Poverty within tropical forest: assets and activities to develop pro-poor forest conservation

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Declaration

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.

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Summary

Poverty within forests is often acknowledged but poorly assessed through economic evidence. To some extent, this lack of evidence explains why even if forest conservation has positive effects on households' welfare, such benefits are quite limited. This thesis is aimed at investigating in three steps how forest conservation can help poor forest households to improve their welfare.

A first chapter deals with assessing poverty of forest households in Bolivia looking at their asset accumulation and allowing for a poverty trap mechanism that may arise, preventing households to be better off. The empirical analysis does not find evidence for the existence of a poverty trap. Households are slowly accumulating assets over time but such an accumulation does not lead to any improvements in their welfare. Households would remain persistently poor.

A second chapter focuses on forest households' labour supply and allocations. Using primary data I collected in Cameroon, a non-separable agricultural household model is employed to identify factors influencing household labour supply and allocations into diverse activities. The empirical results shows that leisure is an inferior good, households working more when having greater income. Furthermore, households participating in forest activities have higher levels of welfare than households that do not. Increasing prices of forest resources helps households to improve their welfare.

The last chapter deals with designing payments for forest conservation so as to encourage forest households to internalise externalities. These payments are theoretically analysed using a principal-agent game in order to define incentives such that a forest group plants and conserves a great number of trees. Payments are non-zero when observing such conservation levels and equal to zero in all other cases. Doing so creates a virtuous circle on forest resources. Pro-poor conservation schemes as opposed to non-pro poor, are achievable with lower payments.

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Acronyms

2SLS	Two-Stage Least Squares
3SLS	Three-Stage Least Squares
AIDS	Almost Ideal Demand System
BLUPs	Best Linear Unbiased Predictors
CDMs	Clean Development Mechanisms
CFA	Communauté Financière Africaine
CIFOR	Center for International Forestry Research
CTOs	Carbon Tradable Offsets
ES	Environmental Services
ESI	Environmental Service Index
FONAFIFO	Fondo Nacional de Financiamento Forestal
FUNDECOR	Foundation for the Development of the Central Volcanic Range
GEF	Global Environment Fund
ICDPs	Integrated Conservation and Development Programmes
IRD	Institut de Recherche du Développement
IVs	Instrumental variables
KHDS	Kagera Health and Development Survey
KMO	Kaiser-Meyer-Olkin
LOWESS	Locally Weighted Scatterplot Smoother

LSMS	Living-Standard Measurement Surveys
MLRP	Monotone Likelihood Ratio Property
NGO	Non-Governmental Organisation
NTFP	Non-Timber Forest Product
OLS	Ordinary Least Squares
PCA	Principal Component Analysis
PES	Payments for Environmental Services
PFA	Principal Factor Analysis
PSA	Pagos por Servicios Ambientales
REDD	Reduced Emissions from Deforestation and Forest Degradations
REML	Restricted Maximum Likelihood
RISEMP	Regional Integrated Silvopastoral Ecosystem Management Project
SE	Standard Errors
TAPS	Tsimane' Amazonian Panel Study
WWF	World Wildlife Fund

Introduction

"The forest is the most beautiful [...], a house of jewels." (Ballard, 1966)

There is a popular tendency towards imagining tropical forests as mysterious preserves of luxurious wealth, flamboyant biodiversity and natural virginity. While these images currently persist, they are in conflict with the fact that in reality forests are becoming profoundly degraded and that within them poverty is widespread. I have always been concerned by the loss of tropical forest and the consequences for people living within them and more particularly, the poor.

A wide range of agents, including cattle ranchers, timber logging companies, agro-industrialists and poorer farmers or indigenous populations, live or operate in forest areas and their actions increase pressures on forest resources. While the actions of the cattle ranchers, timber logging companies and agro-industrialists have a greater impact on forest resources, it is the poorer agents who suffer most, the latter often being engaged in subsistence agriculture and extraction of forest resources (Byron and Arnold, 1999, Angelsen and Wunder, 2003). Though constituting a major part of the poor's livelihoods both in terms of consumption and income, such activities are generally characterised merely as safety nets and last-resort mechanisms that do not help households to get better off (Angelsen and Wunder, 2003). In actual fact, the loss of the resources upon which these activities rely, through the actions of the poor but also more importantly through the actions of other agents, have great negative effects on poor households' welfare.

In addition, considering that forest resources host several sub-ecosystems, losses and degradations of forests contribute to a decrease in water quality and quantity, loss of animals and fish, more frequent floods or droughts,... Such negative environmental consequences have greater negative impacts on poorer households for whom health, security and food depend on their environment (UNEP, 2004). Overall, it is generally acknowledged that forest degradations and poverty have tight linkages such that an increase in forest degradations increases poverty pressures on forest households which in turn feed back to increase pressures on forest (Angelsen and Wunder, 2003).

Such an argument is put forward by the Center for International Forestry Research (CIFOR). A world-leading research agency, CIFOR maintains a dominant position with respect to international research on forest uses and population, and lately has implemented a research project "Poverty Environment Network" (PEN) in order to collect quantitative and qualitative data necessary to assessing the links between poor forest households and forest (CIFOR, 2003, CIFOR, 2007). However, so far, results from the PEN are limited to the most general knowledge of forest households' living conditions. CIFOR and its scientists report that poor forest households depend even more than other households on forest resources but that to a certain extent, poor forest households could alleviate poverty pressures through modifying their uses of forest resources and adopting activities including the provision of environmental services. CIFOR reckons that policy and forestry management reforms should be targeted towards decentralisation and the delegation of power over forest resources to forest communities in order to permit them to reap greater benefits.

However, CIFOR fails both to provide a full assessment of forest households' welfare that utilises rigorous economic tools and to explain what are the factors contributing to households' poverty and what are the benefits gained from using forest resources. Arnold and Townson (1998), Byron and Arnold (1999) and Coomes et al. (2004) have provided further evidence on how poor forest households depend upon forest resources for their livelihoods. Discussing this in terms of economic reliance upon such resources according to levels of income or assets, they affirm that poorer households with low levels of income or assets have a greater share of their income from forests than wealthier households. However, while providing some clarifications about forest households' livelihoods, these studies do not give a thoroughly detailed assessment of households' welfare and how it changes over time.

Such household assessment is often performed at a wider level, i.e. national or sub-national (Sunderlin et al., 2007), or on other types of populations such as agro-pastoralist herders in Ethiopia or Kenya (Lybbert et al., 2004, Carter and Barrett, 2006), or rice cultivators in Madagascar (Carter and Barrett, 2006). These studies, while not focusing on forest households, are interesting in the sense that they present a theoretical framework from within which one can investigate forest households' poverty and what are its dynamics. Generally, such studies analyse the manner in which household asset holdings define household poverty, rejecting monetary measures of poverty in favour of affirming that such measures are too volatile and subject to too many measurement errors to give an appropriate assessment of poverty over time (Klasen, 2000, McKay and Lawson, 2003). With respect to forest households, asset data are better able to capture the wide range of livelihoods implemented by households. Because they are more easily observable than consumption, assets are more easily measurable. As a consequence, asset data are more appropriate generating a consistent narrative of households' poverty both at one point in time and over several periods, and to identifying whether households are able to accumulate assets and to escape poverty or not.

A second means by which to assess forest households' poverty status, given the assets and opportunities they can access, is to analyse households' activities. Forest households are generally engaged in agriculture, NTFP extraction including hunting and fishing, and wage or self-employed activities (Byron and Arnold, 1999). Households may combine various activities, generating their income through several sources depending their assets, capacities and opportunities. However, it is observed that forest households are especially likely to diversify their labour into NTFP extraction in times of shortage in agricultural production so as to guarantee additional food resources or generate extra income. Further studies explain that households engage in NTFP extraction in response to other shocks, e.g. health shocks (Arnold and Townson, 1998, Byron and Arnold, 1999, Angelsen and Wunder, 2003).

Both household characteristics and market factors encourage households to extract forest products and to allocate their labour to diverse activities (Cooke, 1998, Fisher et al., 2005, López-Feldman and Taylor, 2008, Sikei et al., 2009). Earlier studies affirm that due to a lack of off-farm opportunities, poorer forest households are more dependent upon forest resources and that increasing returns in forest-related activities encourages households to spend more time in these activities.

Unfortunately, these earlier studies have failed to explain how participating in different activities affects households' welfare. Assessing the effect of labour on households' welfare consists in determining how leisure and consumption respond to changes in income and wages (Singh et al., 1986). Since forest households are restricted in their ability to sell their labour, wage activities being limited, their decisions regarding allocations of labour and other inputs to home-production are made simultaneously to decisions concerning consumption. Changes in prices or technology have impacts on production function, labour supply and households' consumption.

With such a model, diversified activities have several impacts on consumption and leisure. Participating in forest-related activities can improve households' welfare through consumption or leisure, and higher prices of NTFPs should have positive effects on households' welfare. Therefore, if households are able to develop forest conservation activities, which, by improving the quality of forest resources, increase the prices of such resources, the increase in welfare through the extraction of NTFPs is even higher. In addition to providing higher returns in forest-related activities, the latter have numerous benefits for forest households' welfare. Indeed, conserving forests improves agricultural outputs through better soil quality, a decrease in the occurrence of floods or fewer losses of crops due to animals. In addition to these local benefits on poor forest households, there exist global benefits motivating the development of several forest conservation initiatives.

Recently, Payments for Environmental Services (PES) have been initiated wherein consumers of an environmental service (ES) pay forest users directly for adopting more sustainable practices in order to provide an ES (Wunder, 2005). Using market-based mechanisms, such payments have been designed to internalise the externalities created by land users when deciding their production process. Widely developed in Latin America and more particularly in Costa Rica, these payments focus on the provision and restoration of four environmental services: biodiversity conservation, watershed protection, landscape beauty and carbon sequestration.

When providing the latter, these PES seek recognition under the Kyoto Protocol as Clean Development Mechanisms (CDMs). Such mechanisms consist in allowing an investor to buy Carbon Tradable Offsets (CTOs) generated through afforestation and reforestation programmes in developing countries, only if these credits represent verifiable changes in carbon stocks (United Nations, 1998). In the majority of cases, communities fail to create valid carbon projects due to a lack of financial means and because they are unsuccessful in creating additional carbon sinks through reforestation and afforestation. Furthermore, if a developing country is successful in creating such a carbon projejct, it seems clear that better off communities are more able to participate, though increases in income through these CDMs are quite small, while poorer communities are unlikely to reap any benefits from these mechanisms (Brown et al., 2004). The primary challenge faced by developing countries in receiving the accreditation consists in proving that CTOs have created additional carbon sinks that would have been impossible in the absence of reforestation initiatives.

Reacting to this and so as to relax the requirement that carbon offsets must be created through reforestation and afforestation practices, the Reduced Emissions from Deforestation and Forest Degradations (REDD) programme promotes the creation of carbon credits from avoided deforestation practices. These latter are assumed to be more easily implementable by developing countries and poorer forest communities, the latter either receiving aid money from developed countries to stop forest clearance or selling carbon offsets to developing countries when they have conserved forests in order to store carbon (Griffiths, 2007).

Overall, these payments and initiatives have been successful in improving the conditions of forest resources, which, indirectly, has positive effects on poor forest households' welfare (Pagiola, 2006). However, since these payments and policies are not designed to tackle poverty, in some cases poorer households have suffered. Impediments to participation in these programmes for the poor include both the stringency of eligibility requirements and high participation costs. And in addition of being unable to participate within these schemes, poor forest households often end up being excluded from using the resources (Miranda et al., 2003, Pagiola, 2008). Such schemes and policies, being implemented without popular consultation on accessibility and uses of forest resources, regularly degrade poorer household welfare and fail to provide incentives to protect forest areas.

As a consequence, assessing forest households' poverty status, livelihoods and heterogeneity, and determining the crucial role of households' asset holdings and activities are a pre-requisite to developing forest conservation policies that are efficient and encourage the participation of forest households (Coomes et al., 2004).

Assessing households' livelihoods and welfare and determining a means of successfully encouraging poor forest households to participate in forest conservation are the main objectives of my thesis. Such objectives are aimed at answering the following question: "How can forest conservation help poor forest households to improve their welfare?"
Answering such a broad question involves three steps. In the first step, household welfare is studied through asset holdings in order to determine how important are assets for forest households and whether these assets are being accumulated or not. The second step is an investigation into how forest households combine forest-related activities with other activities and whether participating in the former can improve household welfare or not, so as to highlight if households have incentives to improve forest resources. The third step consists in defining incentives for forest users to conserve forest resources and areas according to their efforts and intrinsic characteristics such as disutility, forest resources prior conservation and poverty.

Chapter one investigates the importance of assets for the Tsimane', an indigenous forest population living in the Bolivian Amazon. According to the literature on household livelihood, since assets are a means households can use to generate their income, determining what are the assets they hold and how they diversified such assets is an appropriate way of measuring household welfare. In this chapter, I investigate households' accumulation of assets. I also test for an asset-based poverty trap, such a test consisting in determining whether households accumulate assets and escape poverty over time or are ensnared into low levels of development without any prospect of escape (Carter and Barrett, 2006).
Developed for studying asset accumulation by agro-pastoralist herders, this poverty trap

model is here applied to the Tsimane', who, contrary to herders, rely on a wide range of assets to generate their livelihood. The data used are the Tsimane' Amazonian Panel Study, collected yearly between 2002 and 2006. An asset index encompassing a wide range of assets is defined and employed to investigate assets accumulation using parametric, non-parametric and semi-parametric regressions. Regressions show that there is no evidence of a poverty trap; households are increasing their levels of asset holdings. But, small initial levels of assets and slow growth in the asset accumulation process allow me to conclude that households are more likely to converge towards a low equilibrium and to remain poor. Nonetheless, asset diversification seems a requirement for the Tsimane', reducing poverty pressures through the creation of earnings from one or several sources. That said until now, a small number of Tsimane' households has managed to reduce poverty pressures and the large majority of households is more likely to live in persistent poverty than escape it.

Studying asset holdings emphasises the role of activities choices in households' welfare. Decisions concerning labour allocations have direct consequences for households' welfare and while forest-related activities are often assumed as being used only as safety and coping mechanism, Chapter two sheds light on the potential role of forest-related activities as a means to improve household welfare (Cooke, 1998, Fisher et al., 2005, López-Feldman and Taylor, 2008). To investigate such an hypothesis, a household model of production based on Singh et al. (1986) is estimated using data I collected in February-May 2009 in thirteen villages in the Province South of Cameroon. Labour supply and labour allocations are estimated as functions of shadow wages, shadow income and different household characteristics. Endogeneity problems occur in most estimations and are controlled for using appropriate and relevant instrumental variables. Welfare analysis is derived from all empirical results and linked to the theoretical model and the descriptive analysis.

Poorer households are more dependent upon NTFP extraction than wealthier households but on average, all households engaged in NTFP extraction appear to be better off than households not engaged in such activities. Labour supply estimations report that households' marginal shadow wage and income have respectively positive and negative effects on leisure; leisure is an inferior good. According to labour allocations estimations, although households are likely to work more in agriculture and off-farm activities following an increase in agricultural earnings, an increase in NTFP earnings does not affect their labour allocations to NTFP activities. However, an increase in NTFP prices has a net positive effect on household consumption and an indeterminate effect on leisure. It seems quite likely that the effects on consumption outweigh any effects on leisure and that overall households are better off. As a consequence, improving forest management and encouraging households to participate in forest conservation would increase the price of NTFPs leading to improvements in forest households' welfare through better prices of forest resources and indirect effects linked to forest conservation.

Since forest-related activities can improve household welfare, households have a direct incentive to protect forest resources. Additional incentives may be provided to encourage households to conserve forests and to make them benefit directly from forest conservation. Inspired by PES case studies, a direct forest conservation payment scheme is theoretically analysed in Chapter three. This theoretical model includes a forest group in charge of providing an environmental service bought by an international non-governmental organisation (NGO) whose utility increases with levels of forest conserved and replanted. Both stakeholders have opposed utility functions; the NGO wants the forest group to spend as much time and investment as possible to conserve a high level of trees at a least cost while the forest group wants to spend as little time and investment as possible in this conservation scheme, while earning more. Opposed utility functions associated with the incapacity of the NGO to monitor the forest group's actions justify the use of a principal-agent game

(Laffont and Martimort, 2002). The NGO needs to create a contract such that the forest group exerts a high effort in order to get a high number of trees conserved and replanted while minimising ES buyer's cost.

According to this model, the incentive contract is such that to have the agent performing a high effort in forest conservation, the buyer should offer a non-zero payment when the output is high and payments equal to zero in all other cases. When the supplier becomes risk-averse, the payment associated with a high level of trees planted and conserved increases since the buyer has to bear part of the risk. Over several periods, if the agent always exerts the high effort, the payments linked to a high level of trees planted and conserved are greater than if the principal observes such an outcome in one of the two periods.

If the NGO wants to contract with poor or highly-degraded forest groups as opposed to wealthier or better-preserved forest groups, she may offer lower payments. The NGO defines a fine so as to reduce forest groups' benefits from leakage when leakage results from increased facilities for adopting more degrading techniques as a result from higher payments. To increase the benefits for non-participants in the scheme, the NGO can either promote the development of local infrastructures or encourage the forest group to hire poor non-participants in the group to conserve forests.

Payments may appear unfair since the forest group is paid only if a high level of trees is planted and conserved, but with such incentives, the NGO is sure to pay only the forest groups that have dedicated a large amount of time and investment in this conservation activity. Only as such a programme has created additionality since the forest group would not have conserved forest resources otherwise.

Chapter 1

Poverty trap or welfare improvements for the Tsimane' indigenous population in the Amazon?

Forest people depend upon forest resources to fulfil their basic needs but also on a wide range of assets that may allow them to implement forest-related or non-forest related activities. Unfortunately, little is known about forest households in terms of how diversified their assets are and what are the impacts of asset diversification on their welfare. This chapter provides evidence on this subject highlighting the importance of assets in order to determine forest people's welfare through asset accumulation in relation to different livelihood strategies. An asset-based poverty trap as developed by Carter and Barrett (2006) is tested to identify whether forest people are accumulating assets and reaching higher levels of welfare or not. This model has been originally tested for agro-pastoralist herders looking at the accumulation of a single asset. In this chapter, the model is applied to the Tsimane' living in the Bolivian Amazon using data from the Tsimane' Amazonian Panel Study, collected yearly between 2002 and 2006. The present test considers a wide range of assets aggregated in an asset index and the test is developed looking at the accumulation of assets using parametric, nonparametric and semiparametric regressions. The results contradict some earlier findings; there is no evidence of a poverty trap and the households are increasing their levels of asset holdings. Asset diversification seems important for the Tsimane' to reduce poverty pressures through the creation of earnings from one or several sources. To date only very few Tsimane' households have managed to reduce poverty pressures and the large majority of households is more likely to live in persistent poverty than to escape it.

1.1 Introduction

Forest people, living near or within forests are strongly dependent upon forest resources to fulfil their basic needs and to develop different forest-related activities. Their livelihoods consist of a variety of activities ranging from forest-product activities, such as timber and non-timber forest product (NTFP) activities, e.g. hunting, fruit extraction and palm collection, to agriculture and wage activities (Arnold and Townson, 1998, Byron and Arnold, 1999, Wunder, 2001, Coomes et al., 2004, Sunderlin et al., 2005). All these activities can be used within different livelihood strategies and these activities depend upon the assets households own; households with different types of assets develop different livelihood strategies, which influences their welfare (Ellis, 2001). However little is known about the importance of assets for forest people's welfare. Previous assessments of forest people's welfare have focused on income and on household dwellings decomposing households according their holdings of assets and their different livelihood strategies (Perz, 2005).

The contribution of this chapter is to provide further evidence on the importance of assets for forest people's livelihoods. Such an assessment is performed examining asset accumulation in relation to the different livelihood strategies forest people can implement and testing for an asset-based poverty trap as developed by Carter and Barrett (2006). This test determines whether forest people are accumulating assets to reach higher levels of welfare or whether households have low levels of asset holdings that keep them in a poverty trap without any prospect of escape.

This poverty trap model was originally developed for the purpose of identifying whether asset accumulations by agro-pastoralist herders in Kenya or Ethiopia appeared to be following a non-linear non-convex process with multiple equilibria, which would draw an S-shaped curve explaining that some households are caught into poverty (Lybbert et al., 2004, Carter and Barrett, 2007, Barrett, 2007). These earlier studies look at livestock accumulation and find that there exists a threshold below which herder households are trapped in poverty without any means to escape it; herder households without a great number of livestock are not able to accumulate assets that would allow them to reach higher levels of welfare.

This chapter applies the same test but drawing attention to the Tsimane', an indigenous population in the Bolivian Amazon that presents a number of characteristics corresponding to a poverty trap situation such as low levels of development, of education, of consumption and earnings. They are marginalised forest households and are poor even when compared to Bolivian society. Their livelihood relies mainly on agriculture and forest resources, and recently they have increased interactions with the market economy.

The data used to run this test are panel data collected yearly by the Tsimane' Amazonian Panel Study between 2002 and 2006. Bolivian and US researchers have surveyed 332 households each year looking at several economic characteristics of this population as well as their health and psychological status in order to assess the impact of an increasing market economy on the indigenous well-being. These quantitative data have been completed by qualitative data that I collected in June-July 2008 in order to observe the living conditions of the Tsimane', their different economic activities and the organisation of their communities.

Contrary to earlier tests by Lybbert et al. (2004) and Carter and Barrett (2006), the poverty trap test is designed to look at asset accumulation of a wide range of assets. This test requires prior construction of an asset index as a way to aggregate assets. Asset accumulation dynamics are then estimated using parametric, nonparametric and semi-parametric regressions.

All these different regressions show neither non-linearities nor non-convexities in the asset accumulation process; there exists no threshold below which a household should be trapped into poverty. According to these regressions, the Tsimane' households are accumulating assets and could reach a higher equilibrium in the future. I investigate the existence of a high-return strategy and a possible higher equilibrium but I am unable to find such an equilibrium within the data. Few households are in what could be a high-return strategy. Most of the households are in a low-return strategy with holdings of assets way below the equilibrium that may correspond to the lower equilibrium. Poverty seems to persist and only external interventions could allow them to escape poverty.

The chapter presents in section 1.2 the literature on the poverty trap mechanism as Carter and Barrett (2006) derive it from a macroeconomic context in order to apply to households, and the earlier evidence of the existence of poverty trap. In section 1.3 a detailed description of the Tsimane' households and of their livelihoods is undertaken using both quantitative and qualitative data. Section 1.4 reports how an asset index is constructed for the Tsimane' households and compares households' asset holdings to an intuitive asset poverty line so as to explain households' poverty status and dynamics. In section 1.5, the poverty trap tests using different regressions are estimated and following these tests, section 1.6 discusses the implications of failing to discover an S-shaped curve. The final section 1.7 concludes and sheds light on some further research and policy implications linked to the Tsimane'.

1.2 Poverty traps at macro and micro levels: description and evidence

A poverty trap arises when an agent (region, country, households...) is caught into low levels of economic development without any prospect of escaping those levels; it can formally be defined as *"self-reinforcing mechanisms that act as barriers to the adoption of more productive techniques and so cause poverty to persist"* (Azariadis and Stachurski, 2004, Barrett, 2007).

The literature on the poverty trap mechanism shows that this can be observed at a macro and a micro level. First presenting the macro level as conceptual basis of the micro level, I focus on the latter to analyse its implementation and resulting shape, to describe the different exclusionary mechanisms that account for such a shape and to present the existing empirical evidence.

1.2.1 Roots and hypotheses of the model

Growth at the macro level is explained by investments in physical or human capital. Standard models of economic growth predict that because marginal returns decrease monotonically, countries starting with lower levels of capital should have higher returns, and as a result should converge towards a steady state situation. If all parameters have the same value, a poorer country will catch up with a wealthier country and have the same income level; if parameters other than technological change differ, convergence will occur but in the growth rates instead of income levels.

These models assume that all differentials in income levels or at least growth rates would be overcome in the long run and that persistent divergences must be due to exogenous factors such as religion, culture...(Azariadis and Drazen, 1990, Azariadis and Stachurski, 2004). Such a conclusion though relies on certain assumptions including the completeness of markets, free entry and exit on these markets, relatively low transaction costs, convexity of technology at an efficient scale relative to the size of the markets and diminishing returns to capital, which do not correspond to reality in poorer countries. This raises doubts on how accurate standard models are (Azariadis and Stachurski, 2004).

In poorer countries, increasing returns to scale may be important when development and industrialisation are based on the adoption of modern technologies which often have a fixed cost and require higher level of skills. Poorer countries are not able to adopt such technologies as they have neither the means to face the fixed cost nor the initial capacities and skills to use them. Also, the underdevelopment of insurance and credit markets in poorer countries constrains agents into adopting inefficient production processes that generate earnings with lower variation but also lower mean values, which could maintain these countries into poverty (Azariadis and Stachurski, 2004).

As a result, poorer countries are unable to make such an investment and cannot catch up with wealthier countries. The assumed convexity of technologies is violated and with increasing returns to scale, returns to investment increase over part of the range impeding the convergence in growth rates and maintaining in poorer countries lower levels of income (Azariadis and Drazen, 1990, Azariadis and Stachurski, 2004).

Looking at different aspects of poverty traps, Sachs et al. (2004) explain that sub-Saharan African countries are caught in poverty from which they are unable to escape; negative savings rate, low capital stock, high demographic growth and poor governance explain persistent poverty and the existence of poverty trap that justifies the need of external assistance to push countries out of this low equilibrium.

Microeconomic models of growth exhibit the same type of limits when explaining the different levels of economic development between agents. Increasing returns to scale and other externalities can be identified at a micro level (Burgess and Venables, 2004). The poverty trap model developed in the microeconomic literature is intended to analyse the shape of the asset accumulation process and to determine whether there is the threshold, where it is located.

1.2.2 Asset-based poverty trap mechanism

Many models have been designed at the microeconomic level to explain why certain individuals or households are ensnared in low levels of economic development while others seem to enjoy greater levels of welfare. Some underline the importance of institutions, kin systems and history in the development of multiple equilibria, while others focus on the lack of insurance and the nature of the risks individuals face (Bowles et al., 2006).

Jalan and Ravaillon (2001) use income and consumption dynamics in order to assess household welfare, but limits of these monetary measures of welfare including seasonality, high volatility and valuation of home-consumption or non-wage activities especially in a forest context justify the use of assets which are supposed to be less volatile, more easily observable and giving a more accurate measure of welfare (Sahn and Stifel, 2003, Gunther and Klasen, 2007, Moser and Felton, 2007).

I then have chosen to focus on assets which are expected to better reflect the heterogeneity of the livelihoods of the forest households. Furthermore, assets being the source of future earnings, their accumulation should enable households to reach higher levels of well-being (McKay and Lawson, 2003, Coomes et al., 2004, Naschold, 2005). In order to assess household welfare, I estimate asset accumulation testing for the existence of a poverty trap using a Carter and Barrett's model of poverty trap (Carter and Barrett, 2006).

Presentation and shape of a poverty trap mechanism

The following analysis of the poverty trap mechanism bases itself on the literature of Carter and Barrett who test such a mechanism in agrarian societies (Carter and Barrett, 2006). In their approach and model (figure 1.1), Carter and Barrett consider that a household chooses to allocate its assets to one of two distinct strategies. A household with a low level of asset holdings $A_L^\star$ chooses to use its assets within a low-return strategy L_1 yielding to a low level of well-being $U_L^\star$ while a wealthier household chooses to use its assets $A_H^\star$ in a higher-return strategy L_2 leading to a higher level of welfare $U_H^\star$. Both asset allocations lead to locally stable equilibria with non-increasing marginal returns.

The level of asset holdings referring to an income poverty line U_P corresponds to a static asset poverty line $\underline{A}$ that can be used to distinguish stochastic or structural poverty (Carter and May, 2001). A household whose level of income is below an income poverty line but whose level of assets is above the asset poverty line is stochastically poor while a household whose both assets and income are below their respective poverty line is structurally poor. In this case, a household can remain persistently poor since low levels of assets impede it any increase in its income that may take it beyond the poverty line. On the contrary, a stochastically poor household with higher levels of assets can escape income poverty through using its assets.

The graph illustrates that there exists an unstable equilibrium $A^\star$ called in this model a Micawber threshold which can be thought as a dynamic asset poverty line. Below this dynamic asset poverty line, a household is poor in terms of consumption and assets; it cannot start saving and has to sell its assets to fulfill its consumption needs. The lower part of the graph shows that a household with such a low level of assets will converge towards the low equilibrium. On the other hand, when a household has reached this unstable equilibrium $A^\star$, it has incentives to reduce its consumption and to start saving in order to reach a switching point A_S. From A_S a household can adopt a high return strategy. Adopting the high-return strategy, a household will converge towards the stable high-equilibrium.

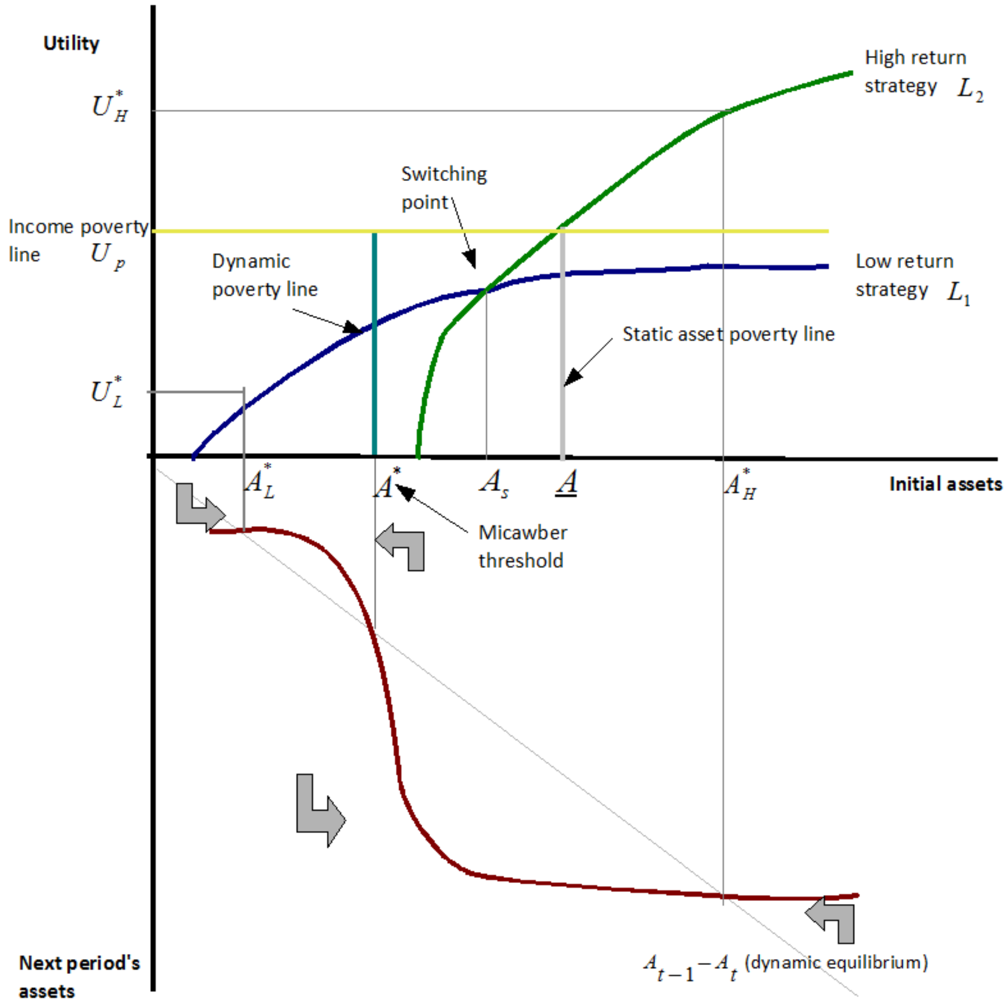
Determining this threshold requires an assessment of the asset accumulation process which is assumed to be non-linear and non-convex due to a range of increasing returns. In the recursion diagram in the lower chart, a household whose assets are below the low equilibrium $A^{\star}_{L}$ will accumulate assets and converge towards this equilibrium over time and a household with assets below $A^{\star}$ will not accumulate assets and as over time assets decrease, it will also converge towards the low equilibrium. On the contrary, a household with assets above the Micawber threshold increase its assets over time and will converge towards the high equilibrium $A^{\star}_{H}$.

