This also makes less innovative and more sceptical potential adopters (cluster 3) willing to adopt, and creates a sort of last-mover disadvantage, by which late adopters feel pressed to adopt in order not to be the last ones to purchase the product. Moreover, at this stage of diffusion, the average DAP improved a lot, and its price considerably declined; for these reasons, the users' expectations are still significant, but have a less relevant impact.

The analyses carried out in this chapter make it possible to draw three kinds of conclusions. The first is that diffusion of consumer products is a complex issue. Several factors can influence the probability of adopting a product like a DAP; some of them are related to the heterogeneity of the potential adopters, others are about the evolution of the product from the supply-side, and finally other factors are originated by the diffusion process itself. All these factors have been considered separately by many diffusion studies. However, mixing the effects coming from these models demonstrates that none of them, alone, can provide an adequate description of the patterns of adoption and diffusion of a consumer product such as a DAP. Moreover, the analysis performed on sub-groups of adopters or on sub-periods of time has revealed that these factors have a different relevance depending on the type of potential adopters or the specific stage of the diffusion process. These considerations may be relevant for policy. In light of this complexity in the set of factors affecting the diffusion of an innovation, a policy aiming at promoting or discouraging the diffusion of a consumer innovation should not rely on a single instrument, but rather on a combination of instruments. First of all, these instruments should be tailored to the specific characteristics of the adopters, the innovation and the stage of diffusion process. Secondly, the supply-side should be considered by policy-makers, for instance by promoting standardisation or by implementing anti-trust measures. Moreover, a diffusion policy should also consider the specificities of the clusters of users to which they are directed, since some instruments may be ineffective on some groups of potential adopters.

The second conclusion regards the role of herd behaviour in influencing the adoption of DAPs. Many mass media have described the DAP sector as one of the most successful consumer electronic markets of the last decade, portraying it as a typical example of a fad. The analysis of the data on the diffusion of DAPs has demonstrated that some social factors have definitely influenced potential adopters' behaviour. However, these factors do not seem to fall into the typical definition of fad – a process of intense and widely-shared enthusiasm about a new product – since the analysis of the data has provided a much more nuanced picture of the history of the sector. The first consideration is that, instead of imitation, one of the strongest forces influencing adoption is an epidemic effect, which is related to the flow of information about the innovation between adopters and potential adopters. The only sort of imitative or herd behaviour has been retrieved from a single, specific group of adopters. These adopters are quite innovative and high-income people, for whom the benefits of adoption are mostly related to the possibility of sharing and revealing their behaviour to others. In contrast, another cluster of adopters did not seem to be influenced at all by any sort of fad or imitative behaviour. This is the case of a group of rational and innovative users, who mostly rely on active sources of information in evaluating a DAP. Finally, the final consideration regards less innovative people, those who are typically considered as being more influenced by imitative behaviour and who could more easily fall into a fad. However, these users seem more influenced by epidemic effects than by other social factors. The only factor that could resemble a fad is an order effect, which urges users to adopt when they realise that they may be the last ones to adopt. For these reasons, describing the DAP sector as simply a fad appears too simplistic.

The final conclusion is that file sharing is definitively a relevant phenomenon that has significantly influenced the diffusion of DAPs. Over recent years, the diffusion of more powerful computers and of broadband connections has made it possible for computer users to accumulate a great amount of music in digital format, thanks to file sharing and downloading over the Internet. At the same time, both the capacity of portable hard drives and flash memories has dramatically increased, making the average DAP available in the market more and more capable in terms of storage space. Thanks to the combination of these two effects, DAPs have emerged as an excellent solution for storing this great amount of music and playing it in any place.

This consideration suggests another kind of implication not necessarily related to the diffusion of DAPs. Computer piracy has always been a problem for software houses; however, the diffusion of broadband Internet has dramatically enhanced the possibilities of exchanging files (music, software, movies, etc.) with other users. At the same time, some of the institutions that have greatly fostered the adoption and diffusion of computers and broadband connections have been the European Union and national governments, which have promoted several policy measures in this direction. In this sense, Internet piracy can be considered an unfavourable consequence of the diffusion of broadband Internet, against which, in turn, governments have reacted by promoting other policies to slow down its diffusion. Therefore, our findings indicate that the adoption of ICT can generate both positive externalities – in the form of learning processes that make users more aware and more willing to adopt further innovations – and less positive externalities – in the form of extensive Internet file sharing, which severely harms some related industries. A policy implication drawn from these considerations seems to suggest the measuring of the effects of diffusion policies of ICT-based consumer products and services using a broader perspective, which also considers post-adoption behaviour and the possible externalities arising from the adoption of a new technology.

CHAPTER 9. CONCLUSIONS

This thesis has aimed at studying the adoption and diffusion of a consumer technology in the context of the digital audio player (DAP) market. The literature on the diffusion of innovations is extensive and thorough. This makes it hard to find large gaps to study. However, the literature review summarised in Chapter 2 highlighted the existence of three aspects deserving some further research. The first regards the demand-side, the second is about the interaction between supply and demand, and the last regards the comparison of different models of diffusion. Chapter 3 presented the history of the DAP sector, beginning with the precursors of DAPs, focusing on the advent of digital music, followed by digital audio compression, and also including some issues such as online file sharing and new patterns of music consumption and distribution. As explained in Chapter 4, each of the three gaps in the literature represents a research question, which have been applied to the case of the DAP sector by using the two sets of data specifically collected for this purpose. The collection of these two original datasets was explained in Chapter 5. The first dataset is about the demand-side, consisting of a questionnaire submitted to a sample of potential adopters from eight European countries and Japan. The second regards the supply-side and includes the technical characteristics, together with the launch date and price, of a sample of DAPs commercialised in the period 2001-2009. Each of the three research questions has been addressed by a specific empirical chapter (Chapters 6, 7 and 8), using different quantitative statistical techniques.

This last chapter regards the final conclusions of this thesis, and it is organised as follows. The first section (9.1) provides some general concluding remarks about the research design, methodology and the choice of the context of the analysis. The second section (9.2) specifically addresses the research questions, summing up the results and providing an answer to each of them. The third section (9.3) summarises the overall contributions of the thesis, at theoretical and empirical levels. The fourth section (9.4) briefly presents some policy implications, while the final section (9.5) provides some potential further research opportunities and concludes this thesis.

9.1. Preliminary remarks

Before answering the research questions, a few considerations should be made about this thesis' methodology. The whole thesis has been based on two original datasets, and in particular on the results of a survey based on the submission of a questionnaire. Due to the lack of available data on the adoption of DAPs, and on the characteristics of their adopters, the use of a questionnaire was unavoidable in order to answer the research questions. However, this choice was risky, since the submission of a questionnaire does not necessarily guarantee that the data collected are quantitatively (in terms of the response rate) and qualitatively adequate to fulfil the academic standards required by a DPhil, especially in terms of data validation, robustness of analysis and generalisability of the results. We believe that, in light of these considerations, the data collection for this thesis has been particularly successful. For this reason, the first conclusion of this work should regard the thesis' methodology and research design.

First of all, the efforts put into the questionnaire design and pilot gave very satisfactory results. Nearly all the measures meant to be extracted from the questionnaire have been successfully validated (aside from a couple of factors, such as relative advantage and compatibility, which showed poor reliability scores), and most of these measures seemed to have significant effects on the timing of adoption. This also benefitted from the decision to pilot the questionnaire on a relatively large sample (173 respondents), which allowed for the development of a sort of *mock-up* dataset to test validation and analysis. Moreover, a study on the adoption of an innovation necessarily needs to include a variable related to time. In this case the questionnaire was also successful, by *transforming* a cross-section dataset into a sort of time-series based on the timing of adoption. This allowed the matching of two very different datasets: one about the adopters and one about the products, thanks to the variables regarding timing of adoption and launch time. In addition to this, the the questionnaire contained a few sections not specifically designed to answer the research questions. This is the case, for instance, regarding the sources of information and the role of multi-adopters. In all cases, an exploratory analysis of these results gave very interesting and perhaps unexpected insights.

The second aspect regards the sampling strategy. One of the major potential limitations of this thesis is that the most important source of data (the survey of potential adopters) is based on an opportunistic sample of university students. This raises questions both on the representativeness of this sample and on the generalisability of the results. The methodological chapter of this thesis put forward some *ex ante* considerations in support of the use of students as respondents. First of all, despite several caveats, university students are often used in consumer research. Secondly, the thesis mainly meant to test different theories or approaches to diffusion on the data collected, rather than making statistical inferences and then expanding the results of the analysis to the whole population of adopters, and this makes a student survey fully acceptable. In addition to this, having collected and analysed the data, we can *ex post* conclude that the use of university students as respondents has been a particularly suitable choice for the kind of research carried out in this thesis. First of all, the data collection procedure ensured an extremely high response rate, and also a high level of accuracy, with only a limited amount of non-valid questionnaires, and a final rate of valid questionnaires of 91.7%. Secondly, a potentially problematic issue regarding the diffusion of DAPs was about the sampling frame; in other words, where to retrieve a sufficient number of DAP adopters. University students appeared to be an ideal population, since 76.9% of the students reported having a DAP, and 56.9% of them even had more than one. In addition, considering that the sample of adopters did not pretend to be representative of the population of DAP adopters, two further results should be mentioned. First of all, the vast majority of the variables collected through the questionnaire showed quite a wide variability, indicating that the respondents in the sample were not too homogenous despite their similar age and occupation. Moreover, and perhaps more interestingly, the cumulative number of adopters in the sample plotted over time follows an s-shaped curve (Figure 6.5). This result is particularly important because, even though the sample did not pretend to be representative of the population, the main dependent variable of the analysis (timing of adoption) is distributed as predicted by most of the empirical and theoretical literature on diffusion.

The last preliminary consideration concerns the context of the research, the DAP market. This sector has proven to be particularly suitable to be the context of a study on the diffusion of innovations, because it is a successful, recent and mature technology. First of all, DAPs have been very successful consumer electronic products over recent years. This made it easier to find a sufficient number of adopters to survey, but also helped them to rapidly identify the object of the research. Secondly, the first DAP was launched at the end of the 1990s, and the fact that the technology is so recent helped respondents to remember information about their first adoption, such as the timing of the purchase. Finally, despite the fact that this sector has only been active for slightly more than a decade, the results of the questionnaire indicate that the adoption rate is already declining over the most recent periods (confirmed by the s-shaped curve diffusion curve). Moreover, the history of the sector also indicates that the sector is already undergoing some changes that will definitely transform the sector in the near future, for example with DAPs transforming into more sophisticated devices, and with an increasing number of consumers using other products, such as smart phones, to listen to their music online. This means that we can consider the DAP sector as a mature market, which has allowed the capture of different phases of the diffusion process.

To conclude, the satisfactory results given by the research design, sampling strategy and choice of the context of the analysis seem to suggest that the conclusions drawn in this thesis should not be considered limited to the sample of respondents and to the case of DAPS, but could be extended to other contexts. First of all, some of the theoretical and empirical conclusions, such as those regarding the classification of adopters, and the simultaneous test of several models of innovations are abstract from the specific context of application, and they are specifically intended to impact on the literature on the diffusion of consumer innovations. On the other hand, other results are more specific to the case of DAPs, such as the role of the supply-side, and the factors affecting the timing of adoption. However, also in this case, the empirical analysis of the DAP case could be generalised to other new electronic consumer products, such as tablets or smart phones. In particular, the results regarding DAPs could be even more easily extendable to other categories of products that are both portable and that have emerged following the digitalisation of previously analogue media; this is the case, for instance, for digital cameras, camcorders, and, more recently, e-book readers.

9.2. Answering the research questions

In order to investigate the adoption and diffusion of DAPs, three research questions have been raised, the first focusing on the demand-side, the second on the supply-side and the last on the overall diffusion process. The following sub-sections will answer each of them.

9.2.1. Question 1: demand-side

In which ways do potential adopters differ, and what factors influence the timing of their adoption?

Chapter 6 was mainly dedicated to answering this research question. A two-step cluster analysis was carried out in order to classify adopters of DAPs. The cluster analysis was based on a set of variables including indicators of socio-economic status, digital literacy and the use of consumer electronics, but excluding any variable specifically related to the timing of the adoption of a DAP. The results of the procedure were three clusters of adopters. The first includes a group of highly-skilled computer and Internet users who take considered and deliberate decisions about the adoption of a DAP. The second cluster consists of consumer technology enthusiasts and high-income people, who like to experiment and adopt multiple electronic consumer products (such as DAPs) before others. The last cluster includes people who are generally more sceptical about new innovative products and who adopted a DAP only after seeing many other people doing so. These three groups show different profiles for a wide range of indicators collected through the questionnaire.

On the other side, the literature on innovation diffusion has considered differences among adopters. First of all, many works have divided users depending on the timing of their adoption into early and late adopters. This is the case, for instance, of the Rogers tradition (2003), in which adopters are divided into five groups (innovators, early adopters, early majority, late majority and laggards) depending on the timing of their adoption. These groups are then characterised by having very different profiles, usually considering early adopters as more experimental, innovative and forward-looking people and late adopters as more cautious, sceptical and prone to imitative behaviour. Similarly, other scholars, such as those referring to the seminal work of Bass (1969) also divide users according to the timing of their adoption, but they stress the role of different sources of information in influencing the adoption decision of these groups. For instance, early adopters seem to take a more deliberate decision based on advertising or other external sources, while late adopters are conditioned by imitation and word-of-mouth. In addition, in another variety of diffusion models, adoption time depends on the distribution of a specific variable (in many cases income) that directly influences the benefits from adoption (rank or probit models). In the case of consumer products, high-income people are assumed to adopt before others, while lower-income users adopt later, with the timing of adoption depending on circumstances such as a price decline.