Evidence of the Micawber threshold is crucial to prove the existence of a poverty trap. Below this threshold, a household with less investible surplus and depressed marginal incentives to save is caught in a poverty trap while from this threshold, a household rationally starts accumulating assets through an autarkic accumulation strategy and can escape poverty (Carter and Barrett, 2006). As a consequence, testing for a poverty trap involves finding an S-shaped relationship between current period's and next period's assets in which the Micawber threshold would simply be the unstable equilibrium where the asset accumulation bifurcates and so gives rise to the high and low stable equilibria (Carter and Barrett, 2006).

Exclusionary mechanisms creating non-linearities and non-convexities

The existence of non-linearities and non-convexities leading to multiple equilibria in the asset accumulation process can be explained by several exclusionary mechanisms: market imperfections and low level of development of insurance and of credit markets; imperfect information and low levels of education; and coordination failures. These exclusionary mechanisms are all quite common in developing countries (Carter and Barrett, 2006, Bar-

Figure 1.1: Poverty trap mechanism from Carter and Barrett (2006)



rett, 2007).

Markets in developing countries are such that costs associated with the adoption of more productive strategies are high and returns on investment are low since to be profitable such strategies require a minimum size, impeding poorer households to adopt such strategies (Carter and Barrett, 2006). The benefits of adopting a higher welfare strategy seem insufficient to overcome the cost and only wealthier households are willing and able to adopt such strategies (Azariadis and Stachurski, 2004, Barrett, 2007). Also, the inefficiency of financial markets in developing countries leads to increase financial constraints, credit constraints and uninsured risks, which restricts the poorer households from switching their actual subsistence strategy to a higher welfare strategy. In developing countries the lack of legal frameworks, effective in enforcing insurance contracts, has been underlined as an important source of failures in the insurance market (Carter and Barrett, 2006, Barrett, 2007). When shocks are idiosyncratic, poorer households who cannot smooth their consumption, can rely on others to reduce the burden from shocks. However, such a coping mechanism is quite limited when supportive households are as poor as they are and de facto unable to provide any insurance (Azariadis and Stachurski, 2004, Barrett, 2007, Barnet et al., 2008). When shocks are covariant, self-insurance, risk mitigation and risk transfers become inapplicable among households and households rely on external aid to cope with such shocks (Carter and Barrett, 2006, 2007).

At the macroeconomic level, creation of knowledge has been advanced as an important feature in the explanation of the divergence in growth rates in the long run (Azariadis and Stachurski, 2004). Analogously, the existence of imperfect information for the poor creates barriers to adopting higher welfare strategies and escaping poverty. Low access to information, due to low levels of education and relatively homogenous social networks, increases the cost of adopting a livelihood strategy relying on more complicated and productive techniques. Moreover poorer households are unable to perfectly predict and observe the consequences of their actions, and even less to monitor the consequences of the actions of other agents, making the impacts of such actions observable only in the future (Carter and Barrett, 2006, Barrett, 2007).

The path-dependent nature of information leads the poor to create norms and institutions that reflect their available information and that retard the evolutions of these institutions according to emerging information. Lack of adaptation of these institutions to new information and context is a crucial element in explaining why poorer individuals are unable to implement higher strategy (Azariadis and Stachurski, 2004, Barrett, 2007).

There exist coordination failures in developing countries due to the fact that one household's actions have an impact on other households' welfare and also on their behaviour

(Barrett and Swallow, 2006, Barrett, 2007). If a household knows that its crop can be contaminated because of a neighbour's negligence in controlling crop diseases, this former has diminished incentives to invest in a higher welfare strategy. Weakness of the institutions and their incapacity to control, monitor, enforce the law, and to provide public goods, as well as actual corruption of these institutions are reasons preventing poorer individuals from implementing higher-earnings strategy (Barrett, 2007, Carter and Barrett, 2006). Some authors have explained that a poverty trap related to environmental resources can occur (Baland and Platteau, 1996, Barrett, 2007). Unclear property rights and prominence of open-access resources wherein agents fail to communicate on the state of the resources, constitute further barriers to the adoption of higher-earnings strategies and lead to the existence of multiple equilibria. Wealthier households are better able to secure their land and to exclude others from their land, encouraging them to adopt higher returns strategies. Poorer households not able to secure their land, are not incentivised to invest in such strategies.

1.2.3 Previous poverty trap tests and contribution of this research

Empirically, testing for a poverty trap is generally performed using assets and developing different parametric, nonparametric or semiparametric regressions. Conclusions of these tests have diverged in the sense that some tests have found evidence for the existence of a poverty trap mechanism and the Micawber threshold, while the others have not.

Evidence from previous studies

Pioneering study by Lybbert et al. (2004) has found evidence for the existence of a poverty trap among Ethiopian pastoralists when studying one asset: herd size. There exist non-convexities in the accumulation of their cattle leading to an S-shaped asset accumulation curve with two stable equilibria: a low one corresponding to a size herd of one head range, and a higher one at herd size of 40-75 head range. Lybbert and co-authors have identified a Micawber threshold of 15 animals from which the households are able to accumulate cattle in order to change their way of raising cattle to a more productive one, and over time they will converge to the higher equilibrium. Below this threshold, households are not able to accumulate cattle and are likely to lose their cattle and return to the lower equilibrium.

Barrett and co-authors have provided evidence for the existence of a poverty trap among Kenyan pastoralists; Northern Kenyan pastoralists with livestock above 5-6 Tropical Livestock Units are able to accumulate livestock and will reach in time a higher equilibrium while the pastoralists with livestock below this bifurcation point will converge to a low equilibrium (Barrett et al., 2006).

Adato et al. (2006) in South Africa have used an asset index constructed through livelihood weighted regression of four types of assets and they have found an S-shaped curve in the asset accumulation process. They have discovered that households below a Micawber threshold equal to twice the poverty line will be captured in low equilibrium with a level of well-being equal to 90 percent of the poverty line.

Barrett et al. (2006) have not found evidence of an asset-based poverty trap for Malagasy households. They have acknowledged the existence of persistent poverty using qualitative findings, but when studying the asset accumulation process of an asset index built following Sahn and Stifel's methodology (Sahn and Stifel, 2000), they have not found nonlinearities and non-convexities in asset accumulation that could explain a poverty trap.

Using an identically built asset index for rural households in Ethiopia and Pakistan, Naschold (2005) has not found evidence of a multiple equilibria pattern in the asset accumulation process.

More recently, Quisumbing and Baulch (2009) in Bangladesh and Giesbert and Schindler

(2010) in Mozambique, using asset indices constructed respectively using Sahn and Stifel (2000) methodology or a weighted-livelihood regression as in Adato et al. (2006), have not found evidence of a poverty trap for households in these two countries.

Contribution of my research

Lybbert et al. (2004) as well as Barrett et al. (2006) have tested the model for herders and pastoralists in both Kenya and Ethiopia, for which both low-return and high-return strategies rely on a single asset: cattle. Because these studied populations rely on one type of asset to generate their strategies, it is easy to identify the presence of various exclusionary mechanisms, such as the lack of insurance against the loss of animals from diseases or the lack of liquidity to buy medicines to take care of the cattle, that will generate an S-shaped curve in the asset accumulation and multiple equilibria with a Micawber threshold.

My contribution is to thoroughly assess the welfare of households living within or near forests looking at their assets instead of other measures. Under analysis I determine how forest households have diversified their livelihood strategies and what are the resulting consequences on their welfare.

More importantly I provide more evidence on how relevant and accurate is the test for a poverty trap and I apply this test to forest households which has not been done yet. Forest households have more diversified livelihoods but remain largely poor and the findings from the following test provide more insights on the role of assets for household livelihoods.

The forest population for which the test is applied is the Tsimane' indigenous group living in the Bolivian Amazon. This group of households appears to have low levels of welfare even if it seems that they have diversified their assets and livelihood strategies. Furthermore while there exist many anthropological studies about these households, assessment of their welfare in general and assessment through the analysis of their asset accumulation have not yet been done.

1.3 Presentation of the Tsimane”s characteristics and data

Several anthropologists, ethno-biologists and other social science researchers have studied the Tsimane' to assess the impact of market on their living standards. Since 1995, a more systematic data collection has been undertaken and a panel data set using yearly collected data between 2002 and 2006 has been created. Using this five-wave panel data and my own qualitative data, I try to assess the Tsimane' welfare and compare them to an average Bolivian household.

1.3.1 Presentation of the Tsimane'

The Tsimane' are a native Amazonian population living in the plains and rainforests of the department of Beni in Bolivia. The Tsimane' territory is equal to 1.2 million hectares and in the last census from the Vice-Ministry of Indigenous Affairs, the Tsimane' population exceeds 8,000 inhabitants in 2004 while they were only 5,000 inhabitants in 1995 (Godoy et al., 2004). Traditionally a semi-nomadic population, they have settled in 100 communities mainly located along the Maniqui and Apere rivers, rarely moving from one community to another (Godoy and Jacobson, 1999, Reyes-García, 2001, Apaza et al., 2002). Access to many communities is feasible by road, but some are highly remote and only connected to other communities by river channels. The Tsimane' spend their life in the communities, going to a Tsimane' school where education takes place not in Spanish but in Tsimane'. This limits migration outside the communities. They marry either within the community or in a neighbouring one, inter-cousin marriages still being the rule in these communities.

Historically living in autarky, they have multiplied contacts with outside agents since the beginning of the 19th century, first through gold extraction and now through sales of agricultural and non-timber forest products (NTFPs), and through wage work with cattle ranchers and timber loggers (Godoy and Jacobson, 1999, Reyes-García, 2001, Apaza et al., 2002).

The closest town to the communities is San Borja where the Tsimane' may go to sell their products and buy the goods they need. San Borja has certain health amenities, including a public hospital, doctors and an evangelist dispensary. In this town, they can also find schools up to the highest grade before university and transport services to the capital-city La Paz, to Santa Cruz de la Sierra and several other towns (Godoy et al., 1998, Reyes-García, 2001).

Agriculture and extraction of timber or NTFPs are important parts of their livelihood. Through traditional slash-and-burn agriculture, they cultivate rice, maize, cassava and plantain. Their production process is quite simple: from May to August, they clear a fallow or old-growth forest plot; in September-October, they set the cleared plot on fire; in November, before the rainy season they sow rice for the first year. After harvesting rice, they mix maize, cassava and plantain on the same plot. The cultivation cycle of these staples lasts only one or two years after which the plot is left in transition for forest regeneration and they clear another plot. After a normal period of five years the same plot will be cleared again (Godoy et al., 1998, Vadez et al., 2003, Reyes-García, 2001).

They extract NTFPs such as firewood, bamboo, a thatch palm called jatata and medicinal plants they consume. Recent development programmes have promoted extractions and trade of jatata not only in San Borja but Santa Cruz de la Sierra. They trade only high-value timber since timber logging requires authorisations and capital that a minority of households can afford. Hunting and fishing are their main sources of protein but loss of game and increased contacts with the outside world have encouraged them to raise chicken and pigs as alternative sources (Vadez et al., 2003, Reyes-García, 2001).

As said above, the Tsimane' trade and barter their agricultural and forest products in San

Borja, but more importantly with traders traveling the communities bringing with them durable, manufactured and consumption goods the Tsimane' cannot produce, e.g. clothes, radios, batteries, tools, alcohol and sugar (Apaza et al., 2002, Reyes-García, 2001, Godoy et al., 2008).

In the last decade, the Tsimane' villages have been profoundly affected by floods; in 2006, severe rainfalls and floods destroyed the majority of their agricultural cultivations. International non-governmental organisations such as the Belgian Red Cross intervened in the communities to help them, providing buckets for collection and treatment of water and the storage of food, or mosquito nets to prevent insect-borne diseases.

Missionaries have had an important role in modifying social organisation within and between the communities. Besides unsuccessful attempts to evangelize them, their main contribution has been to introduce monolingual and bilingual schools in Tsimane' and Spanish, to build and maintain dispensaries within the communities and to set up a radio channel allowing the Tsimane' communities to communicate among themselves. This radio channel has assisted in promoting awareness of future market fairs and of technological changes (Reyes-García, 2001).

To these external influences, the Tsimane' have adapted certain aspects of their way of life, but none more so than that of their community organisation. Becoming more and more sedentary has led to a manifest change in the composition of the communities in two particular ways. Firstly, from small communities in which the households were related by blood, they have developed larger communities composed of three to eight related families. Secondly, there has been a transfer of authority in the village from the shaman to an elected corregidor with essential connections in the market economy (Reyes-García, 2001). These external forces have also served to increase the frequency of conflicts between the Tsimane' and outside agents.

1.3.2 Two sources of data: quantitative and qualitative data

Quantitative data: TAPS 2002-2006

Since 1995, the TAPS (Tsimane' Amazonian Panel Study) has gathered data on the Tsimane' to analyse the evolution of different welfare indicators. The final panel data available only encompasses five years (2002 to 2006) as the first seven years of the surveys were taken up by the need to *"identify communities, win the trust of the villagers, train local researchers, build logistical infrastructure, and refine methods of data collection"* (Leonard and Godoy, 2008).

Out of the 100 Tsimane' communities in Beni, the panel data survey focuses on 13 villages located at different distances from the main town of San Borja, and while some of these are located along the Maniqui river, others are only accessible by roads. The data available through the panel covers around 332 households, comprising nearly 1,985 individuals who have been interviewed every year since 2002. The following table (table 1.1) gives the number of households interviewed in each community.

Absence of changes in the size of the sample reports low levels of attrition; people are not

Table 1.1: Sample size from 2002 to 2006

Villages	2002		2003		2004		2005		2006	
	Ind.	Hhold	Ind.	Hhold	Ind.	Hhold	Ind.	Hhold	Ind.	Hhold
San Antonio	142	26	140	24	143	23	134	23	143	23
Yaranda	152	27	155	28	157	27	173	29	168	28
Alta Gracia	147	24	145	24	125	19	135	18	111	17
Arenales	85	15	83	14	92	15	97	15	116	19
Campo Bello	140	23	131	22	132	20	141	21	147	23
Cara Cara	91	16	87	19	62	11	35	7	33	8
La Pampita	76	13	49	10	72	12	84	14	91	15
Maraca	68	12	73	12	59	11	54	10	82	13
Puerto Mendez	93	14	95	14	95	14	102	15	103	16
Puerto Yucumo	141	23	145	22	165	24	176	25	186	29
San Ramon	49	8	42	7	53	9	64	11	63	12
Santa Maria	157	24	142	21	159	27	184	32	157	27
Uvasichi	118	21	96	17	135	24	147	24	148	25
Total	1459	246	1383	234	1449	236	1526	244	1548	255

mobile and stay in the area. When absent during the survey, the household is interviewed later upon returning to the research area (Apaza et al., 2002, Leonard and Godoy, 2008). To fulfil their goals with respect to the market economy on the Tsimane' well-being, the research team has collected different data on demography, agriculture, income, consumption and expenditures, the shocks they faced as well as their psychological status. TAPS researchers' aim is to construct a series of welfare indicators dealing with the economic status of the Tsimane' households, how they are socially integrated, their psychological status, their biological and health situation and their human capital holdings (Leonard and Godoy, 2008).

The economic data gathered are well developed; they encompass measures of the Tsimane' income according to different sources such as wage, sales, barter and remittances. For the wage earnings, the researchers have sought to ascertain the number of days worked in each type of wage labour and who was the contractor. They have collected food and non-food consumption data as well as asset data at the household level asking question about quantities and expenses. With the asset data, the TAPS team has created three aggregates: animal wealth, encompassing the different animals possessed by the household; traditional wealth, being the assets the household can fabricate; and modern wealth, manufactured goods the household has to buy (Leonard and Godoy, 2008).

When first analysing the data, consumption data presented certain problems; consumptions of staples (rice, cassava, plantain and maize) reported in local units, e.g. mancornas, arrobas[1] or regimes, were valued with village buying prices per kilograms, and I have made sure to correct these errors. Missing prices of birds, chick peas, chicken, pork or duck, in 2002 and 2003, forced me to construct a price based on the ratio of consumption in value on quantities consumed in 2006. I valued consumption of these goods in each year with the 2006 prices. When constructing deflated food aggregates, I kept the values of these 5 products at their 2006 prices and deflated values of goods for which I have prices in all waves to 2006 prices using a consumer price index.[2] Doing so has allowed me to construct

[1]Local unit and 6 mancornas=1 arroba = 11.5kg
[2]Construction of the index is presented in appendix of this chapter.

comparable food aggregates deflated to 2006 prices in all five waves.

With respect to income data, the latter income data are too aggregated and there are missing observations in 2002, 2003 and 2004 concerning remittances, meaning that total earnings are not composed of the same earnings in all five waves.

Beside these technicalities and specificities of the data, the short period of recollection even if always more appropriate since giving more accurate data, generates high volatility in the consumption pattern and data may not be representative in a longer period. In the income data, there exists high seasonality; since the data were collected throughout the clearing season which requires households to use their labour mainly for this task, non-agricultural wage earnings may be underestimated. As a consequence, volatility in consumption or income can be a significant problem when measuring poverty and can lead to an overestimation of transient poverty (McKay and Lawson, 2003, Gunther and Klasen, 2007).

Asset data are likely to be less volatile than consumption or income; using asset data to assess Tsimane' welfare may be an easier and more reliable option. During the interview, the enumerator may easily observe whether or not the household possesses the assets mentioned.

Finally, TAPS data are also limited in terms of time use. Knowing time use would have been relevant to the qualification of household livelihood diversification. TAPS data also omit the overall size of fields and land holdings providing only the area cleared. Some data on gifts and educational levels are only reported for the last three waves of the panel.

Qualitative data

In addition to these quantitative data, I undertook a qualitative survey with the object of learning how the Tsimane' use the forest and its resources, to understand what motivates their participation, or lack of, in wage activities, to appreciate how they insure themselves against future shocks and finally to learn how organised they are both within the community and in their interactions with non-indigenous communities.

My fieldwork took place in June-July 2008; during five weeks, I went to 19 villages to run interviews with three or four households in each village and to observe households' differences and similarities. Most villages I went to were accessible by motorbike, and a minority accessible by canoe. On average, the time needed to reach most of them varied from half an hour up to an hour or so. Of those surveyed, three villages were not in the TAPS panel data, although these three were interesting cases since timber logging companies were stationed in their communities and offered them some job opportunities.

I was accompanied by a translator who worked frequently with TAPS researchers and was known by all the Tsimane' we interviewed. The interviews lasted up to half-an-hour and were either run individually, with several members of the household, or more collectively with members of different households.

Generally I interviewed the male head of the household in his house as men participate to a greater degree in wage activities than women. When male heads were away, I attempted to question their wives but most of these interviews were unsuccessful; the women were busy taking care of their children and not willing to answer my questions. As often as I could, I tried to interview both the corregidor and the teacher, both playing important roles within the community. Furthermore I attended many community meetings, there gaining an insight into both the strength of communities and how democracy works in these communities.

From these visits and meetings, I can assert that all villages visited were either small or widely geographically spread, with the school in the center of the village. There was no market place in the villages, nor were there official buildings representing either the Tsimane' governing body or the Bolivian government. Sense of community was lacking with regard to certain villages that consisted merely of two or three families.

From my point of view, all these households were highly deprived and live in poverty; though they do not suffer malnutrition, there is a low diversification of food sources and they are dependent upon home-production of agriculture, chicken raising, hunting and fishing to fill their basic needs.

1.3.3 The Tsimane': descriptive analysis resulting from these two types of data

From the TAPS data and my qualitative data, I can give a snapshot of the Tsimane' living conditions, the composition of their households, the different sources of their income, their agricultural activities, the levels of their consumption and their assets.

Physical living conditions

The TAPS survey does not collect data on interviewees' dwellings. From my own survey, I can describe their dwellings as being ground-floor houses with or without walls, and with thatch-palm roof and earth floor. In the majority of households, all their belongings are kept in a single room wherein cooking and sleeping also take place, though some households have a shelter for the kitchen away from the main room.

Construction material require that houses are rebuilt regularly, especially after heavy rains and flooding; light material also allow them to change their location within the village and between villages quite easily and quickly.

Most of the households do not have shelters for animals which are free to wander in their houses and in the village.

Most of drinking water comes from the river; water can be of poor quality in some villages and at certain times of the year. The water must be boiled prior to consumption though this does not seem to be widely done. A small number of villages has a well or fountain for the provision of cleaner water. In none of the villages, I could observe sanitation systems.

Some villages have solar panels at the school; the electricity generated is supplied for televisions and VHS players used in an alphabetization programme. This programme uses these items and VHS tapes to teach children and adults to speak, read and write in Spanish. The communication medium mainly used is the Tsimane' radio created by the Evangelist missionaries in San Borja.

Household composition and characteristics of household members

Over the five waves 98% of the households have a male household head but the number of households headed by a woman increases over the period from 7 to 12 households (table 1.2). However, only 2 households are female-headed households in each year; in the other cases, the gender of household head varies from one year to the other. This can hide some temporary migration of male household heads leaving woman in charge of the household. Between 2002 and 2006, the average age of the male household head is 42 years old; the number of male head of households aged more than 65 years old doubles over the 5 years while the number of household heads aged less than 25 years old is cut by more than a third.

Households headed by a man are bigger and younger than households headed by a woman; male-headed households have more children younger than 14 than female-headed households but number of children in these latter households increases over time.

Between 2002 and 2006, the average age of the household has increased from 20.3 years old in 2002 to 22.1 years old; they are on average composed of 6 members, half of these being children.

Educational levels are quite low; on average Tsimane' household members aged more than 15 years old have attained the 2nd grade at primary school. Over time, educational attainments do not change; considering household head education, younger household heads have higher educational levels and have attained on average a 3rd or 4th grade at primary

Table 1.2: Description of Tsimane' households according to the gender of the household head

	2002			2003			2004			2005			2006		
	Female	Male	All	Female	Male	All	Female	Male	All	Female	Male	All	Female	Male	All
Nb Hhold	7	237	244	12	218	230	8	222	230	8	243	251	12	250	262
Head Age	60.5	38.9	39.5	50.2	39.1	39.7	59.7	38.0	38.8	53.0	44.0	44.3	53.6	44.7	45.1
Hhold Age[a]	35.9	19.7	20.3	33.8	19.6	20.4	28.9	24.2	24.6	26.6	21.4	21.5	28.5	21.8	22.1
Hhold Size	3.8	6.5	6.4	4.9	6.6	6.4	5.2	6.2	6.1	4.8	6.3	6.2	4.4	6.1	6.0
Children[b]	1.4	3.2	3.1	1.2	3.4	3.2	3	3.3	3.3	2.6	3.3	3.2	2.2	3.2	3.2
Hhold Edu	0.8	2.0	1.9	1.1	2.0	2.0	0.5	1.8	1.8	1.3	2.1	2.1	0.8	2.1	2.1

[a]Average age of household members
[b]Number of household members aged less than 14

school.

I can now undertake a descriptive analysis of the Tsimane' households' sources of earnings as defined by TAPS researchers.

Sources of earnings

To summarise the different sources of earnings of the Tsimane', the TAPS researchers have built four aggregates: sales earnings of agricultural products and NTFPs, wage earnings from different wage activities, barter earnings[3] of agricultural products and NTFPs and remittances.[4] The aggregation of the earnings data does not allow me to distinguish clearly which type of goods were sold. From the qualitative data, it seems that most of the goods sold are agricultural products (rice and corn) and few households sell NTFPs (jatata mainly).

Table 1.3 describes earnings from all four sources as well as total earnings for all households that answer having any earnings.[5] Over the five waves, more households are selling than participating in a wage activity though wage earnings are more important both in

[3]They use village selling prices to find the values of bartered products.
[4]They report remittances only for 2005 and 2006, total earnings in 2002-03-04 do not include remittances.
[5]Implied Purchasing Parity Power (PPP) exchange rate for bolivianos was US$1=1.995 in 2002, 2.077 in 2003, 2.185 in 2004, 2.23 in 2005 and 2.454 in 2006. Source EconomyWatch.com.

values and in terms of contribution to the total earnings. In 2006, the contribution of wage earnings to total earnings increases while the contribution of sales earnings to total earnings decreases.

A non-negligible and increasing proportion of households reports bartering products but contribution of barter earnings to total earnings decreases over time from 15% to less than 12%.

In 2005 and 2006, respectively 26 and 20 households report receiving remittances but for

Table 1.3: Nominal earnings in Bolivianos during the last two weeks (2002-2006)

Year	Sale			Wage			Barter			Remittances			Total earnings[a]	
	N	Bol	% [b]	N	Bol	%	N	Bol	%	N	Bol		N	Bol
2002	153	186.0	67.8	133	171.6	60.7	128	31.0	15.2	n/a	n/a	n/a	230	240.3
2003	141	142.9	56.6	110	200.9	71.3	130	34.9	14.4	n/a	n/a	n/a	206	227.2
2004	143	137.1	56.2	133	238.3	73.2	122	35.7	14.8	n/a	n/a	n/a	219	254.1
2005	172	249.9	59.6	140	246.1	48.8	135	50.4	11.8	26	252.9	38.0	237	383.2
2006	156	204.5	50.1	141	284.8	65.6	146	45.4	11.8	20	409.6	48.8	235	369.7

[a]Sum of all 4 earnings.
[b]Percentage of household total earnings for households reporting earnings from such source.

these households, both the total amount of remittances received and their contribution to their total earnings are important and increasing.

Households with young household heads have less earnings from sales than other households; they are more likely to participate in wage activities whose earnings represent around 80% of their total earnings.

It is interesting to consider in which wage activities household members participate. Unfortunately, individual wage data available are limited to the last three years. Main activities for the Tsimane' are working as an unskilled labourer for a Bolivian farmer, a logging company, a cattle rancher, other Tsimane' households or the State. Individuals working in these five activities have higher earnings from these activities than individuals working in another type of activity (table 1.4). In all three waves, individuals working for the State generate greater earnings than other individuals and these earnings appear less volatile than earnings from a Bolivian farmer or other Tsimane' households.

Households working for the State, a cattle rancher or a logging company[6] are the ones

Table 1.4: Nominal wage earnings in Bolivianos in the last 7 days in each type of activities and number of days worked (2004-2006)

	2004			2005			2006		
Labour types	N	Bol	days	N	Bol	days	N	Bol	days
Farmer	12	46.6	2.5	13	114.1	4.8	7	107.4	5.7
Logger	36	111.5	4.0	40	168.8	5.3	28	194.0	5.9
Trader	3	66.7	3.3	0	0	0	3	103.3	4.3
Other Tsimane'	20	230.4	4.5	12	86.7	3.33	17	95.9	3.7
Cattle rancher	16	73.4	3.3	32	109.5	4.9	32	124.5	5.0
Teacher	2	72.5	2.5	2	8	4	6	86.9	2.8
Project Felicidad	6	149.5	4.3	6	137.7	4.8	6	316.6	7
Other sources	4	125.5	4.5	2	140	4.5	1	175	7
State	13	256.8	6.15	13	227.2	6.5	26	237.7	5.1
Tsimane' Council	1	161	7	2	116.5	7	0	0	0
Colons	2	40	2	4	117.5	4.7	5	131	5.8
Horeb	0	0	0	2	227.5	7	0	0	0

working more often, 5 to 6 days in the last week, while individuals working as a teacher report working only 2 days during the last 7 days. Unfortunately, interpreting the data must be done cautiously since it could be that the last 7 days are not representative of the whole year. During the qualitative survey, most of the households with a member working for a cattle rancher or a logger say that they usually work in these activities on a daily basis, for a specific task, and sporadically at times when they need to cope with an unexpected event that requires them to spend on medicines or tools.

During the qualitative survey, the Tsimane' explain that they do not work for someone else all the time because it is tiring and they are not willing to follow someone else rules and orders. They prefer rather to work on their own than to work with and for somebody else. Individuals working more permanently tend to be young single men without the responsibility of a head of a household such that they may live in the logging camp or at the ranch.

The individuals use their wage mainly to help their family in coping with events and to buy durable goods (clothes, radios...). In the case of important emergency, they said that

[6] I want to notice here that even households working for the State, as teacher, for a cattle rancher or a logging company have an agricultural plot and use the same range of basic assets and tools as households not engaged in these activities.

they can ask the cattle rancher they usually work with for loans and would repay them by working for them.

Regarding sales of NTFPs, the TAPS survey lacks sufficient information to appreciate the different NTFP productions. In the qualitative survey I asked households how production and sales of jatata work. Jatata production is mainly done in upriver villages where palm trees are still abundant. Its production process does not require great labour investment nor skills but it is time intensive since households need to let the palm dry for at least a month. Households are either regular jatata producers or only using this product to reimburse a debt. To sell their products, they rely on the traders coming to the village or they go to San Borja.

Agricultural activities and forest clearance

In the data set, data on rice and corn production and sales are only available for 2004, 2005 and 2006. Participation in agriculture is quite high; 213 households in 2004 and 243 in 2006 report cultivating rice and 116 in 2004 and 138 in 2006 report cultivating corn. All households cultivating rice or corn report selling a part of their production.

Between 2004 and 2006, rice production (upper part of table 1.5) increases from 62.2 arrobas (around 715.3kg) up to 71.0 arrobas (816.5kg) but rice sales decrease from 33.9 arrobas (389.85kg) which represents 54% of their production to 29.2 arrobas (335.8kg), 44% of the production.

Corn production between 2004 and 2006 (lower part of table 1.5) decreases from 83.3 mancornas (160.0kg) down to 40.8 mancornas (78.2kg) and so have the sales from 53.8 mancornas (103.1 kg) down to 8.6 mancornas (16.5kg). Corn production and sales have decreased over three years, and corn sales have decreased in a larger measure leading to a decrease in the ratio of sales on production.

Over time, rice production is more important for the Tsimane' both in terms of quantities harvested but also in terms of quantities sold.

Between 2004 and 2006, rice selling price in each village has increased by 2 to 8 bolivianos

Table 1.5: Household agricultural production and sales of rice and corn (2004-2006)

Products	2004	2005	2006
Rice in arrobas			
Rice production	62.2	81.7	71.0
Rice sales	33.9	41.6	29.2
Ratio sales/production	0.54	0.53	0.44
Corn in mancornas			
Corn production	83.3	67.3	40.8
Corn sales	53.8	18.8	8.6
Ratio sales/production	0.64	0.52	0.40

in 9 of the 13 villages; half of the households increase their rice sales but this increase has not been high enough to counterbalance the sales reduction from the other households. Households do not seem to be really responsive to rice price variations.

During the qualitative survey, I ask households their strategy when deciding how much to plant, harvest and sell. Their answer has been that when harvesting they first keep what they need for their home-consumption and if there exists a surplus they sell it or barter it.

Overall, all households cultivate the same quantities of rice and corn and no organisation or cooperative system has been implemented. Only a small proportion of households has developed a “rice strategy” which consists in cultivating and selling a type of rice with a higher price while simultaneously cultivating a smaller proportion of a cheaper rice used for home-consumption.

Besides rice and corn, the Tsimane’ report growing other crops; around 80% of the Tsimane’ households report cultivating plantain. Cassava, sugar cane and sweet potato are also important crops while onion and peanut are cultivated by a small number of households (table 2.5).

However, it seems that the Tsimane’ are diversifying their agricultural production as more households in 2006 cultivate different products.