The classification obtained in this thesis both confirms and expands the classifications presented in the literature review. First of all, a main division between early and late adopters is respected by the cluster analysis. Clusters 1 and 2 are early adopters, while cluster 3 represents the late adopters or laggards. Furthermore, the profile of late adopters more or less reflects the profile demonstrated by Rogers and Bass. However, the differences among early adopters shown in this thesis do not correspond to any representation of adopters in the models of diffusion reviewed. According to the results shown in Chapter 6, not all the early adopters in the sample resemble the literature's picture of them, e.g. they are more innovative, experimental, not so influenced by other people's behaviour, and more able to make independent decisions. In contrast, while cluster 2 is experimental and enthusiastic, they are also strongly influenced by others, while cluster 1 is innovative and independent but not experimental. In other words, the factors influencing adoption are not the same for the two groups of early adopters, and neither fits Rogers' profile of the very early adopter well.

At this point, two further considerations should be taken into account. The first is about the role of imitation. Being influenced by other people's behaviour has often been considered a prerogative of late adopters, who are sceptical and afraid to make independent decisions. According to our data, this is not the case; those who are most influenced by imitation include some of the early adopters, specifically the members of cluster 2. It seems that these people prefer to be the first ones to have the latest electronic gadget among their group of friends, having a sort of pre-emptive epidemic effect. This is confirmed by the results of Chapter 8, in which we find both a *snob effect*, a negative effect on the probability of adoption of a variable representing the stock of people who have already adopted, and an *order effect*, a positive effect accelerating the adoption of a DAP if an increase in the number of future adopters is expected.

A second consideration regards the sources of information. As explained in Section 6.1.4, the thesis studies the relative importance for adopters of a list of sources of information, including the two sources most often considered by the literature, i.e. internal sources (word-of-mouth), and external sources (advertising). An exploratory factor analysis carried out on this list of sources outputted a more detailed list of sources that includes both internal and external ones, but also previous experience and so-called active sources of information. In particular, this last category of sources is particularly important because it highlights the role of potential adopters as active seekers of relevant information rather than simply being passive recipients.

Having pointed out that the classification provided in this thesis both confirms and expands the classifications based on the timing of adoption, the case of the so-called rank or threshold models should also be considered. This is the case in which the differences between adopters are summarised by a single variable, on which distribution of the diffusion curve will depend. Regarding this classification of adopters, the results of this thesis suggest two kinds of considerations. First of all, the validity of these kinds of models to the case of DAPs has been tested in Chapter 8, with positive results. This means that we found rank effects affecting the timing of adoption.

However, aside from the traditional role of income (the variable put forward by most of the literature), another variable which is sector-specific always significantly influences the timing of adoption: the number of MP3 files owned by a potential adopter. This variable seems to have important effects on shaping the adoption decision, suggesting that having only one variable encompassing all the differences between adopters might be too simplistic, since some sector-specific factors should be considered. The second consideration questions the fact that these models seem to suggest that potential adopters with higher incomes and a large quantity of digital music should necessarily adopt earlier than others. The results of this thesis only partially confirm this speculation. It is true that early adopters (clusters 1 and 2) have on average a similar number of MP3 files and that this amount is significantly higher than for members of cluster 3, but the same is not the case for income. Cluster 1 is the group with the lowest average income. This seems to suggest that the effects of these neoclassical models are significant, but also that they might take effect *within* a cluster of adopters. This means that high-income users do not necessarily adopt earlier, but rather that higher-income users within each cluster of adopters do.

9.2.2. Question 2: Supply-side

How has the DAP sector evolved over time? Is there a relationship between the product's technical features and the perception of these features by adopters over time?

This research question was mainly addressed in Chapter 7. The main conclusion regarding the evolution over time is that the DAP sector has been very innovative and competitive. The first part of Chapter 7 analysed the evolution of the product from the point of view of its technical characteristics. The main results show that the product has significantly improved over time without resulting in a dominant product design. Product innovation has involved both core characteristics, such as product size, weight, memory size, etc. (vertical innovation), and adding new characteristics, such as FM radio, voice recording, touch screens, etc. (horizontal innovation). The analysis only considered measurable and verifiable characteristics, not including any subjective (such as aesthetics, design, etc.) or operational features (such as ease of use, ergonomics, etc.). However, based on the knowledge acquired about the history of the DAP sector, we can, although anecdotally, confirm that the products offered have also significantly improved in terms of these features. Together with product innovation, a great deal of product differentiation has also occurred. Product differentiation has been analytically taken into account by considering the coefficient of variations for each of the product characteristics. The main conclusion is that, aside from a few marginal extra features, the evolution of the DAP market did not converge towards a dominant architectural design, but instead yielded to a rather differentiated market. Over the last ten years, new product configurations or designs have been launched and have coevolved. In parallel with technical innovation and differentiation, another important phenomenon has occurred: price decline. This is confirmed by a hedonic price estimation carried out in the second part of Chapter 7, which indicated that even holding constant all the technical improvements in the sector, the average price of DAPs has constantly and even more significantly declined over time.

These three phenomena suggest some considerations about the competitive activity in the sector. Two sorts of competitive forces seem to be present: a hedonic competition and a price competition. On one side, firms have undertaken strong innovative efforts in order to launch more innovative and differentiated products, meeting the preferences of different kinds of market segments. On the other side, a price competition has taken place in the DAP sector in the last years. Firms, supported by the very remarkable success of DAPs and by an increasing adoption rate, have strived to offer cheaper products, even considering all the technical advances implemented.

However, the analysis of these two competitive forces may lead to another kind of interpretation. Considering its characteristics, the DAP sector could resemble a monopolistic competition market, i.e. a sector in which several producers coexist by selling close but imperfect substitute products. This allows the exertion of a sort of monopolistic power by selling differentiated products and generating extra profits. However, this situation is sustainable only in the short-term, since the entry of new competitors selling other differentiated products will further fragment demand and reduce firms' profits to zero. The DAP market seems to embed some of the characteristics of a monopolistic competition, such as the coexistence of several producers offering similar but still differentiated products. Moreover, it also seems that none of the competitors can have control over the market price. Despite Apple's leadership in terms of market share, the hedonic price estimation did not highlight the existence of any premium price for Apple's products (aside from HD players in the first years after the launch of the first iPod).

The entry of new firms had the consequence of intensifying price competition; however, the final long-term effect is not the one predicted. First of all, in the previous section we concluded that we have been able to capture a mature market, which should exclude that firms are still operating in the short-term. However, DAP manufacturers are still continuing to invest in launching new products, and this may indicate that there is no evidence of a decline in profitability in the sector.

In other words, the demand fragmentation induced by the entry of new firms, which was supposed to reduce the quantity sold by each firm by making the demand curve shift to the left, does not seem to have affected market profitability. This might be due to the other competitive force: hedonic competition, or differentiation. It seems that the great product innovation and differentiation that has occurred in the DAP market may have attracted new customers that had not adopted before, or adopters who decided to buy more than one DAP (56.9% of multi-adopters in our sample), and could be considered as a way to keep monopolistic profits in the medium- and long-term. This has allowed the presence of several competitors, but has also led to exits from the market of those companies that have failed to differentiate their products from those offered by others. The case of Microsoft seems to confirm this. Microsoft entered in the sector at the end of 2006, manifestly challenging Apple's iPod by launching the Zune, a product similar to the iPod with a hardware-software combination, and other additional services such as an online music store (similar to the iTunes store). However, Microsoft Zune never took off, and Microsoft launched its latest MP3 player in 2009, without a clear indication of whether they will launch other DAPs in the future.[106] In light of the previous considerations, the demise of Microsoft in the DAP sector seems to mostly stem from the fact that they failed to be different.

Regarding the second part of the research question about the relationship between demand and supply, there were several findings. The first is that, according to the data collected, three phenomena regarding the DAP market are definitely correlated: the rise in the adoption rate, the decline in average prices of the product and the rate of the product's technical improvements. However, it is difficult to establish direct causal relationships. One might expect that the evolution of the supply-side could change users' preferences about DAPs. The questionnaire on DAP adoption included a specific question regarding the relative importance of several product characteristics. The

[106] Following a Bloomberg article (http://www.bloomberg.com/news/2011-03-14/microsoft-said-to-stop-releasing-new-zune-models-as-demand-ebbs.html; last accessed 06/09/2011), Microsoft will not introduce any new versions of the Zune player. However, in response to that article (http://anythingbutipod.com/2011/03/zune-is-not-dead; last accessed 06/09/2011), Microsoft announced that they have not officially decided to exit the DAP market, although at the moment, they are mainly concentrating on developing music listening software for other portable devices, such as smart phones.

merging of this data with the other dataset from the supply-side indicated that adopters' preferences and the technical characteristics of products are not correlated. Although there were dramatic technical improvements in DAPs launched during the last years of the sample period, users' preferences regarding these characteristics did not change, but rather remained quite stable over time. Only the relative importance given to product price has increased over time, and it is negatively correlated with the decrease of the average product price. In brief, apart from product prices, the adopters in our sample did not show any particular reaction to products' technical improvements in terms of their preferences about these product characteristics. However, it is important to point out that these considerations only hold for the first adoption, since Section 7.1.1 demonstrated that the reasons for purchasing another DAP after the first are related with adopters' preferences about certain specific technical features.

In any case, regardless of this relative stability in preferences for single product characteristics, the demand-side showed different propensities to adopt a DAP at different periods of time, which depend on several factors. The thesis directly addressed the factors that could affect the probability of adopting a DAP in Chapter 8 (and, in a more exploratory way, in Section 6.3). Even though users do not change their preferences with regard to product characteristics, according to the supply-side, they do take the product's technical evolution into consideration in their adoption decisions. In particular, users appear to formulate expectations both on prices and on improvements in the product's features. These preferences have an impact on the timing of adoption. In particular, potential adopters appear to be willing to delay their first adoption in order to wait for product improvements or price declines. If we also consider that product improvements is another factor stimulating multiple purchases of DAPs, it is possible to conclude that slowing down technical change in the sector would mean slowing down the ongoing diffusion process, and would undermine repeated purchases. This would amplify demand fragmentation that is normally associated with long-term profit erosion, typical of monopolistic competition models.

In conclusion, the competitive activity on the supply-side towards product innovation and differentiation and price drops did not have an impact on the preferences of first adopters. However, the supply-side affected DAP adopters, both influencing the timing of their adoption (through the formulation of expectations), and their propensity to purchase other DAPs after the first (giving them reasons to desire a new product). On the other side, demand influenced the supply-side. The fulfilment of these expectations, together with an effort to keep the product differentiated appear to be crucial conditions for firms in order not to slow down the ongoing diffusion process, and hence to survive in the market. In brief, one of the conclusions of this thesis is that in the DAP sector demand and supply have influenced each other, creating, in turn, a pressure for firms to sustain technical change and diffusion.

9.2.3. Question 3: overall diffusion process

Are conventional models of innovation diffusion able to provide an adequate explanation of the diffusion of a consumer technology?

This research question was analytically addressed by Chapter 8. First of all, the review of the literature carried out in Chapter 2 gave an idea about the variety of diffusion models proposed by the literature. The review divided them into three groups, depending on their main focus: models based on the adopters, models based on the innovation, and models based on the diffusion process. The empirical literature on diffusion has tested most of these models of diffusion, in some cases using aggregate data on the diffusion of an innovation, or in other cases using data at a micro level regarding the adoption of these innovations by single adopters (in most cases firms or individuals/households).

In the case of this thesis, two datasets, and particularly the questionnaire, had the purpose of retrieving and constructing measures and indicators matching some of the models reviewed. In particular, five models have been considered, by including their potential effects on the probability of adoption: epidemic, rank, expectations, stock and order effects, plus a series of other control variables. A survival analysis (duration model) has been implemented in order to estimate the probability of adopting a DAP at a certain period of time without having adopted before. The results coming from the above-mentioned models of diffusion have been tested on this probability. The validation of these measures (explained in Chapter 5) and the use of different kinds of duration models (both continuous and discrete, with both parametric and semi-parametric hazard functions) should ensure that the results of the estimations are sufficiently robust and allow the conclusion that all the models considered provide, to a certain extent, a correct explanation of the adoption of a DAP.

For this reason, taking into account the results of the duration models estimated, it is hard to provide a yes or no answer to the research question. None of the diffusion models tested can, alone, account for and explain the entire probability of adopting a DAP. At the same time, all the effects tested make some contribution to an explanation of adoption behaviour. In particular, some effects seem to be stronger during particular phases of the diffusion process, for instance the early phases; in other cases, some effects are only significant for a particular cluster of adopters and not for others.