With respect to agricultural plots and forest clearing, the Tsimane' households cleared

Table 1.6: Number of households cultivating other types of products

Products	2004	2005	2006
Cassava	91	145	130
Plantain	193	232	200
Onion	55	50	72
Peanut	58	57	63
Sugar cane	114	127	134
Sweet potato	94	130	145

on average 5.7 tareas[7] of fallow forest and 4.1 tareas of old-growth forest over 2004 to 2006 (table 1.7). Areas of cleared fallow and old-growth forest for agriculture are increasing over the period but not the number of plots. Tsimane' households have on average 1.5 plots dedicated to agriculture and these plots are becoming bigger over the period. Areas cultivated with rice are increasing between 2004 and 2006 while the size of land dedicated to corn production remains without variation. It seems then that households are opening bigger plots in order to increase rice production in the first year; then they do not increase corn production but they tend to mix corn and other products (cassava, plantain or sugar cane) on one plot.

During the fieldwork, I asked households whether they were selling trees standing on

Table 1.7: Size and number of agricultural plots (2004-2006)

Field	2004	2005	2006
Tareas of cleared fallow forest	5.4	5.3	6.4
Tareas of old-growth forest	3.4	4.6	4.3
Tareas of rice	7.7	8.2	8.7
Tareas of corn	1.3	1.3	1.3
Number of plots	1.4	1.6	1.5

the plot while clearing. Households answered that they prefer keeping trees to dry and to collect them for use as firewood. Very few of them have ever sold firewood as a way of increasing their earnings and only one householder says he sold a tree once although it was too costly to be profitable.

[7]10 tareas are equal to 1 hectare.

Household food consumption

Consumption values are deflated in order to compare values over time. Since there are no deflators in the data, I constructed a price deflator using price information available in the data (Appendix A.1).

I first tried to construct consumer price index (CPI) using village price information and looking at weights of all food products in households' total consumption. Unfortunately, missing values in the price information resulted in missing values for CPI and I chose to look at price changes at the village level for a set of 10 commodities over the five years using weights defined for the whole research area.[8] With these weights, I cover 33% of total consumption (appendix table A.1). Inflation is flat over the three first years and jumps between 2004 and 2005 (appendix table A.2).

Keeping only households that report information about consumption and assets in all five waves, the size of the sample decreases to 176 households; the other households have not answered either questions about consumption or assets. The end of this chapter relies on these 176 households.

At first glance, over time per capita household consumption during the last 7 days decreases but not monotonically (table 2.8). Consumption[9] increases until 2004 before decreasing; in 2006, per capita consumption at the household level is lower than in 2002.

Over time, in terms of value, households consume mainly game and fish and this remains true when consumption of game and consumption of fish decrease, as between 2004 and 2006. The large decrease in game consumption is explained by both a decrease in the price of game and a decrease in quantities consumed. Caution is required when talking about

[8] I also tried using as a deflator the price of rice in 2006 which has brought the same results.

[9] Table 2.8 does not include all food products consumed by households but only the most important ones.

game consumption since the dataset price of game is an average price of different game and not a price for each game households can consume. Overall this decrease in the price of game is quite surprising and cannot be explained by the available information.

Concomitantly to the decrease in consumption of wildlife products (game and fish), consumption of chicken and beef has increased between 2002 and 2006 while consumption of dry meat, eggs, ducks and sardines has remained the same over time. It seems that to compensate their loss of proteins from game or fish, households have increased their consumption of domestic animals.

Consumption of rice, cassava and plantains is also important for households in terms of value consumed. These products are mainly home-produced and have been valued at their buying price in the data set to allow aggregation. Consumption of rice increases over time though not monotonically. Consumption of plantains in 2006 is smaller in values than in 2002, while consumption of cassava and maize has changed little over time.

Consumption of other products bought on the market (noodle, cooking oil or flour) has ei-

Table 1.8: Per capita consumption during the last 7 days (values deflated to 2006 Bolivianos)

Food products	2002	2003	2004	2005	2006
Beef	1.3	1.9	1.4	1.9	2.4
Cassava	1.5	1.2	0.8	1.4	1.1
Chicken	1.1	1.8	1.0	1.1	1.6
Dry meat	1.6	1.2	1.6	2.0	1.8
Duck	0.3	0.2	0.1	0.1	0.01
Egg	0.1	0.2	0.3	0.2	0.3
Flour	0.2	0.4	0.3	0.6	0.5
Maize	0.1	0.2	0.1	0.3	0.2
Noodle	1.3	1.1	1.5	1.4	1.0
Oil	0.7	0.6	0.5	1.0	1.4
Plantain	3.2	2.7	1.9	2.2	2.6
Pork	0.2	0.6	0.2	0.2	0.09
Rice	1.1	2.1	1.3	1.5	1.8
Sardines	0.5	0.3	0.7	0.6	0.7
Sugar	1.6	1.5	1.5	1.5	1.4
Bird	0.4	0.2	0.2	0.5	0.3
Fish	11.4	10.7	14.7	12.6	8.4
Game	12.9	14.9	18.7	13.2	5.1
Total	41.5	45.1	49.7	47.4	34.7

ther increased between 2002 and 2006, e.g. cooking oil and flour, or decreased, e.g. noodle.

In summary, there exists a big decline of per capita consumption in 2006 compared to 2002 which is largely due to a decrease in their consumption of wildlife products resulting from a decrease in quantities of game and fish consumed. On the other hand, households have not succeeded in compensating losses of consumption through consumption of other products and hence they appear to be worse-off in terms of consumption.

Asset holdings and wealth

Asset data are aggregated in three different measures: modern, traditional and animal assets. Looking at the values of different aggregates and particular assets deflated to 2006 prices using the CPI I have created (table 1.9), on average, household total wealth has slightly increased between 2002 and 2006 but this increase has been undermined by a large decrease between 2005 and 2006.

Over the five years, the Tsimane' have accumulated mainly modern assets; they own on average more mosquito nets, bikes and rifles than other assets and this is true both in terms of value and quantities of assets. Between 2002 and 2006, households possess more radios but these assets are cheaper in the last year thus reducing their contribution to total household wealth.

The Tsimane' also own many traditional assets; these assets encompass different objects from bags and bows to canoes and grinder stones, canoes being the most valuable. Over time traditional asset holdings have decreased in value. However a closer look at the composition of traditional assets shows that the decrease in these asset holdings is mainly due to a decrease in their price since quantities have either increased or remained unchanged. For instance, the Tsimane' have on average the same number of canoes or bags in 2002 and 2006.

Their animal asset holdings are composed of cows, ducks, chickens and pigs. Over the period, animal asset holdings have first increased then decreased in value and in 2006, values of animal asset holdings are lower than in 2002. They have slightly more cows both in value and quantity in 2006 than in 2002 but considerably fewer pigs between the first and last year. Price of cows remains the same over time while pigs become more expensive. Overall, the Tsimane' appear to be better-off in 2006 in terms of asset holdings;

Table 1.9: Household asset holdings: quantities owned and values (values deflated to 2006 Bolivianos)

Assets	2002		2003		2004		2005		2006	
	Qties	Bol	Qties	Bol	Qties	Bol	Qties	Bol	Qties	Bol
Animal assets		673.6		529.8		810.5		733.6		560.1
Cow	0.3	262.5	0.4	196.7	0.6	507.5	0.7	489.2	0.4	269.1
Pig	1.0	225.7	0.8	125.9	0.7	118.1	0.3	81.4	0.5	99.1
Modern assets		2068.2		2204.8		2422.4		2647.0		2286.1
Hook	5.5	29.3	5.3	25.9	5.1	39.0	5.5	13.0	5.8	23.2
Bike	0.3	239.5	0.3	250.8	0.3	100.1	0.4	226.2	0.4	234.3
Machete	3.4	87.5	3.1	92.7	3.4	155.4	3.7	128.3	3.8	135.1
Mosquito net	3.5	157.0	3.8	340.6	3.9	314.9	4.2	228.4	5.4	322.3
Radio	0.6	218.1	0.8	310.8	0.9	376.3	1.0	194.0	1.0	155.1
Rifle	0.5	511.1	0.5	306.5	0.4	356.0	0.5	473.4	0.5	375
Traditional assets		910.7		856.9		802.8		904.3		816.6
Bag	5.5	431.9	5.9	518.0	6	496.7	7.1	429.4	6.6	356.3
Bow	0.5	95.7	0.4	54.3	0.4	83.6	0.4	84.6	0.4	82.9
Canoe	1.6	216.6	1.6	175.0	1.5	108.8	1.6	275.6	1.6	238.6
Total assets		3652.5		3591.6		4035.8		4285.0		3662.9

looking at quantities, assets seem either to have increased or remained unchanged. Values of assets have either increased or decreased; decreases in value of assets correspond more to decrease in prices than loss of assets.

In the end, there does not seem to be any correlation between consumption and asset holdings and earnings; while consumption decreases, households seem to have both increased earnings and assets. The different problems linked to the valuation of consumption items and the fact that earnings in the last 7 days may not represent the general trend of yearly earnings strengthen my choice of using asset data in order to assess the welfare of the Tsimane'.

Tsimane' in the national Bolivian poverty context

Bolivia is the second poorest country in South America, after Guyana when considering GDP per capita (PPP) in 2009. In 2002, 67% of the population was poor and 84% of the rural households were poor according to this definition (Grosse et al., 2005). In 2002, 57% of the population was extremely poor in rural Bolivia (less than US$1 a day PPP) and three quarters of the extreme poor were living in rural areas (O'Hare and Rivas, 2007).

To appreciate how poor the Tsimane' households are, I compare the Tsimane' income and consumption to the average rural Bolivian household, keeping in mind that the Tsimane' data may be underestimated and not fully comparable. With respect to the 2006 National Survey, the Tsimane' households have much lower levels of earnings than the majority of rural Bolivian households. In the 2006 survey, the income poverty line is set at 294 Bolivianos per capita per month for households living in dispersed communities, such as the Tsimane'. Estimating Tsimane' total income as closely as defined in the National Survey, i.e. adding up earnings from sales, wage labour, remittances, bartering products and agricultural production, I find that average monthly total income per capita is 120 Bolivianos. As a result 97% of the households in the sample have their total income below the income poverty line.

With respect to consumption, in 2006, the Tsimane' have levels of consumption much lower than rural poor Bolivian households. The average consumption per capita per month for the Tsimane' is 138 Bolivianos in 2006 while the average consumption per capita for a Bolivian household living in a dispersed community was 299 Bolivianos. Comparing their monthly consumption per capita to 80% of a consumption poverty line[10], 84% of the Tsimane' are poor in terms of consumption and deflating values of consumption in previous

[10] I estimated a consumption poverty line comparing in the National Survey households's consumption when their income is equal to the income poverty line. In the National Survey, consumption encompasses food and non-food products and I assume that 80% of the consumption poverty line represents the food poverty line.

years show that 90% of the poor in 2006 were poor in 2002.

On average, a rural Bolivian individual goes up to a 5th grade at primary school while a Tsimane' adult reaches the 2nd grade at primary school.

On average, the Tsimane' have a body-mass index[11] (BMI) around 20.8 which is not low but does not show any improvements. On average, 4% of the Tsimane' women aged 15 or more are underweight with their BMI below 18.5 while in rural Bolivia, around 1% of the women have their BMI below 18.5 (WHO, 2008).

This descriptive analysis and presentation of the Tsimane' shows that they can generate their revenue from different sources by implementing different activities but that overall they remain poor. In what follows I look more closely at the characteristics of Tsimane' according to their different livelihood strategies.

1.3.4 Tsimane' livelihood strategies

Carter and Barrett (2006) model sheds light on the fact that households have different types of livelihood strategies and that they choose either to be in a low- or high-return livelihood strategy in respect with their asset holdings (Carter and Barrett, 2006, 2007). The following subsection determines the existence of different strategies for the Tsimane' and whether there are groups of households with better welfare than others. As in the Carter and Barrett model, I assume that a Tsimane' household with higher levels of asset holdings, i.e. in the two upper quintiles at least three years,[12] who sells more than half of its rice production and has relatively large agricultural plots, is engaged in a high-return strategy. On the contrary, a Tsimane' household with lower levels of assets and/or partic-

[11] weight in kilograms divided by height in centimeters squared kg/cm^2

[12] I choose three years such as to avoid the fact that some households use sales of assets or rice to cope with an unexpected event; being on the upper quintile once does not guarantee that a household is in a high-return strategy while a household with assets and production in the top quintiles over a longer period of time is more likely to be engaged in a high-return strategy.

ipating less in agricultural sales or with smaller plots is engaged in a low-return activity in which agricultural production is mainly directed to fulfil its basic needs.[13]

With this specification, 32 households are engaged in a high-return activity since they have more assets and higher agricultural production, and the 144 remaining households are engaged in a low-return strategy.

Households in a high-return strategy have higher earnings than households in a low-return strategy (table 1.10); nonetheless differences between both strategies are not striking even if they increase over time. Households in a high-return strategy have on average between 1.4 and 2 times greater earnings than households in a low-return strategy. Differences in sales earnings between both strategies are bigger than differences in wage earnings; this result corroborates the fact that sales depend to some extent on rice sales used to define the strategies.

By construction, households in a high-return strategy have also more assets but the gap tends to reduce over time since households in a low-return strategy have increased asset holdings in 2006 over 2002 while households in the high-return strategy have fewer asset holdings. This decrease in total wealth for households in a high-return strategy is mainly accounted for the reduction in their holdings of modern and animal assets.

Consumption does not seem to be correlated to wealth or agricultural production which suggests that consumption may not be well-estimated. Across strategies, consumption is either more important in a high-return strategy or in a low-return strategy from one year to the other.

Looking at household characteristics, households in a low-return strategy are smaller. Average age of households seem to be similar between strategies; households in a high-return strategy are sometimes younger or older than households in the low-return strategy. How-

[13]In appendix, I present a distinction of the Tsimane' livelihood according to assets and earnings.

Table 1.10: High- and low-return strategy according to agricultural production and assets (values deflated to 2006 Bolivianos)

	2002		2003		2004		2005		2006	
Variables	High	Low	High	Low	High	Low	High	Low	High	Low
Sale	150.2	96.1	243.8	95.5	214.7	83.3	483.6	136.1	281.8	108.4
Wage	120.2	117.5	105.3	139.9	184.3	164.3	193.0	128.5	206.8	165.3
Total earnings	292.8	237.7	385.9	259.2	438.1	269.3	732.6	331.5	597.2	300.7
Animal wealth	1516.9	483.5	1212.1	380.9	2273.9	485.3	1850.1	485.5	972.5	468.5
Traditional wealth	1282.0	826.9	1233.0	774.7	1260.1	701.1	1372.0	800.4	1152.1	742.0
Modern wealth	3759.9	1686.9	3981.6	1816.9	3919.0	2089.8	4092.5	2325.7	3258.7	2069.9
Total wealth	6558.9	2997.5	6426.8	2972.6	7453.1	3276.4	7314.7	3611.7	5383.4	3280.5
Beef	2.5	1.0	1.1	2.1	1.6	1.4	1.3	2.1	3.1	2.2
Chicken	1.8	0.9	0.9	1.9	1.1	1.0	0.9	1.1	2.4	1.4
Plantains	2.3	3.3	2.1	2.8	2.0	1.9	2.1	2.2	2.2	2.7
Cassava	1.4	1.5	1.0	1.2	0.5	0.9	1.4	1.4	1.4	1.0
Game	11.2	13.2	10.6	15.9	22.0	18.0	10.2	13.8	5.6	5.0
Fish	8.9	12.0	8.1	11.3	9.9	15.8	9.6	13.2	8.6	8.3
Total Consumption	41.4	41.5	35.9	47.1	47.2	50.3	38.9	49.3	38.9	33.8
Household characteristics										
Household size	8.1	6.3	8.1	6.3	7.9	6.2	8.2	6.5	7.8	6.6
Household age	23.6	21.4	21.8	21.8	23.8	21.4	20.6	20.7	23.1	21.3
Head Age	50.1	41.8	47.9	43.7	52.4	42.9	48.5	42.6	52.5	41.6
Household education	1.5	1.9	1.5	1.9	1.8	1.6	2.5	1.8	2.5	1.8
Agricultural production										
Rice production	n/a	n/a	n/a	n/a	101.0	54.8	159.2	69.6	130.0	63.5
Rice sales	54.8	20.6	n/a	n/a	64.0	28.5	94.2	35.7	61.0	25.9
Corn production	n/a	n/a	n/a	n/a	72.1	72.8	126.0	66.7	54.2	34.1
Corn sales	22.7	8.6	n/a	n/a	49.8	47.1	47.6	17.8	8.3	8.7
Plot size	16.0	7.8	16.4	8.8	14.1	8.1	18.0	9.0	17.1	9.8

ever, households in a high-return strategy tend to have older heads of household which implies that there may be certain experience effects. Older household heads know from whom to obtain better prices and what are the best cultivation techniques to use. Over time, households in the high-return strategy have higher educational levels.

By construction, households in a high-return strategy have sales of rice 2 to 3 times larger than households in a low-return strategy. Considering corn, differences in production are not important in 2004 and 2006, and sales in 2006 are similar between the two types of households.

Size of plots has increased over time but as it increases in the same range for both types of households, difference remains unchanged.

Overall, households with higher assets in a high-return strategy have also greater earnings and may be better-off. However, the number of households in a high-return strategy is quite small and even smaller when identifying other groups.[14] However, low evidence of the existence of high- and low-return strategies does not undermine the existence of an S-shaped curve in the asset accumulation.

In addition, there are clearly various mechanisms preventing Tsimane' households to improve their welfare (Carter and Barrett, 2006). Firstly, there exist market imperfections for the Tsimane'; these imperfections imply that to implement higher-return strategies, the Tsimane' need to adopt more expensive tools or production processes. Consequently, wealthier Tsimane' are more able to adopt such tools while the poorer ones are unable as the costs of adoption are higher than the returns. Also, the Tsimane' have weak access to markets resulting from the remoteness of their communities and the lack of infrastructure. Wealthier Tsimane' households participate to a greater extent in the market whereas poorer Tsimane' households are more dependent upon those traders who offer lower prices than on the market. The Tsimane' do not have access to financial and insurance markets. All credits reported have been obtained on an informal credit system in which cattle ranchers and loggers lend to the Tsimane' they know who may repay them directly out of wages. Only Tsimane' working with outside agents would receive such loans, which creates an immediate barrier to those not participating in such activities.

Secondly, incomplete information resulting from the low levels of education of some Tsimane' households and their inability to speak Spanish impede access to better-quality information regarding the availability of higher-yielding seeds or advanced production techniques. The lack of infrastructure also explains why such information may not reach all of the Tsimane' households.

Thirdly, the lack of well-defined property rights on agricultural lands does not encourage

[14]Refer to appendix table A.3.

them to invest in improving their production. Furthermore, the multiplication of legal institutions in charge of forest resources discourages them from undertaking more forest-related activities such as jatata extraction and sales which could have higher returns.

Their poverty situation, dependence upon natural resources and the existence of different exclusionary mechanisms justify the focus on testing for the existence of a poverty trap for these Tsimane' households.

1.3.5 Summary of the descriptive analysis and justification of a poverty trap test

To resume, the Tsimane' appear to be a poor population even when comparing to an average rural Bolivian household. They have low levels of earnings and their consumption which relies mainly on natural resources and home-production fluctuates over time. Households in a high-return strategy appear to be better-off than other households but they are only a minority of the Tsimane' households.

Considering non-income measures of welfare, the Tsimane' are less educated than the average rural Bolivian. Over time, there appear to be no improvements in their education since younger Tsimane' do not reach higher grades than their parents. When looking at the different strategies, households in a high-return strategy have slightly higher average educational attainment but it remains lower than the average rural Bolivian household. With respect to their BMI, more women than in rural Bolivia have their BMI below the normal line.

Furthermore, large majority of households being engaged in a low-return strategy justifies the fact that poverty for the Tsimane' households is a persistent phenomenon. Even if some households seem to accumulate assets and increase their earnings, poorer households do not catch up; different mechanisms suggest that welfare improvements are difficult to achieve for poorer households but easier to achieve for wealthier ones.

Overall there does not seem to be a sharp distinction between high- and low-return strategies since very few households are in a high-return strategy. Apart from differences in their earnings and assets (which result from construction), the Tsimane' appear to be quite an homogeneous group in terms of household characteristics. Different mechanisms and circumstances impede some households raising their welfare which may create different equilibria in the accumulation process.

As a result, it seems relevant to test whether a majority of households is caught in a poverty trap as defined by Carter and Barrett (2006) and if the other households have managed to overtake the Micawber threshold and are in a high-equilibrium, or whether there exists a single (low) equilibrium toward which all households are converging. In order to test for the existence of a poverty trap, the following section presents the asset index used in the test and this asset index is also used to assess where the Tsimane' are according to different values of asset index.

1.4 Poverty status and dynamics using an asset index

Asset data are preferred since they better describe forest household livelihoods and provide better measures of their welfare. Assets as many non-monetary measures to counterbalance problems related to measure of welfare with consumption or income data (Gunther and Klasen, 2007) but it requires to choosing a method to aggregate the assets. Besides adding up values of assets which here may not be appropriate, there exist different methods. Primarily one may use the coefficients of a regression of assets on consumption or income normalised to a poverty line to determine the weights of each asset and construct an asset index (Adato et al., 2006). Another technique, this one more flexible, consists in combining all assets in an asset index using the patterns of correlation between assets to determine the weights of each asset in the asset index (Sahn and Stifel, 2000, 2003).

I prefer this last method for building the asset index since in this instance the weights are not defined by consumption aggregates, the latter being in my opinion not reliable. The resulting asset index seems then more relevant to look at poverty status and dynamics of forest households.

1.4.1 Methodology for the construction of an asset index

To build an asset index, I select a factor analysis methodology which *"consists in representing a set of variables in terms of lower number of hypothetical variables"* (Lawley and Maxwell, 1973, Friel, 2007). Factor analysis aims at identifying the hypothetical unobserved variables, called underlying factors, and at explaining that the assets are created out of these underlying factors (Lawley and Maxwell, 1971, Lewis-Beck, 1994). A single common underlying factor accounting for a larger part of the variance of the variables is selected when its eigenvalue is above 1 (Lewis-Beck, 1994, Friel, 2007).

This common factor is used to divide the variance of each asset into a *"common variance"* and a *"unique variance"* which is *"a combination of the reliable variance specific to the variable and a random-error variance"* (Lewis-Beck, 1994). As a result, the common factor is a weighted average of multiple assets in which the weights are the factor scores estimated through the projection of an unobserved common factor on household assets (Sahn and Stifel, 2000).

Various types of factor analysis methodology are available, the most common being principal component analysis (PCA) and principal factor analysis (PFA). The difference between these techniques rests on the manner in which the factors explain the variance. Regarding PCA, this technique forces all components to explain totally the variance of the variables, while PFA permits the variance of the variables not to be fully explained by the factors (Lewis-Beck, 1994, Sahn and Stifel, 2000). I use here PFA in order to allow for the existence of elements that cannot be measured but that account for the part of the variance not explained by the assets.

In order to proceed to a factor analysis, the first step is to determine by running two tests whether or not the assets are correlated. The Bartlett's test for sphericity consists in measuring the strength of the correlation between variables and its null hypothesis consists in stating that the correlation matrix comes from a sample in which the variables are non-collinear. Rejecting the null hypothesis from this test leads us to affirm that the variables share at least one common factor explaining their variance. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy compares the magnitude of the observed coefficients of correlation to the magnitudes of the partial correlation coefficients (Lewis-Beck, 1994, Naschold, 2005). If this magnitude is strong enough then a factor analysis is a relevant technique to define an asset index.

The second step consists in estimating the different coefficients required to construct an asset index, as described by Sahn and Stifel (2000), whose form is

$$AI_i = \hat{\gamma}_1 a_{i1} + ... + \hat{\gamma}_K a_{iK} \tag{1.1}$$

AI_i is the asset index estimated for the i households in the sample; it is a function of their k different assets, a_{ik}, whose weights γ_k have to be estimated through factor analysis. There exists a common factor accounting for a portion of the variance of each asset, the remainder being explained by a unique element whose variance is not correlated across assets (Sahn and Stifel, 2000).

$$a_{ik} = \beta c_i + u_{ik} \tag{1.2}$$

Both the common variance c and its coefficient β are not observed and must be estimated. This estimation would lead us to construct a matrix of factor loadings that reflect the relationship between the assets and the common factor. The common factor is then derived from this unique matrix of factor loadings (Bhorat et al., 2006).

$$c_i = f_1 a_{i1} + f_2 a_{i2} + ... + f_k a_{ik} \tag{1.3}$$

The common factor is a linear combination of the scoring coefficients f_k of each asset and the asset holdings a_k; a large factor score would mean that the asset associated with this score is more suited to explain the differences of welfare between households (Sahn and Stifel, 2003).

The asset index is calculated as a weighted normalised sum of asset holdings using the factor scoring coefficients as weights and normalising around the mean and the standard variation of each asset (Sahn and Stifel, 2000, Bhorat et al., 2006)

$$AI_i = f_1(a_{i1} - \bar{a}_1)/\sigma_{a_1} + ... + f_1(a_{iK} - \bar{a}_K)/\sigma_{a_K} \tag{1.4}$$

where f_k are the factor scores for each asset, $\bar{a}_k$ are the mean value of each factor and σ_{a_k} the standard deviation.

Pooling asset data over the 5 years, an asset index is estimated for each Tsimane' household in each year (Naschold, 2005). After constructing such an asset index for each household, this latter is employed to investigate poverty at a single point in time and over time, and to confirm whether households accumulate assets or not.

1.4.2 Asset index through factor analysis

In order to erase any time-specific effect, I start the factor analysis by pooling all Tsimane' asset data (Naschold, 2005). Since the Tsimane' livelihoods and way of life require holding different types of assets, I include assets employed in agricultural production, for hunting and fishing, their ability to speak Spanish and their mathematical skills, assets facilitating communication with the other communities and the external world, and assets facilitating interactions among Tsimane' households according to their culture (table 1.11). All these different assets reflect Ellis (2001) forms of capital in the sustainable livelihood framework.

Table 1.11: Description of assets included in asset index (pooled data)

Variable	Description	Mean	Std Dev.
Axe	Number of axes used for agriculture and timber logging	1.40	0.98
Bike	Number of bikes used to go to market to sell NTFPs and agricultural products	0.35	0.73
Bow	Number of bows used for hunting	1.61	1.38
Canoe	Number of canoes used for fishing and to go to market to sell NTFPs and agricultural products	0.47	0.69
Cow	Number of cows owned by households	0.48	2.09
Hook	Number of hooks used for fishing	5.47	3.57
Knife	Number of knives used for hunting, fishing and agriculture	3.50	2.28
Machete	Number of machetes used for hunting, agriculture and NTFPs	3.51	1.96
Mosquito net	Number of mosquito nets used as first protection against insects and snakes	4.19	2.28
Net	Number of nets used for fishing	0.79	1.02
Radio	Number of radios used to communicate between communities, with traders and with markets	0.89	0.87
Rifle	Number of rifles used for hunting	0.51	0.59
Shotgun	Number of shotguns used for hunting	0.42	0.56
Size plot	Total size of plots used for agriculture (tareas)	10.10	7.53
Gifts	Number of gifts received by households from other households	1.13	1.30
Spanish	Number of household members speaking Spanish	1.22	1.14
Maths	Dummy whether households have a member having maths skills	0.92	0.26

Physical assets encompass different durable goods such as bike, canoe, mosquito net and radio, which are relevant for increasing the welfare of the Tsimane'. Households with bikes and canoes are better able to go to San Borja and to benefit from its amenities. Having a mosquito net is their only means of protection against insects, snakes and mosquitoes. The Tsimane' communicate by broadcasting radio messages which justifies the importance of having a radio.

Productive capital is composed of axe, bow, hook, knife, machete, net, rifle and shotgun. These assets are used either for agriculture (axe, machete, knife), hunting (bow, rifle, shotgun and knife) or fishing (net, hook and knife). Having an axe can increase Tsimane' earnings through the creation of larger agricultural plots and consequently greater agricultural outputs, or through sale of trees. Rifles and shotguns are better hunting weapons than a bow but create additional costs in purchases of powder or bullets. With a fishing net, catches of fish tend to be larger than with a hook and a line.

Natural capital is composed of the number of cows they have and the size of cleared forest. The Tsimane' use cows as savings and safety nets, purchasing them when means are available and selling them at last resort in the case of an emergency. Having bigger plots increases earnings through an increase in agricultural production.

The proxy for social capital is the number of gifts received by the households. Human capital takes into account both the number of Spanish speakers within a household and whether any member holds mathematical skills (either addition or subtraction).

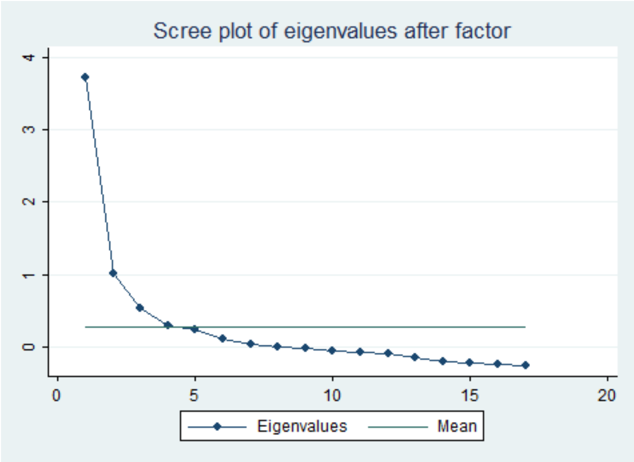
Proceeding to the factor analysis, the Bartlett's test gives a determinant of the correlation matrix equal to 0.023 which allows us to reject the null hypothesis so that the variables are collinear. The KMO measure supports this conclusion; its value is 0.849 which is high enough to conclude that a factor analysis is useful and relevant.

These two tests confirm that there exists at least one common factor explaining the ownership of the assets and that we could proceed to a PFA confining the analysis to a single factor.

The matrix of correlations (table A.4 in appendix) and the screeplot of eigenvalues (figure 1.2) show that the first two factors have values above 1. However, since the first factor explains around 80% of the variance and its value is larger than 1, I retain only one factor to proceed with the analysis.

From the factor loadings (table A.5 in appendix), the factor scores (table 1.12) are estimated as a linear combination using a Bartlett's methodology. All factor scores have a positive sign and explain positively the variance in assets between households (Sahn and Stifel, 2000).

Figure 1.2: Screeplot of eigenvalues from factor analysis



The assets that better explain the variance in assets are mosquito nets, machete and knife; having more of one of these assets would increase the value of household asset index. On the other hand, having better math skills at the household level helps little in explaining the variance in assets.

For each household in each year, the asset index is estimated as a weighted sum of each

Table 1.12: Factor scores estimated through factor analysis

Variable	Factor scores
Axe	0.14
Bike	0.05
Bow	0.12
Canoe	0.06
Cow	0.03
Hook	0.16
Knife	0.20
Machete	0.26
Mosquito net	0.27
Net	0.08
Radio	0.09
Rifle	0.04
Shotgun	0.07
Size plot	0.09
Gifts	0.03
Spanish	0.04
Maths	0.01

asset normalised around its mean and standard deviation whose weight is the factor score. Over time, the average asset index has increased along with the median value of asset index (table 1.13). Differences between mean and median values of the asset index decrease between 2002 and 2006, though not monotonically.