In conclusion, the diffusion of a consumer technology is a complex phenomenon, which is difficult to frame within the assumptions of a single model of diffusion. If this thesis had had a pre-conceived idea about the diffusion of DAPs, and we had decided to test only one model, for instance a rank model, we would have certainly achieved positive and significant results, and probably concluded that the adoption of a DAP depended on the download of music and on the income of potential adopters. However, Chapter 8 demonstrated that this is not (or at least not only) the case. These factors are undoubtedly relevant, but other effects should be taken into consideration. Having focussed only on one particular approach to diffusion would have had the consequence of having only a partial view of the reality. For this reason, the main lesson that could be learned from the answer to this research question is that, in the case of innovation diffusion, generalisations and simplifications are difficult, and multiple views of the diffusion of an innovation should be considered, rather than choosing a single model or approach.

9.3. Contributions to knowledge

This thesis makes two contributions to knowledge.

Theoretical contribution

We believe that this thesis has an impact on the theoretical literature on the diffusion of innovation. This contribution regards the classification of adopters of a consumer innovation. Based on the data collected and the analysis carried out, we can conclude that the some of the classifications put forward by the literature appear simplistic, in particular those mainly focussed on the timing of adoption or on a single variable, such as income. However, the classification provided in this thesis instead of contradicting these classifications seems to expand them, providing further interesting insights.

Empirical contribution

The second contribution regards the empirical literature on innovation. Most of the empirical literature on diffusion has concentrated on explaining the diffusion of an innovation as an s-shaped curve, and on modelling it in different ways. This approach has provided some essential understandings of the diffusion process; however, it has also sometimes offered some over-simplified views of the diffusion of innovations. The main contribution regards the use of a single approach in studying the adoption and diffusion of a consumer innovation. This thesis has proven that relying on a pre-conceived approach could lead to significant results, but with the risk of accounting for only a part of the phenomenon, not considering other relevant aspects. So far, different models of diffusion have mostly been seen as competing alternatives. The conclusions of this thesis go in a different direction by questioning the use of a single approach, and suggesting that it may be necessary to simultaneously pursue different models in the empirical study of the diffusion of an innovation.

In addition to this main contribution, another contribution to the empirical literature should be mentioned. The thesis has highlighted a difference between the factors influencing the first and subsequent adoptions of a consumer innovation. This seems to suggest that the use of sales in estimating a diffusion curve is risky, since sales account for both kinds of adoption. The use of micro data on adoption or aggregate data about penetration rates seems to be a more recommended choice, instead of overall sales.

9.4. Policy implications

Providing any sort of policy recommendation was not one of the aims of this thesis. However, we believe that some of the results of this thesis can provide some interesting insights to policy-makers.

One of the phenomena that has accompanied the history of DAPs and also influenced their adoption has been the use of the Internet to exchange and download a large amount of music in digital format. File sharing is mostly carried out through the so-called peer-to-peer networks and has emerged as a mass behaviour on the Internet. The issue regarding file sharing is that it often becomes Internet piracy, since most of the material exchanged in these networks is copyright-protected (e.g. music, movies, software). Therefore, copyright holders claim that file sharing is responsible for some significant losses that they have experienced over the last decade.

Although the sample used in this thesis is not representative of the entire population of Internet users, its analysis can provide some useful insights. What has emerged from the analysis of the results of the questionnaire is that young Internet users in the sample very often download copyrighted material from the Internet. The use of P2P software is the most frequent activity on the Internet after chatting and social networking. This has allowed respondents to accumulate a large amount of music in digital format (more than 40% of the respondents have more than 10GB of music, which represents more or less 2000 songs), making sources not compliant with copyright laws, such as file sharing on the Internet or offline representing the most relevant source for the music respondents own.

However, according to the results, the most active file sharers are not only the early adopters of DAPS, but also some of the most skilled and sophisticated users of the Internet, computers and other consumer electronics. This means that these users might find other ways to elude or circumvent even the strictest law (for instance by proxy navigation, encryption or other defensive measures). Another consideration is that respondents did not have any problems declaring that they are heavy downloaders of copyright-protected music. It is true that the questionnaire did not collect any personal data and that it contained a cover page regarding confidentiality and privacy. However, despite the fact that downloading copyrighted music is illegal in all the surveyed countries, the vast majority of respondents felt very free to declare that they have downloaded music from the Internet.

In light of the fact that not only is the academic literature still debating the real negative effects of file sharing, but that also the numerous initiatives against Internet piracy have not been very effective, so far, in eradicating the phenomenon of file sharing, the empirical results provided in this thesis could have an impact on the current policy debate on file sharing. This thesis does not only indicate that file sharers, who are in general sophisticated Internet users, may always find ways to download illegal material circumventing anti-piracy measures, but also raises some doubts about their awareness of such anti-piracy laws, or even about their understanding of what is a legal or an illegal online behaviour. This seems to indicate that before prohibiting file sharing and raising punitive measures, policy-makers should promote education campaigns with the aim of diffusing the message that the exchange and download of copyright-protected music over the Internet is to be considered an unacceptable online behaviour. Moreover, business models providing alternative ways of accessing digital music in a legal way rather than through file sharing should be promoted.

9.5. Avenues for future research

Based on the results of this thesis, a number of potentially fruitful avenues for future research could be suggested.

First of all, the analysis has concentrated on adopters, and on the differences between different clusters of adopters, with only limited emphasis on the differences between adopters and non-adopters. In most of the regressions, the dependent variable has been the timing of adoption, or the probability of adopting at a specific time *t*. A potentially interesting further avenue of research might use the decision to adopt instead of timing of adoption as dependent variable. In addition to this, the thesis has highlighted the existence of a difference between adopters of only one DAP and so-called multi-adopters. It would be interesting to study this more analytically, for instance using survival models that allow for more than one failure (adoption).

Secondly, the supply-side has been studied in terms of single product characteristics. However, from the history of the sector, we know that several market niches have been developed over recent years. Another idea for further research would be to classify these products. The classification could be discrete, for instance by applying a cluster analysis to classify products instead of adopters, and to verify if the product characteristics cluster in a meaningful way, or are continuous, for instance using the already-performed hedonic regression to predict estimated product prices that could in turn be used as proxies for product quality. This would allow the study of firms' strategies and their decisions about the positioning of their products in the marketplace.

Thirdly, regarding the interaction between supply and demand, a potentially interesting idea could make use of both datasets in order to create a model of diffusion of two complementary goods, such as hardware-software (see for instance Stoneman, 1991b and Gandal *et al.*, 2000). It would be interesting to study what are the effects on the adoption rate of a MP3 player when the price of the complementary good (MP3 files) drops to zero. This could be applied to the case of DAPs, but also to other emerging sectors, for instance the market of e-books and e-book readers. In particular, e-books suffer from the same problem as MP3 files, in the sense that they can be easily exchanged on the Internet. For this reason, a comparison of the cases of MP3 players and e-book readers could provide some interesting results. However, in contrast to the case of digital music, users were offered the possibility to legally purchase digital books some time before the availability of portable e-book readers. This may allow for a sort of counterfactual analysis of the MP3 sector regarding what effect the launch of online digital music stores (such as iTunes) would have had at an earlier stage of the diffusion process (and not after take-off) on copyright-infringing file sharing. We believe that from this comparison, extremely useful policy implications would arise.

Finally, the fact that the questionnaire on the adoption of DAPs has been demonstrated to be particularly successful and insightful would suggest its application to different kinds of consumer innovations, not necessarily electronic products. Two potentially interesting applications will be mentioned. The first is the market for e-book readers. As mentioned above, this market has several similarities to the DAP market, but it started much earlier to provide users with a legal way to download digital books, and for this reason the two sectors could be usefully compared. The second application regards the performance of different models of diffusion in explaining the adoption of new low-emission products or more sustainable lifestyles, which would have very relevant policy implications.

REFERENCES

Abdulai, A. & Huffman, W.E. (2005) The Diffusion of New Agricultural Technologies: The Case of Crossbred-Cow Technology in Tanzania. *American Journal of Agricultural Economics,* 87 (3), 645-59.

Abrahamson, E. & Rosenkopf, L. (1993) Institutional and Competitive Bandwagons. *Academy of Management Review,* 18 (3), 487-517.

Abrahamson, E. & Rosenkopf, L. (1997) Social Network Effects on the Extent of Innovation Diffusion: A Computer Simulation. *Organization Science,* 8 (3), 289-309.

Ahn, I. & Shin, I. (2010) On the optimal level of protection in DRM. *Information Economics and Policy,* 22 (4), 341-53.

Akhavein, J., Frame, W.S. & White, L.J. (2005) The Diffusion of Financial Innovations: An Examination of the Adoption of Small Business Credit Scoring by Large Banking Organizations. *The Journal of Business,* 78 (2), 577-96.

Allison, P.D. (1995) *Survival Analysis Using SAS. A Practical Guide.* Cary, NC: SAS Publishing.

Amendola, G. (1990) The Diffusion of Synthetic Materials in the Automobile Industry: Towards a Major Breakthrough? *Research Policy,* 19, 485-500.

Arcangeli, F., Dosi, G. & Moggi, M. (1991) Patterns of diffusion of electronics technologies: An international comparison with special reference to the Italian case. *Research Policy,* 20 (6), 515–29.

Arthur, W.B. (1988) Competing Technologies: An Overview. *In* G. Dosi, C. Freeman, R.R. Nelson, G. Silverberg & L. Soete eds. *Technical Change and Economic Theory.* London: Pinter.

Arthur, W.B. (1989) Competing Technologies, Increasing returns and Lock-in by Historical Events. *Economic Journal,* 99, 116-31.

Bain, A. (1964) *The Growth of Television Ownership in the UK since the War: A Lognormal Model.* Cambridge: Cambridge Unviersity Press.

Balcer, Y. & Lippman, S.A. (1984) Technological Expectations and Adoption of Improved Technology. *Journal of Economic Theory,* 34 (2), 292-318.

Banerjee, A.V. (1992) A Simple Model of Herd Behavior. *The Quarterly Journal of Economics,* 3, 797-817.

Bass, F. (1969) A new product growth model for consumer durables. *Management Science,* 15, 215-27.

Belleflamme, P. (1998) Adoption of network technologies in oligopolies. *International Journal of Industrial Organization,* 16 (4), 415–44.

Bettman, J.R. & Park, C.W. (1980) Effects of Prior Knowledge and Experience and Phase of the Choice Process on Consumer Decision Processes: A Protocol Analysis. *Journal of Consumer Research,* 7 (3), 234-248.

Bijker, W.E. (1995) *Of Bicycles, Bakelites, and Bulbs: Toward a Theory of Sociotechnical Change.* Cambridge, MA: MIT Press.

Bikhchandani, S., Hirshleifer, D. & Welch, I. (1992) A Theory of Fads, Fashion, Custom, and Cultural Change as Informational Cascades. *The Journal of Political Economy,* 100 (5), 992-1026.

Bikhchandani, S., Hirshleifer, D. & Welch, I. (1998) Learning from the Behavior of

Others: Conformity, Fads, and Informational Cascades. *Journal of Economic Perspectives,* 12 (3), 151-170.

Bofondi, M. & Lotti, F. (2006) Innovation in the Retail Banking Industry: The Diffusion of Credit Scoring. *Review of Industrial Organization,* 28 (4), 343-58.

Bonus, H. (1973) Quasi-Engel curves, diffusion, and the ownership of new consumer durables. *Journal of Political Economy,* 81, 655-77.

Bull, M. (2007) *Sound Moves. iPod culture and urban experience.* Abingdon: Routledge.

Burt, R.S. (1987) Social Contagion and Innovation, Cohesion versus Structural Equivalence. *American Journal of Sociology,* 92, 1287-335.

Burt, R.S. (1999) The Social Capital of Opinion Leaders. *The ANNALS of the American Academy of Political and Social Science,* 566 (1), 37.

Byrne, B.M. (2006) *Structural Equation Modelling With EQS: Basic Concepts, Applications, and Programming. 2nd Edition.* Lawrence Erlbaum Associates.

Cainarca, G.C., Colombo, M.G. & Mariotti, S. (1989) An Evolutionary Pattern of Innovation Diffusion: the Case of Flexible Automation. *Research Policy,* 18, 59-86.

Calder, B.J., Philips, L.W. & Tybout, A.M. (1981) Designing Research for Application. *Journal of Consumer Research,* 8 (2), 197-207.

Chanan, M. (1995) *Repeated takes: a short history of recording and its effects on music.* London: Verso.

Chandrasekaran, D. & Tellis, G.J. (2007) A Critical Review of Marketing Research on Diffusion of New Products. *Review of Marketing Research,* Vol.3, 39-80.

Chatterjee, R. & Eliashberg, J. (1990) The Innovation Diffusion Process in a Heterogeneous Population: A Micromodeling Approach. *Management Science,* 36 (9), 1057-79.

Choi, J.P. & Thum, M. (1998) Market structure and the timing of technology adoption with network externalities. *European Economic Review,* 42 (2), 225–44.

Chow, G.C. (1967) Technological Change and the Demand for Computers. *American Economic Review,* 57 (5), 1117-30.

Chwelos, P.D. (2003) Approaches to Performance Measurement in Hedonic Analysis: Price Indexes for Laptop Computers in the 1990s. *Economics of Innovation and New Technology,* 12 (3), 199-224.

Chwelos, P.D., Berndt, E.R. & Cockburn, I.M. (2004) Faster, Smaller, Cheaper: An Hedonic Price Analysis of PDAs. *NBER Working Paper.*

Citrin, A.V., Sprott, D.E., Silverman, S.N. & Stem, D.E. (2000) Adoption of Internet shopping: the role of consumer innovativeness. *Industrial Management and Data Systems,* 100 (7), 294-300.