The scatterplots show that some households do not greatly modify their asset index

Table 1.13: Asset index for each year 2002-2006

Variables	Obs.	Mean	Std Dev	Min	Max	Median
AI 2002	172	-0.16	1.07	-2.12	3.95	-0.39
AI 2003	172	-0.14	1.06	-2.05	3.24	-0.42
AI 2004	175	-0.094	1.07	-1.91	5.47	-0.28
AI 2005	175	0.12	1.21	-1.53	5.55	-0.12
AI 2006	176	0.30	1.10	-1.92	4.38	0.14

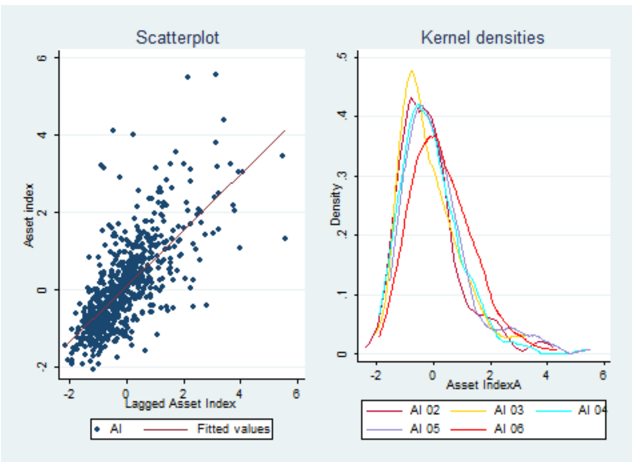
from one year to the next as there exists some concentration around the 45 degree line. Still some dispersion in the left-hand or right-hand parts of the figure prove that certain households have moved either upward or downward their values of asset index. The Kernel densities show that the distributions are shifting to the right over time meaning that households tend to accumulate assets.

Overall, 68% of households have higher values of asset index in 2006 than in 2002. For 30% of these households, this increase in asset index is constant since they have higher values of asset index in 2004 compared to 2002, higher values of asset index in 2006 compared to 2004. 60% of the households with higher values of asset index in 2002 still remain with the higher values of asset index in 2006.

In 2006, the distribution of the asset index is more dispersed its peak being lower than in the previous years (figure 1.3).

Both scatterplots and Kernel densities of the asset index show that the Tsimane' are

Figure 1.3: Scatterplot and Kernel densities of asset index



an homogenous population and no polarised groups with clustered values of asset index appear on these graphs.

However, neither the scatterplots nor the Kernel densities curve lead us to reject the idea that there could be some non-linearities and discontinuities on the asset accumulation process over time and studying the asset accumulation seems relevant.

Before studying asset index accumulation, this asset index is used to define poverty, severe poverty and chronic poverty for the Tsimane'. Looking at poverty status and dynamics can shed light on whether asset index holdings are increasing or not, and can help with comparing values of asset index among households.

1.4.3 Poverty status and dynamics

I define severe poor households, households whose level of assets index is in the first two deciles of asset index and poor households, households with an asset index in the first four deciles.

A components definition of chronic poverty is used to look at households whose mean levels of asset index over the five years is always below the fourth decile of pooled asset index (Yaqub, 2000).

Severe poverty and poverty in terms of asset index

Considering values of asset index over time, non-severely poor households have increased their asset index and so have severely poor households. However increases in asset index are higher for the non-severely poor than for the severe poor (table 1.14).

Non-severely poor households have the same total wealth in 2002 and in 2006 while severely poor households increase their asset holdings; for both categories of households household wealth has fluctuated over the five years.

Table 1.14: Asset index, household asset holdings and household earnings according to severe poverty (deflated values to 2006 Bolivianos)

Year	Number		Asset index		Total wealth		Total earnings	
	Non-severe	Severe	Non-severe	Severe	Non-severe	Severe	Non-severe	Severe
2002	142	34	0.13	-1.34	4145.9	1620.9	260.1	196.0
2003	142	34	0.13	-1.26	4021.8	1832.5	324.9	104.1
2004	141	35	0.21	-1.32	4613.1	1710.1	316.6	232.9
2005	141	35	0.43	-1.13	4848.1	2016.5	461.8	173.1
2006	140	36	0.64	-1.04	4158.9	1733.8	398.3	184.5

Looking at total earnings, severely poor households have fewer earnings than non-severely poor households, which confirms the idea that earnings and assets are positively correlated. Severely poor households in the last two years have fewer total earnings than in the first year, while non-severely poor households have greater earnings.

With respect to poor households with asset index in the first four deciles, values of asset index fluctuate over time and in 2006 these values are greater than in 2002 (table 1.15). On average, non-poor households have values of asset index increasing over time.

Household total wealth decreases over time for non-poor households while earnings of non-poor and poor households increase.

Table 1.15: Asset index, household asset holdings and household earnings according to poverty (deflated values to 2006 Bolivianos)

Year	Number		Asset index		Total wealth		Total earnings	
	Non-poor	Poor	Non-poor	Poor	Non-poor	Poor	Non-poor	Poor
2002	108	68	0.43	-1.07	4663.3	2076.8	283.8	190.5
2003	107	69	0.46	-1.05	4563.8	2126.2	332.0	205.1
2004	106	70	0.51	-1.01	5225.4	2234.3	356.2	214.8
2005	106	70	0.78	-0.85	5379.8	2627.1	502.9	255.2
2006	106	70	0.96	-0.71	4555.1	2311.8	446.7	215.2

Poverty dynamics and overlaps between chronic poverty and extreme poverty

Having determined poverty at a specific point in time, it would be interesting to estimate how many households are poor in several periods. Because the panel covers five years, using a components definition of chronic poverty seems more appropriate and robust than using a spells definition (Yaqub, 2000). A components definition of chronic poverty consists in comparing the mean value of the asset index against a poverty line.[15]

With this definition of chronic poverty, 68 households have their mean asset index below the poverty line and are chronically poor while 108 are non-chronically poor (table 1.16). Over time, the chronic poor have increased their values of asset index which have nearly doubled between 2002 and 2006. In 2006, chronically poor households have greater total wealth than in 2002 although total wealth has been decreasing between 2005 and 2006. Such a decrease in household wealth can be potentially explained by the 2006 floods and one can wonder whether chronically poor households are accumulating assets or whether this downward trend will persevere.

Non-chronically poor households have their asset index increasing between 2002 and 2006

Table 1.16: Asset index, household asset holdings and household earnings according to chronic poverty (deflated values to 2006 Bolivianos)

Year	Asset index		Total wealth		Total earnings	
	Non-chronic	Chronic poor	Non-chronic	Chronic poor	Non-chronic	Chronic poor
2002	0.37	-1.01	4587.6	2194.9	296.1	170.9
2003	0.37	-0.96	4484.9	2143.2	338.9	192.3
2004	0.44	-0.94	4996.5	2510.0	341.1	234.5
2005	0.69	-0.76	5234.2	2777.4	520.4	220.2
2006	0.86	-0.59	4470.0	2380.9	448.8	205.1

while their total wealth decreases between 2002 and 2006, following an increase between 2003 and 2005.

Looking at total earnings, total earnings have increased for both chronically poor and non-chronically poor households while consumption has decreased.

Comparing with severe poverty, 94% of the severely poor in 2002 are chronically poor over time and 86% of the severely poor in 2006 have been chronically poor.

To summarise even if some households seem to accumulate assets, others have very low

[15] I pooled all asset index data and I estimated a normal poverty line at the maximum asset index value in a fourth decile, which is equal to -0.44 asset index unit.

values of asset index over time which causes poverty to persist.

Livelihood strategies have shown that some households have managed to implement potentially high-return strategies while other households have strategies with lower returns. Coupling this information with poverty dynamics, a poverty trap test seems relevant.

The problem is now to identify whether there exist different equilibria with different levels of returns such that some households cannot accumulate assets or whether there is a slow growth process with only one single equilibrium towards which all households would converge.

In the following section various tests to find evidence for the existence of a poverty trap are applied and their results are discussed.

1.5 Tests for a poverty trap for the Tsimane' households

To be able to test for a poverty trap I have to assume that households are the same over time and that the asset accumulation process is the same for each household (Naschold, 2005, Carter and Barrett, 2006). Testing for a poverty trap by defining an accumulation process for each household or for each household strategy would never be practical. Assuming that there exists an identical pattern of asset accumulation sets an important limit because in reality, strategies lead to different uses of the assets and to different asset accumulation preferences.

Nonetheless, proceeding with the tests consists in demonstrating that there are non-linearities and non-convexities in the asset accumulation leading to several equilibria which could be either stable or unstable. To deal with non-linearities, different parametric, non-parametric and semiparametric regression techniques are available such as parametric high degree polynomials, nonparametric locally weighted scatterplot smoother (LOWESS) or penalised splines and semiparametric penalised splines (Naschold, 2005).

1.5.1 Specifications of the test

Analysing a non-linear asset accumulation process consists in regressing the current value of asset index against its lagged value such that:

$$AI_{i,t} = \alpha_0 + \sum_{m=1}^{M} \beta_m A_{i,t-1}^{m} + \gamma Z_{i,t} + T_t + \varepsilon_{i,t} \tag{1.5}$$

where $AI_{i,t}$ is the value of the asset index of household i at time t with $t = 2, ..., T$, $Z_{i,t}$ are household characteristics (age of household head, household size, education...) and T_t are time-dummies that take value 1 if time is t and 0 otherwise (Naschold, 2005).

However identifying an unstable threshold requires either to use a parametric specification with a large sample or more flexible forms (Naschold, 2005).

Parametric - High-degree polynomial regression

Certain tests for the existence of a poverty trap have employed polynomial regression techniques to estimate the asset accumulation process (Ruppert et al., 2003, Barrett et al., 2006). Likewise, I use a fourth-degree polynomial regression to estimate the relationship between the change in asset index and its lagged value.

Use of the change in asset index instead of its current value is supported by the fact that there could be some over/underestimations in asset index values which would bias the model. Furthermore, using the change in asset index leads to the elimination of some individual effects potentially correlated with the lagged values (Jalan and Ravaillon, 2001, Naschold, 2005).

$$\Delta AI_{it} = \beta_0 + \beta_1 AI_{it-1} + \beta_2 AI_{it-1}^2 + \beta_3 AI_{it-1}^3 + \beta_4 AI_{it-1}^4 + \Gamma_i Z_i + T_t + \varepsilon_{it} \tag{1.6}$$

with $\varepsilon_{it} \backsim N(0;\sigma_{\varepsilon}^2)$, $1 \leq i \leq N$ and $1 \leq t \leq T$.

The change in asset index over time is a function of a fourth-degree polynomial of its lagged value AI_{t-1}, of household characteristics Z_i, e.g. the age of the household head, the squared age of the household head, the size of the household and the average educational attainment of household members, and of time dummies T_t.

Naschold (2005) affirms that the age of the household head and its squared value are used to include life-cycle effects in the analysis. Only one single lag in the asset index is possible due to the shortness of the survey period (Naschold, 2005).

Nonparametric - Penalised splines and LOWESS

Contrary to parametric regressions, nonparametric regressions assume that the relationship between the asset index and its lagged value is unknown and must be estimated by fitting a function f through a scatterplot without any assumptions on its functional form (Ruppert et al., 2003, Naschold, 2005).

The following function is estimated

$$AI_{it} = f(AI_{it-1}) + \varepsilon_{it}, 1 \leq i \leq N, 1 \leq t \leq T \tag{1.7}$$

with $\varepsilon_{it} \backsim N(0;\sigma_{\varepsilon}^2)$.

Different estimation techniques could be used to smooth this relationship and I privilege a smoothing first through penalised splines and then through LOWESS.

Penalised splines Adapting the notation from Ruppert et al. (2003) and Naschold (2005), in a spline model, the function f takes the following form

$$f(AI_{it-1}) = \beta_0 + \beta_1 AI_{it-1} + \ldots + \beta_p AI_{it-1}^p + \sum_{k=1}^{K} u_k (AI_{it-1} - \kappa_k)_+ + \varepsilon_{it}, 1 \leq i \leq N, 1 \leq t \leq T \tag{1.8}$$

with $\varepsilon_{it} \backsim N(0;\sigma_\varepsilon^2)$, $u = [u_1, ..., u_K]' \backsim N(0;\sigma_u^2)$.

κ represents a knot and there are K number of knots (Ruppert et al., 2003, Naschold, 2005).

The penalised spline model can be explained by a mixed model methodology where:

$$y = X\beta + Zu + \varepsilon \tag{1.9}$$

with $\beta = [\beta_0, \beta_1]'$, $X = \left(\begin{bmatrix} 1 & AI_{11} & \dots & AI_{1J} \\ \vdots & \vdots & \ddots & \vdots \\ 1 & AI_{n1} & \dots & AI_{nJ} \end{bmatrix}\right)$ and $Z = \begin{pmatrix} (AI_{11}-\kappa_1)_+ & \dots & (AI_{11}-\kappa_K)_+ \\ \vdots & \ddots & \vdots \\ (AI_{1t}-\kappa_1)_+ & \dots & (AI_{1t}-\kappa_K)_+ \\ \vdots & \ddots & \vdots \\ (AI_{n1}-\kappa_1)_+ & \dots & (AI_{n1}-\kappa_K)_+ \\ \vdots & \ddots & \vdots \\ (AI_{nt}-\kappa_1)_+ & \dots & (AI_{nt}-\kappa_K)_+ \end{pmatrix}$

u is treated as a random effect with $cov(u) = \sigma_u^2 I$ and $\sigma_u^2 = \sigma_\varepsilon^2/\lambda^2$.

λ is a smoothing parameter that controls for the amount of smoothing. It is estimated through a restricted maximum likelihood (REML) since the penalised splines (equation (1.8)) are estimated as best linear unbiased predictors (BLUPs) from a mixed model (Ruppert et al., 2003). The parameter λ penalises the knot coefficient u_k (Ruppert et al., 2003, Naschold, 2005).

LOWESS The locally weighted smooth scatterplot is a method for smoothing the scatterplot $(AI_{it-1}AI_{it})$ with $i = 1, \dots, n$ being the number of observations in each period t. At each value of AI_{it-1}, a fitted value is estimated by running a regression in a local neighbourhood of AI_{it-1} using weighted least squares. The neighbourhoods are defined as a proportion of the total number of observations (Naschold, 2005, Cleveland, 1979). The weight is large if AI_{it-1} is close to the fitted value, and small if it is not, and therefore the points close to AI_{it-1} play a larger role in the determination of the fitted value of AI_{it} while the ones further away play a smaller role (Cleveland, 1979).

Then n weighted local regressions would be estimated at each value of AI_{it-1} in order to find the smoothed value of AI_{it} (Naschold, 2005).

Semiparametric - Penalised splines

As explained by Ruppert et al. (2003), semiparametric regressions consist in combining both parametric and nonparametric regression techniques (Ruppert et al., 2003). Here this consists in adding to the nonparametric specification of equation (1.7) the parametric element of equation (1.6). The semiparametric model could be written as

$$A_{it} = \beta_0 + \beta_x X_{it} + f(A_{it-1}) + \varepsilon_{it} \tag{1.10}$$

with $1 \leq i \leq N$, $1 \leq t \leq T$ and $\varepsilon \backsim N(0; \sigma^2_\varepsilon)$.

The equation (1.10) introduces to the nonparametric equation (1.7) different parametric elements, X_{it} such as household characteristics (education, size of the household, age,...), or time dummies taking the value 1 at time t and the value 0 otherwise. These time dummies as well as the age of the household head and its squared value, absorb the time-specific effects, while the household-specific effect are contained by household characteristics (Naschold, 2005).

To fit the regression, the nonparametric element are smoothed using penalized splines through a mixed model as described before (Ruppert et al., 2003, Naschold, 2005).

1.5.2 Results of these different estimation techniques

Parametric - high-degree polynomial results

The estimation of a fourth-degree polynomial regression is done using the variables presented in table A.7 in appendix. Over the whole period the change in asset index is on average equal to 0.12 but this change varies over time. The change in asset index between 2002 and 2003 is on average equal to 0.02 while it is on average equal to 0.21 between 2004 and 2005.

A household fixed-effect estimation is selected since an Hausman test fails to accept the null hypothesis that the random-effect estimators are more efficient than the fixed-effect estimators. It seems that the regressors are correlated with the household effect; household fixed-effect estimators are consistent and efficient.

The coefficients obtained from the parametric regression show that the lagged asset index at a first-degree power has a negative and significant impact on the change in the asset index, while all lagged asset indices with higher degree powers have no significant effects on the change in the asset index (table 1.17). The negative sign of the lagged asset index illustrates the fact that the higher the asset index in the previous period, the lower the change in the asset index at the current period.

None of the high-degree coefficients being significant means that there are not any non-linearities in the accumulation of assets. Plotting the values of the lagged asset index using these coefficients show greater are the values of asset index, smaller the changes. Over time, asset accumulation by the Tsimane' seems to follow a linear process and household asset index may converge towards a single equilibrium.

It seems that changes in asset index are linked to the age of the household head. As household head ages, the changes in asset index increase from one year to the other but at a decreasing rate. Also, as expected, larger households need more assets than smaller

Table 1.17: Estimation of change in asset index (Household fixed effects)

Variables	Change asset index (1)	Change asset index (2)	Change asset index (3)
Lagged asset index	-1.071*** (0.0824)	-1.048*** (0.0610)	-1.075*** (0.0826)
Squared lagged asset index	0.0528 (0.0363)	0.0548 (0.0360)	0.0536 (0.0363)
Cubed lagged asset index	-0.00366 (0.0233)	-0.0125 (0.00838)	-0.00379 (0.0234)
Fourth degree lagged asset index	-0.00155 (0.0038)		-0.00151 (0.00382)
Age household head	0.0449** (0.0224)	0.0441** (0.0223)	0.0441* (0.0225)
Squared age household head	-0.000449** (0.0002)	-0.000440** (0.000208)	-0.000442** (0.000209)
Education household head	0.02 (0.0261)	0.0217 (0.0261)	0.0206 (0.0262)
Household size	0.280*** (0.0266)	0.280*** (0.0266)	0.280*** (0.0266)
Children			-0.0152 (0.0170)
Dummy for 2002	0 (0)	0 (0)	0 (0)
Dummy for 2003	-0.189**(0.0733)	0 (0)	-0.197***(0.0739)
Dummy for 2004	-0.1 (0.0731)	0.0929 (0.0705)	-0.102 (0.0734)
Dummy for 2005	0 (0)	0.187** (0.0730)	0 (0)
Dummy for 2006	0.170**(0.0733)	0.360*** (0.0735)	0.165** (0.0736)
Constant	-2.902***(0.5759)	-3.075*** (0.576)	-2.833*** (0.581)
Observations	580	580	580
Number of hhid	176	176	176
R-squared	0.595	0.595	0.596

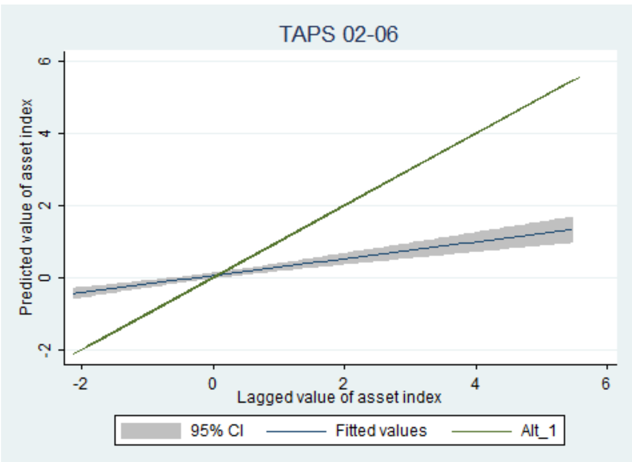
Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

households and are incentivised to accumulate assets from one period to another.

With the parametric coefficients from regression (1), the values of the current asset index can be predicted. A plot of these predicted values of the asset index against its lagged value (figure 1.4) shows that there is no S-shape in the asset accumulation and no Micawber threshold that would keep household in a poverty trap.

The asset accumulation process seems linear which is consistent with the result that only

Figure 1.4: Scatterplot predicted asset index against its lagged value



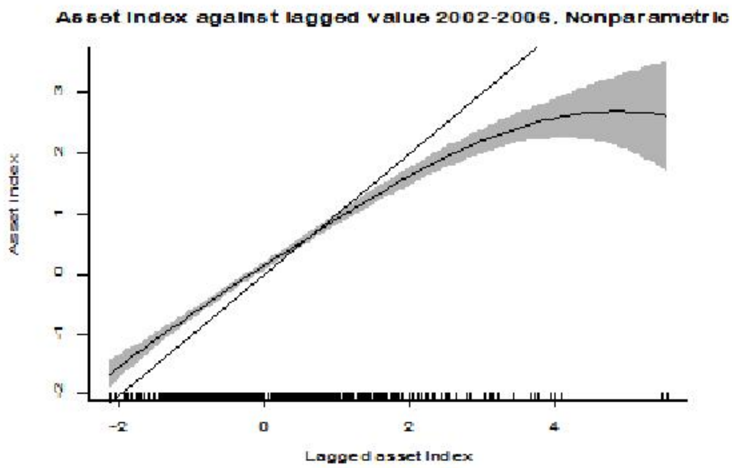
the lagged asset index at a single power is significant.

Nonparametric - Penalised splines and Lowess results

Penalised splines The estimations of nonparametric and semiparametric penalised splines have been done using the package SemiPar 1.0 on R (Wand et al., 2005). 3.335 degrees of freedom and 35 knots have been retained.[16] Having a small number of degrees of freedom suggests that the asset accumulation may be not very non-linear (Naschold, 2005).

The curve (figure 1.5) confirms that there are not any non-linearities. It seems that there is not an S-shape as required to obtain a poverty trap mechanism. However there is a smooth concavity in the asset accumulation leading to conclude that asset accumulation would be larger for smaller values of asset index (Naschold, 2005).

Figure 1.5: Scatterplot asset index against its lagged value using penalized splines (non-parametric)



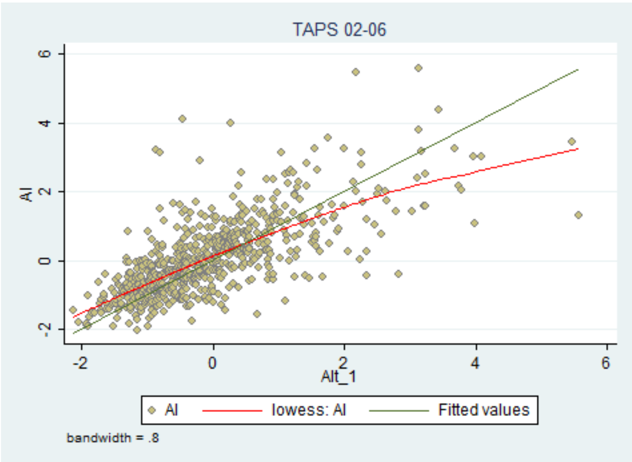
The asset accumulation would reach a single equilibrium around $[0.9, 1.1]$ represented by the intersection of a 45-degree line and the curve. However, the slope of the curve suggests that reaching this asset equilibrium would take time.

[16] I have tried with different degrees of freedom and different number of knots, but I have obtained the same results, no S-shape and no Micawber threshold; only the slope changed.

LOWESS The estimation of the asset accumulation with a LOWESS used as smoothing parameter has been plotted using STATA 10 and gives a curve quite similar as the one obtained with nonparametric penalised splines.

Figure 1.6 shows that there are no non-linearities or non-convexities in the asset accumulation. There is no S-shape and no evidence of a poverty trap situation. On the other hand,

Figure 1.6: Scatterplot asset index against its lagged value using LOWESS (nonparametric)



the curve confirms that there could be a single equilibrium that lies between $[0.9; 1.1]$ asset units.

Semiparametric - Penalised splines results

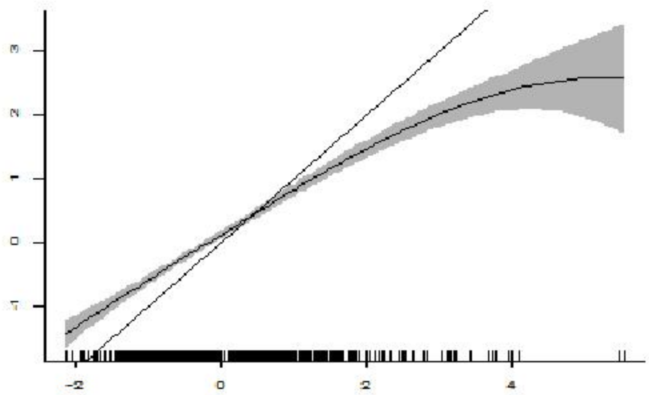
I attempted different specifications starting by considering only the time dummies, then all the time dummies and some household characteristics, but these tests have failed. The specification finally retained consists in estimating the level of asset index at the current period as a function of the household size at the current period, of a time dummy for 2006[17], and of a nonparametric function. In this specification, time-specific effects are only captured by a time dummy for 2006.

[17] I try different specifications starting by considering only the time dummies, then all the time dummies and all household characteristics of the high-polynomial but the regressions could not converge and the coefficients be estimated. The only other specification that could be estimated includes the age and squared age of household head and a time dummy for 2003 and I obtain the same results as the ones presented here.

2.194 degrees of freedom and 35 knots are retained to proceed to the smoothing of the lagged asset index.

In this specification, both the household size and the time dummy have positive and significant effects on the current asset index. Here as well, there is no S-shape in the asset

Figure 1.7: Scatterplot asset index against its lagged value using penalized splines (semiparametric)



accumulation, and there is no evidence of a poverty trap situation. Asset accumulation seems to be concave.

The asset accumulation would reach a single equilibrium also around $[0.9; 1.1]$ asset index units.

Even when introducing more flexibility in the estimation of the asset accumulation by using semiparametric regression, none of these models show that a poverty trap could arise while considering the Tsimane' assets.

All these models have a concave shape with a single equilibrium around $[0.9; 1.1]$ asset index units. The concavity of the curves implies that even if asset accumulation is larger for households with small quantities of assets, these households need more time to reach the equilibrium than the households with higher levels of assets.

As a consequence, even if there is no evidence of the existence of a poverty trap, the

Tsimane' households are really poor in terms of asset index and escaping their low welfare level situations seems quite infeasible. The concavity of the different curves suggest that reaching an asset index equilibrium would take time for the Tsimane' households.

1.6 Discussion on the non-existence of a poverty trap

Testing for a poverty trap has required a number of flexible specifications, however even when using flexible functional forms, none of these estimations has brought any evidence for the existence of a poverty trap for the Tsimane'. The accumulation of assets seems to be linear and a single equilibrium towards which the households should converge appears to exist.

The hypothesis of the existence of a poverty trap and of a Micawber threshold as formulated by Carter and Barrett (2006) is rejected. This conclusion contradicts what Lybbert et al. (2004) and Carter and Barrett (2006) have found in their own studies but it also confirms what Naschold (2005), Quisumbing and Baulch (2009) and Giesbert and Schindler (2010) have established in other countries. It seems though that the nature of the Tsimane' livelihoods and their asset diversification impede to find evidence of a threshold and an S-shaped curve.

However, even if there is no poverty trap as Carter and Barrett's definition, it is quite plausible that the single equilibrium found in the previous estimations correspond to an equilibrium in the lower part of the S-shaped curve. The Tsimane' households are poor and more likely to remain poor all their life than to escape poverty.

1.6.1 Absence of poverty trap for the Tsimane'...

Most studies identifying a poverty trap (Lybbert et al., 2004, Carter and Barrett, 2006) look at the accumulation of a single asset: cattle. For Ethiopian and Kenyan herders, cattle is an asset but also has a religious value and can be used as food. The loss of livestock and the absence of other means to generate their livelihood and fulfil consumption needs explain why some herders are trapped into poverty while others can manage to have a herd size large enough to improve their welfare. On the contrary, the Tsimane' have a wider range of assets upon which they rely to generate their livelihood; when a Tsimane' household loses one asset used in activity, it can switch to another asset to sustain its livelihood. As a consequence, this diversification tends to smooth the differences between households and creates a linear pattern in asset accumulation.

Using an asset index, Adato et al. (2006) has found evidence of a poverty trap but in their study, households seem more heterogenous; there are more observations at different levels of assets which allows the detection of an S-shaped curve. On the contrary, the values of the asset index for the Tsimane' are clustered around 0, and there are no sharp differences in the values of asset index between households over time. There are too few observations at high and low values of asset index and even less observations to capture the unstable threshold.

Naschold (2005) has not found any asset poverty trap neither in Ethiopia nor in Pakistan and he affirms that asset accumulations in both countries are smoothly concave, which implies that poorer households accumulate assets and recover from shocks more slowly than wealthier households. Quisumbing and Baulch (2009) explain that the lack of evidence of an S-shaped curve in Bangladesh is due to an absence of the exclusionary mechanisms as defined by Carter and Barrett (2006) and to a lack of sharp differences between household livelihoods. Giesbert and Schindler (2010) have not found the S-shaped curve in the asset accumulation in Mozambique arguing that rural livelihoods are too homogenous and that households may actually be in the lower equilibrium.

These latter studies conclude that as it is the case for the Tsimane', not finding the poverty trap does not mean the end of poverty; households are more likely to stay poor and external aid is required to help them to improve their welfare.

1.6.2 ...but not the end of poverty

Failing to prove that a poverty trap does exist among the Tsimane' households does not imply that they are able to escape the low levels of economic development in which they persist. What seems a more plausible story is that even if the model does not show evidence of a poverty trap situation, the Tsimane' are stuck into poverty and the equilibrium may be the low equilibrium toward which households converge. Poor living standards, poor quality of assets and volatile consumption confirm that the households are more likely to live all their life into poverty than reaching higher levels of welfare.

Considering their BMI, the average BMI of the Tsimane' adult has not improved over time. On average, the BMI for the children aged less than 5 years old has decreased from 17.06 to 16.56 between 2002 and 2006. Malnutrition does not seem to affect the majority of adults but Tsimane' children may suffer from it.

Furthermore, lack of increase in education levels proves that persistent poverty is a reality for the Tsimane' households. Between 2002 and 2006, average education has stagnated at a 2nd grade in primary education for household members aged more than 15 years old meaning that on average young adults have not reached higher grades than older adults. No improvements in average education have been observed in younger individuals, aged 6-15 years old, for whom average grade remains a first grade in primary education.

Persistence of poverty is confirmed by the estimations. According to these latter, the Tsimane' should reach an equilibrium found at $[0.9; 1.1]$ asset index units; however, in all five years, more than 80% of the households have their asset index below 0.9 asset index units during the period. Defining chronic poverty as equal to half of the equilibrium in asset index units (0.5 asset index units), 75% of the households in the sample are chronically poor.

Most Tsimane' households are far from the equilibrium and even if accumulating assets, 80% in 2006 of the households in a low-return strategy have their asset index smaller than [0.9;1.1] asset index units. 60% of the households in a high-return strategy have their asset index above the equilibrium in 2006 with higher wage and sales earnings. However, since the number of households in the high-return strategy is small, the large majority of Tsimane' households is more likely to remain poor.

Even if household wealth increases, the estimations show that asset accumulation is a slow process that won't help households to escape poverty in their lifetime.

Furthermore, a majority of changes in asset holdings is to some extent related to external aid. During the last decade, the Tsimane' have faced many floods that have attracted attention from international NGOs and increased their interventions in the area. After the 2006 floods, 67% of the households answered receiving small assets such as machete, knives and buckets from the Red Cross. External aid and interventions of international NGOs appear to be one of the main reasons why households are able to slowly accumulate assets and without such interventions, one can wonder whether the Tsimane' living conditions would not be even worse.

1.7 Conclusion

My results show that there is no evidence of a poverty trap as Carter and Barrett's definition. But this result does not rule out the existence of a poverty trap situation for the Tsimane'. The Tsimane' have low levels of earnings and assets and they are poor when compared to an average Bolivian household.

With respect to the asset index, the majority of households are below the equilibrium in the last year of the survey and even if they are accumulating assets, this is a slow process starting from low levels of assets. As a result, the Tsimane' households won't escape poverty in their lifetime.

But clearly, asset diversification is important for the Tsimane' in order to reduce poverty pressures through the creation of earnings from one or several sources. Even if they are low values, earnings and sales are more important when households have higher levels of asset holdings, and agricultural production also increases when asset holdings increase.

It seems that households are using their labour in activities that may or may not be related to forest resources. As a consequence, further research should deal with determining and analysing those factors pushing households to allocate their labour to different activities and, furthermore, whether allocations of labour in forest-related activities could provide an improvement in household welfare.