Clark, R.A. & Goldsmith, R.E. (2006) Interpersonal influence and consumer innovativeness. *International Journal of Consumer Studies,* 30 (1), 34-43.

Clarysse, B. & Muldur, U. (2001) Regional cohesion in Europe? An analysis of how EU public RTD support influences the techno-economic regional landscape. *Research Policy,* 30 (2), 275-96.

Coleman, J.S., Katz, J.E. & Menzel, H. (1966) *Medical Innovations: A Diffusion Studies.* New York: Bobbs-Merrill.

Colombo, M.G. & Mosconi, R. (1995) Complementary and Cumulative Learning Effects in the Early Diffusion of Multiple Technologies. *Journal of Industrial Economics,* 43, 13-48.

Cooper, R.B. & Zmud, R.W. (1990) Information Technology Implementation Research: A Technological Diffusion Approach. *Management Science,* 36 (2), 123-39.

Cooper, R.G. & Kleinschmidt, E.J. (1987) New Products: What Separates Winners from Losers? *Journal of Product Innovation Management,* 4 (3), 169-184.

Corrocher, N. (2006) Internet adoption in Italian banks: An empirical investigation. *Research Policy,* 35 (4), 533-44.

Corrocher, N. & Guerzoni, M. (2009) Product variety and price strategy in the ski manufacturing industry. *Journal of Evolutionary Economics,* 19, 471-86.

David, M. (2010) *Peer to peer and the music industry: the criminalization of sharing*. London: SAGE.

David, P.A. (1966) The mechanization of reaping in the ante-bellum Midwest. *In* H. Rosovsky ed. *Industrialization in Two Systems: Essays in Honor of Alexander Gerschenkron*. New York: Wiley and Sons, 3-39.

David, P.A., (1969) A Contrbution to the Theory of Diffusion. Center for Research in Economic Growth Research Memorandum, no. 71, Stanford University.

David, P.A. (1985) Clio and the Economics of QWERTY. *American Economic Review,* 75 (2), 332-7.

David, P.A. & Greenstein, S. (1990) The economics of compatibility standards: an introduction to recent research. *Economics of Innovation and New Technology,* 1 (1), 3–41.

David, P.A. & Olsen, T. (1986) Equilibrium Dynamics of Diffusion when Incremental Technological Innovations are Foreseen. *Ricerche Economiche,* 40, 738-70.

Davies, S. (1979) *The Diffusion of Process Innovations*. Cambridge: Cambridge University Press.

Davis, F.D. (1989) Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly,* 13 (3), 319-40.

Deroian, F. (2002) Formation of social networks and diffusion of innovations. *Research Policy,* 31 (5), 835-46.

Dickerson, M.D. & Gentry, J.W. (1983) Characteristics of Adopters and Non-Adopters of Home Computers. *Journal of Consumer Research,* 10 (2), 225-35.

Dixon, A.N. (2009) Liability of Users and Third Parties for Copyright Infringements on the Internet: Overview of International Developments. *In* A. Strowel ed. *Peer-to-Peer File Sharing and Secondary Liability in Copyright Law*. Cheltenham: Edward Elgar Publishers.

Dosi, G. (2000) The Research on Innovation Diffusion: An Assessment. *In* G. Dosi ed. *Innovation, organization and economic dynamics: selected essays*. Edward Elgar.

Eastin, M.S. (2002) Diffusion of e-commerce: an analysis of the adoption of four e-commerce activities. *Telematics and Informatics,* 19 (3), 251-67.

Eveland, J.D. & Tornatzky, L.G. (1990) The Deployment of Technology. *In* L.G. Tornatzky & M. Fleischer eds. *The Processes of Technological Innovation*. Lexington, MA: Lexington Books.

Farrell, J. & Saloner, G. (1985) Standardization, Compatibility and Innovation. *Rand Journal of Economics,* 16, 70-83.

Feder, G. & O'Mara, G.T. (1982) On information and innovation diffusion: a bayesian approach. *American Journal of Agricultural Economics,* 64 (1), 145-7.

Feenstra, R.C. & Levinsohn, J.A., (1989) Distance, demand and oligopoly pricing. NBER Working Papers 3076.

Fichman, R.G. & Kemerer, C.F. (1999) The illusory diffusion of innovation: an examination of assimilation gaps. *Information Systems Research,* 10 (3), 255-275.

Field, A. (2009) *Discovering statistics using SPSS. Third Edition*. London: SAGE Publications Ltd.

Fisher, J.C. & Pry, R.H. (1971) A Simple Substitution Model of Technical Change. *Technological Forecasting & Social Change,* 3, 75-81.

Fisher, R.A. (1930) *The genetical theory of natural selection*. London: Oxford University Press.

Flamm, K. (1993) Measurement of DRAM Prices: Technology and Market Structure. *In* M.F. Foss, M.E. Manser & A.H. Young eds. *Price Measurements and their Uses*. C: National Bureau of Economic Research Studies in Income and Wealth, Vol. 57. Chicago and London: The University of Chicago Press.

Fontana, R. (2007) Technical change, prices and communications technology: Insights from the Local Area Networking industry. *Technological Forecasting & Social Change,* 74 (3), 313–330.

Freeman, C. (1994) The economics of technical change. *Cambridge Journal of Economics,* 18, 463-514.

Fudenberg, D. & Tirole, J. (1985) Preemption and rent equalization in the adoption of new technology. *The Review of Economic Studies,* 52 (3), 383–401.

Fusaro, M.A. (2009) The Rank, Stock, Order and Epidemic Effects of Technology Adoption: An Empirical study of Boune Protection Programs. *Journal of Technology Transfer,* 43, 24-42.

Gabszwicz, J.J. & Thisse, J.F. (1986) On the Nature of Competition with Differentiated Products. *Economic Journal,* 96 (381), 160-72.

Gandal, N., Kende, M. & Rob, R. (2000) The Dynamics of Technological Adoption in Hardware/Software Systems: The Case of CD Players. *Rand Journal of Economics,* 31 (1), 43-61.

Garofalo, R. (1999) From Music Publishing to MP3: Music and Industry in the Twentieth Century. *American Music,* 17 (3), 318-54.

Gatignon, H. & Robertson, T.S. (1985) A Propositional Inventory for New Diffusion Research. *Journal of Consumer Research,* 11 (4), 849-67.

Geroski, P.A. (2000) Models of technology diffusion. *Research Policy,* 29, 603-25.

Goldsmith, R.E., Freiden, J.B. & Eastman, J.K. (1995) The generality/specificity issue in consumer innovativeness research. *Technovation,* 15 (10), 610-12.

Goldsmith, R.E. & Hofacker, C.F. (1991) Measuring consumer innovativeness. *Journal of the Academy of Marketing Science,* 19 (3), 209-21.

Goolsbee, A. & Klenow, P.J. (2002) Evidence on Learning and Network Externalities in the Diffusion of Home Computers. *Journal of Law and Economics,* 45 (2), 317-43.

Graham, G., Burnes, B., Lewis, G.J. & Langer, J. (2004) The transformation of the music industry supply chain. A major label perspective. *International Journal* *of Operations & Product Management,* 24 (11), 1087-103.

Greene, W.H. (2003) *Econometric Analysis (Fifth Edition).* Upper Saddle River, NJ: Prentice Hall.

Greenhalgh, T., Roberg, G., Paul, B., Macfarlane, F. & Kyriakidou, O. (2005) *Diffusion of Innovations in Health Service Organizations: A systematic literature review.* BMJ Books.

Griliches, Z. (1957) Hybrid corn: an exploration in the economics of technological change. *Econometrica,* 48, 501-22.

Griliches, Z. (1971) *Price Indexes and Quality Change: Studies in New Methods of Measurement.* Harvard University Press.

Griliches, Z. (1980) Hybrid Corn Revisited: A Reply. *Econometrica,* 48 (6), 1463-5.

Hair, J.F., Black, W.C., Babin, B.J. & Anderson, R.E. (2010) *Multivariate Data Analysis: a global perspective (7th Edition).* Pearson Education.

Hall, B.H. (2005) Innovation and Diffusion. *In* J. Fagerberg, D. Mowery & R.R. Nelson eds. *The Oxford Handbook of Innovation.* Oxford: Oxford University Press.

Hannan, T.H. & McDowell, J.M. (1984) The determinants of technology adoption: the case of the banking firm. *Rand Journal of Economics,* 15, 328-35.

Harkola, J. & Greve, A. (1995) Diffusion of Technology: Cohesion or Structural Equivalence? *Academy of management Best Papers Procedings*, 422-6.

Harrison, A. (2008) *Music: The Business - The Essential Guide to the Law and the Deals.* London: Virgin.

Haupert, M. (2006) *The Entertainment Industry.* Westport, CT: Greenwood Press.

Hirschman, E.C. (1980) Innovativeness, Novelty Seeking, and Consumer Creativity. *Journal of Consumer Research,* 7 (3), 283-95.

Hirunyawipada, T. & Paswan, A.K. (2006) Consumer innovativeness and perceived risk: implications for high technology product adoption. *Journal of Consumer Marketing,* 23 (4), 182-98.

Holmes, T. (2006) *The Routledge Guide to Music Technology.* New York, NY: Routledge.

IFPI, (2009) Digital music report 2009. New business models for a changing environment. Available at: http://ifpi.org/content/library/dmr2009.pdf.

IFPI, (2010) Digital music report 2010. Music how, when, where you want it. Available at: http://ifpi.org/content/library/dmr2010.pdf.

IFPI, (2011) Digital music report 2011. Music at the touch of a button. Available at: http://ifpi.org/content/library/DMR2011.pdf.

Im, S., Bayus, B.L. & Mason, C.H. (2003) An Empirical Study of Innate Consumer Innovativeness, Personal Characteristics, and New-Product Adoption Behavior. *Journal of the Academy of Marketing Science,* 31 (1), 61.

Ireland, N. & Stoneman, P. (1985) Order effects, perfect foresight and intertemporal price discrimination. *Recherches économiques de Louvain,* 51 (1), 7–20.

Ireland, N. & Stoneman, P. (1986) Technological Diffusion, Expectations and Welfare. *Oxford Economic Papers,* 38, 283-304.

Jenkins, S.P., (2005a) Survival Analysis. *Unpublished Lecture Notes manuscript.* Institute for Social and Economic Research, University of Essex.

Jenkins, S.P., (2005b) Lessons. *(to accompany Survival Analysis op.cit.), 9 pdf files.*

Institute for Social and Economic Research, University of Essex.

Jensen, R. (1982) Adoption and diffusion of an innovation of uncertain profitability. *Journal of Economic Theory,* 27 (1), 182-93.

Jöreskog, K.G. & Sörbom, D. (1993) *LISREL 8: Structural equation modeling with the SIMPLIS command language*. Chicago: Scientific Software International.

Kahney, L. (2005) *The Cult of iPod*. San Francisco, CA: No Starch Press.

Kakati, M. (2003) Success criteria in high-tech new ventures. *Technovation,* 23 (5), 447-57.

Kapur, S. (1995) Technological Diffusion with Social Learning. *The Journal of Industrial Economics,* 43 (2), 173-195.

Karshenas, M. & Stoneman, P. (1992) A Flexible Model of Technological Diffusion Incorporating Economic Factors with an Application to the Spread of Colour Television Ownership in the UK. *Journal of Forecasting,* 11 (7), 577-601.

Karshenas, M. & Stoneman, P. (1993) Rank, Stock, Order, and Epidemic Effects in the Diffusion of New Process Technologies. *The Rand Journal of Economics,* 24 (4), 503-28.

Karshenas, M. & Stoneman, P. (1995) Technological Diffusion. *In* P. Stoneman ed. *Handbook of the Economics of Innovation and Technological Change*. Cambridge MA: Blackwell Publishers Inc.

Katz, M.L. & Shapiro, C. (1985) Network Externalities, Competition and Compatibility. *American Economic Review,* 75 (3), 424-40.

Katz, M.L. & Shapiro, C. (1986) Technology Adoption in the Presence of Network Externalities. *Journal of Political Economy,* 94 (4), 822-41.

Katz, M.L. & Shapiro, C. (1994) System Competition and Network Effects. *Journal of Economic Perspectives,* 8, 93-115.

Kauffman, R.J. & Techatassanasoontorn, A.A. (2005) International Diffusion of Digital Mobile Technology: A Coupled-Hazard State-Based Approach. *Information Technology and Management,* 6 (2), 253-92.

Kleinbaum, D.G. & Klein, M. (2005) *Survival Analysis. A self-learning text. Second Edition*. Springer Science.

Knopper, S. (2009) *Appetite for self-destruction. The spectacular crash of the record industry in digital age*. London: Simon & Schuster UK.

Koski, H. & Kretschmer, T. (2007) Innovation and Dominant Design in Mobile Telephony. *Industry and Innovation,* 14 (3), 305-24.

Kusek, D. & Leonhard, G. (2005) *The future of music. Manifesto for the digital music revolution*. Boston, MA: Berklee Press.

Lancaster, K.J. (1966) A New Approach to Consumer Theory. *The Journal of Political Economy,* 74 (2), 132-57.

Lancaster, K.J. (1971) *Consumer Demand: A New Approach*. New York: Columbia University Press.

Lattin, J.M. & Roberts, J.H., (1989) Modeling the Role of Risk-Adjusted Utility in the Diffusion of Innovations. *Working paper 1019, Graduate School of Business, Stanford University*.

Lawrence, K.D. & Lawton, W.H. (1981) Applications of Diffusion Models: some Empirical Results. *In* Y. Wind, V. Mahajan & R.C. Cardozo eds. *New Product Forecasting*. Lexington, MA: Lexington Books, 529-41.

Lekvall, P. & Wahlbin, C. (1973) A Study of Some Assumptions Underlying Innovation Diffusion Functions. *The Swedish Journal of Economics,* 75 (4), 362-77.

Levin, S.G., Levin, S.L. & Meisel, J.B. (1987) A dynamic analysis of the adoption of a new technology: the case of optical scanners. *The Review of Economics and Statistics,* 69 (1), 12-7.

Levy, S. (2006) *The perfect thing: how the iPod became the defining object of the 21st Century*. London: Elbury Press.

Liebowitz, S.J. (2006) File sharing: creative destruction or just plain destruction? *Journal of Law and Economics,* 49 (1), 1-28.

Liebowitz, S.J. (2008) Testing File Sharing's Impact on Music Album Sales in Cities. *Management Science,* 54 (4), 852-9.

Liker, J.K., Fleischer, M. & Arnsdorf, D. (1992) Fulfilling the Promises of CAD. *Sloan Management Review,* 33 (3), 74-86.

Lissoni, F. (2000) La diffusione delle innovazioni. *In* F. Malerba ed. *Economia dell'innovazione*. Roma: Carocci.

Lissoni, F. & Metcalfe, J.S. (1994) Diffusion of Innovation Ancient and Modern: A Review of the Main Themes. *In* M. Dodgson & R. Rothwell eds. *The Handbook of Industrial Innovation*. Edward Elgar Publishing.

Mahajan, V. & Muller, E. (1979) Innovation Diffusion and New Product Growth Models in Marketing. *Journal of marketing,* 43 (4), 55-68.

Mahajan, V., Muller, E. & Bass, F. (1990) New product diffusion models in marketing: a review and directions for research. *Journal of Marketing,* 54 (1), 1-26.

Mahajan, V., Muller, E. & Srivastava, R.K. (1990) Determination of Adopter Categories by Using Innovation Diffusion Models. *Journal of Marketing Research,* 27 (1), 37-50.

Mahajan, V. & Peterson, R.A. (1978) Innovation Diffusion in a Dynamic Potential Adopter Population. *Management Science,* 24 (15), 1589-97.

Mahajan, V. & Sharma, S. (1986) Simple Algebraic Estimation Procedure for Innovation Diffusion Models of New Product Acceptance. *Technological Forecasting & Social Change,* 30 (4), 331-45.

Mansfield, E. (1961) Technical Change and the Rate of Imitation. *Econometrica,* 29 (4), 741-66.

Mariotti, M. (1989) Being identical, behaving differently: A theorem on technological diffusion. *Economics Letters,* 30 (4), 275–278.

Mariotti, M. (1992) Unused Innovations. *Economic Letters,* 38 (3), 367-71.

McMeekin, A., Tomlinson, M., Green, K. & Walsh, V. (2002) *Innovation by Demand: An Interdisciplinary Approach to the Study of Demand and Its Role in Innovation*. Manchester University Press.

Metcalfe, J.S. (1981) Impulse and diffusion in the study of technical change. *Futures,* 13, 347-59.

Metcalfe, J.S. (1988) The Diffusion of Innovation: An Interpretative Survey. *In* G. Dosi, C. Freeman, R.R. Nelson, G. Silverberg & L. Soete eds. *Technical Change and Economic Theory*. London: Pinter, 560-89.

Metcalfe, J.S. & Gibbons, M. (1988) On the Economics of Structural Change and the Evolution of Technology. *In* L. Pasinetti & P. Lloyd eds. *Structural Change and Economic Interdependence*. London: Macmillan.

Midgley, D.F. & Dowling, G.R. (1978) Innovativeness: The Concept and Its Measurement. *Journal of Consumer Research,* 4 (4), 229-42.

Midgley, D.F., Morrison, P.D. & Roberts, J.H. (1992) The Effect of Network Structure in Industrial Diffusion Processes. *Research Policy,* 21 (6), 533-52.

Milligan, G.W. (1980) An Examination of the Effect of Six Types of Error Perturbation on Fifteen Clustering Algorithms. *Psychometrika,* 45 (3), 325-42.

Milligan, G.W. & Cooper, M.C. (1987) Methodology Review: Clustering Methods. *Applied Psychological Measurement,* 11 (4), 329-54.

Mokyr, J. (1994) Cardwell's Law and the Political Economy of Technological Progress. *Research Policy,* 23 (5), 561-74.

Moore, G.C. & Benbasat, I. (1991) Development of an instrument to measure the perceptions of adopting an information technology innovation. *Information Systems Research,* 2 (3), 192-222.

Myers, J.H. & Robertson, T.S. (1972) Dimensions of Opinion Leadership. *Journal of Marketing Research,* 9 (1), 41-46.

Nelson, R.R., Peterhansl, A. & Sampat, B. (2004) Why and how innovations get adopted: a tale of four models. *Industrial and Corporate Change,* 13 (5), 679-99.

Nelson, R.R. & Winter, S. (1982) *An Evolutionary Theory of Economic Change.* Cambridge, MA: The Belknapp Press of Harvard University Press.

O'Hara, K. & Brown, B. (2006) *Consuming Music Together: Social and Collaborative Aspects of Music Consumption Technologies.* Dordrecht, The Netherlands: Springer.

Oberholzer-Gee, F. & Strumpf, K. (2007) The Effect of File Sharing on Record Sales: An Empirical Analysis. *Journal of Political Economy,* 115 (1), 1-42.

Oberholzer-Gee, F. & Strumpf, K., (2010) File Sharing and Copyright. NBER Innovation Policy & the Economy (MIT Press).

Oh, S., Ahn, J. & Kim, B. (2003) Adoption of broadband Internet in Korea: the role of experience in building attitudes. *Journal of Information Technology,* 18 (4), 267-80.

Okazaki, S. (2006) What do we know about mobile Internet adopters? A cluster analysis. *Information & Management,* 43 (2), 127-41.

Oren, S.S. & Schwartz, R.G. (1988) Diffusion of New Products in Risk-Sensitive Markets. *Journal of Forecasting,* 7 (4), 273-87.

Pakes, A. (2003) A Reconsideration of Hedonic Price Indexes with an Application to PCs. *American Economic Review,* 93 (5), 1578-96.

Park, C.W. & Lessig, V.P. (1981) Familiarity and Its Impact on Consumer Decision Biases and Heuristics. *Journal of Consumer Research,* 8 (2), 223-31.

Park, S. (2004) Quantitative Analysis of Network Externalities in Competing Technologies: the VCR case. *The Review of Economics and Statistics,* 86 (4), 937-45.

Peek, H., Bergmans, J., Haaren, J. & toolenaar, F. (2009) *Origins and Successors of the Compact Disc. Contributions of Philips to Optical Storage.* Springer.

Peitz, M. & Waelbroeck, P. (2006a) Piracy of digital products: A critical review of the theoretical literature. *Information Economics and Policy,* 18 (4), 449-76.

Peitz, M. & Waelbroeck, P. (2006b) Why the music industry may gain from free downloading - The role of sampling. *International Journal of Industrial Organization,* 24, 907-13.

Peña, J.M., Lozano, J.A. & Larrañaga, P. (1999) An empirical comparison of four initialization methods for the K-Means algorithm. *Pattern Recognition Letters,* 20 (10), 1027-40.

Peterson, R.A. (2001) On the Use of College Students in Social Science Research: Insights from a Second-Order Meta-analysis. *Journal of Consumer Research,* 28 (3), 450-461.

Pohlmann, K.C. (1992) *The Compact Disc Handbook*. Oxford: Oxford University Press.

Punj, G. & Stewart, D.W. (1983) Cluster Analysis in Marketing Research: Review and Suggestions for Application. *Journal of Marketing Research,* 20 (2), 134-48.

Pyatt, F.G. (1964) *Priority Patterns and the Demand for Household Durable goods*. Cambridge University Press.

Quirmbach, H.C. (1986) The diffusion of new technology and the market for an innovation. *The Rand Journal of Economics,* 17 (1), 33–47.

Ramiller, N.C. (1994) Perceived compatibility of information technology innovations among secondary adopters: Toward a reassessment. *Journal of Engineering and Technology Management,* 11 (1), 1-23.

Rayna, T., Striukova, L. & Landau, S. (2009) Crossing the Chasm or Being Crossed Out: The Case of Digital Audio Players. *International Journal of Actor-Network Theory and Technological Innovation,* 1 (3), 36-54.

Reinganum, J.F. (1981) On the Diffusion of New Technology: A Game Theoretic Approach. *Review of Economic Studies,* 48 (3), 395-405.

Reinganum, J.F. (1983) Technology adoption under imperfect information. *The Bell Journal of Economics,* 14 (1), 57–69.

Richard, K.D. (2000) The music industry and its digital future: introducing MP3 technology. *IDEA: The Journal of Law and Technology,* 40 (3), 427-49.

Rob, R. & Waldfogel, J. (2006) Piracy on the High C's: Music Downloading, Sales Displacement, and Social Welfare in a Sample of College Students. *Journal of Law and Economics,* 49 (1), 29-62.

Roehrich, G. (2004) Consumer Innovativeness. Concepts and Measurements. *Journal of Business Research,* 57 (6), 671-77.

Rogers, E.M. (1962) *Diffusion of innovations. First Edition*. New York: Free Press.

Rogers, E.M. (1976) New Product Adoption and Diffusion. *Journal of Consumer Research,* 2 (4), 290-301.

Rogers, E.M. (2003) *Diffusion of innovations. Fifth Edition*. New York: Free Press.

Rogers, E.M. & Shoemaker, F.F. (1971) *Communication of innovations*. Free Press New York.

Rohlfs, J.H. (2001) *Bandwagon Effects in High-technology Industries*. MIT Press.

Rosen, S. (1974) Hedonic prices and implicit markets: product differentiation in pure competition. *Journal of Political Economy,* 82 (1), 34-55.

Rosenberg, N. (1982) *Inside the Black Box*. Cambridge: Cambridge University Press.

Rosenbloom, R. & Cusumano, M. (1987) Technological Pioneering and Competitive Advantage: the Birth of the VCR Industry. *California Management Review,* 29 (4), 51-76.

Ryan, B. & Gross, N.C. (1943) The diffusion of hybrid seed corn in two Iowa communities. *Rural sociology,* 8 (1), 15-24.

Saloner, G. & Shepard, A. (1995) Adoption of Technologies with Network Effects: An Empirical Examination of the Adoption of Automated Teller Machines. *Rand Journal of Economics,* 26 (3), 479-501.

Sanderson, S. & Uzumeri, M. (1995) Managing product families: The case of the Sony Walkman. *Research Policy,* 24 (5), 761-82.

Sarkar, J. (1998) Technological Diffusion: Alternative Theories and Historical Evidence. *Journal of Economic Surveys,* 12 (2), 131-176.

Saviotti, P.P. & Metcalfe, J.S. (1984) A theoretical approach to the construction of technological output indicators. *Research Policy,* 13 (3), 141-51.

Sharif, M.N. & Kabir, C. (1976) System Dynamics Modelling for Forecasting Multilevel Technological Substitution. *Technological Forecasting & Social Change,* 9 (1-2), 89-112.

Shaw, D.B. (2008) *Technoculture: The key Concepts*. Oxford: Berg.

Shepherd, J., Wicke, P., Oliver, P., Laing, L. & Horn, D. (2003) *Continuum Enciclopedia of Popular Music of the World. Volume I: Media, Industry and Society*. London, New York: Continuum.

Silverberg, G., Dosi, G. & Orsenigo, L. (1988) Innovation, diversity and diffusion: a self-organization model. *Economic Journal,* 98 (393), 1032-1054.

Sinha, R.K. & Chandrashekaran, M. (1992) A Split Hazard Model for Analyzing the Diffusion of Innovations. *Journal of Marketing Research,* 29 (1), 116-27.

Smith, M.D. & Telang, R. (2010) Piracy or promotion? The impact of broadband Internet penetration on DVD sales. *Information Economics and Policy,* 22 (4), 289-98.

Smith, R. (2002) *Inventions and Inventors*. Salem Press, Inc.

Soete, L. & Turner, R. (1984) Diffusion and the Rate of Technical Change. *The Economic Journal,* 94 (375), 612-23.

Stoneman, P. (1991a) Technological Diffusion: the Viewpoint of Economic Theory. *In* P. Mathias & J.A. Davis eds. *Innovation and Technology in Europe*. Basil Blackwell.

Stoneman, P. (1991b) Copying Capabilities and Intertemporal Competition between Joint Input Technologies: CD vs DAT. *Economics of Innovation and New Technology,* 1 (3), 233-42.

Stoneman, P. (2002) *The Economics of Technological Diffusion*. Oxford: Blackwell Publishers Ltd.

Stoneman, P. & Battisti, G. (2000) The Role of Regulation, Fiscal Incentives and Changes in Tastes in the Diffusion of Unleaded Petrol in the UK. *Oxford Economic Papers,* 52 (2), 326-56.