Chapter 2

Welfare impacts from non-timber forest product extractions in South Cameroon

Households living within forests are assumed to combine non-timber forest product (NTFP) extraction to other activities in order to cope with shocks or manage risks. The potentialities of participating in NTFP extraction to improve household welfare are often undermined. This study is aimed at analysing whether participating in NTFP activities and combining these activities with others can improve household welfare. A non-separable household model of production is estimated to analyse labour supply and allocations employing data I collected in February-May 2009 in the Province South of Cameroon. Marginal and average shadow wages are respectively estimated through production functions and through the quotient of earnings on time. Endogeneity problems are controlled for using relevant instrumental variables. Welfare analysis is derived from all empirical results, theoretical model and descriptive analysis. Poorer households depend more on NTFP extraction than wealthier households but on average, households engaged in NTFP extraction appear to be better off than households not engaged in such activities. Labour supply estimations report that household marginal shadow wage and income have respectively positive and negative effect on leisure. Whether agricultural prices increase and increase shadow income, this has a positive or negative effect on consumption depending whether household is net-buyer or net-seller and an indeterminate effect on leisure. However, according to labour allocations estimations, households would work more in agriculture and off-farm activities after an increase in agricultural earnings. On the contrary, if the increase in household shadow income results from an increase in NTFP prices, this has a net positive effect on household consumption and an indeterminate effect on leisure, but it seems quite likely that the effects on consumption outweigh any effects on leisure. An increase in NTFP prices allows households to get better off without pushing them to spend more time extracting NTFPs.

2.1 Introduction

Households living within forests use forest resources to implement activities such as non-timber forest product (NTFP) extraction or hunting, agriculture, logging or raising animals (Byron and Arnold, 1999, Wunder, 2001). Households also develop off-farm off-forest activities and participate in wage activity or create their own self-employed activity. However even if forest households seem to have diversified livelihoods combining a wide range of activities, it is generally acknowledged that these households are poor and that they diversify into NTFP activities in order to manage their risks or cope with shocks (Arnold and Townson, 1998, Byron and Arnold, 1999, Angelsen and Wunder, 2003, Sunderlin et al., 2007). However, such a conclusion is generally acknowledged without any strong empirical findings.

Little empirical evidence exists on forest household's welfare and even less is known whether households can improve their welfare through the extraction of different NTFPs or the combination of NTFP activities with other activities. López-Feldman and Taylor (2008) report that households extracting a single NTFP in Mexico are able to improve their welfare through this extraction. However, their analysis fails to explain how households combine this activity with others and what are the effects from different combinations of activities.

As a consequence, the lack of evidence on forest household's welfare and on the role of forest activities to improve it, has motivated this study. This chapter intends to provide an analysis on how forest households supply their labour and what are the factors explaining activity combinations, and it investigates whether or not NTFP extraction can improve households' welfare.

Following pioneering studies like Jacoby (1993) and Skoufias (1994), I use a non-separable household model of production as specified by Singh et al. (1986) and Benjamin (1992) to analyse household labour supply. Prior to estimating household labour supply, I estimate the marginal shadow wage from agriculture and NTFP production functions, and I calculate shadow income, both shadow values explaining household labour supply. As in Fisher et al. (2005), López-Feldman and Taylor (2008) and Sikei et al. (2009), labour allocations to different activities are also analysed in such a framework. Average shadow wages in agriculture, NTFP activities and off-farm employment are estimated using the quotient of earnings over time since marginal values in off-farm employment and NTFP activities are respectively not estimable and implausible. Since some households do not participate in the latter two activities, Heckman specifications control for the selection bias. Endogeneity problems occur in most estimations and these are controlled for using appropriate and relevant instrumental variables. Finally I combine these results with the model and the descriptive analysis to examine how to improve household welfare.

Since household data usually do not focus on the specificities of forest activities, I have collected my own data in February-May 2009 in thirteen villages of the Province South in Cameroon. Following a 1999 survey, forest households in this Province are engaged in a wide range of activities and the data collected focus on production and time spent in agriculture, NTFP extraction, hunting, wage and self-employment activities.

Overall, I find that for households in the research area, NTFP extraction and hunting contribute to 8 and 2% of their total production respectively. Poorer households depend more on NTFP extractions than wealthier households but on average, households engaged in NTFP extraction appear to be better off than households not engaged in such activities. Labour supply estimations report that household marginal shadow wage and income have respectively positive and negative effect on leisure which is an inferior good. Whether agricultural prices increase and increase shadow income, this has a positive or negative effect on consumption depending whether the household is a net-buyer or a net-seller, and it has an indeterminate effect on leisure. However, according to labour allocations estimations, households work more in agriculture and off-farm activities after an increase in agricultural earnings. On the contrary, if the increase in household shadow income results from an increase in NTFP prices, this has a net positive effect on household consumption and an indeterminate effect on leisure, but it seems quite likely that the effects on consumption outweigh any effects on leisure. An increase in NTFP prices allows households to get better off without pushing them to spend more time extracting NTFPs.

The different steps to reach these conclusions are as follows. Section 2.2 presents the research area and the 1999 survey as well as the questionnaire used in 2009 and the fieldwork. Section 2.3 gives a detailed description of the forest households and their activities. The theoretical model and the existing literature are presented in section 2.4. Section 2.5 is dedicated to the estimation of agricultural and NTFP production functions and the estimation of the total labour supply function. Section 2.6 looks at labour allocations to agriculture, NTFP extraction, off-farm employment and hunting. Section 2.7 analyses whether households engaged in NTFP extraction are better off and how they can improve their welfare. Section 2.8 concludes and gives some policy implications linked to the management of forest resources.

2.2 Fieldwork, research area and data collection

Analysing labour allocations and livelihood strategies of people living near or within forests requires data on NTFP extractive activities but also agriculture, wage activities, self-employment, and their different levels of output, inputs and sales. It is also relevant to know about their non-labour income and consumption levels to have a full analysis of households' livelihood.

However the lack of detailed household data on all these questions in forest areas forces me to collect my own data. Searching for areas with forest covers and with households using natural resources and intervening in agricultural and NTFP markets, the Province South in Cameroon seems to be a suitable research area. Besides, the fact that in 1999 a survey has been done by Tropenbos International motivates the collection of another round of data.

2.2.1 Tropenbos International in Cameroon and the 1999 survey

In the late 1990s, Tropenbos International, a Dutch non-governmental organisation (NGO) launched an innovative research project in some villages of the Province South in Cameroon to promote community involvement in the sustainable management of forest resources. The research area was about 200,000 hectares of forest land in the plains and mountains of the Bipindi-Akom II area (figure 3.2) which was a former concession of a Dutch logging company. This area was not densely populated and main tribes were Bulu, Ngoumba, Bassa, Fang and Pygmies. Poor infrastructure limited trade among villages and small towns and households were mainly engaged in subsistence agriculture (van Dijk and Wiersum, 1999).

Tropenbos International's goal was *"to develop methods and strategies for natural forest management directed at sustainable production of timber and other forest products and services"* (Jonkers and Foahom, 2004). They implemented 14 research projects to assess the legal, ecologic, economic and social aspects of forest uses in the area (Lescuyer et al., 1999).

In relation to ecological and forestry management issues, these research projects showed that land uses were not intensive and had only modest impacts on flooding, erosion and draughts. According to their findings, villages were poorly organised and households have no legal title on their land which they secure through customary property rights. The projects recognised that forest management should ensure forest regeneration and growth through forest conservation and animal protection. Furthermore, if they organise in small cooperatives, villagers could take control of this management (Jonkers and Foahom, 2004). In 1999, one of these research projects was a household survey collecting *"socio-economic information about the households living in the area and determining what were their different economic activities related to forest cover"* (Lescuyer et al., 1999). Its objectives were four-fold: to describe the different types of villages in the area; to report households' main activities; to estimate their uses of forest cover; and to define which forest conservation measures could be implemented in the area (Lescuyer et al., 1999). The questionnaire encompassed questions about households' characteristics, the different food and cash crops cultivated, households' participation in wage activities and their food and non-food expenditures. The researchers listed all NTFPs collected and game hunted.

To summarise, this survey found that a household was on average composed of five members and their average educational level was the certificate of primary school ("CEPE"). In terms of participation, food crop agriculture was households' main activity and was mainly done by women. Cocoa cultivation was the second activity and was mainly done by men. The third highest participation rate was in wage activities (Lescuyer et al., 1999).

Manioc is their main source of production and sale, followed by macabo (cocoyam) and plantain. Cocoa was an important source of production and sales for households living in the south of the research area. Considering NTFPs, ndo'o (wild mango, *irvinga gabonensis*), palm nut (*elaeis guineensis*) and ekouk (*alstonia boonei*) represented respectively 24, 12 and 10% of total NTFP extractions, other NTFPs being quite marginal; all NTFPs were aimed at home-consumption. Porcupine, palmist rat and hare were the most important game hunted and they were mainly consumed (Lescuyer et al., 1999).

They reported that households generated 32% of their monetary revenues from sales of agricultural products and 26% from self-employed activities and non-labour income. Household average income was CFAF 470,000 per year and half of the households had an income below CFAF 200,000 per year. Considering their cash expenditures, households spent yearly around CFAF 272,000; 30% of these expenditures were food expenditures whereas health, school and other expenditures represent each 15% of total expenditures (Lescuyer et al., 1999).

Starting from this report I wanted to do a follow-up survey on the research area to estimate whether changes had occurred over 10 years and whether community forests were implemented as Tropenbos had recommended villages to do so.

2.2.2 Description of research area and sample definition.

At first, my objective in collecting these data was to create a panel dataset which involved interviewing the same households as were surveyed in 1999. Unfortunately, the loss of the original household list made this impossible and instead of surveying identical households as ten years ago, the survey was limited to interviewing households in the same villages.

In 1999, 18 villages were surveyed; out of these 18, I decided to undertake the data collection in 13 villages that are located in 5 districts. The research area consists of villages organised around three small-size towns: Lolodorf, Bipindi and Akom II. Lolodorf was not surveyed but both Bipindi and Akom II were. The capital of the region South is Ebolowa and another important town is Kribi, though I did not survey any villages close to these towns. The villages surveyed are (ranged in order of data collection dates): Mbango-Bitouer, Ebom, Mekalat, Bipindi, Lambi, Bidjouka, Ebimimbang, Bongwana, Akom II, Nkomakak, Abiete, Mvie and Nyangong (table 2.1 and figure 2.1).

Table 2.1: Villages: district, size, distance to market and remoteness

Villages	District	Village size[a]	Distance Market (km)	Remote village[b]
Mbango-Bitouer	Lolodorf	75	8	No
Ebom	Efoulan	60	20	No
Mekalat	Efoulan	50	20	No
Bipindi	Bipindi	200	0	No
Lambi	Bipindi	100	3	No
Bidjouka	Bipindi	100	10	No
Ebimimbang	Bipindi	100	15	Yes
Bongwana	Bipindi	20	10	Yes
Akom II	Akom II	300	0	No
Nkomakak	Akom II	100	3	No
Abiete	Akom II	70	18	Yes
Mvie	Akom II	n/a	12	Yes
Nyangong	Ebolowa	70	60	Yes

[a]Number of households
[b]Whether commuting to main town is not easy and cannot be done all year round

The first three villages are well-connected to Lolodorf from where bus services connect the town to Yaoundé, the capital city, to Ebolowa and to Kribi. Lambi and Bidjouka are on a road between Lolodorf and Bipindi but are closer to Bipindi. Ebimimbang and Bongwana are close to Bipindi but poor roads make the connection to the town incredibly difficult. Bipindi has road infrastructure to go to Lolodorf, Yaoundé and Kribi. Akom II is well-connected to Kribi and Ebolowa. Nyangong is reachable from Ebolowa and Akom II through a road that goes deep into the forest and requires a four-hour drive from Ebolowa and Akom II but access is unfeasible when it rains.

From the 1999 survey, I had an idea about the size of these villages, and using the original sample size (380 households) I decided that I should interview the same number of households. When planning the course of the survey, such as the number of days in each village,

Figure 2.1: Research area: Former Program Tropenbos Area

Source: GoogleEarth©

the number of enumerators and the number of interviews they could do in a day, I established an objective of 450 households. This estimation was drawn from the assumption of having at least five or six enumerators, with each of them doing three questionnaires a day. I estimated that in 49 days, we should be able to interview 450 households.

2.2.3 Description of the key parts of the questionnaire

The questionnaire I designed is based upon different World Bank Living-Standard Measurement Surveys (LSMS) and in particular upon the Kagera Health and Development Survey (KHDS). However my questionnaire is shorter than the aforementioned and focuses more on forest resources and their uses, as well as hunting and fishing.

It is structured around 7 main parts that are described below. The questionnaire and code-book are presented in the appendix of this chapter.

Household roster Household definition requires determining whether or not to include in consideration multiple wives, servants or other relatives (Deaton, 1997). In this case, household and household members are defined as being all individuals living under the same roof, sharing meals and cultivating the same agricultural plots.

In this part of the questionnaire, the household head lists all household members, their relationship and age. For members over the age of 16, I asked the household head to report their marital status and their partners.

Education and health The household head or the most knowledgeable person has to report educational attainment (been to school, highest grade, literacy...) and health conditions (ill, health care and chronic diseases) of the different household members aged 1 or more.

Agriculture Regarding agricultural production, I designed a chart where each row refers to a crop reported as being cultivated in the 1999 survey (Lescuyer et al., 1999). I obtained a table with seven different products: manioc, macabo (cocoyams), plantains, peanuts, cucumber, corn and cocoa and I included two additional lines for any other products households could cultivate.

For each product, households reported conventional elements of production and sales using local units, values of sales, and whether crops they stored for seeds or consumption. Households described the different tools used for production, the number of hours spent in agriculture in the peak and slack season, the number of plots and sizes as well as expenditures on seeds, fertilizers and large equipments.

A final set of questions looked at animals raised by households (chicken, pig, goat or sheep) in terms of number of animals owned, bought and sold in the last 12 months.

Forest resources extraction From the 1999 socio-economic report, I selected seven products households often extract from forest: ndo'o (wild mango, *irvinga gabonensis*), palm nuts (*elaeis guineensis*), ekouk (*alstonia boonei*), cola (nuts), mushrooms, essok (*garcinia lucida*) and okok (*gnetum africanum*) (Lescuyer et al., 1999, Kekeunou et al., 2006).

For each product, households reported quantities extracted, sold, consumed and transformed using local units as well as values of sales. I also questioned them about the month they could find more products, time dedicated to NTFP extraction, distance to extraction sites and tools.

With respect to hunting and fishing, I previously selected certain types of game and fish from the 1999 report; for each type of game and fish, households reported quantities caught, consumed or sold and what were the techniques employed to catch these animals.

When first started the fieldwork, I was particularly keen to understand forest management designing a set of questions on this particular issue asking all households if they had taken part in collective initiatives linked to forests and how. Unfortunately few households answered these questions. A lack of involvement in forest management and a small number of community forests in the research area[1] show that there is still much to do in relation to forest management.

I also asked households whether they were members of any village organisations (religious, tontine, agricultural...).

Wage and self-employment activities A following part focused on wage and self-employment activities looking at their different activities, earnings and time spent in each wage or self-employed activity.

A final set of questions in this part concerned non-labour earnings (remittances, pensions,...).

[1]Only one village, Mbango-Bitouer has a community forest.

Credit In this part, I interrogated households on whether they received credit from a bank, other households or tontine, and whether they reimbursed it.

Consumption and expenditures In this last part, I looked at their food consumption (both autoconsommation or market products) regarding a large range of products. I finished the questionnaire with questions about their non-food expenditures.

2.2.4 Implementation and progress of the survey

Prior to beginning the actual survey,a week-long pilot survey was conducted for the purpose of determining length and accuracy of the questionnaire, and sourcing and training the enumerators. After finalising the questionnaire and practicalities, the core survey lasted 6 weeks during which I went to 12 remaining villages.

Pilot questionnaire and team training

Tropenbos International helped me to find an assistant with whom they had worked ten years ago in the South of Cameroon. With him, I went down to Lolodorf to run the pilot-survey in Mbango-Bitouer which is about 30 minutes from Lolodorf. In Lolodorf, I hired two local people who had already worked with Tropenbos and in Mbango-Bitouer two other persons were added to our group.

The qualifications of the five enumerators were pretty basic; I required them to be able to read and write in French and to know at least one local tongue. Enumerators had to be able to commit themselves to travel with the project for more than a month.

In Mbango-Bitouer, I started the interviews with the whole team to show them how to introduce themselves and the project, how to do an interview and what I expected from the interviews. Afterwards, taking turns the enumerators ran interviews under my observations, receiving my help whenever they encountered difficulties. In a third step, I paired them and they went to interview households. I observed each enumerator at least once and following each interview, I gave each of them advice. Their main difficulty laid in understanding the system of codes for units or frequencies; consequently, for the beginning I asked them to report each unit in letters without entering its code.

In Mbango-Bitouer, interviews were conducted early in the morning so that households would be found before they went to their plot. Further interviews were done later in the day. We tried as much as possible to ask people in the morning if they could be home in the afternoon to do the interviews. However, the system was not successful and households were not ready to meet us at the time agreed. I had to find another way to contact households before the enumerators arrived in their house.

After Mbango, I had to dismiss two enumerators who appeared not to have the qualifications required and I hired three new enumerators. I had then a team of six enumerators which would be more practical for interviewing 450 households. We went to another village Mvog-Esson, not part of the sample, to train the new enumerators and to be sure that all six were ready. At the end of this second village, I left the enumerators with samples of the questionnaire as well as instructions on the purpose and methods of the survey. I agreed with them to meet in two-week time to start the survey.

After the pilot survey, I made small changes to the questionnaire[2] which appeared to last between one hour and one hour and a half. Knowing that I could hope that each enumerator would interview three households per day, then with the objective of 450 households to survey, I estimated that the fieldwork would last six weeks.

During the pilot-survey, my assistant and I organised practicalities such as traveling between villages, and eating and sleeping arrangements in each village. Back in Yaoundé, I had to finish preparing the fieldwork, sequencing a final planning, determining the order to be taken between villages and days spent in each village. I also used this time

[2]Data from Mbango-Bitouer are comparable to data from the rest of the survey since changes concerned mainly codes, products that were not listed and the way of writing the questions

to organize transport from and back to Yaoundé with the Institut de Recherche pour le Développement (IRD), to print the questionnaire and to buy all the soaps and presents for the households and village chefs.

Course of the fieldwork

In any village we arrived, immediately, we had to present ourselves to local and traditional authorities. In the bigger towns we had to present ourselves to the "sous-préfet" and the commandant of gendarmerie, to provide them documents authorising my research in their district and to register at the gendarmerie in order not to have trouble with the local population.

After visiting local authorities, I presented myself and the project to the village chef; I interviewed him about the different characteristics of the village and asked him if he could prepare a list of households residing in the village. In the first day, I also had to settle the team in a hotel or at the village "chefferie", arrange meals with a cook and find drivers if the village was big.

From the household list prepared by the chef, I randomly selected half of the households and went to each selected to introduce myself, the project and my team, and to make an appointment for the enumerator to come to interview the household head. This way, I wanted to be sure that households would be home and available when the enumerator would come to their house.

The interviews started at seven in the morning, enumerators either interviewed another household at eleven or two households in the afternoon. In any case, we tried neither to disturb their daily life nor to be intrusive. Households were happy to talk to us, they respected their appointments and we encountered no major difficulties. Local authorities were also helpful in the good implementation of the survey.

The interviews lasted on average one hour and at the end of each interview, the enumerators gave the household two soaps as a present. Most days, the enumerators interviewed three households and at the end of the fieldwork, we managed to survey 457 households in all 13 villages.

2.2.5 Data entry and limits faced during data cleaning

Data entry on CSPro

During the fieldwork, I tried as often as possible to input data using CSPro but the lack of electricity made this impossible. Thus I was forced to read the questionnaires and to ask clarifications of enumerators and households.

CSPro requires the creation of a data dictionary, defining all variables, their length and their nature (numeric or alphanumeric). In the majority of cases, I created codes before starting the survey but in other cases I had to create codes when households used local units that were not coded yet. After creating the dictionary, an item was defined for each section and for each question and a form was attached to each questionnaire. At the end there were as many forms as households interviewed.

After inputting data I exported them to STATA where I could clean them and solve any problems arising with the units.

Cleaning data and limits of data

Since I asked households to report how often they were producing and the quantities, cleaning the agricultural data and searching for extremely high or low values required standardising units of time to a single period; I decided to convert every production for a period of two weeks.

I also converted quantities in value since quantities were reported using local units (bag, “filet”, basket and bucket) and I had only an incomplete set of conversion factors. It seems as legitimate to add up values of different products as adding up kilograms and the majority of studies estimating agricultural production employ production values rather than quantities (Jacoby, 1993, Skoufias, 1994, Abdulai and Regmi, 2000).

To define values of production, I first estimated a median price for each commodity in each unit in each district depending on the available number of observations. In a few cases, for instance bucket of maize or bucket of peanuts, the small number of observations for a particular crop in a particular unit forced me to estimate research level median prices instead of district prices. With respect to NTFPs, I estimated prices at the level of the research area since the number of price data at the district level was fairly small. Overall, prices for cash crops did not vary much between districts while prices for kilograms of manioc or macabo can vary by two to six times between districts.

The last step of this process consisted in looking for extremely high or low values. Extremely high values occurred when a small size household reported harvesting large quantities of crops quite frequently while selling smaller quantities less frequently. For instance, four, five and eight households report strangely high quantities harvested for respectively manioc, macabo and plantain while quantities sold were small; as a result for the frequency of harvest I substituted to that of sales, the latter frequency data being more plausible.

Five households had extremely low values and reported sales greater than harvest without having stored from previous seasons; again for the frequency of harvest I substituted to that of sales.

In the end, I had 30 cases that could not be used for the purpose of this study because of missing or unusable answers in most parts of the questionnaire. In these cases, households gave qualitative instead of quantitative answers for their production or did not give any frequency data. The following analysis is drawn on 427 households instead of 457.

2.3 Descriptive analysis and findings from the survey

2.3.1 Villages and household description

Observing that the sample surveyed in each village represents half of the village population, a succinct description of the villages can be done (table 2.2).

Generally in the research area, households seem to be from a "Bulu" ethnicity although in Mbango-Bitouer, Lambi and Bidjouka, households are mostly from the "Ngoumba" ethnicity. Villages where "Bulu" households are predominant are less ethnically diversified than other villages; Bipindi is the most ethnically diversified.

From my observations and conversations with households, Mbango-Bitouer, Bipindi,

Table 2.2: Villages: number of households, ethnicity, religion and language

Villages	Sample size	Ethnicity		Religion	Language
		Main	Second		
Lolodorf					
Mbango-Bitouer	29	Ngoumba (90%)	Bulu(7%)	Protestant(60%)	French (45%)
Efoulan					
Ebom	32	Bulu (93%)	Fang (3%)	Protestant (85%)	French (65%)
Mekalat	17	Bulu (100%)		Protestant (72%)	Bulu (55%)
Bipindi					
Bipindi	74	Bassa (53%)	Other (14%)	Catholic (53%)	French (72%)
Lambi	28	Ngoumba (91%)	Fang (5%)	Protestant (70%)	French (50%)
Bidjouka	35	Ngoumba (75%)	Fang (16%)	Catholic (41%)	French (64%)
Ebimimbang	42	Fang (78%)	Bulu (9%)	Catholic (57%)	Other (43%)
Bongwana	16	Fang (78%)	Ngoumba (22%)	Catholic (66%)	Other (77%)
Akom II					
Akom II	46	Bulu (84%)	Bagyeli (14%)	Protestant (53%)	French (63%)
Nkomakak	18	Bulu (78%)	Bagyeli (22%)	Protestant (94%)	French (100%)
Abiete	21	Bulu (95%)	Other (5%)	Protestant (90%)	French (90%)
Mvie	21	Bulu (100%)		Protestant (53%)	Bulu (66%)
Ebolowa					
Nyangong	48	Bulu (98%)	Other (2%)	Protestant (77%)	French (51%)

Lambi and Bidjouka have more degraded forest areas than other villages. Size of these villages associated with a greater competition over land, and better road infrastructure seem to be positively correlated with forest degradations. On the other hand, both Akom II and Nyangong are fairly large villages but both have quite well-preserved forest areas; competition over land is low in both villages and in addition, Nyangong remains very remote due to poor road infrastructure.

Households are mainly protestant and no households report being animist in the survey. Against all expectations, households seem to have answered more often in French than in their local tongue to the questionnaire.

Pursuing with a description of household characteristics, households are generally equal in size across the research area; a household is on average composed of 4 to 5 members (table 2.3). The size of households varies from one to thirteen members and households composed of 7 members or more live in bigger villages.

Households are composed on average of 2.5 adults (16-64 years old) most of them being young adults (16-40 years old) and 2 children (less than 15 years old); 20% of the households are headed by someone aged more than 65 years old (figure 2.2). Households are on average older in Mvie where young adults seem to have migrated leaving the village with a predominantly older population.

As common in African countries, households often consist of extended families with several generations. Around 22% of the households take care of their grand-children and 6% of their own parents or one of their siblings. Some households practice polygamy; 5% of the household heads have two or more wives and 21% of household heads are either widowed, divorced or single.

Table 2.3: Household characteristics: size, age and grade

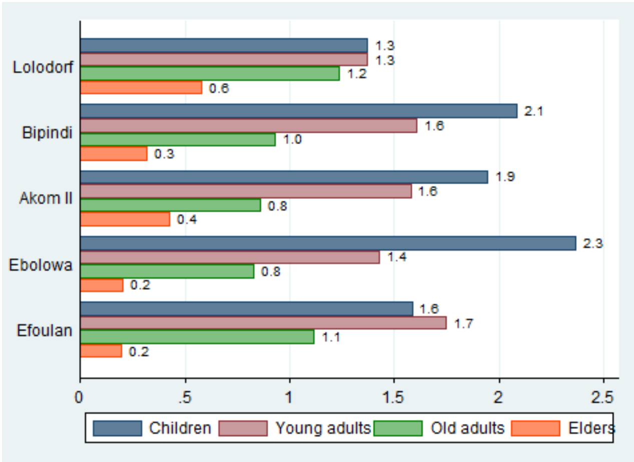
District	Household size	Age		Grade	
		Head	Mean	Mean	Max
Lolodorf	4.6	58.6	40.2	3	4
Bipindi	4.9	48.6	30.0	3	4
Akom II	4.8	53.0	34.3	4	5
Ebolowa	4.8	46.0	29.1	3	4
Efoulan	4.6	49.9	30.1	3	4
Total	4.8	50.2	31.7	3	4

Looking at the age distribution in the research area, the average age of household heads is about 50 years old and the average age of household members is around 31.7 years old.

Households living in the district of Lolodorf are on average older than households in the other districts.

The maximum educational attainment for individuals aged more than 15 years old is

Figure 2.2: Household composition in each district

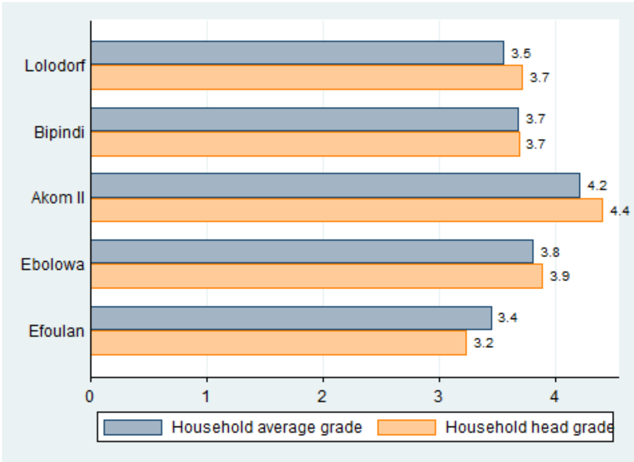


secondary school (Collège but without a "Brevet") and the average level of education is the last years of primary school (CMI1-CM2). Educational attainments do not vary between districts (figure 2.3) however there exist some differences with respect to the average education of household heads. In the villages of Akom II and Nkomakak, household heads have higher levels of education with more household heads holding a Brevet certificate.[3] When looking at education across age categories, older individuals have lower levels of education while those younger tend to have been enrolled in lower secondary school.

92% of the households with children aged between 6 and 15 years old have their children still attending school. During the survey it became apparent that children tend to repeat school grades since farm labour obligations impede their attending all classes. It is worth noting that a lack of committed teachers was a commonly expressed complaint during the survey.

[3]Grading certificate at the end of secondary school

Figure 2.3: Education in each district: average grade (educational levels) of individuals more than 15 years old and of household head



2.3.2 Productive activities: description of different sources of production and revenue and their related productive process

408 out of 427 households confirmed that they cultivate agricultural products in the sample. 379 households confirmed that they extract NTFPs. After normalising for two weeks I have 5 missing values in agricultural production and 31 in NTFP extraction.[4] Some missing values are either due to the fact that households report quantity but not the frequency of harvest or collection for all products or because households use units for which I cannot estimate a price (e.g. a single piece of manioc or a plate of mushrooms).

There were 15 missing values for animal raising, 6 for hunting, 13 for wage activities and 8 for self-employment activities. In these latter cases, missing values were due to the fact that households recounted performing a certain activity but yet failed to provide quantity or earning data.

As said earlier, prices for agricultural products were estimated at the district level for each commodity in each unit when enough observations were available, and these prices were equal to the median prices received by households when selling the commodity. Since

[4]NTFP extraction values are underestimated because ekouk does not have a price and some missing prices for some units for okok and essok

less households were engaged in sales of NTFPs or hunting products, prices for NTFPs and the ones for hunting were estimated for the whole research area. Since there were no prices for fishing products, I did not include fishing in the productive activities even if 255 households reported fishing.

In the end, I rejected households from a productive activity for which I had missing production values, but I kept them in the analysis of the other productive activities for which I could estimate production values. As a result, the descriptive analysis of different productive activities is still based on 427 households but with 403 households working in agriculture, 348 households extracting NTFPs, 169 households hunting, 88 households with wage income and 136 with self-employment earnings.

Sources of revenue

Production values from agriculture, NTFP extraction and hunting, earnings from wage and self-employed, and income from non-labour sources presented in the table 2.4 below seem plausible. On average, household total production[5] per capita for two weeks is equal to CFAF 25,792 which is about PPP US$105[6] per capita for two weeks.

Because the villages are all located in rural areas, agriculture, as expected, is their main source of production (table 2.4). It seems that wage earnings are on average more important than expected; but such result should not lead us to underestimate the importance of NTFP extraction to household total production.

Looking at the data, on average, during two weeks agricultural production represents CFAF 16,485 per capita which is around 64% of household total production while NTFP extraction for the whole sample is about 8% of household total production. Wage earnings

[5]I refer here as household total production being the value in CFA Francs equal to the sum of agricultural production in value, NTFP extraction in value, hunting production in value, wage and self-employed earnings, livestock earnings and non-labour income.

[6]Implied PPP exchange rate in 2009 US$1=244.832CFAF. Source EconomyWatch.com

account for 13% of household total production and the remainder is from self-employment and hunting, and more marginally from livestock earnings and non-labour income (table 2.4).

The most remote village, Nyangong in the Ebolowa district is the poorest village in the research area, while Mbango-Bitouer in the Lolodorf district is the wealthiest one. Households in the Efoulan district seem to be better off than households in the districts of Bipindi and Akom.

Agricultural production accounts for most of the variation in household total production between villages. In Lolodorf, households have on average greater agricultural production both in absolute terms and as a share of their total production; on average agricultural production in Mbango-Bitouer accounts for 84% of household total production while accounting for between 42% and 70% of household total production in the other districts. The importance of agriculture for households in the district of Lolodorf could result from better soil quality, since households reported clearing their plots more recently, and from easier access to bigger markets in Lolodorf and Yaoundé. In addition since I did not survey the main town, wage activities are quite marginal for households in this district.