Stoneman, P. & Ireland, N.J. (1983) The Role of Supply Factors in the Diffusion of New Process Technology. *The Economic Journal,* 93 (Supplement: Conference Papers), 66-78.

Stoneman, P. & Kwon, M. (1994) The Diffusion of Multiple Process Technologies. *The Economic Journal,* 104 (423), 420-31.

Stoneman, P. & Toivanen, O. (1997) The Diffusion Of Multiple Technologies: An Empirical Study. *Economics of Innovation and New Technology,* 5 (1), 1-17.

Strowel, A. (2009) *Peer-to-Peer File Sharing and Secondary Liability in Copyright Law*. Cheltenham: Edward Elgar Publishers.

Sujan, M. (1985) Consumer Knowledge: Effects on Evaluation Strategies Mediating Consumer Judgments. *Journal of Consumer Research,* 12 (1), 31-46.

Tanny, S.M. & Derzko, N.A. (1988) Innovators and imitators in innovation diffusion modelling. *Journal of Forecasting,* 7 (4), 225-234.

Tarling, R. (2009) *Statistical Modelling for Social Researchers. Principles and Practice*. New York: Routledge.

Thirtle, C.G. & Ruttan, V.W. (1987) *The Role of Demand and Supply in the Generation and Diffusion of Technical Change*. London: Harwood Academic Publishers.

Tonks, I. (1986) The Demand for Information and the Diffusion of New Product. *International Journal of Industrial Organization,* 4 (4), 397-408.

Tornatzky, L.G. & Klein, K.J. (1982) Innovation Characteristics and Innovation Adoption-Implementation: A Meta-Analysis of Findings. *IEEE Transactions on Engineering Management,* 29 (1), 28-45.

Triplett, J. (1989) Price and Technological Change in a Capital Good: A Survey of Research on Computers. *In* D. Jorgenson & R. Landau eds. *Technology and Capital Formation*. Cambridge (MA): MIT Press.

Triplett, J. (2004) *Handbook on Hedonic Indexes and Quality Adjustments in Price Indexes: Special Application to Information Technology Products*. OECD Science, Technology and Industry Working Papers, 2004/9, OECD Publishing.

Tschmuck, P., (2010) The Economics of Music File Sharing - A Literature Overview. Vienna Music Business Research Days, University of Music and Performing Arts, Vienna, June 9-10, 2010.

Turnbull, P.W. & Meenaghan, A. (1980) Diffusion of Innovation and Opinion Leadership. *European Journal of Marketing,* 14 (1), 3-33.

Valente, T.W. & Davis, R.L. (1999) Accelerating the Diffusion of Innovations using Opinion Leaders. *The ANNALS of the American Academy of Political and Social Science,* 566 (1), 55.

Valente, T.W. & Rogers, E.M. (1993) *Towards Clarification of Thresholds and the Critical Mass*. Working Paper: Johns Hopkins University.

Van den Bulte, C. & Lilien, G.L. (2001) Medical Innovation Revisited: Social Contagion versus Marketing Effort. *The American Journal of Sociology,* 106 (5), 1409-35.

Van den Bulte, C. & Stremersch, S. (2004) Social Contagion and Income Heterogeneity in New Product Diffusion: A Meta-analytic test. *Marketing Science,* 23 (4), 530-44.

Venkatraman, M.P. (1991) The impact of innovativeness and innovation type on adoption. *Journal of Retailing,* 67 (1), 51-67.

Walden, E.A. & Browne, G.J. (2002) Information Cascades in the Adoption of New Technology. *Proceedings of the Twenty-Third International Conference on Information Systems*, 435-443.

Waldfogel, J. (2010) Music file sharing and sales displacement in the iTunes era. *Information Economics and Policy,* 22 (4), 306-14.

Williamson, J. & Cloonan, M. (2007) Rethinking the music industry. *Popular Music,* 26 (2), 305-22.

Zentner, A. (2006) Measuring the effect of file sharing on music purchases. *Journal of*

Law and Economics, 49 (1), 63-90.

Zettelmeyer, F. & Stoneman, P. (1993) Testing Alternative Models Of New Product Diffusion. *Economics of Innovation and New Technology,* 2 (4), 283-308.

APPENDICES

APPENDIX A. Questionnaire on DAPs adoption (English version)

University of Sussex
SPRU – Science & Technology Policy Research

The adoption and diffusion of consumer electronics: The case of Digital Audio Players.

Dear Respondent,

I am inviting you to participate in a research project to study the **adoption and diffusion of MP3 players**. This research project is funded by the European Commission, under the NEST (New and Emerging Science and Technology) programme of the 6th Framework Programme for Research (FP6). The project involves several universities and research centres in Europe, including the University of Sussex.

Along with this letter you will find a short questionnaire that asks a variety of questions about your attitude towards MP3 players. **Both users and non-users of MP3 players** are invited to respond. The questionnaire should take about 15 minutes to complete. Once you finish it, please hand it to me.

All the information collected through the questionnaires will be treated with the maximum confidentiality. None of the questions concerns ethical or sensitive issues. The information collected will be used **only** for statistical and academic research purposes.

Your participation is voluntary. By completing and returning the survey you have shown your agreement to participate in the study. If you have any question or concerns about completing the questionnaire please do not hesitate to contact me for further information.

Sincerely,

Roberto Camerani

The people involved in the project who will have direct access to the data are: Nicoletta Corrocher (nicoletta.corrocher@unibocconi.it), Roberto Fontana (roberto.fontana@unibocconi.it), at CESPRI (Bocconi University, Milan) and Roberto Camerani (r.camerani@sussex.ac.uk), at SPRU (University of Sussex, UK).

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1. Age: ____
2. Gender: 1. Male ☐ 2. Female ☐
3. Nationality: ______________________________
4. City of residence (in capital letters):______________________________
5. Are you financially independent of your family?
   ☐ Yes, I am financially independent. In this case:
   a. Are you supporting anyone beside yourself?
   ☐ Yes, please indicate how many people _____ (including yourself)
   ☐ No, just myself
   b. What is your personal annual income?

☐ 1. Less than 4.999€	☐ 9. 70.000€ – 79.999€	☐ 17. 150.000€ – 159.999€
☐ 2. 5.000€ – 9.999€	☐ 10. 80.000€ – 89.999€	☐ 18. 160.000€ – 169.999€
☐ 3. 10.000€ – 19.999€	☐ 11. 90.000€ – 99.999€	☐ 19. 170.000€ – 179.999€
☐ 4. 20.000€ – 29.999€	☐ 12. 100.000€ – 109.999€	☐ 20. 180.000€ – 189.999€
☐ 5. 30.000€ – 39.999€	☐ 13. 110.000€ – 119.999€	☐ 21. 190.000€ – 199.999€
☐ 6. 40.000€ – 49.999€	☐ 14. 120.000€ – 129.999€	☐ 22. More than 200.000€
☐ 7. 50.000€ – 59.999€	☐ 15. 130.000€ – 139.999€	
☐ 8. 60.000€ – 69.999€	☐ 16. 140.000€ – 149.999€	

   ☐ No, I depend on someone (e.g. your parents). In this case:
   a. How many dependents are in your family _____ (including your parents)?
   b. What is your family annual income?

☐ 1. Less than 4.999€	☐ 9. 70.000€ – 79.999€	☐ 17. 150.000€ – 159.999€
☐ 2. 5.000€ – 9.999€	☐ 10. 80.000€ – 89.999€	☐ 18. 160.000€ – 169.999€
☐ 3. 10.000€ – 19.999€	☐ 11. 90.000€ – 99.999€	☐ 19. 170.000€ – 179.999€
☐ 4. 20.000€ – 29.999€	☐ 12. 100.000€ – 109.999€	☐ 20. 180.000€ – 189.999€
☐ 5. 30.000€ – 39.999€	☐ 13. 110.000€ – 119.999€	☐ 21. 190.000€ – 199.999€
☐ 6. 40.000€ – 49.999€	☐ 14. 120.000€ – 129.999€	☐ 22. More than 200.000€
☐ 7. 50.000€ – 59.999€	☐ 15. 130.000€ – 139.999€	
☐ 8. 60.000€ – 69.999€	☐ 16. 140.000€ – 149.999€	

6. Are you currently a student?
   ☐ 1. I am an undergraduate student in: ______________________________(e.g. economics)
   ☐ 2. I am a postgraduate student in: ______________________________(e.g. economics)
   In this case, which first degree do you have? ______________________________
   ☐ 3. I am not a student. In this case, which degree do you have? ______________________________
7. Which kind of computer do you usually use? (select only one option)
   ☐ 1. An Apple Macintosh
   ☐ 2. A PC based on Windows 95/98/ME/2000/NT/XP/Vista
   ☐ 3. A Computer based on other open source OS (e.g. Linux/Unix/Ubuntu/Debian)
   ☐ 4. Other

8. On average, how long do you use a computer for during a day?
   - ☐ 1. Never
   - ☐ 2. Less than ½ hour
   - ☐ 3. From ½ hour to 1 hour
   - ☐ 4. 1 – 3 hours
   - ☐ 5. 3 – 5 hours
   - ☐ 6. More than 5 hours

9. On the total time you spend using a computer, which percentage is for work or study, and which percentage is for leisure activities? (e.g. 60% study/work; 40% leisure)

   _____% Study or Work

   _____% Leisure

   ----

   100 % Total

10. Relative to the average computer user, how would you describe your skills in using a computer?
    - ☐ 1. Much below the average (novice user)
    - ☐ 2. Moderately below the average (still learning the basics)
    - ☐ 3. On the average (intermediate user)
    - ☐ 4. Moderately above the average (expert user)
    - ☐ 5. Much above the average (professional user)

11. Do you have access to a broad band Internet connection? (select only one option)
    - ☐ 1. Both at home and at work/university
    - ☐ 2. Yes, at home
    - ☐ 3. Yes, at work/university
    - ☐ 4. No

12. How frequently do you carry out the following activities when you are connected to the Internet?

		Never	**Almost never**	**Sometimes**	**Often**	**Very often**
a.	Buy products and/or services	☐	☐	☐	☐	☐
b.	Buy songs in digital format	☐	☐	☐	☐	☐
c.	Make phone calls through the Internet	☐	☐	☐	☐	☐
d.	Manage your personal page (e.g. blog, Facebook, Flickr, Myspace, etc.)	☐	☐	☐	☐	☐
e.	Send emails/instant messages	☐	☐	☐	☐	☐
f.	Watch videos (e.g. on YouTube)	☐	☐	☐	☐	☐
g.	Upload videos (e.g. on YouTube)	☐	☐	☐	☐	☐
h.	Use peer-to-peer software	☐	☐	☐	☐	☐
i.	Listen to Internet Radios	☐	☐	☐	☐	☐

13. Among these music genres which ones do you regularly listen to? (select all those that apply)
    - ☐ Blues
    - ☐ Classical
    - ☐ Country/Folk
    - ☐ Dance
    - ☐ International/World
    - ☐ Electronic
    - ☐ Hip-hop/Rap
    - ☐ Jazz
    - ☐ Pop
    - ☐ R&B/Soul
    - ☐ Rock
    - ☐ Other

14. Have you ever owned one of the following portable music players? (select all those that apply)
    - ☐ a. Walkman or another portable cassette player
    - ☐ b. Discman or another portable CD player
    - ☐ c. Minidisc Player
    - ☐ d. None of them

15. Do you have one of the following consumer electronics products? (select all those that apply)
- ☐ a. Blue-ray Disc Player
- ☐ b. Camcorder
- ☐ c. Digital Camera
- ☐ d. Global Positioning System (GPS)
- ☐ e. High-Definition (HD) Television
- ☐ f. Personal Digital Assistant (PDA)
- ☐ g. Smart Phone (e.g. as iPhone, Blackberry, etc.)

16. Do you have a portable MP3 player?

☐	1. No, I do not have an MP3 player	**Please go to question 42**
☐	2. The **<u>only</u>** MP3 player that I own is a mobile phone that can play MP3 files	**Please go to question 42**
☐	3. The **<u>only</u>** MP3 player that I own is a CD player capable of playing MP3 files	**Please go to question 42**
☐	4. Yes, I own an MP3 player, one on which I can download MP3 (MP4, AAC, WMA, etc.) files and play them	**Please <u>continue</u> with the question 17**

17. How did you get your **<u>first</u>** MP3 player? (select only one option)
- ☐ 1. I purchased it on my own
- ☐ 2. I requested a specific model as a gift
- ☐ 3. I requested an MP3 player as a gift but not a specific model
- ☐ 4. I received it as an unexpected gift
- ☐ 5. I won/found it

18. When did you purchase or receive your **<u>first</u>** MP3 player?

Before July 2001	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	After July 2008
	July 2001	January 2002	July 2002	January 2003	July 2003	January 2004	July 2004	January 2005	July 2005	January 2006	July 2006	January 2007	July 2007	January 2008	July 2008		
	2001		2002		2003		2004		2005		2006		2007		2008		

19. Which was the brand of your **<u>first</u>** MP3 player?

☐ 1. Acer	☐ 6. Microsoft	☐ 11. Samsung
☐ 2. Apple	☐ 7. MpMan	☐ 12. SanDisk
☐ 3. Cowon	☐ 8. Packard Bell	☐ 13. Sony
☐ 4. Creative	☐ 9. Philips	☐ 14. Other brand
☐ 5. iRiver	☐ 10. Rio	☐ 15. I do not know/I do not remember

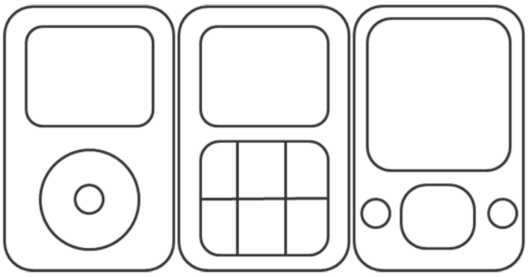
20. Which features did your **<u>first</u>** MP3 player have? (select all those that apply)

Screen	**Other features**	
☐ a. No screen	☐ d. Alarm/calendar	☐ g. Podcasting
☐ b. Monochromatic screen	☐ e. Built-in speakers	☐ h. Rechargeable battery
☐ c. Colour	☐ f. Games	

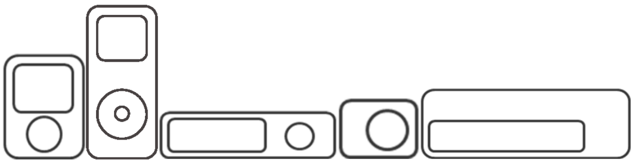
21. My **<u>first</u>** MP3 player could... (select all those that apply)

☐ a. Display Pictures	☐ d. Record Voice
☐ b. Play Videos	☐ e. Record FM Radio
☐ c. Play FM Radio	☐ f. Record Videos

22. Which type of MP3 player was the **first** one you purchased or requested?
   - ☐ 1. It was an MP3 player with hard-drive memory
     (usually bigger, with large display and big storage memory, similar to one of the models below)



   - ☐ 2. It was an MP3 player with a flash memory
     (usually smaller, lighter, with small screen and with limited storage memory, similar to one of the models below)



23. Which was the storage capacity of your **first** MP3 player in megabytes (MB) or gigabytes (GB)
   - ☐ 1. Less than 128 MB
   - ☐ 2. 128 MB – 511 MB
   - ☐ 3. 512 MB – 0.99 GB
   - ☐ 4. 1 GB – 3.99 GB
   - ☐ 5. 4 GB – 7.99 GB
   - ☐ 6. 8 GB – 29.99 GB
   - ☐ 7. 30 GB – 79.99 GB
   - ☐ 8. More than 80 GB
   - ☐ 9. I do not know/ I do not remember

24. On average, how long do you use your MP3 player during the day?
   - ☐ 1. Never
   - ☐ 2. Less than ½ hour
   - ☐ 3. From ½ hour to 1 hour
   - ☐ 4. 1 – 3 hours
   - ☐ 5. 3 – 5 hours
   - ☐ 6. More than 5 hours

25. How many gigabytes (GB) of songs in digital format do you have on your computer (not necessarily stored on your MP3 player)?
   - ☐ 1. Less than 1 GB
   - ☐ 2. 1 GB – 4.99 GB
   - ☐ 3. 5 GB – 9.99 GB
   - ☐ 4. 10 GB – 29.9 GB
   - ☐ 5. More than 30 GB
   - ☐ 6. I do not know/ I do not remember

26. What's the most important source of knowledge for learning how to use your MP3 player? (select only one option)
   - ☐ 1. Myself
   - ☐ 2. Product manual
   - ☐ 3. My friends or relatives
   - ☐ 4. The employees in the store where I purchased it
   - ☐ 5. Online support service
   - ☐ 6. Online forum or community

27. How often do you use the following features of your MP3 player?

		Not available in my player	Never	Almost never	Sometimes	Often	Very often
a.	Alarm / calendar	☐	☐	☐	☐	☐	☐
b.	Built-in speakers	☐	☐	☐	☐	☐	☐
c.	Games	☐	☐	☐	☐	☐	☐
d.	Photo display	☐	☐	☐	☐	☐	☐
e.	Podcasting	☐	☐	☐	☐	☐	☐
f.	Radio FM Player	☐	☐	☐	☐	☐	☐
g.	Radio FM Recording	☐	☐	☐	☐	☐	☐
h.	Video playback	☐	☐	☐	☐	☐	☐
i.	Voice Recording	☐	☐	☐	☐	☐	☐
j.	Video Recording	☐	☐	☐	☐	☐	☐

28. Where do you regularly get the music files you listen to with your MP3 player? Please rank from 1 to 4 the following sources (1=the most important, 4=the least important)
    ____ From Internet sources that <u>require</u> a payment
    ____ From Internet sources that <u>do not require</u> a payment
    ____ From my collection of CD
    ____ From friends

29. How do you regularly listen to music with your MP3 player? Please rank from 1 to 3 the following "modes of music playing" of your MP3 player (1=the style you use the most, 3=the style you use the least)
    ____ Shuffle songs
    ____ Play playlist
    ____ Search each time the specific album/artist/song

30. How important are each of the following characteristics in choosing which MP3 player to buy?

		Unimportant	Of little importance	Moderately important	Important	Very Important
a.	Battery life	☐	☐	☐	☐	☐
b.	FM radio	☐	☐	☐	☐	☐
c.	Possibility of watching pictures	☐	☐	☐	☐	☐
d.	Possibility of watching videos	☐	☐	☐	☐	☐
e.	Price of the MP3 player	☐	☐	☐	☐	☐
f.	Display's size	☐	☐	☐	☐	☐
g.	Storage capacity	☐	☐	☐	☐	☐
h.	Voice recording	☐	☐	☐	☐	☐
i.	Warranty	☐	☐	☐	☐	☐
j.	Weight of player	☐	☐	☐	☐	☐
k.	Product design/aesthetics	☐	☐	☐	☐	☐

31. Did you try one or more MP3 player(s) before owning one? (select all those that apply)
    ☐ a. Yes, I tried a friend's one
    ☐ b. Yes, I tried it in a generic electronics store
    ☐ c. Yes, I tried it in a specific brand store (e.g. Apple Store)
    ☐ d. No

32. Please rate your level of agreement with the following statements

		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
a.	After trying an MP3 player it is easier to appreciate its quality	☐	☐	☐	☐	☐
b.	It would be easy for me to try out one or more MP3 players	☐	☐	☐	☐	☐
c.	Before deciding whether or not to buy an MP3 player I would like to try it	☐	☐	☐	☐	☐

33. Please rate your level of agreement with the following statements

	I have an mp3 player because…	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
a.	It allows me to gather all my MP3 in only one device	☐	☐	☐	☐	☐
b.	I can always bring it with me and listen to music anywhere I want	☐	☐	☐	☐	☐
c.	I like to have electronic gadgets	☐	☐	☐	☐	☐
d.	Many of my friends/colleagues have one	☐	☐	☐	☐	☐

34. Please rate your level of agreement with the following statements

		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
a.	I knew how to use an MP3 player before owning it	☐	☐	☐	☐	☐
b.	Learning how to use an MP3 player was easy for me	☐	☐	☐	☐	☐
c.	Learning how to convert CDs into MP3 files was easy for me	☐	☐	☐	☐	☐
d.	Learning how to load my MP3 files into the MP3 player was easy for me	☐	☐	☐	☐	☐

35. How important are each of the following characteristics in evaluating an MP3 player?

		Unimportant	Of little importance	Moderately important	Important	Very Important
a.	Compatibility with the music file stored in my computer	☐	☐	☐	☐	☐
b.	Availability of a dedicated software that connects the player to a computer (e.g. iTunes, Zune software)	☐	☐	☐	☐	☐
c.	Availability of dedicated accessories (e.g. speakers, skins, car adapter kits)	☐	☐	☐	☐	☐

36. How important are each of the following characteristics in evaluating an MP3 player?

		Unimportant	Of little importance	Moderately important	Important	Very Important
a.	Number of people using that product	☐	☐	☐	☐	☐
b.	Number of friends with whom exchanging MP3 files	☐	☐	☐	☐	☐

37. Please rate your level of agreement with the following statements

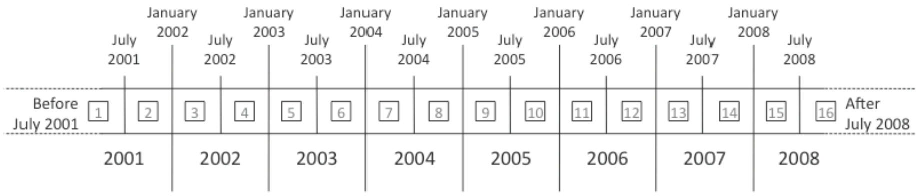
		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
a.	It was easy to identify which was the best MP3 player for me	☐	☐	☐	☐	☐
b.	It was easy to compare the performance of the different MP3 players available	☐	☐	☐	☐	☐
c.	I could easily explain the reasons for having an MP3 player to others	☐	☐	☐	☐	☐

38. Please rate your level of agreement with the following statements

		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
a.	Before owning an MP3 player I used to observe what other people like me did with that product	☐	☐	☐	☐	☐
b.	My friends all have the same model of MP3 player	☐	☐	☐	☐	☐
c.	Having an MP3 player makes me feel part of a group	☐	☐	☐	☐	☐
d.	Having an MP3 player makes me gain prestige among my friends	☐	☐	☐	☐	☐

39. How many MP3 players have you owned?
- ☐ 1. One **(Please go to question 44, page 11)**
- ☐ 2. More than one **(Please <u>continue</u> with question 40)**

40. When did you purchase or receive your other MP3 player(s) after the first one?



41. Why did you get one or more MP3 players after the first one? (select all those that apply)
- ☐ a. The old one broke down/did not work properly
- ☐ b. The old one got lost or stolen
- ☐ c. I wanted to use the new functions of a novel product
- ☐ d. I needed a smaller model
- ☐ e. I needed more space to store my MP3 files
- ☐ f. All my friends had a new one
- ☐ g. I got it as a gift

Please continue with the question 44 on page 11

42. Why have you not bought an MP3 player yet?
Please rate your level of agreement with the following statements

		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
a.	Because they are too expensive and I am expecting that the price will decline	☐	☐	☐	☐	☐
b.	Because I am waiting for a model with some specific functions	☐	☐	☐	☐	☐
c.	Because I think I will not use it after buying	☐	☐	☐	☐	☐
d.	Because I am afraid I will not be able to use it	☐	☐	☐	☐	☐
e.	Because I am using another portable music player (e.g. CD player or Minidisc)	☐	☐	☐	☐	☐
f.	Because I believe that mobile phones will be the best mobile music platform in the future	☐	☐	☐	☐	☐

43. Are you interested in buying an MP3 player?
(different than a phone or a CD player able to read MP3 player)
- ☐ 1. No, I am not interested in buying one
- ☐ 2. Yes, I would like to buy one soon,

In this case, what is the maximum price you would be willing to pay?
- ☐ 1. Less than 30€
- ☐ 2. From 30€ to 59.99€
- ☐ 3. From 60€ to 124.99€
- ☐ 4. From 125€ to 189.99€
- ☐ 5. More than 190€

Please continue with the question 44 on next page

44. In choosing an MP3 player how important are the following sources of information?

		Unimportant	Of little importance	Moderately important	Important	Very Important
a.	Advertisement	☐	☐	☐	☐	☐
b.	Celebrity endorsers	☐	☐	☐	☐	☐
c.	MP3 player producers' websites	☐	☐	☐	☐	☐
d.	My family or relatives	☐	☐	☐	☐	☐
e.	My friends	☐	☐	☐	☐	☐
f.	My previous experience with products of the same brand	☐	☐	☐	☐	☐
g.	My previous experience with similar products	☐	☐	☐	☐	☐
h.	Online forum or communities	☐	☐	☐	☐	☐
i.	Online shops/retailers	☐	☐	☐	☐	☐
j.	Traditional shops/retailers	☐	☐	☐	☐	☐
k.	Other people around me	☐	☐	☐	☐	☐
l.	Specialized magazines	☐	☐	☐	☐	☐

45. Please rate your level of agreement with the following statements

		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
a.	If I want to know more about a product, I would ask my friends about it	☐	☐	☐	☐	☐
b.	To make sure I choose the right product or brand, I always observe what others are buying and using	☐	☐	☐	☐	☐
c.	Before trying a new product, I try to learn what friends who possess this product think about it	☐	☐	☐	☐	☐
d.	I seek out the opinion of those who have tried new products or brands before I try them	☐	☐	☐	☐	☐

46. Please rate your level of agreement with the following statements

		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
a.	A consumer electronics product is more beneficial if many people use it	☐	☐	☐	☐	☐
b.	I would not buy a consumer electronics product if I thought that many other people will not buy it in the future	☐	☐	☐	☐	☐

47. Please rate your level of agreement with the following statements

		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
a.	If I want to be like someone, I often try to buy the same brands that they buy	☐	☐	☐	☐	☐
b.	When buying products, I generally purchase those brands that I think other people will approve	☐	☐	☐	☐	☐

48. Please rate your level of agreement with the following statements

		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
a.	I am reluctant about adopting new ways of doing things until I see them working for people around me	☐	☐	☐	☐	☐
b.	I rarely trust new ideas until I can see whether the vast majority of people around me accept them	☐	☐	☐	☐	☐
c.	I am aware that I am usually one of the last people in my group to accept something new	☐	☐	☐	☐	☐
d.	I must see other people using new innovations before I will consider them	☐	☐	☐	☐	☐
e.	I am generally cautious about accepting new ideas	☐	☐	☐	☐	☐

49. Please rate your rate of agreement with the following statements

		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
a.	In general, I am the last in my circle of friends to know about the latest new consumer electronics products	☐	☐	☐	☐	☐
b.	Compared to my friends, I own very little consumer electronics products	☐	☐	☐	☐	☐
c.	I do not know the names of new consumer electronics products before other people do	☐	☐	☐	☐	☐
d.	If I heard that a new consumer electronics product was available in the store, I would be interested enough to buy it	☐	☐	☐	☐	☐
e.	I would not buy a new item of consumer electronics if I had only a little experience with it	☐	☐	☐	☐	☐

END OF THE QUESTIONNAIRE, THANKS FOR YOUR COLLABORATION!