With respect to NTFP extraction, households in the district of Ebolowa have on average 10% of their total production from such activity. While I expected households in Akom II to have similar contribution, only 5% of their total production is explained by NTFP extraction. This is quite unexpected for Akom II since the district has large forest cover.

Hunting contribution tends to be linked to forest depletion. Villages with depleted forest areas, e.g Lolodorf and Bipindi, have households with 1 and 3% of their total production coming from hunting respectively. In Ebolowa where forests are better preserved, hunting represents about 10% of household total production. Similarly as NTFP extraction, households in the Akom II district have smaller hunting values than expected since I observed

Table 2.4: Production values of different economic activities (CFA Francs per capita for two weeks)

	Agriculture	Animal raising	Non-timber forest products	Hunting	Wage	Self-employment	Non-labour income	**TOTAL**
Districts								
Lolodorf	46107.8	29.4	6875.2	958.6	568.9	25.8	294.7	54860.8
Bipindi	16202.5	140.7	1924.1	770.3	2200.7	1414.3	281.9	22934.6
Akom II	10276.6	230.6	1397.4	704.8	7292.0	3336.1	662.6	23900.3
Ebolowa	9485.6	152.8	2021.9	2103.5	2359.7	3217.2	187.7	19528.5
Efoulan	20365.6	275.0	2168.8	1526.2	3003.5	2683.6	168.3	30191.3
Per capita production quintile								
Lowest	2082.5	82.6	561.3	165.3	168.7	321.3	221.9	3603.7
2nd	4421.7	122.3	758.4	395.9	877.3	756.9	317.9	7650.5
3rd	8901.2	192.4	1400.4	619.7	1537.6	1210.9	431.4	14293.8
4th	16321.6	212.0	3012.6	1591.7	2117.7	3049.9	336.6	26642.2
Highest	50957.4	252.7	5138.6	2259.0	12679.1	5420.4	461.0	77168.4
Total	16485.1	172.2	2168.7	1003.4	3463.8	2145.4	353.7	25792.5

that many restaurants were serving game. Such a result could be linked to the presence of a nearby national reserve which pushes households to under-report hunting.

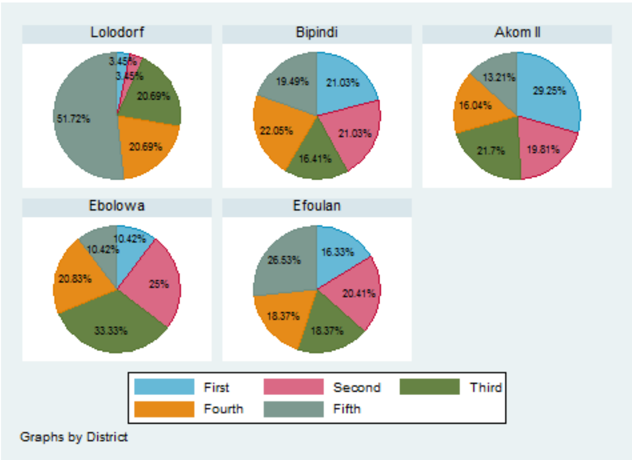
Overall, wage activities account for 13% of household total production; households living in the Akom II district have more than 30% of their total production from wages. In the latter district, I surveyed the main town and here the importance of wage may be explained by the presence of administrative infrastructure.

Looking at the distribution across quintiles of per capita production, total production in the lowest quintile is fairly small but households in this quintile are larger households with more children and elders than households in the other quintiles. In addition, 14% of the households in this first quintile do not participate in agriculture and generate their livelihood through NTFP extraction, self-employment and non-labour income.

In values, NTFP extraction increases with the quintile but at a slower rate than agricultural production. Contribution of agriculture to total production also increases with the quintile; agriculture accounts for about 57% of the total production in the lowest quintile and 66% in the highest one. This increase seems quite counterintuitive but is explained by the fact that households in the lowest quintile have a greater share of their production from NTFP extraction (15%) and hunting (5%) than households in the highest quintile for which NTFP and hunting activities contribute respectively to 6 and 2% of household total production. Poorer households in the lowest quintile are more dependent upon forest resources than wealthier households.

However, across all quintiles households participating in NTFP extraction but not in wage activities have on average greater production values than households not participating in NTFP activities but in wage, although households in the highest quintile generate around 16% of household total production from wage activities. Self-employment activities and non-labour income represent respectively 8% and 6% of poorer household total production while accounting respectively 7% and only 0.6% for households in the upper quintile.

Figure 2.4: Percentage of households in each quintile of total production per district



Combining both tables and figure 2.4, it seems that wealthier villages (Mbango-Bitouer, Ebom and Mekalat) are in districts closer to Yaoundé and have either a specialisation in agriculture, as in Mbango-Bitouer, or more diversified and balanced sources of revenue, which allow them to generate sufficient income.

Households living in Nyangong, even if more dependent upon forest resources for generating their production values, manage to be less poor than households living in Akom II where NTFP extraction values are smaller.

To summarise, agriculture accounts for a large part of household production for both poor and rich households, while wage activities account for a significant part of household production of richer households. With respect to NTFP extraction, wealthier households seem to be less dependent upon these resources than poorer households but it still accounts for a non-negligible part of their total revenue. Overall, households participating in NTFP extraction have greater production values than households not participating in these activities.

Agricultural production

Households cultivate mainly manioc, macabo, plantain, peanut, cucumber, maize and cocoa. While most crops can be sown once or twice a year, cocoa is cultivated only once a year. 85% of the households in the sample cultivate manioc, macabo and plantain and nearly half of the households cultivate peanut, cocoa or cucumber.

Households usually work daily on their plots and collect manioc, macabo and plantain required for their consumption or for selling when they are participating in agricultural markets. They pick peanut and cucumber once or twice a year depending on how often they have planted these products. Cocoa is collected once a year and sold to traders generally along the road or in the village.

Agricultural production is not capital intensive; households use mainly a machete (99%) and a hoe (95%), and only few of them use a pick (26%) or a sickle (10%). Overall, 60% of the households have purchased seeds, most commonly to cultivate peanut, cucumber and maize; 43% of the households purchasing seeds are in the highest quintiles. 6 and 27 households which are on average wealthier have bought respectively fertilizer or pesticides which are mainly used for cocoa production.

The production process starts using a machete to clear the plot before the rainy season and after the plot is cleaned and burnt, they sow the different products. On the same plot, they mix indifferently manioc, macabo, plantain, peanut and cucumber but tend to plant cocoa on a separate plot further into the forest.

The average total area of all plots cultivated is about 2.3 hectares and ranges from 1.4 hectares in Mbango to 3.1 in Nyangong. Households in Mbango have opened more plots more recently than other households; soil for households in Mbango may contain more nutrients and be of better quality. Furthermore, opening a larger number of plots can help mitigating the risk of losing all the production if a negative shock arises.

When looking at production values, on average manioc, macabo and plantain production account respectively for 29, 27 and 21% of the total agricultural production; the importance of these crops in terms of contribution to agricultural production and their ranking do not vary when looking across districts (table 2.5).

On average, cocoa contributes to 9% of agricultural production; its contribution to agricultural production varies across districts. In Ebolowa, cocoa represents on average 17% of agricultural production while only 3% in Mbango-Bitouer. Cocoa production seems to be linked to the location of the households, the southern part of the research area being more suitable.

Table 2.5: Crop production in values (CFA Francs per capita for two weeks)

District	Manioc	Macabo	Plantain	Peanut	Cucumber	Maize	Cocoa	Total
Lolodorf	17247.7	15423.7	4649.1	2771.2	2172.8	2352.3	1490.9	46107.8
Bipindi	4047.4	3785.0	4775.2	877.5	243.0	820.5	1653.6	16202.5
Akom II	3329.4	3120.7	1469.2	818.2	278.3	659.1	601.8	10276.6
Ebolowa	2546.2	2051.3	1020.1	904.0	902.6	384.5	1676.8	9485.6
Efoulan	5362.5	6828.7	4951.7	899.4	424.3	684.2	1214.7	20365.6
Per capita production quintile								
Lowest	579.5	419.1	388.7	141.4	90.6	129.6	333.4	2082.5
2nd	1102.8	1153.0	638.7	254.3	141.0	202.6	929.1	4421.7
3rd	2138.5	2439.4	1520.2	521.0	634.0	404.8	1243.1	8901.2
4th	4530.4	4152.1	3370.2	1127.9	715.4	899.6	1526.0	16321.6
Highest	15467.6	14735.0	11863.4	2955.4	810.6	2475.4	2649.8	50957.4
Total	4747.8	4565.0	3544.1	996.9	477.8	819.8	1333.7	16485.1

The other crops remain quite marginal in terms of contribution to agricultural production both at the level of the research area and across districts mainly as a result of small values of these products in comparison to others.

Across quintiles of per capita production, production of manioc, macabo and plantain slightly increase with the quintile. 30 and 29% of the agricultural revenue of wealthier households is generated through the production of manioc and macabo respectively while for poorer households manioc and macabo account for 27% and 20% of their total agricultural production. The production of cucumber and of cocoa decreases with the quintiles. This result is quite surprising since both products have high unitary prices but it can be explained by the fact that on average across quintiles, the production values of manioc and macabo have more increased than the production values of cucumber and cocoa.

With respect to sales, around 84% of the households engaged in agriculture sell their products in the markets or to traders. 90% of households in the upper quintile sell agricultural products while 75% of the poorer ones do so. Households sell mainly manioc, macabo and plantain and to a lesser extent households sell peanut and cucumber.

Non-timber forest product extraction values

348 households in the research area extract a wide range of NTFPs which are either perennial (palm nuts, mushrooms) or annual (ndo'o). I focus on ndo'o, palm nuts[7], ekouk, wild nuts, okok, essok, cola and mushrooms. Households explain that they collect ndo'o and wild nuts once or twice a year while other products can be collected at any time. When considering production values, I have not included ekouk because this product is not sold and its price cannot be estimated. However 60% report extracting ekouk from the forest and they extract this bark to prepare an anti-malaria medicine.

31% of the households in the area collect ndo'o; more than 44 and 56% of the households in Mbango and Nyangong collect ndo'o but less than 23% and 14% do it in the districts of Bipindi and Efoulan. 72% of the households extract palm nuts but only 37% of the households in Mbango-Bitouer do so. Considering the other NTFPs, 35% of the households

[7] regimes of palm nuts which are used to prepare red oil and are more important than thatch palm or the wine from palm nuts.

extract mushrooms, 15% essok, 10% cola and 5% okok.

Overall, palm nuts and ndo'o are the most important NTFPs for the households and they represent respectively 40% and 29% of the total NTFP production; the other products are quite marginal (table 2.6).

Ndo'o extractions in Lolodorf have extremely high values and represent 85% of household total extraction; 6 households in the district of Lolodorf are bigger extractors of ndo'o extracting greater quantities than any household in the other villages. Both the facts that I went to this village close to the end of the ndo'o season and that there may be more ndo'o trees in this district can explain why households living in the district of Lolodorf have higher extraction values.

Palm nuts account for 63% of household total extraction in Akom II, around 50% in

Table 2.6: Non-timber forest product extraction values (CFA Francs per capita for two weeks)

Districts	Ndo'o	Palm nut	Nuts (cola)	Mushrooms	Essok	Okok	Total
Lolodorf	5855.6	171.2	750.1	98.3	0	0	6875.2
Bipindi	347.1	937.6	9.7	282.7	184.7	162.1	1924.1
Akom II	161.4	889.4	12.8	192.0	141.7	0	1397.4
Ebolowa	361.8	1056.9	25.1	270.5	306.5	0.9	2021.9
Efoulan	45.4	952.0	33.2	193.7	109.0	835.4	2168.8
Per capita production quintile							
Lowest	54.8	439.6	16.6	12.3	20.4	17.5	561.3
2nd	84.1	455.0	5.7	169.8	39.4	4.3	758.4
3rd	248.8	872.0	23.4	80.6	133.7	41.8	1400.4
4th	515.8	1367.7	52.9	489.7	302.8	283.5	3012.6
Highest	2318.9	1314.4	228.3	432.4	338.2	506.1	5138.6
Total	642.2	888.7	65.2	236.1	166.5	170.0	2168.7

Bipindi, Efoulan and Ebolowa and only 2% in Lolodorf. Contrary to households in the district of Ebolowa who have to produce their red oil, households in the district of Lolodorf can more easily buy red oil in the main town which reduces their incentives to extract palm nuts. Only in Efoulan is okok important (38% of NTFP extraction).

Looking at NTFP extraction across quintiles, wealthier households extract more ndo'o than regimes of palm nuts, the latter representing 25% of household total extraction and ndo'o 45%.[8] Households in the lowest quintile have 78% of their NTFP extraction from palm nuts and less than 10% from ndo'o.

For the other products, differences between quintiles are not that important but households in the highest quintile have more diversified extraction than households in the lowest quintile.

Extracting NTFPs does not require a large amount of inputs. 80% of the households answered they use a basket for collecting NTFPs.

Overall, 37% of households extracting NTFPs sell what they collect; more than a third of these households are in the highest quintile of household total production and these households sell 4 times more than households in the lowest quintile.

Considering transformation of NTFPs, 35% of the households transform ndo'o into cake and sauce they consume themselves and only 37% of these are likely to sell the present products. 85% of the households derive from palm nuts a red oil they consume while 28% of these processing palm nuts are also likely to sell the red oil produced.

When looking at where they extract the products, 85% of the households extracting ndo'o say the site is far from their house. Palm nut extractions are generally close to their home although 43% of the households extracting palm nuts reporting the site as being far from their house.

Hunting production values

Hunting occurs either on agricultural fields or within forests using traps, machetes or rifles; 25% of the households hunt with a rifle and 87% hunt using traps. 46% of the households hunting with a rifle are in the two highest quintiles of total production.

Around 58% of the hunting households report catching their game in the forest with an

[8] This result is quite driven by the fact that a few of these households are households living in the district of Lolodorf and extracting only great values of ndo'o.

average distance to their hunting zone being 4.9 kilometers. Hunting is essentially done by men though it happens that women may have traps around their agricultural plots.

In the sample, 175 households report going hunting[9] and 124 of them have caught at least one rat during the last two weeks. Around 75-80 households have caught at least one porcupine, hedgehog or snake during the last two weeks, while 25 and 11 households have caught at least one antelope or doe during the last two weeks respectively. Households use their rifle mainly to capture monkeys and birds.

Porcupine appears to be their main source of hunting production (22%), while hedgehog, rat, antelope and monkey each account for around 10-14% of the hunting production, the remaining products accounting for 4% or less of hunting production.

When looking at the distribution of hunting production across districts (table 2.7), households in the district of Ebolowa generate 36% of their total hunting production catching porcupines while households in the district of Efoulan generate only 10% from porcupines but more than 15% from antelopes, hedgehogs and rats.

Poor and rich households tend to have the same composition of their hunting production.

Table 2.7: Hunted game values (CFA Francs per capita for two weeks)

District	Rat	Hare	Porcupine	Antelope	Monkey	Hedgehog	Doe	Snake	Birds	Total
Lolodorf	0	75.4	301.3	94.8	30.8	221.5	177.8	56.9	0	958.6
Bipindi	70.6	66.5	131.5	147.6	112.0	114.0	20.8	76.0	30.9	770.3
Akom II	82.6	76.5	167.4	46.8	62.2	134.4	2.9	86.1	45.7	704.8
Ebolowa	294.4	261.2	771.1	201.4	198.3	115.1	33.1	110.6	118.2	2103.5
Efoulan	228.1	78.4	151.9	242.9	177.8	262.0	117.3	188.0	79.6	1526.2
Per capita production quintile										
Lowest	23.4	9.5	29.5	24.9	8.9	29.0	8.7	15.5	15.8	165.3
2nd	67.4	37.2	50.7	41.8	64.8	50.7	15.0	50.3	17.9	359.9
3rd	71.9	64.6	159.4	60.1	47.4	118.2	0	67.8	30.3	619.7
4th	238.0	71.5	363.3	232.3	121.6	219.1	34.9	173.0	137.8	1591.7
Highest	160.9	282.8	531.1	323.1	316.1	302.1	139.7	164.6	38.4	2259.0
Total	112.0	92.9	226.2	136.0	111.4	143.5	39.5	94.0	47.9	1003.4

Porcupine hunting accounts for 18 and 25% of hunting production, followed by hedgehogs with 13 and 17% for respectively poor and rich households. Richer households are less

[9] I have only 169 production values due to missing frequency of hunting.

likely to hunt rats (only 7% of their hunting production) preferring hunting monkeys which account for 14% of hunting production for wealthier households and only for 5% of poorer households' hunting production.

Other sources of earnings: wage, self-employment and non-labour income

Considering the 88 households with wage income, their main activities are clearing a plot for somebody else (41 households), unskilled labour (14 households) and driving (9 households). Regarding self-employment activities, 58 households, among the 138 engaged in self-employed activities, have a shop, 19 households a handicraft activity (tailor, sculptor or repairing motorbikes) and 8 a restaurant, the remainder being composed of drivers, health practitioners...

Half of the households with either a wage or self-employment activity live in Bipindi; households with unskilled workers are mainly in the upper quintiles, while households with a shop are spread across all quintiles of total production.

With respect to non-labour income, 145 households have received remittances while 25 and 26 households respectively have received interests from a bank account or a pension. The main source of non-labour income is through receiving remittances which represent 64% of the household total non-labour income while pension represent on average 21% of household non-labour income. For poorer households, remittances contribute to 48% of their total non-labour income and pension to 44%.

2.3.3 Food consumption and non-food expenditures

Food consumption: autoconsommation and purchases

Households have two sources of food consumption: autoconsommation or market food expenditures. Using values of expenditures on food products, I estimated buying prices for the whole sample in order to value autoconsommation. The following table presents values for the 8 main products consumed by households during the last two weeks (table 2.8). Autoconsommation in the research area accounts for 67% of household consumption and around 80% for households in the most remote village. Autoconsommation does not seem to be correlated with the quintiles; if anything, wealthier households have a higher share of consumption from autoconsommation than poorer households.

Consumption figures validate the data; production and consumption values are plausible and consumption values (table 2.8) are smaller than production values (table 2.4) in each district and quintile. Comparing production and consumption, inequalities between districts are smaller when looking at consumption but the ranking of districts is similar. Mbango-Bitouer remains the wealthiest district in terms of consumption and households living in Akom II or Ebolowa are the poorest ones. When looking at the distribution across quintiles, consumption is less unequal than production but the amplitude of change between quintiles is quite similar.

The most valuable consumption goods consumed by the households in the research area are fish, plantain and macabo which represent each around 11% of the total consumption (table 2.8).

In all districts, consumption of staples is most important and rice represents less than

Table 2.8: Consumption values (CFA Francs per capita for two weeks)

District	Manioc	Macabo	Plantain	Cucumber	Rice	Fish	Chicken	Game	**TOTAL**
Lolodorf	1917.6	4045.0	2783.7	9614.2	0	1684.8	338.1	654.3	26993.6
Bipindi	667.3	1600.9	1844.2	381.3	737.2	2090.5	231.2	623.5	12024.5
Akom II	721.1	816.7	1311.5	711.2	651.9	1563.6	377.6	847.4	11210.1
Ebolowa	1395.5	1663.9	1254.1	737.4	892.5	936.7	379.6	961.7	11378.9
Efoulan	1567.4	2596.3	1252.2	1463.0	847.6	1910.6	189.5	438.1	21340.9
Per capita production quintile									
Lowest	596.8	869.3	846.5	433.4	552.9	1122.5	111.7	457.7	7801.9
2nd	639.8	824.0	1196.7	531.7	625.6	1434.6	173.2	611.8	8891.4
3rd	673.7	1395.6	1613.5	803.1	804.4	1798.8	269.5	580.6	12963.0
4th	782.4	1702.8	1847.9	571.5	399.3	2087.6	5545.6	811.7	12271.1
Highest	2068.4	3689.1	2712.6	3947.3	1098.7	2473.1	626.0	1032.0	27331.1
Total	950.7	1693.5	1641.5	1254.4	696.1	1781.8	286.6	697.9	13835.5

5% of food consumption. Game represents around 8% of household consumption in Akom II and Ebolowa. Fish represents more than 17% of household consumption in Bipindi.

Across quintiles of per capita production, values of total consumption increase with the quintiles. Wealthier households have consumption values more than three times those of poorer households and this is mainly explained by an increase in consumption of manioc, macabo and rice. Such a difference between consumption values is fairly small when compared to the differences in production of manioc and macabo between the highest and lowest quintiles of production.

Across quintiles, households have quite similar consumption patterns, the main difference being between fish and cucumber consumption. Households in the highest quintile consume more cucumber (14% of total consumption) than fish (9%) while households in other quintiles consume more fish (15%) than cucumber (5%).

Non-food expenditures

Non-food expenditures are computed for 16 items. Compared to total expenditures[10], non-food expenditures represent 16% of total expenditures, varying between 23% of the total expenditures of households in the district of Akom II and 4% for households in Lolodorf. Overall, households mainly buy soap (96% of households), gasoline (88%) and medicines (74%). On average, for two weeks, households spend the most for medicines which represents 4% of their total expenditures (table 2.9) while expenditures in the other items represent less than 1% of household total expenditures.

Across districts, households make similar purchases, medicines always being the most important items. In Lolodorf and Efoulan, school fees are higher than in the other districts; more than 20% of households in these two districts pay school fees while 10% of households pay such fees in the other districts.

Across quintiles of total production, non-food expenditures increase with quintiles of total production, except between second and third quintiles, this being due to remittances. Ra-

[10]Sum of consumption values and non-food expenditures.

Table 2.9: Non-food expenditures (CFA Francs per capita for two weeks)

District	Medicines	Soap	School fees	Batteries	Gasoline	Transport	Sent remittances	**TOTAL**
Lolodorf	601.8	131.4	605.1	99.5	4.3	156.2	0	2189.4
Bipindi	520.8	196.0	62.1	157.7	201.9	315.3	486.9	2406.7
Akom II	945.3	176.9	78.7	66.5	192.2	435.7	448.5	3414.7
Ebolowa	570.1	143.4	17.7	52.9	216.4	287.8	413.8	2473.2
Efoulan	525.7	106.8	552.6	63.5	184.1	154.7	232.1	2065.8
Per capita production quintile								
Lowest	681.1	101.2	43.1	40.2	115.1	252.7	253.0	1836.0
2nd	639.2	157.8	64.7	58.0	170.3	336.6	741.1	2549.0
3rd	500.2	181.7	236.8	72.5	182.7	263.5	239.5	2138.0
4th	616.4	197.7	86.0	77.2	180.0	329.9	359.6	2232.9
Highest	753.2	215.8	341.8	295.9	281.0	382.9	444.7	4311.3
Total	637.8	170.7	154.4	108.5	185.7	312.9	406.8	2610.5

tio of non-food expenditures on total expenditures varies quite irregularly across quintiles of production but broadly decreases from 19% in the lowest of production to 13% in the highest. When looking at quintiles of total expenditures, wealthier and poorer households have non-food expenditures contributing to respectively 15 and 18% of their total expenditures.

Households tend to have a similar pattern of purchases, although those in the lowest quintile spend more on medicines than other households; medicines purchases account for 6% of poorer households' total expenditures.

Overall, people seem to spend a lot more on food than on non-food. Greater shares of their total expenditures are accounted for by food products which are mainly from autoconsommation. The importance of autoconsommation and the small shares of non-food expenditures would indicate that though not desperately impoverished, households remain quite poor. In addition, while one can ask whether certain items have not been taken into account, I did not observe during the data collection that any non-food products were missing from the list here presented.

2.3.4 Activity combinations and time use

Up to this point, households' activities have been analysed independently one from the other. However, since the objective of this chapter is to look at the factors that influence their labour allocations to different activities, it is important to understand how households' total production result from combining different activities and how they devote their time to these activities.

Activity combinations and livelihood strategies

In what follows, I focus on how these 427 households diversify their labour from agriculture in NTFP extraction, hunting and off-farm off-forest activities. Defining 5 most common livelihood combinations, 362 households fit in these livelihood combinations, the 65 remaining ones having marginal livelihood combinations, for instance agriculture and hunting only or off-farm activities only.

Among these 362 households, 25% of them combine agriculture with NTFP extraction, 18% combine these two activities with hunting, or with off-farm activities, or with both and 5% of the households only work in agriculture.

When looking at production values and income from each activity in each combination (table 2.10), households engaged in the four activities have higher values of production than households engaged in agriculture only or combining agriculture with NTFPs and hunting.

Overall, agriculture remains the main source of household total production.[11] Except when households combine agriculture and NTFP extraction with off-farm off-forest activities, the latter explain 50% of household total production while agriculture accounts for 44%.

When households combine only agriculture and NTFP extraction, NTFP extraction contributes to 13% of household total production. For the other strategies, NTFP and hunting contributions to household total production are fairly homogenous, on average 9% each.

[11] In all activity combinations, residuals are accounted for revenues from animal raising and non-labour income

However when households are engaged in agriculture, NTFP extraction and off-farm activities, NTFP extraction accounts for only 5% of household total production.

At the district level (figure 2.5), 62% of the households living in the district of Lolodorf

Table 2.10: Production values in each activity combinations (CFA Francs per capita for two weeks)

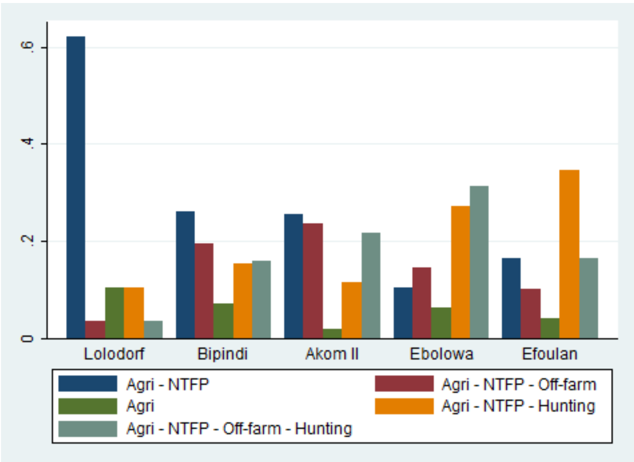
Combinations	Obs.	Agriculture	NTFPs	Hunting	Off-farm[a]	**TOTAL**[b]
Agriculture	24	15956.3	0	0	0	16385.0
Agriculture & NTFPs & Hunting	75	18576.2	2408.4	2300.1	0	23985.9
Agriculture & NTFPs	109	23048.5	3653.0	0	0	27270.2
Agriculture & NTFPs & Off-farm	76	13106.9	1419.3	0	14451.8	29497.8
Agriculture & NTFPs & Hunting & Off-farm	78	17372.6	2907.8	2969.5	7873.4	31401.4

[a] Off-farm is sum of revenues from wage and self-employment
[b] Total encompasses revenues from these 4 activities plus animal raising production and non-labour income

combine agriculture and NTFP extraction with the latter contributing to 16% of household total production. In the other districts, combinations are better balanced, more households participating in 3 or 4 activities. In Efoulan and Ebolowa, combining agriculture, NTFPs and hunting with or without off-farm activities are the most important strategies.

Across quintiles of total production, agriculture only decreases sharply with the quintile;

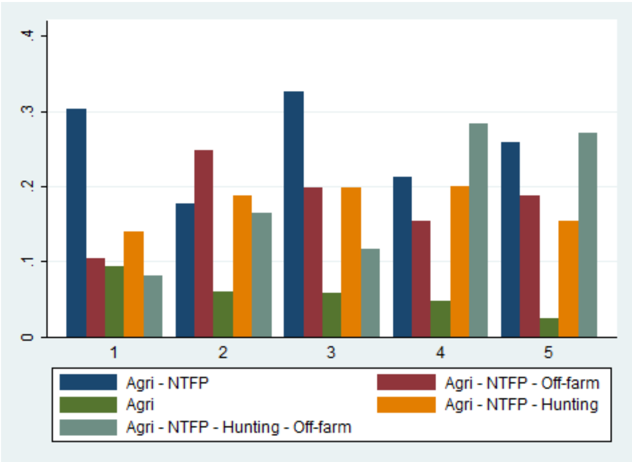
Figure 2.5: Livelihood strategies in each district



households in the highest quintile more often combine 3 or 4 activities with 27% of households in the highest quintile working in all 4 (figure 2.6).

However when looking at household strategies by quintiles of total expenditures, 23% of the households in the highest quintile of total expenditures are engaged in agriculture

Figure 2.6: Livelihood strategies in each quintile



and NTFP extraction and only 16% of households in this quintile are engaged in all 4 activities.

Being engaged in all 4 activities does improve households' production but does not seem to allow them to increase their consumption of food and non-food products. On average, households engaged in agriculture and NTFP extraction or in agriculture, NTFP extraction and hunting have higher expenditures on food and non-food products.

Time use

Considering time use defined as household hours per week, the average total time spent working per household is equal to 73 hours per week (table 2.11). On average, an adult works 32 hours per week and half of these adults work less than 25 hours a week. On the other hand, a quarter of the adults in the sample work more than 40 hours per week with 40% of them working more than 60 hours a week. Adults spend most of their time in agriculture while time spent in NTFP extraction, hunting or off-farm off-forest activities remain small, diminishing respectively (figure B.1 in appendix).

In terms of time use, agriculture remains the main activity, households spending on it on average 48 hours per week.[12] Time spent in NTFP extraction is quite important (14 hours

[12]These are hours per household and on average 2.7 members participate in agricultural production

a week) and represents 19% of total time use while wage and self-employment activities represent only 6% each.

Across districts, households living in the district of Ebolowa spend more than twice as much time working than households living in the district of Lolodorf. In Lolodorf, households dedicate around 84% of their time to agriculture and only 2% to wage employment while in the other districts, households spend around 60% of their time in agriculture, 20% in NTFP extraction and around 5% in wage activities.

Across quintiles of total production, households in the highest quintile of production do

Table 2.11: Time spent (hours per week) in each activity

District	Agriculture	NTFP	Hunting	Wage	Self-employment	**TOTAL**
Lolodorf	34.6	5.1	0	0.9	0.4	41.1
Bipindi	45.9	10.9	0.9	4.9	4.7	67.5
Akom II	49.7	18.1	2.0	4.6	7.4	81.9
Ebolowa	63.4	21.5	4.9	7.4	5.5	102.8
Efoulan	45.1	14.2	1.8	5.5	1.8	68.5
Per capita production quintile						
Lowest	40.8	10.9	0.7	2.4	4.9	59.8
2nd	47.6	12.6	1.6	6.4	3.7	72.0
3rd	57.4	18.2	1.9	4.6	3.9	86.2
4th	50.4	16.3	3.1	4.2	5.9	80.1
Highest	43.4	11.4	1.03	6.9	5.8	68.6
Total	47.9	13.9	1.6	4.9	4.9	73.3

not spend more time working than other households. Time and production seem not to be correlated; time does not increase with the quintiles of total production and household total production does not increase with the total of time working.

Across all quintiles, households allocate more than 60% of their time to agriculture. Both poorer households and those in the 3rd and 4th quintiles allocate more than 19% of their time to NTFP extraction. Wealthier households dedicate more than 10% of their time to wage work while poorer households only 5%.

In addition, time does not increase across quintiles of per capita total expenditures, households in the highest quintile of per capita total expenditures spending more time in agriculture and NTFP extraction than in wage and self-employment activities.

Across activity combinations, households participating in 3 or 4 activities work more and they tend to reduce time spent working in agriculture in order to dedicate more labour to other activities.

Household size and composition affect time spent in different activities; bigger households spend more time working in agriculture and NTFP extraction. Time spent working in wage activities tends to remain constant over household size. On average households with more young adults spend more time in wage activities and less time hunting than households with more old adults.

Although possible, calculating leisure time remains too imprecise for my purpose and I refrained from collecting such data during my survey.