APPENDIX B

Table B.1 Results of hedonic prices regression with time dummies by semester

	ALL PLAYERS		*HD PLAYERS*		*FLASH PLAYERS*	
CONSTANT	**5.112*** **	(0.279)	**5.547*** **	(0.947)	**5.953*** **	(0.347)
LN_STORAGE	**0.240*** **	(0.0191)	**0.190*** **	(0.0312)	**0.347*** **	(0.0236)
LN_PIXELS	**0.127*** **	(0.0285)	-0.0458	(0.0794)	**0.117*** **	(0.0351)
LN_LIFE	-0.0137	(0.0454)	0.264	(0.181)	-0.0354	(0.0540)
LN_WEIGHT	**-0.865*** **	(0.187)	-0.686	(0.450)	**-1.052*** **	(0.356)
WEIGHT*PIXELS	**0.0437*** **	(0.0147)	**0.0834** **	(0.0365)	**0.0800** **	(0.0324)
WEIGHT*LIFE	**0.146*** **	(0.0416)	-0.0597	(0.0968)	0.101	(0.0758)
BATT_REC	**0.112*** **	(0.0432)	-0.258	(0.247)	**0.154*** **	(0.0465)
FM	0.0443	(0.0406)	0.0249	(0.0597)	0.0710	(0.0504)
REC_VOICE	**-0.105*** **	(0.0375)	**0.125** **	(0.0490)	**-0.162*** **	(0.0472)
REC_FM	0.00250	(0.0352)	-0.0692	(0.0651)	-0.0139	(0.0402)
REC_VIDEO	**0.504*** **	(0.108)	**0.279** **	(0.117)	**0.598*** **	(0.143)
COL_SCR	-0.00627	(0.0595)	-0.111	(0.140)	0.0417	(0.0666)
PICS	-0.00295	(0.0604)	0.147	(0.134)	**-0.132** **	(0.0666)
VIDEO	0.0620	(0.0532)	0.0670	(0.0671)	0.0682	(0.0632)
SPEAKERS	**0.152*** **	(0.0541)	0.0237	(0.0787)	**0.158** **	(0.0662)
TOUCH_SCR	**0.188*** **	(0.0560)	0.0998	(0.0885)	0.0893	(0.0727)
TYPE	**0.361*** **	(0.0706)				
APPLE	-0.0229	(0.0503)	0.0774	(0.0523)	-0.0135	(0.0790)
S2	**-0.378** **	(0.152)	0.154	(0.226)	**-0.374** **	(0.183)
S3	**-0.827*** **	(0.151)	-0.0139	(0.290)	**-0.814*** **	(0.287)
S4	**-0.490*** **	(0.127)	-0.0831	(0.329)	**-0.533*** **	(0.134)
S5	**-0.808*** **	(0.148)	-0.0590	(0.298)	**-0.871*** **	(0.177)
S6	**-1.030*** **	(0.131)	-0.171	(0.291)	**-1.140*** **	(0.177)
S7	**-0.985*** **	(0.122)	-0.241	(0.290)	**-1.063*** **	(0.136)
S8	**-1.144*** **	(0.130)	-0.255	(0.293)	**-1.220*** **	(0.150)
S9	**-1.332*** **	(0.125)	-0.427	(0.293)	**-1.569*** **	(0.140)
S10	**-1.527*** **	(0.129)	**-0.599** **	(0.296)	**-1.845*** **	(0.144)
S11	**-1.851*** **	(0.138)	**-0.655** **	(0.306)	**-2.276*** **	(0.155)
S12	**-1.824*** **	(0.141)	**-0.782** **	(0.301)	**-2.236*** **	(0.163)
S13	**-2.252*** **	(0.144)	**-0.926*** **	(0.307)	**-2.709*** **	(0.163)
S14	**-2.434*** **	(0.152)	**-1.082*** **	(0.315)	**-2.932*** **	(0.170)
S15	**-2.435*** **	(0.154)	**-0.678** **	(0.331)	**-2.952*** **	(0.172)
S16	**-2.579*** **	(0.156)	**-1.427*** **	(0.328)	**-3.079*** **	(0.174)
S17	**-2.799*** **	(0.163)			**-3.307*** **	(0.183)
S18	**-2.800*** **	(0.169)	**-1.535*** **	(0.359)	**-3.382*** **	(0.188)
Observations	479		138		341	
R-squared	0.827		0.824		0.779	
Prob F test	.000		.000		.000	

*Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1*

Table B.2 Results of hedonic prices regression by adjacent years

	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009
CONSTANT	11.34**	5.750***	5.502***	5.602***	4.186***	2.653***	2.547***	1.827***
	(4.589)	(1.149)	(1.073)	(0.502)	(0.524)	(0.569)	(0.422)	(0.455)
LN_STORAGE	0.221*	0.323***	0.300***	0.222***	0.190***	0.244***	0.312***	0.363***
	(0.117)	(0.0439)	(0.0422)	(0.0280)	(0.0318)	(0.0390)	(0.0329)	(0.0386)
LN_PIXELS	-0.895	-0.223*	-0.0877	-0.00680	0.106*	0.106*	0.116***	0.234***
	(0.657)	(0.123)	(0.119)	(0.0552)	(0.0553)	(0.0562)	(0.0437)	(0.0520)
LN_LIFE	0.128	0.234*	0.0636	-0.132**	-0.0414	0.295***	0.0239	-0.117
	(0.381)	(0.117)	(0.110)	(0.0553)	(0.0682)	(0.113)	(0.0903)	(0.100)
LN_WEIGHT	-7.189	-1.953**	-0.573	-1.105***	-1.142***	0.849*	-0.479	-2.094***
	(6.211)	(0.786)	(0.646)	(0.333)	(0.334)	(0.483)	(0.448)	(0.666)
WEIGHT*PIXELS	1.003	0.316***	0.0880	0.0725**	0.0529**	-0.0374	0.0410	0.107**
	(0.783)	(0.0953)	(0.0667)	(0.0297)	(0.0251)	(0.0323)	(0.0364)	(0.0497)
WEIGHT*LIFE	-0.470	-0.371***	-0.0993	0.140**	0.207***	-0.104	0.000502	0.285***
	(0.354)	(0.128)	(0.127)	(0.0575)	(0.0704)	(0.117)	(0.0790)	(0.0909)
BATT_REC	0.376**	0.654***	0.138	0.135**	0.140**	0.178*	0.182*	
	(0.176)	(0.0739)	(0.0834)	(0.0533)	(0.0624)	(0.103)	(0.103)	
FM	-0.167	-0.238**	0.0611	0.0101	0.186***	0.0756	-0.250***	-0.255***
	(0.482)	(0.0854)	(0.125)	(0.0705)	(0.0701)	(0.0754)	(0.0725)	(0.0917)
REC_VOICE	0.132	0.203***	-0.0599	0.00954	-0.141**	-0.0826	-0.0174	-0.0543
	(0.472)	(0.0671)	(0.112)	(0.0659)	(0.0685)	(0.0862)	(0.0649)	(0.0630)
REC_FM	0.277	0.298***	-0.0807	0.00903	0.0167	0.0756	0.121**	-0.00993
	(0.185)	(0.0661)	(0.102)	(0.0605)	(0.0618)	(0.0761)	(0.0566)	(0.0582)
REC_VIDEO				0.188	0.617***	0.650***	0.355	0.471**
				(0.235)	(0.146)	(0.172)	(0.281)	(0.216)
COL_SCR	-3.038	-1.010***	0.0209	-0.0159	-0.0555	-0.0515	0.261***	0.0483
	(2.418)	(0.312)	(0.179)	(0.108)	(0.108)	(0.108)	(0.0875)	(0.113)
PICS			0.0994	0.0163	-0.0269	-0.0795	0.213**	-0.0274
			(0.239)	(0.101)	(0.110)	(0.0988)	(0.0968)	(0.185)
VIDEO			0.109	0.0576	0.00308	-0.0544	-0.226**	-0.103
			(0.226)	(0.0817)	(0.0757)	(0.0980)	(0.0982)	(0.161)
SPEAKERS				-0.00760	-0.00639	0.224*	0.0890	0.213***
				(0.129)	(0.111)	(0.130)	(0.0739)	(0.0767)
TOUCH_SCR				0.602*	0.432**	0.267**	0.134	-0.0290
				(0.314)	(0.203)	(0.131)	(0.0816)	(0.0796)
TYPE	1.793**	1.516***	0.810***	0.296***	0.0188	0.110	0.422***	0.608***
	(0.832)	(0.237)	(0.176)	(0.100)	(0.100)	(0.127)	(0.138)	(0.159)
APPLE	-0.503	-0.00328	0.0107	-0.0207	-0.0209	0.0867	-0.0956	-0.313**
	(0.723)	(0.0952)	(0.122)	(0.0760)	(0.0904)	(0.111)	(0.0944)	(0.128)
Y2002	-0.256							
	(0.154)							
Y2003		-0.364***						
		(0.0614)						
Y2004			-0.0443					
			(0.0662)					
Y2005				-0.338***				
				(0.0435)				
Y2006					-0.335***			
					(0.0501)			
Y2007						-0.391***		

*Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1*

Figure B.1 Correspondence between evolution of product characteristics and users' perception over time (1)

Figure B.2 Correspondence between evolution of product characteristics and users' perception over time (2)

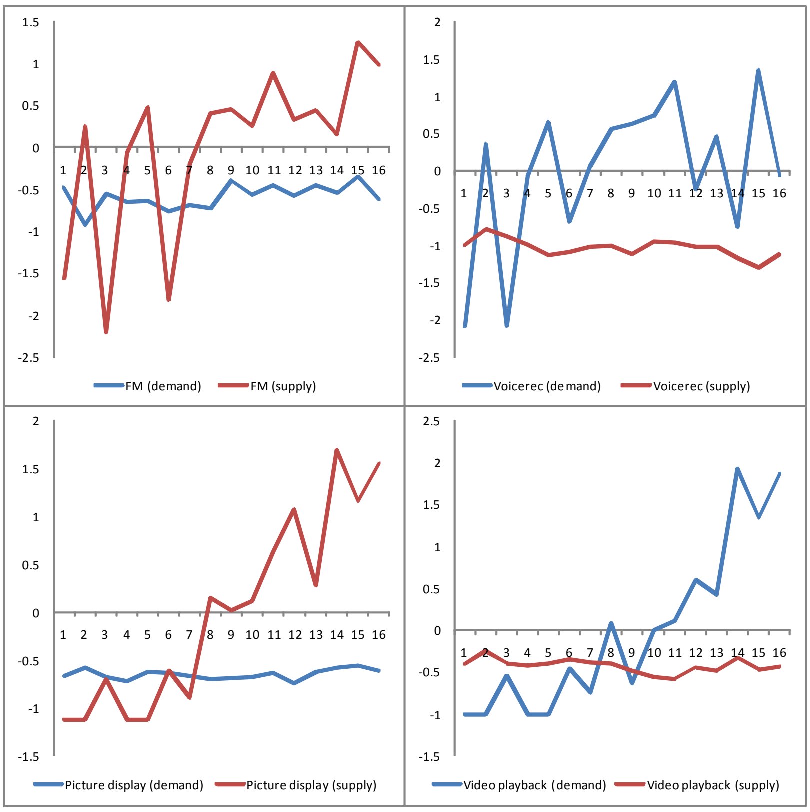


Table B.3 Estimation of the discrete parametric hazard function using logit regression

	Logit	
GENDER	**0.203****	[0.0959]
PREV_PLAY	**0.455*****	[0.167]
COMP_SKILLS	0.0211	[0.0562]
COMP_USE	-0.0106	[0.0496]
INNOV	-0.0557	[0.0514]
DOM_SP_INNOV	**0.229*****	[0.0535]
UK	**1.108*****	[0.192]
EU_NORTH	**0.765*****	[0.150]
EU_SOUTH	**1.052*****	[0.168]
LN_T	**2.360*****	[0.136]
LN_INCOME	**0.152*****	[0.0506]
GB_MUSIC	**0.115****	[0.0462]
EXP_STORAGE	**-0.0219*****	[0.00500]
EXP_WEIGHT	**0.0964*****	[0.0324]
EXP_PRICES	**0.695*****	[0.172]
CUMUL	**-0.129*****	[0.0188]
NETWORK	**-0.145*****	[0.0546]
IMITATION	0.0756	[0.0578]
INFO_CASC	-0.0472	[0.0452]
ORDER	**0.0483*****	[0.0168]
Constant	-7.941***	[0.650]
Observations	6,277	
Pos. outcomes	.	
Log likelihood	-1778	
Chi-square	531.4	
Prob Chi2	0	

*Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1*