2.3.5 Summary of descriptive analysis

According to the descriptive analysis, the data looks plausible. Household consumption confirms the ranking of districts. However, inequalities between districts or between quintiles of total production are smaller when looking at household consumption than when looking at household production.

In the research area, on average, households remain mainly dependent upon agriculture to generate their livelihood. Similarly as in the 1999 survey, households produce and sell mainly manioc, macabo and plantain. Cocoa constitutes a larger share of household production for households in the southern part of the research area but compared to the 1999 survey, an increasing number of households in the other parts of the research area tends to cultivate cocoa.

In my data, NTFP extraction represents a non-negligible part of their total production and as in 1999, households extract mainly ndo'o and palm nuts. On average, households not participating in NTFP extraction have lower production values than households extracting NTFPs.

Poorer households and households living in Ebolowa are more dependent upon forest resources than others, both in terms of contribution of NTFP extraction to their total production and in terms of time spent extracting NTFPs. Households in the highest quintile of total production tend to reduce time spent in agriculture in favour of time spent in wage; on average time spent in NTFP extraction varies little across quintiles.

In addition, across quintiles of per capita total expenditures, households in the higher quintiles do work more in agriculture and NTFP extraction than households in the lower quintiles.

Households do not seem to have a time constraint even though a quarter of them have adult members working more than 40 hours per week, 40% of these being in the district of Bipindi. However, it seems that working more has a positive effect on household production and consumption since 50% of the households with adult members working more than 40 hours per week are in the two highest quintiles of total production and 44% in the two highest quintiles of total expenditures.

Household livelihoods are diversified and greater diversification encourages households to reduce time spent in agriculture while keeping time spent in NTFP extraction constant. 30% of the poorer households work only in agriculture and NTFP extraction while richer households tend to have more diversified livelihoods. The latter are less dependent upon NTFPs but still tend to spend a non-negligible share of time in NTFP extraction.

The descriptive analysis highlights that households allocate their time to a greater number of activities so as to modify their levels of production. The following analysis studies the factors encouraging households to supply labour and to combine activities, and looks at the resulting impacts on welfare.

2.4 Theoretical framework and theoretical model: literature and specification of agricultural household model

To look at households' decisions in terms of labour supply and allocations, Singh, Squire and Strauss's agricultural household model is commonly used (Singh et al., 1986). But since households are constrained in their time working in wage activities, households decisions are non-separable and an extension of Singh and co-authors' model like the one by Benjamin (1992) seems more appropriate.

2.4.1 Literature review on household model and applications to NTFP extraction

Empirical studies have used this household model to look at household labour supply (Jacoby, 1993, Skoufias, 1994). This theoretical model has also been used to look at households' labour allocations to agriculture and off-farm activities including NTFP extraction (Cooke, 1998, Fisher et al., 2005, López-Feldman and Taylor, 2008, Sikei et al., 2009).

Methodology and findings from previous studies on labour supply

In these studies, since households are constrained in their labour, a "shadow wage" determined from within the household must be estimated in order to analyse labour supply. A shadow wage is a value of household time that at the equilibrium is equal to the marginal rate of substitution between consumption and leisure (Skoufias, 1994). The shadow wage is a function of both consumption preferences and production technology (Singh et al., 1986).

Jacoby (1993) and Skoufias (1994) estimate the shadow wage for both men and women deriving their marginal productivity of time spent in agriculture either using a Cobb-Douglas or a translog production function. They obtained shadow wages significantly lower than the market wage although the difference can be put down to transaction costs and market imperfections (Jacoby, 1993, Skoufias, 1994).

To capture the income effects, a "shadow income" is estimated as a sum of farm profits and exogenous income with farm profits being the difference between output and value of time calculated with the shadow wage. Labour supply is then a function of shadow wage and shadow income which are endogenous, and of household characteristics. Both studies use instrumental variable (IV) procedures to control for the endogeneity of these parameters. They found that labour supply among men and women vary not only with their own shadow wages but also with that of the other gender (Jacoby, 1993, Skoufias, 1994). Furthermore shadow income has a negative impact on labour supply, showing that when getting wealthier, both men and women increase their leisure (Jacoby, 1993, Skoufias, 1994).

Methodology and findings from previous studies on labour allocations

There is a broad literature analysing labour allocations to agriculture and off-farm activities; from this literature I select studies on labour allocations to forest-related activities. Earlier studies on labour allocations to NTFP extraction and different activities have estimated demand systems for time spent extracting different NTFPs (Cooke, 1998), labour share equations (Fisher et al., 2005, Sikei et al., 2009) or labour time (López-Feldman and Taylor, 2008).

To estimate such models, either the opportunity cost of time spent in non-NTFP activities defined as the quotient of earnings from non-NTFP activities on time spent in these activities (López-Feldman and Taylor, 2008) or a predicted shadow wage for NTFP activities (Cooke, 1998, Fisher et al., 2005, Sikei et al., 2009) can be used. In order to estimate an NTFP shadow wage for all households, although some do not participate in such an activity, the shadow wage, equal to the quotient of earnings on time spent in NTFP extraction, is predicted by using a Heckman model. The latter corrects the sample selection bias since it determines simultaneously the participation in NTFP activities and the quotient of earnings on time spent in NTFP activities.

When estimated as hours or days spent in NTFP activities (Cooke, 1998, López-Feldman and Taylor, 2008), no constraint on time spent in these activities is included in the models while estimating labour share models following an Almost Ideal Demand System (AIDS) introduces restrictions and constraints on time and wage effects, the latter being binding (Fisher et al., 2005, Sikei et al., 2009).

What these studies conclude is that poorer forest households are more dependent upon forest resources. They find that forest activities are for most households substitutes to off-farm activities (Fisher et al., 2005, López-Feldman and Taylor, 2008, Sikei et al., 2009); off-forest employment should be promoted and wealthier households tend to allocate less time to NTFP extraction.

These studies show that households' labour allocation to NTFPs activities increase with the price of NTFPs which could lead to over-exploitation of NTFPs. However according to López-Feldman and Taylor (2008) such an increase in NTFP price while likely to increase time spent in NTFP activities would not necessarily encourage a greater number of households to engage in NTFP extractions. As a result, such pressures may even be attenuated, improving the welfare of the original NTFP extractors.

2.4.2 Theoretical model: household model of production

As previously said, the studies looking at labour supply and labour allocations in different activities are set up in a household model of production. In this model, a representative household decides to allocate its labour to agricultural production, to NTFP extraction, to hunting and to off-farm activities.

In this model, reflecting the Cameroonian situation described above, households are able to easily sell their agricultural products and NTFPs in the market or to traders, but they rarely sell hunting products. They can work outside agriculture in wage activities but the small degree of urbanisation and the presence of a few administrative offices are an impediment to selling as much labour as they would like. I assume also that there is no market for agricultural labour since households claim not to hire labour from outside their households to cultivate and harvest with them.

Consequently, since the labour market is underdeveloped and the market for hunting products is absent, consumption and production decisions are non separable. Both the shadow wage and the shadow price for hunting are determined from within the household (Singh et al., 1986, Skoufias, 1994, Sadoulet and De Janvry, 1995). Here, I estimate only the shadow wage and not the shadow price for hunting since I am interested in analysing labour supply and related effects on welfare.

In order to include all four activities the Cameroonian households are commonly engaged in, I base the following model, with some modifications, on Singh et al. (1986) and Skoufias (1994).

In the resulting model, the agricultural production function is assumed to be a function of household labour (l_a), different inputs (x) and farm characteristics (Z_a) such as the size of land.

The NTFP production is a function of household labour devoted to NTFP collection (l_f) and different fixed factors associated with the forest (Z_f) such as the distance to forest areas.

The hunting production is only a function of household labour to hunting (l_u) and the different fixed inputs associated with hunting (Z_u) that could be the distance to the hunting area and whether households hunts with guns or traps.

Households may also participate in off-farm activities and receive a wage w. The time they can allocate to labour l_w is constrained by the availability of off-farm work in the village and by households' skills.

Households maximise their utility subject to several production, budget and time constraints. They derive their utility from the consumption of market goods (C_m), agricultural goods (C_a), NTFPs (C_f), hunting game (C_u) and leisure (l). Their utility is a function of fixed household characteristics (H) which could include the size of the household, the number of adults and children within the household, the education of the household head... Both agricultural goods and NTFPs may be bought in the market place or produced by households. Households' utility maximisation programme takes the following form:

$$MaxU(C_m, C_a, C_f, C_u, l : H) \tag{2.1}$$

subject to different constraints. Households have a budget constraint defined as follows:

$$p_m C_m = p_a Q_a(L_a, x; Z^a) - p_a C_a - p_x x + p_f Q_f(l_f; Z^f) - p_f C_f + w l_w + Y \tag{2.2}$$

where $l_i, i = a, f, w$ are the different labour allocations, $p_i, i = m, a, f, x$ refer to the prices of the different goods and inputs, and Y is the exogenous household income (remittances, pension and bank account interest).

Households have a fixed time endowment E given exogenously (Cooke, 1998, Bagamba et al., 2009) which takes the following form:

$$E = l + l_a + l_f + l_u + l_w \tag{2.3}$$

The labour time constraint takes the following form:

$$l_w = l_w^{max} = E - l - l_a - l_f - l_u \tag{2.4}$$

with $l, l_a, l_f, l_u, l_w \geq 0$. There is a limited amount of time households can sell to off-farm employment because there is a limited number of wage opportunities available in the research area.

The absence of a market for hunting products creates an equality between consumption and production:

$$C_u = Q_u(l_u; Z^u) \tag{2.5}$$

The Lagrangean function can be written as

$$\Gamma = U(C_m, C_a, C_f, C_u, l; H) + \lambda(p_m C_m - p_a Q_a(L_a, x; Z^a) + p_a C_a + p_x x - p_f Q_f(l_f; Z^f)$$
$$+ p_f C_f - w l_w^{max} - Y) + \psi(l_w^{max} - E + l + l_a + l_f + l_u) + \eta(C_u - Q_u(l_u; Z^u)) \tag{2.6}$$

Maximising the Lagrangean with respect to C_m, C_a, C_f, C_u, l_a, l_f, l_u and l, yields the following set of first-order conditions:

$$\frac{\partial U}{\partial C_i} = -\lambda p_i \tag{2.7}$$

with $i = m, a, f$ meaning that the equilibrium condition implies that the marginal utility from consuming one good (market, agricultural or forest) will be proportional to its price in the market.

$$\frac{\partial U}{\partial C_u} = -\eta \tag{2.8}$$

The first-order condition (2.8) associated with hunting good consumption equates the marginal utility to the shadow price.

First-order conditions are also derived from production functions:

$$p_i \frac{\partial Q_i}{\partial l_i} = w + \frac{\psi}{\lambda} = w^{\star} \tag{2.9}$$

with $i = a, f$. This optimal condition stipulates that at the equilibrium, households equate their marginal productivity of labour to their shadow wage $w^\star$. In the case of hunting production

$$\frac{\eta}{\lambda}\frac{\partial Q_u}{\partial l_u} = w + \frac{\psi}{\lambda} = w^\star \tag{2.10}$$

When maximising household utility with respect to leisure, the marginal utility of leisure is proportional to the shadow wage.

$$-\frac{1}{\lambda}\frac{\partial U}{\partial l} = w + \frac{\psi}{\lambda} = w^\star \tag{2.11}$$

Since the Lagrangean multiplier λ is negative and ψ is positive, the shadow wage $w^\star$ is less than the market wage w. The shadow wage is function of both consumption parameters through λ and production parameters through ψ which confirms that household decisions are non-separable.

The shadow price of hunting is

$$\eta^\star = \frac{\lambda w^\star}{\partial Q_u / \partial l_u} \tag{2.12}$$

and it is function of the shadow wage and of the marginal productivity of hunting.

The full income constraint can be written as

$$V^\star = \Pi_a^\star(w^\star, x; Z^a) + \Pi_f^\star(w^\star; Z^f) + \Pi_u^\star(w^\star; Z^u) + Y \tag{2.13}$$

where $\Pi_a^\star = p_a Q_a(l_a, x; Z^a) - w^\star l_a - p_x x$

$\Pi_f^\star = p_f Q_f(l_f; Z^f) - w^\star l_f$

$\Pi_u^\star = \eta^\star Q_u(l_u; Z^u) - w^\star l_u$

The model can be rewritten as

$$MaxU(C_m, C_a, C_f, C_u, l : H) \tag{2.14}$$

subject to

$$p_m C_m + p_a C_a^\star + p_f C_f^\star + \eta^\star C_u^\star + w^\star l = V^\star + w^\star E \tag{2.15}$$

where the left-hand side of the equation is the value of household full expenditures on goods and leisure, including imputations; $C_a^\star$ denotes the amount of agricultural goods consumed at at the optimum $l_a^\star$, $C_f^\star$ the amount of forest products consumed at the optimum $l_f^\star$,$C_u^\star$ the amount of hunting products consumed at the optimum $l_u^\star$ with $w^\star$ being the shadow value of time defined above. The expression on the right-hand side is the "shadow full-income" (Skoufias, 1994).

Maximising this problem with hunting production, the structural demand function for leisure is expressed as being a function of exogenous and endogenous parameters:

$$l^\star = l(p_m, p_a, p_f, \eta^\star, w^\star, V^\star; H) \tag{2.16}$$

Household labour supply function is:

$$L_S^\star = L_S(p_m, p_a, p_f, \eta^\star, w^\star, V^\star; H) \tag{2.17}$$

and household labour supply function can be seen as the sum of all labour supply functions to different activities:

$$L_S^\star = E - l^\star = l_a^\star + l_w^{max} + l_f^\star + l_u^\star \tag{2.18}$$

Here the shadow wage $w^\star$ and the shadow full income $V^\star$ are endogenous and functions of different parameters. Having an estimate of the shadow wage $w^\star$ would lead to find the shadow full income $V^\star$ and derive the demand for leisure $l^\star$ and supply of labour $L_s^\star$.

Given this theoretical framework, I model total labour supply (section 2.5) and labour allocations which consist in supplying labour in each activity (section 2.6).

2.5 Estimations of production function, shadow wages and total labour supply

In the estimations, all households being already engaged in agriculture decide whether or not to diversify their total labour supply among other activities. Focusing on agricultural households, the estimations of production function, total labour supply and later labour allocations are derived on a sub-sample of 384 households all devoting at least 7 hours per week to agriculture. Out of these 384 households, 304 extract NTFPs[13], 184 participate in an off-farm activity and 160 in hunting.

To analyse household labour supply, I first calculate household shadow wage estimating Cobb-Douglas and translog production functions for agriculture and NTFP activities.[14] The shadow wages are proportional to the value of marginal productivity of labour. I test whether shadow wages from both production functions are equal and I estimate the full shadow income. Labour supply is estimated as a function of the household shadow wage and income, household characteristics and village characteristics.

In the production functions, as response to weather or other production shocks, households can modify their labour and other inputs to use. Decisions about labour time and other inputs and the resulting output are simultaneous, and the former two may be endogenous. Since both time and inputs may be correlated with the error term, I instrument them

[13] 317 extract NTFPs but only 304 report time spent in NTFP extraction different from 0

[14] I look only at Cobb-Douglas production function for NTFPs.

using valid and strongly correlated IVs (Jacoby, 1993).

In the labour supply function (equation (2.17)), there exists simultaneity between labour supply defined as households' weekly hours in all activities and shadow wage and income (Skoufias, 1994, López-Feldman and Taylor, 2008). I use a two-stage least squares (2SLS) estimation identifying relevant, valid and consistent IVs to reduce the bias of ordinary least-squares (OLS) (Murray, 2006).

The IVs need not to explain the original dependent variable nor to be correlated with the error term but to be correlated with the endogenous variables (Murray, 2006, Baum, 2006). To find valid IVs, I select instruments that economically explain the endogenous explanatory variables but have no direct effect on the dependent variable in the original equation. I check their validity looking at correlation matrices and testing for significance. All instruments presented here are not correlated with the dependent variable but have a significant effect on the endogenous variables and these instruments seem to be valid instruments (Murray, 2006). I look at a Sargan test of overidentification that shows the validity of the instruments, at a weak identification test that determines whether instruments are weakly correlated with the endogenous variable, and an underidentification test which reports whether instruments are relevant (Murray, 2006, Baum, 2006).

2.5.1 Estimating shadow wages from an agricultural production function

From the theoretical model (equation (2.9)), the empirical specification to find the shadow wage $w^\star$ consists in estimating the value of the marginal productivity of labour from the agricultural production function.

Estimation of the marginal productivity of labour is first performed using a Cobb-Douglas form in which coefficient of an input represents the elasticity of that input (Abdulai and Regmi, 2000); I also try using a translog functional form (Jacoby, 1993).

The Cobb-Douglas agricultural production function takes the following form:

$$\ln Q_{ia} = \sum \beta_i^a ln X_{ij}^a + v^{ia} \tag{2.19}$$

where Q_{ia} is the total value of agricultural crops produced by household h, β^a are parameters from the agricultural production function, X_{ij}^a is the quantity of inputs j used by household i in agriculture, and v^a is an error term summarizing the influence of all other variables. Inputs used are the hours of household labour in agriculture, the total land size, the total values of agricultural expenditures for fertilizers, pesticides and transportation, and the total values for seeds (table B.1).

Since a quarter of households have no expenditures in inputs, so as not to lose these observations when log-linearising the Cobb-Douglas function, I add 1 to all the inputs, except hours spent in agriculture and land. No bias is introduced in the estimates since the expenditures are in thousands of CFA Francs and adding 1 to these numbers will not change much the estimates (Skoufias, 1994, Battese, 1997).

Since the number of hours in agriculture and of the input expenditures are endogenous, instrumental variables are required. I have tried as instrumental variables different household composition variables (household size, number of adults, number of elder, dependency ratio) and different measures of welfare (dummy for holdings of equipment, value of large equipment, different dummy for each type of equipment, equipment index,...) and the results here presented are obtained using two valid and relevant instruments: household size and an index for the large equipment owned by the household.[15]

Household size explains time spent in agriculture; I expect that bigger households would spend more time in agriculture. I expect that wealthier households with higher values of

[15] I create an equipment index using a factor analysis methodology retaining only 1 factor explaining all the different assets households own; the assets I included are big equipments such as motorbike, spray, chainsaw, agricultural buildings...

equipment index are those with higher expenditures on inputs. Neither IV has an influence upon the level of production, rather affecting it through the endogenous variables.

All instruments have the expected signs and the Cragg-Donald Wald statistic is over 10 meaning that the instruments are not weakly correlated with the endogenous variables. The Sargan test fails to reject the null hypothesis that the instruments are valid (Murray, 2006, Baum, 2006) and the underidentification test reports that instruments are relevant. However, the coefficients for hours in agriculture and inputs are not significant when using a 2SLS procedure while when using OLS, both variables have a significant and positive effect on household agricultural production. Furthermore, the coefficients in OLS are nearly identical to those obtained in 2SLS.

Using a Wu-Hausman test, it seems that if there is endogeneity among the regressors, using 2SLS does not improve the bias in the estimation and since OLS gives better results I prefer using the latter. The small effect of endogeneity on the estimations results from the way I collected the data on time, since I asked households how much time they usually spend working in agriculture. As a consequence, the bias of an OLS estimation is minimised by the fact that the data on time and expenditures are unable to capture any shocks or disturbances in the production process.

I can use the OLS estimations (regressions (3) and (4) in table 2.12) which have smaller standard errors and give better results than 2SLS.

As generally expected, time spent working in agriculture has a positive and significant effect on agricultural production. This is an interesting result since in the descriptive analysis, household agricultural production and household time in agriculture were not correlated.

Both total expenditures and total cultivated area have a positive and significant effect. Expenditures on seeds have no significant effect on agricultural production which shows

Table 2.12: Estimations of Cobb-Douglas agricultural production functions

Variables	Log Agric. prod Cobb-Douglas (2SLS) (1)	Log Agric. prod Cobb-Douglas (2SLS) (2)	Log Agric. prod Cobb-Douglas (OLS) (3)	Log Agric. prod Cobb-Douglas (OLS) (4)	Log Agric. prod Translog (OLS) (5)
Log hours agriculture	0.410 (0.268)	0.459 (0.283)	0.372*** (0.0840)	0.385*** (0.0851)	0.714 (0.779)
Log input expenditures	0.0883 (0.0733)	0.0948 (0.0724)	0.0764*** (0.0201)	0.0763*** (0.0202)	0.0265 (0.129)
Log seed expenditures	-0.00590 (0.0158)	-0.00754 (0.0155)	-0.00402 (0.0128)	-0.00445 (0.0128)	-0.0616 (0.0627)
Log land area	0.0723 (0.0477)	0.0687 (0.0478)	0.0796** (0.0397)	0.0809** (0.0397)	0.163** (0.0680)
Age head		-0.00373 (0.00395)		-0.00338 (0.00357)	-0.00187 (0.00341)
Secondary edu head		-0.129 (0.108)		-0.119 (0.108)	
Log squared hours					-0.0492 (0.103)
Log squared input expenditures					0.0174 (0.0145)
Log squared land size					0.0368*** (0.0120)
Log square seed expenditures					0.00615 (0.00671)
Log hours*expenditures					-0.0176 (0.0307)
Log seed*land					0.00636 (0.00860)
Mbango	1.758*** (0.253)	1.793*** (0.256)	1.516*** (0.327)	1.550*** (0.329)	1.449*** (0.323)
Ebom	0.562** (0.255)	0.567** (0.257)	0.346 (0.319)	0.370 (0.320)	0.289 (0.310)
Mekalat	0.286 (0.295)	0.265 (0.297)	0.0634 (0.356)	0.0574 (0.357)	0 (0)
Bipindi	0.762*** (0.190)	0.793*** (0.192)	0.525* (0.283)	0.560** (0.284)	0.524* (0.275)
Lambi	0.512* (0.274)	0.563** (0.277)	0.253 (0.332)	0.293 (0.333)	0.255 (0.331)
Bidjouka	0.00341 (0.221)	0.0274 (0.222)	-0.240 (0.304)	-0.215 (0.305)	-0.319 (0.301)
Ebimimbang	0.508** (0.219)	0.514** (0.219)	0.262 (0.298)	0.269 (0.299)	0.189 (0.296)
Bongwana	0.255 (0.304)	0.259 (0.304)	0 (0)	0 (0)	0.00123 (0.357)
Nkomakak	0.0380 (0.306)	0.150 (0.312)	-0.221 (0.348)	-0.123 (0.357)	-0.165 (0.350)
Akom	0.0474 (0.217)	0.0907 (0.218)	-0.194 (0.296)	-0.148 (0.298)	-0.224 (0.290)
Mvie	0.483 (0.297)	0.526* (0.294)	0.240 (0.348)	0.285 (0.351)	0.212 (0.351)
Abiete	-0.306 (0.285)	-0.284 (0.284)	-0.560* (0.335)	-0.543 (0.336)	-0.584* (0.336)
Nyangong			-0.235 (0.295)	-0.226 (0.295)	-0.301 (0.291)
Constant	7.689*** (0.985)	7.733*** (0.965)	8.079*** (0.401)	8.235*** (0.424)	7.552*** (1.491)
Observations	384	384	384	384	384
Cragg-Donald Wald F-stat	13.52	13.63			
Sargan Test P-value	0	0			
R-squared	0.267	0.268	0.268	0.271	0.295

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

that expenditures on seeds are not as important as expected. This results from the fact that households generally buy seeds for cucumber, peanuts and maize that are less cultivated than manioc and macabo for which households do not buy seeds.

The results from the translog function are not satisfactory; the size of land has the only significant effect on household agricultural production while labour and all interaction terms are insignificant. There are similar village effects than when using a Cobb-Douglas function.

Following the theoretical model, the shadow wage is estimated using the fitted value of household total agricultural production and is equal to

$$W^{\star}_{ia} = \frac{\hat{Q}_{ia}}{l_{ia}}\hat{\beta}^{a} \tag{2.20}$$

with $\hat{Q}_{ia}$ being the fitted value of agricultural output by household i predicted with the estimated coefficient $\hat{\beta}^{a}$.

Estimating the shadow wage using the two OLS regressions and the translog regression, on average, the agricultural shadow wage is on average equal to CFAF 194.2, 201.6 and 376.8 per household per week for regressions (3),(4) and (5) respectively (table 2.13). Focusing on the estimates from the Cobb-Douglas functions (regressions (3) (4)), households living in the district of Lolodorf have higher shadow wages than households living in the district of Ebolowa or Akom II, these latter being poorer when looking at their total production.

Across quintiles of household total time, households working less have higher shadow

Table 2.13: Agricultural shadow wages by quintiles of total time [95% Confidence interval]

Quintiles	Shadow wage Cobb-Douglas (3)	Shadow wage Cobb-Douglas (4)	Shadow wage Translog (5)
Lowest	327.7 [269.2;386.2]	339.4 [277.8;401.1]	610.8 [508.8;712.9]
2nd	191.0 [162.5;219.5]	199.2 [169.7;228.6]	376.1 [319.4;432.8]
3rd	184.8 [156.0;213.7]	192.6 [161.6;223.6]	368.9 [311.9;425.9]
4th	151.5 [129.9;173.1]	155.3 [133.3;177.3]	313.5 [258.8;368.3]
Highest	111.7 [96.6;126.8]	116.8 [101.1;132.5]	207.1 [177.4;236.9]
Total	194.2 [177.5;211.0]	201.6 [184.1;219.1]	376.8 [345.2;408.1]

wages than households working more. Households' marginal productivity seems to decrease when households work more; time spent working and shadow wage seem to be inversely correlated.

2.5.2 Estimating shadow wages from NTFP production function

Following the same methodology, the shadow wage could be estimated from a Cobb-Douglas NTFP production function:

$$\ln Q_{if} = \beta^f lnl_{if} + v^{if} \tag{2.21}$$

where $Q_f(h)$ is the total value of NTFP extraction by households h, β^f is the parameter from the NTFP production function, $l_f(h)$ is the time allocated to NTFP extraction by household h, and $v^f(h)$ is an error term summarising the influence of other variables. I tried using several dummies for small tools households could use to extract NTFPs but none of them were significant. I present here the best estimates that exclude these tools. NTFP extraction requires only labour but I control for whether household extracts ekouk and ndo'o.[16] I include an interaction term for the distance of ndo'o being a function of whether households extract ndo'o and whether it is far away or not[17] (table B.1).

Here as well, time spent extracting NTFPs may be endogenous. After different tests, I select two instruments to control for the endogeneity of time: size of households and number of ill adults. At the household level, bigger households imply spending more time in NTFP extraction, and so does the presence of ill adults since sickness requires households go extracting medicinal plants in the forest. Again the instruments explain the time spent in NTFP extraction but not the NTFP production.

[16] I consider these two products because ekouk is often extracted but does not have a value but is often extracted by households while ndo'o is only extracted twice a year when it is the season.

[17] I have tried without these two variables and I have obtained the same results.

Both instruments have the expected positive sign on the endogenous variable; having more members would increase time spent extracting NTFPs and so does having more ill adults (table B.3). The Cragg-Donald Wald statistic shows that the instruments are not weakly related to the endogenous variable and the Sargan test fails to reject the invalidity of the instruments.

However, with a 2SLS procedure, hours spent extracting NTFPs has no significant effect on NTFP production while with OLS, time spent in NTFP extractions has a positive effect on production. Most coefficients are nearly identical when using OLS to the ones obtained with a 2SLS estimation and all standard errors with OLS are smaller. As with the test for agricultural time and inputs, a Wu-Hausman test of endogeneity of hours spent in NTFP extraction fails to reject the null hypothesis; using 2SLS does not reduce the bias from endogenous variable. Again, the way I collected the data on time spent in NTFPs, asking households how long they usually spend in this activity, may not capture any responses to eventual shocks, which could explain why OLS gives better results (regressions (3) and (4) in table 2.14).

Controlling for other effects, spending more time extracting NTFPs and extracting ekouk or ndo'o increase NTFP production.

The distance between the house and the ndo'o extraction site has no effect on NTFP production. There are no significant effects derived from where households live.

Here as well the shadow wage is estimated using the fitted value of household total NTFP extraction and is equal to

$$W^{\star}_{if} = \frac{\hat{Q}_{if}}{l_{if}}\hat{\beta}^{f} \tag{2.22}$$

with $\hat{Q}_f$ being the fitted value of forest product output by household i predicted with the estimated coefficient $\hat{\beta}^f$.

For respectively regressions (3) and (4), shadow wages in NTFP extraction are fairly

Table 2.14: Estimations of Cobb-Douglas NTFP extraction production functions

Variables	Log NTFP prod (2SLS) (1)	Log NTFP prod (2SLS) (2)	Log NTFP prod (OLS) (3)	Log NTFP prod (OLS) (4)
Log hours NTFP	0.142 (0.231)	0.158 (0.231)	0.283*** (0.0773)	0.286*** (0.0776)
Ekouk	0.507*** (0.175)	0.500*** (0.179)	0.461*** (0.164)	0.456*** (0.167)
Ndo'o	0.856** (0.380)	0.848** (0.379)	0.738** (0.342)	0.742** (0.343)
Age head		-0.00385 (0.00509)		-0.00410 (0.00522)
Secondary edu. head		-0.0534 (0.157)		-0.0695 (0.158)
Distance ndo'o	-0.230 (0.360)	-0.250 (0.360)	-0.325 (0.337)	-0.336 (0.338)
Mbango	0.893** (0.417)	0.950** (0.423)	0.892 (0.564)	0.915 (0.566)
Ebom	0.607 (0.398)	0.612 (0.399)	0.379 (0.522)	0.372 (0.523)
Mekalat	0.108 (0.482)	0.132 (0.482)	0 (0)	0 (0)
Bipindi	-0.0531 (0.291)	-0.0477 (0.290)	-0.215 (0.482)	-0.226 (0.485)
Bidjouka	0.369 (0.324)	0.379 (0.323)	0.207 (0.505)	0.199 (0.506)
Lambi	0.449 (0.364)	0.479 (0.365)	0.365 (0.534)	0.370 (0.536)
Ebimimbang	0.294 (0.297)	0.298 (0.297)	0.147 (0.487)	0.129 (0.489)
Bongwana	0.111 (0.394)	0.0966 (0.393)	-0.0140 (0.564)	-0.0529 (0.567)
Akom	-0.375 (0.284)	-0.352 (0.287)	-0.501 (0.493)	-0.495 (0.498)
Nkomakak	-0.317 (0.403)	-0.232 (0.419)	-0.409 (0.559)	-0.341 (0.568)
Abiete	-0.333 (0.374)	-0.313 (0.375)	-0.416 (0.539)	-0.423 (0.540)
Mvie	0.351 (0.378)	0.388 (0.381)	0.178 (0.547)	0.200 (0.549)
Nyangong			-0.109 (0.493)	-0.133 (0.496)
Constant	6.644*** (0.385)	6.828*** (0.446)	6.567*** (0.466)	6.814*** (0.556)
Cragg-Donald Wald F stat	17.16	16.91		
Sargan Test P-value	0.807	0.779		
Observations	304	304	304	304
R-squared	0.228	0.232	0.237	0.239

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

low, being on average equal to CFAF 91.8 and 92.7 per household per week respectively. Households living in the districts of Akom II and Ebolowa have lower shadow wages while they spend more time extracting NTFPs than households in Lolodorf. This shows that households' marginal productivity decreases when they work more.

Across quintiles of total time spent working, there is an inverse correlation between

Table 2.15: NTFP shadow wages by quintiles of total time [95% Confidence interval]

Quintiles	Shadow wage Cobb-Douglas (3)	Shadow wage Cobb-Douglas (4)
Lowest	160.4 [121.2;199.6]	157.8 [117.9;197.6]
2nd	104.3 [87.5;121.0]	106.6 [89.3;123.8]
3rd	89.9 [73.4;106.5]	91.7 [74.4;108.9]
4th	79.9 [63.7;96.2]	80.0 [63.5;96.5]
Highest	53.4 [39.0;67.8]	54.3 [39.7;68.9]
Total	91.8 [82.4;101.1]	92.4 [83.3;102.2]

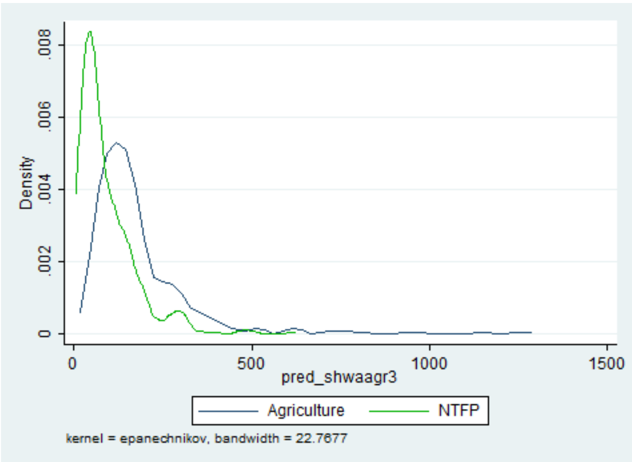
shadow wages and time since households working less have higher shadow wages from NTFPs than other households.

2.5.3 Equality of shadow wages and full shadow income

According to the theory, shadow wages found in agriculture and NTFP extraction should be equal since both are measures of the value of time. Looking at the distribution of shadow wages[18] for households engaged in both activities, half of the households have their NTFP shadow wages below CFAF 65 per household per week (figure 2.7). Even if most of households have a higher agricultural shadow wage, 60 of them have higher shadow wages from NTFP extraction.

However, I still want to test the equality of shadow wages as Barrett et al. (2005) did.

Figure 2.7: Distribution of agricultural and NTFP shadow wages using Cobb-Douglas



The test can be written as follows:

$$W^{\star}_{ia} = \alpha + \beta W^{\star}_{if} + \epsilon \tag{2.23}$$

where ϵ is the iid error term. The null hypothesis of this test is that $\alpha = 0$ and $\beta = 1$. A F-test rejects the null hypothesis. The shadow wages from NTFP extraction and from agricultural production are not equal.

In this regression, the coefficient associated to shadow wage in NTFP extraction is positive,

[18]In this test, I am using the agricultural shadow wage from regression (3) and the NTFP shadow wage from regression (3) and I find similar results when using agricultural shadow wage from regression (4) and NTFP shadow wage from regression (4).

significant and equal to 0.85 (SE=0.092) while the constant is equal to 101.8. The F-test is equal to 69.98 and its probability allows me to reject the null hypothesis that both shadow wages are equal.[19]

Inequality between the shadow wages may arise due to joint-production; households often extract NTFPs while on their way to their agricultural plot or during their agricultural work, leading to an overestimation of time devoted to NTFP extraction.

Here I assume that households' value of time is equal to a shadow wage derived from the agricultural production since households spend most of their time working in agriculture. The shadow wage estimated from the NTFP production is too low to be plausible.

In addition, since some households do not extract NTFPs and do not have any NTFP shadow wage, these households would be excluded from the rest of the analysis if I were using the NTFP shadow wage.

Consequently, agricultural shadow wage is used to estimate the shadow income. Such shadow income is derived from the profits in agriculture, profits in NTFP extraction and profits in hunting[20] and takes the following form:

$$V_i^{\star} = Q_{ia}^{\star} - w_{ia}^{\star} l_{ia} - p_x X_i + Q_{if}^{\star} - w_{ia}^{\star} l_{if} + Q_{iu}^{\star} - w_{ia}^{\star} l_u + Y \tag{2.24}$$

in which $Q_{ik}^{\star}$, with $k = a, f, u$, are the predicted productions from a Cobb-Douglas estimation, l_{ik} is the labour allocated to each activity and valued by the agricultural shadow wage $w_{ik}^{\star}$ and Y is the exogenous income.

Using respectively agricultural shadow wages from regressions (3) and (4), the values of shadow income are on average CFAF 22,499 and 22,234 per household per week (table

[19] I have tried with agricultural and NTFPs shadow wages from model (4) and I have found the same results.

[20] Hunting production function is estimated using a Cobb-Douglas and while I assumed first that time spent hunting and use of a rifle might be endogenous, the Wu-Hausman test reports that 2SLS does not improve the regression. Through OLS, time spent hunting and dummy for rifle explain positively hunting production. Results are presented in table B.4 in appendix.

2.16). Across districts households living in the district of Lolodorf are wealthier while households in Ebolowa are the poorest, which is consistent with what seen in the descriptive analysis.

Across quintiles of total time, there is a positive relationship between shadow income

Table 2.16: Shadow income by quintiles of total time [95% Confidence interval]

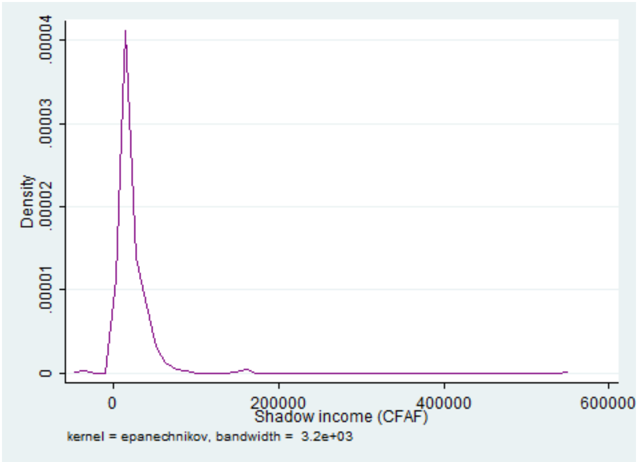
Quintiles	Shadow income with shadow wage from (3)	Shadow income with shadow wage from (4)
Lowest	16542.0 [13355.2;19728.8]	16250.3 [13070.2;19430.4]
2nd	18545.5 [15743.5;21347.5]	18369.8 [15599.9;21139.7]
3rd	19825.4 [15233.8;24417.0]	19606.0 [14990.6;24221.5]
4th	24398.3 [19561.9;29234.8]	24018.9 [19174.4;28863.4]
Highest	33533.1 [18883.2;48183.0]	33266.3 [18613.3;47919.3]
Total	22499.7 [19201.7;25787.5]	22234.1 [18934.2;25521.2]

and time spent working (table 2.16); households working more have higher shadow income while households with greater per capita total production do not seem to work more (table 2.11). Another way, households with lower shadow income have more leisure; there exists an inverse association between shadow income and leisure.

Figure 2.8 representing the distribution of shadow income with shadow wage from regression (3), shows some extreme values on the right and a concentration close to the median which is equal to CFAF 16,026 per week per household. Three households seem to have negative full shadow income because of negative profits in agriculture or NTFP extraction. Shadow income is smaller than household production since calculating shadow income consists in considering expenses in inputs and time values.

Knowing the shadow wage and the shadow income, I can estimate a labour supply function corresponding to the equation (2.17) log-linearising the model which results in dropping from the analysis the three households with a negative shadow income.

Figure 2.8: Distribution of shadow income



2.5.4 Estimating household labour supply function

To analyse how households supply labour to all activities, I estimate total time spent working during the seven days as being a function of the agricultural shadow wage, the shadow income, different household characteristics and other control variables (table B.1 in appendix).

Both shadow wage and shadow income are endogenous requiring the use of IV estimators in order to obtain unbiased and consistent coefficients. Here are presented different specifications relying on different sets of instruments which are valid, consistent and not correlated with the error term. Overall, I use expenditures in durable goods, a dummy for whether household receives non-labour income, a dummy for whether household hunts with a rifle, a village average level of input expenditures, a village wage for clearing plots, a district price of a bag of cocoa[21] and the number of sheep. I assume that spending more on durable goods, the number of sheep and having non-labour income are measures of household wealth and are expected to have positive effects on household shadow income. Hunting with a rifle shows that households are wealthier, being able to afford such a weapon to go hunting, and is assumed to have a positive effect on household shadow

[21] I have tried with other crop prices such as manioc or cucumber but these prices were correlated with the error terms and not valid instruments.

income. A village level of input expenditures is assumed to have a positive effect on household shadow wage since it represents how easy it is for households to access inputs which would improve their productivity. The village wage for clearing plots is a measure of several village wages and it should also have a positive effect on household shadow wage. The district price of cocoa should be positively correlated with the shadow wage and all its effects go through this shadow wage.

Looking at model (2) which gives the best estimates, the Cragg-Donald Wald F statistic reported in table 2.17 is equal to 6.310 and greater than the Stock-Yogo critical values at 20%. In addition, the Sargan statistic fails to reject the null hypothesis that the instruments are valid (Murray, 2006, Baum et al., 2007).

Looking at first-stage coefficients (regression (2) in table B.5 in appendix), the instruments have expected signs except for the district price of cocoa which was assumed to have a positive effect on the shadow wage. This negative effect of the price of cocoa on the shadow wage may capture a geographic effect since prices of cocoa[22] are greater in Ebolowa in which households have smaller shadow wages. Furthermore, having non-labour income has a negative effect on household shadow wage since households receiving money without working tend to give less value to their time.

Looking at the instruments for shadow income, having income-oriented hunting practices and more expenditures on durable goods shows that households are wealthier than others, and both instruments have a positive effect on shadow income. Having more liquidity from non-labour income and living in a village where expenditures on inputs are more important also have a positive effect on shadow income. Some household characteristics have significant and expected effects on shadow wage or income.

Moving to the the second-stage results in model (2), the shadow wage does have a sig-

[22] Price of bag of cocoa has four values and varies between CFAF 34,100 in Akom II up to 50,000 in Ebolowa.

nificant effect on total labour supply and its sign reflects a negative relationship between shadow wage and time. When having higher shadow wages, households decrease their labour supply.[23] In this estimation, an income effect dominates; the income effect outweighs the substitution effect between work and leisure and household demand for leisure increases when shadow wage increases. This effect could be explained by the fact that shadow wage and labour supply are measured at the household level and may actually be heterogenous within households. Distinguishing labour supply and shadow wage according to gender and age categories could give different results since it is the women who are occupied in agriculture and NTFP extraction while the less time-consuming activities tend to be male occupations.[24]

Shadow income has a significant and positive effect on household labour supply; this suggests that leisure decreases when households become wealthier, implying that leisure is an inferior good. This result can be explained by the fact that in the sample most households do not seem to be constrained in the time they are working; and this lack of hours constraint associated with poverty tend to push households to work more when having higher shadow income[25] (Barrett et al., 2005). On the other hand, in a quarter of the households, adults work more than 40 hours a week[26]; for these households, an increase in labour supply when shadow income increases may be harder to achieve.

Looking at household characteristics, having more children has a positive effect on total labour supply which suggests that adults need to work more to sustain the needs of the

[23]Here I am only interested on the effect of shadow wage and income on labour supply and using IV procedure allows me to control for the reverse effect that labour supply has an effect on shadow wage and shadow income.

[24]According to my observations, women spend more time working than men but the way I collected the data does not allow me to separate labour supply according to gender.

[25]All regressions here confirm this result; I also check it looking at total labour supply for all households except households living in Mbango-Bitouer redefining the shadow income in this case and I find similar results.

[26]However I have tried with households with adult members working more than 40 hours per week, leisure-scarce households, and I have the same results as for the whole sample; only the coefficient associated with the shadow wage is higher than for the whole sample.

Table 2.17: Estimation of labour supply

Variables	Log total time OLS (1)	Log total time 2SLS (2)	Log total time 2SLS (3)[a]	Log total time 2SLS (4)	Log total time 2SLS (5)[b]
Log shadow wage	-0.800*** (0.0596)	-0.357** (0.175)	-0.219 (0.141)	-0.00296 (0.229)	0.0519 (0.231)
Log shadow income	0.243*** (0.0361)	0.239** (0.0982)	0.214* (0.117)	0.271** (0.114)	0.239** (0.114)
Child	0.0102 (0.0116)	0.0334** (0.0138)	0.0220* (0.0131)	0.0411** (0.0166)	0.0256 (0.0156)
Wives	0.114*** (0.0436)		0.179*** (0.0559)		0.192*** (0.0626)
Age household head	0.0225*** (0.00772)	0.0297*** (0.00853)	0.0344*** (0.00896)	0.0379*** (0.0104)	0.0416*** (0.0106)
Squared age head	-0.000244*** (7.46e-05)	-0.000286*** (8.08e-05)	-0.000337*** (8.52e-05)	-0.000345*** (9.55e-05)	-0.000389*** (9.67e-05)
Bulu	0.102 (0.0977)		0.222** (0.111)		0.294** (0.127)
Ngoumba	0.0558 (0.0900)		-0.0204 (0.0933)		0.0172 (0.108)
Average grade		0.0533* (0.0317)		0.0530 (0.0368)	
Maximum grade	0.0440 (0.0326)		0.0801** (0.0389)		0.0900** (0.0434)
Primary education	0.0152 (0.0899)		0.0526 (0.0995)		0.0644 (0.111)
Higher education	0.0200 (0.119)		-0.0343 (0.132)		-0.0416 (0.150)
Education head	-0.0288 (0.0254)	-0.0150 (0.0199)	-0.0573* (0.0295)	-0.0169 (0.0231)	-0.0729** (0.0337)
Secondary education head	0.0133 (0.0878)		0.0446 (0.0967)		0.0919 (0.117)
Distance field	0.000406 (0.000949)	-0.000877 (0.00120)	-0.00125 (0.00118)	-0.00176 (0.00131)	-0.00194 (0.00131)
Village ethnicity	0.116 (0.115)	0.259* (0.137)	0.238 (0.190)	-0.0397 (0.168)	0.205 (0.177)
Village distance market	0.00340 (0.00228)	0.00669** (0.00260)	0.00284 (0.00385)	0.00259 (0.00251)	0.00222 (0.00253)
Village palm	-0.0576 (0.0975)	0.0228 (0.0976)	-0.0593 (0.0950)	-0.0192 (0.163)	-0.0435 (0.167)
More rain	0.191* (0.111)	-0.0185 (0.106)	0.227* (0.135)	0.148 (0.125)	0.205 (0.129)
Mbango	0.556*** (0.170)	-0.138 (0.229)	-0.412 (0.271)	-0.748* (0.430)	-0.865** (0.429)
Ebom	0.291** (0.120)		-0.236 (0.154)	-0.0889 (0.146)	-0.416** (0.195)
Mekalat	0 (0)		-0.252 (0.244)	-0.319 (0.282)	-0.374 (0.283)
Bipindi	0.510*** (0.112)			-0.125 (0.211)	-0.177 (0.223)
Lambi	0.222 (0.154)	-0.228 (0.141)		-0.205 (0.195)	-0.219 (0.205)
Bidjouka	0 (0)	-0.182 (0.173)			
Ebimimbang	0.329*** (0.125)	0.0265 (0.112)			
Bongwana	0.0748 (0.157)				
Akom	0 (0)	0.0109 (0.136)	-0.152 (0.164)	0.0585 (0.167)	-0.158 (0.177)
Mvie	0.384*** (0.143)	0.416** (0.167)	0.219 (0.226)		
Abiete	-0.330** (0.131)		-0.126 (0.199)		
Constant	4.648*** (0.594)	2.461** (1.145)	1.683 (1.060)	0.413 (1.652)	-0.0582 (1.680)
Observations	371	371	371	372	372
Cragg-Donald Wald F-stat		6.310	6.105	6.701	6.455
Sargan Test P-value		0.519	0.407	0.253	0.329
R-squared	0.570	0.466	0.439	0.274	0.288

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

[a] Regressions (1)(2)(3) estimated using shadow wage and shadow income from agricultural Cobb-Douglas estimation (3)

[b] Regressions (4)(5) estimated using shadow wage and income from agricultural Cobb-Douglas estimation (4)

children. This effect is also explained by the fact that children participate in both agriculture and NTFP extraction which leads to an increase in total labour supply.

The age of the household head is positive and significant while its squared value is negative and significant; this means that when the household head gets older, the total labour supply increases but at a decreasing rate. Labour supply is always increasing with the age of the household head and reaches a maximum when household head becomes 52 years old.

Households with higher average education work more but the education of the household head has no effect on labour supply.

Reduced forms of labour supply estimations (table B.6 in appendix) confirm these results. Larger, older and more educated households work more while households with agricultural plots away from their house work less. These reduced form estimations report the price of manioc does not have any effect on household labour supply which can illustrate that overall households consume manioc and the price of manioc would not affect their production.

To conclude this section, the marginal productivity of agricultural labour estimated through a Cobb-Douglas production function seems to be a more plausible value of households' time than the estimated shadow wage in NTFP extraction. The latter suggests that households have really low productivity but this could either result from an over-estimation of time spent collecting NTFPs or the lower price of NTFPs compared to agricultural products.

The agricultural shadow wage is used to estimate the shadow income which is an estimation of households' total income for a budget constraint. Regressing labour supply on these two variables, controlling for different household composition, education, activities and location effects, shows that total labour supply decreases with the shadow wage and increases with shadow income. Household unconstrained in their labour supply prefer working presumably more in order to have higher welfare through increasing consumption and decreasing leisure.

However the estimation of total labour supply does not show in which activities households are engaged and does not reflect the importance of forest activities for households' welfare. In order to examine such questions, I proceed with the analysis of factors affecting labour supply to the four activities, e.g. agriculture, NTFPs, off-farm off-forest and hunting.

2.6 Labour allocations to agriculture, NTFP extraction, off-farm activities and hunting

Estimating household labour allocations requires the analysis of how labour returns in different activities affect households' decisions, i.e. how households allocate their time considering the earnings they forego by substituting out in other activities (Fisher et al., 2005). Unable to estimate marginal shadow wages from a production function for off-farm off-forest activities and obtaining only a somewhat implausible value of marginal shadow wage from NTFP production function, in what follows I define an alternative concept of shadow wage and use an average shadow wage equal to the average earnings per unit of time. Indeed, estimating household production function for self-employed activities is a complex exercise that the data do not allow since households can develop a wide range of self-employed activities differing in services and products offered, and in inputs and capitals required. Analogously, because NTFPs are different by nature and require different inputs, and because households do not grow such products, estimating household production function for NTFP extraction is not as straightforward as agricultural production and provides less reliable results for the NTFP shadow wage.

As a consequence, instead of using households' marginal shadow wage, I estimate shadow wages as being the ratio of earnings on time dedicated to the activity. I predict such value in all three activities for all households, controlling for a censorship problem in the case of NTFP extraction or off-farm off-forest activities since some households may decide not to participate in such activities. I need these shadow wages for everyone in all three activities in order to analyse why some households do participate in one activity while others do not.

Households decide whether or not to extract NTFPs and they may or may not be able to work off-farm depending on the existence of wage opportunities, their skills or their capacity to develop a self-employed activity. As a result, predicting their shadow wages requires the use of a Heckman model. This model estimates jointly participation in one activity and the quotient of earnings per unit of time in this activity correcting for the sample selection bias. If such predictions are not undertaken, households not participating in these activities will be dropped when estimating labour allocations, which would bias the analysis (Fisher et al., 2005).

The labour allocation specifications try to explain how households allocate their time to one activity given the wage predicted above in this activity and the opportunity costs in the other activities but also controlling for households characteristics. All three shadow wages are potentially endogenous. However, since I could not find relevant instruments[27] I decide in each allocation estimation to control for the endogeneity of the own-shadow wage and not for the endogeneity of the cross-shadow wages.[28] I define specific instruments for each shadow wage and the majority of these succeeds the tests for weak identification and overidentification (Murray, 2006).

I estimate the time allocated to agriculture through a 2SLS procedure, the time in NTFPs and off-farm off-forest activities through ivtobit regressions and the time in hunting through

[27]Using the most relevant and well-defined instruments, I have tested whether these cross-shadow wages are endogenous or not, and according to a Wu-Hausman test it appears that controlling for their endogeneity does not improve the estimations.

[28]The shadow wage in the alternative activities.

a tobit since in the three latter, labour allocations can either be null with a positive probability or continuous over positive values, which leads to a censoring problem (Wooldridge, 2002, López-Feldman and Taylor, 2008). Estimation of time allocated to hunting appears not to have any endogenous shadow wages since hunting does not have own shadow wage. In the case of an ivtobit, following López-Feldman and Taylor (2008), I select the instruments in a 2SLS regression by looking at the Cragg-Donald Wald statistic and the Sargan statistic, and I check their significance and relevance in the ivtobit.

2.6.1 Average shadow wages in agriculture, NTFP extraction and off-farm activities

Estimating agricultural shadow wage does not require the use of a specific procedure since all households participate in such activity. Table 2.18 shows that overall, only village control variables explain the differences in shadow wages across households while household characteristics do not affect households' agricultural earnings.

On the other hand, to estimate the shadow wages for NTFP extraction and for off-farm off-forest estimations, Heckman models are implemented in which at least one instrument in the participation estimation is different from the instruments in the shadow wage specification (Wooldridge, 2002). I use a maximum-likelihood procedure to predict the shadow wages for NTFP extraction and for off-farm employment in order to relax the hypothesis that the factors determining the participation and the wage are identical and of same sign. Such a procedure is also consistent and efficient in a small sample (Fisher et al., 2005, Baum, 2006).

In these models, the different explanatory factors refer to household composition, household education, the availability of NTFPs, different district and village control variables. The identifiers for NTFP participation and off-farm off-forest participation include the number of ill adults, the number of children at school, the size of land, a dummy for whether households have earnings from livestock, a dummy for non-labour income or belonging to a tontine. Additionally, in the estimation of participation in NTFP extraction I use a dummy for whether households have a self-employed activity, and, in the estimation of participation in off-farm off-forest activities, a dummy for whether households extract palm nuts (appendix table B.7).

I assume that households with ill adults are more likely to participate in NTFP extraction so as to directly extract medicinal products or to participate in off-farm activities so they can purchase medicinal products. Households with more children at school are less likely to participate in NTFP extractions since children participate to a fair share in NTFP extraction and when at school, they won't be able to participate in NTFP extraction. In the light of the dummy variables I assume that households with other sources of income are less likely to participate in NTFP extraction or off-farm activities. The identifiers affect a household's decision to participate in NTFP extraction or in off-farm employment without affecting directly its wage (Fisher et al., 2005).

For the NTFP model, the value of rho allows to reject the null hypothesis that rho equals to 0, meaning that participation and shadow wage are not correlated (Greene, 2002). On the contrary, the value of rho in the off-farm estimation fails to reject the null hypothesis that rho is equal to 0; participation and average earnings appear not to be correlated.

In both estimations of participation, the instruments have the expected effects.[29] Households with children attending school are less likely to participate in NTFP extractions while households with a number of ill adults are more likely to participate in off-farm activities (table 2.18). NTFP extraction and off-farm activities appear to be substitutes since households with a self-employed activity are less likely to participate in NTFP ex-

[29] In the appendix table B.8, I present another specification of Heckman models using a different set of variables but keeping the same identifiers.

traction while reciprocally households extracting palm nuts are less likely to participate in off-farm activities. Households with non-labour income, typically receiving it in cash, are less likely to participate in off-farm off-forest activities.

While households with older household members and a literate household head are more likely to extract NTFPs, younger households with a household head aged 31-55 years old tend to have greater earnings. Households with primary or secondary education are unlikely to participate in off-farm off-forest activities but they earn more per hour.

Households living in a village with palm nut trees[30] are more likely to participate in NTFP extraction and in self-employed activities. Such a geographical effect is associated with the fact that villages with more palm nuts like Akom II or Nyangong are also villages where households participate more in off-farm activities while for example in Mbango-Bitouer fewer households extract palm nuts or participate in off-farm activities.

On the other hand, households living in villages with more palm nuts have lower earnings per hour in NTFP extraction. This suggests that palm nuts may be a low-value NTFP even if households extract it more than they extract ndo'o. Therefore palm nut extraction seems to require a lot more time to have greater earnings.

Predicting all households' shadow wages for agriculture, NTFP extractions and off-farm off-forest activities, shadow wages in off-farm off-forest activities are higher than agricultural and NTFP shadow wages. The distribution of shadow wages[31] shows that NTFP shadow wage is smaller than off-farm shadow wage in most cases but that agricultural shadow wage and the NTFP shadow wage follow a same distribution (figure 2.9).

The agricultural shadow wage is on average equal to CFAF 482, the NTFP shadow wage to

[30] Villages where access to palm nut trees is easier are Ebom, Lambi, Ebimimbang, Akom II, Nkomakak, Abiete, Mvie and Nyangong.

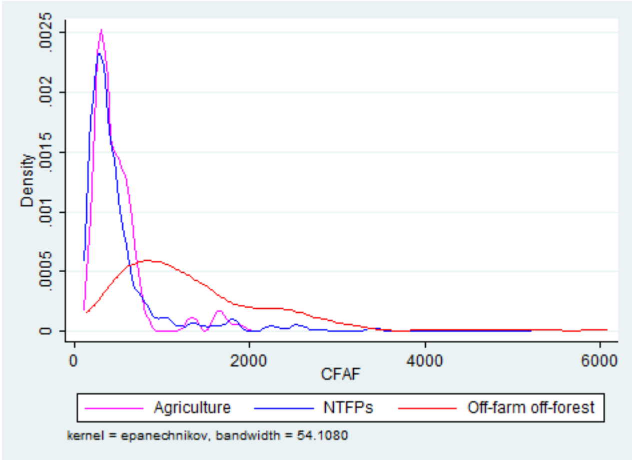
[31] NTFPs and off-farm off-forest shadow wages from respectively model (1) and (2).

Table 2.18: Estimation of shadow wage in agriculture, and estimations of participation and shadow wage in NTFP extraction and off-farm off-forest activities

	Agriculture	NTFP (1)		Off-farm off-forest (2)	
	Log (earnings/hours)	Log (earnings/hours)	Participation	Log (earnings/hours)	Participation
Ill adults			-0.124 (0.0998)		0.249*** (0.0875)
Children at school			-0.0757* (0.0414)		-0.0689 (0.0485)
Area			-0.0243 (0.0322)		-0.0560 (0.0345)
Livestock dummy			0.218 (0.152)		0.0367 (0.158)
Self employment			-0.369** (0.160)		
Non-labour income			-1.119 (0.734)		-7.972*** (2.317)
Tontine			-0.155 (0.143)		0.137 (0.148)
Palm					-0.412** (0.167)
Head aged less than 30	0.326 (0.237)	0.565 (0.399)	-0.841**(0.328)	-0.504 (0.418)	0.408 (0.327)
Head aged [31;55]	0.177 (0.137)	0.423* (0.227)	-0.331* (0.192)	-0.292 (0.251)	0.175 (0.181)
Household age less than 20	-0.181 (0.185)	-0.469 (0.306)	0.455 (0.280)	0.359 (0.323)	0.207 (0.276)
Household age [21;40]	-0.206 (0.147)	-0.142 (0.242)	0.386*(0.217)	0.753*** (0.281)	0.0939 (0.211)
Literacy head	0.219 (0.196)	-0.437 (0.325)	0.454* (0.262)	-0.708* (0.387)	0.244 (0.251)
Primary education	0.0796 (0.164)	0.794***(0.273)	-0.0448 (0.224)	0.560* (0.312)	-0.512** (0.221)
Secondary education	0.0632 (0.148)	0.452* (0.241)	0.0177 (0.206)	0.637**(0.276)	-0.444** (0.197)
Village electricity	0.152 (0.233)	-0.639 (0.428)	0.177 (0.306)	0.164 (0.453)	0.115 (0.290)
Village distance market	-0.00998 (0.00635)	0.0165 (0.0110)	-0.0133 (0.00965)	8.01e-05 (0.0117)	-0.00272 (0.00798)
Village palm	-0.205 (0.333)	-1.084* (0.605)	1.389*** (0.525)	-0.472 (0.633)	0.745* (0.421)
Mbango	1.136*** (0.317)	1.105* (0.578)	0.0711 (0.404)	-1.240 (1.412)	-1.741*** (0.624)
Ebom	0.276 (0.317)	1.171** (0.558)	-0.986** (0.458)	0.475 (0.621)	-0.497 (0.396)
Lambi	0.00324 (0.409)	1.723** (0.698)	-0.652 (0.614)	0.324 (0.723)	0.130 (0.514)
Bidjouka	-0.553* (0.298)	-0.561 (0.544)	0.740* (0.386)	0.291 (0.565)	0.720* (0.373)
Ebimimbang	-0.00398 (0.321)	0.706 (0.539)	-0.247 (0.532)	-0.707 (0.594)	-0.384 (0.401)
Bongwana	-0.399 (0.362)	-0.969 (0.647)	0.907* (0.499)	-0.204 (0.690)	0.415 (0.454)
Akom	-0.461 (0.353)	-0.0165 (0.552)	-0.384 (0.658)	0.372 (0.594)	0.251 (0.455)
Nkomakak	-0.613 (0.424)	1.489** (0.735)	-1.368** (0.621)	-0.709 (0.824)	-0.373 (0.553)
Abiete	-0.723** (0.341)	0.188 (0.541)	-0.590 (0.584)	-0.0268 (0.561)	0.464 (0.453)
Constant	6.069*** (0.304)	6.261*** (0.560)	0.238 (0.433)	7.162*** (0.702)	-0.220 (0.434)
athrho		-1.272*** (0.370)		-0.525 (0.342)	
lnsigma		0.479*** (0.0681)		0.289*** (0.0979)	
Observations	384	383	383	384	384

Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Figure 2.9: Distribution of predicted shadow wages in agriculture, NTFPs and off-farm off-forest activities



CFAF 510 per household per week and off-farm shadow wage is on average equal to CFAF 1,381 (table 2.19). Households in Lolodorf have higher shadow wages in agriculture and NTFP extraction than households living in the other districts but on the contrary, their shadow wages from off-farm off-forest activities are lower. Households living in Efoulan have higher shadow wages from off-farm off-forest activities.

Table 2.19: NTFP and off-farm shadow wages by quintiles of total time [95% Confidence interval]

Quintiles	Agriculture shadow wage	NTFP shadow wage (1)	Off-farm off-forest shadow wage (2)
Lowest	614.9 [515.7;714.2]	713.5 [527.7;899.3]	1394.6 [1142.3;1646.9]
2nd	485.5 [409.5;561.5]	559.1 [439.7;678.4]	1303.9 [1100.7;1507.1]
3rd	468.1 [398.3;538.0]	505.2 [406.8;603.5]	1500.1 [1258.0;1742.1]
4th	444.4 [377.5;511.3]	427.2 [317.7;536.7]	1328.4 [1114.4;1542.3]
Highest	390.4 [356.1;424.8]	339.1 [293.8;384.3]	1381.0 [1197.2;1564.8]
Total	482.0 [449.3;514.8]	510.0 [455.3;564.6]	1381.9 [1284.9;1478.9]

Across quintiles of total time, the shadow wages for agriculture and NTFP extractions decrease while there seems to be no linear relationship between households' shadow wage for off-farm off-forest activities and total time spent working.[32] Across quintiles of per capita total production, on average, the shadow wages for agriculture and NTFP extractions increase with the quintile; the shadow wage for off-farm activities is on average higher in

[32] I present in appendix the results found with the other Heckman models; changes between quintiles are similar for these shadow wages.

the middle quintile than in the lowest and highest quintiles in which shadow wages are on average equal.

2.6.2 Labour allocations to agriculture, NTFP extraction, off-farm employment and hunting

Estimating labour allocation consists in estimating the number of hours spent in each activity as a function of the shadow wages in each activity, household composition characteristics, different activities characteristics and village characteristics (appendix table B.7).

When looking at the allocation of labour to agriculture, I use a 2SLS procedure instrumenting the agricultural shadow wage using a proxy for the wealth of the household and the district price of cucumber. The proxy for wealth is a dummy for whether the household has any livestock or not[33] and I expect this variable to explain positively the average product in agriculture as wealthier households should be able to be more productive. The village price of cucumber is assumed to give the level of agricultural prices within the village; all the effect this price has on the time spent cultivating goes through the agricultural shadow wage. The tests justify that both IVs are consistent and valid. The first-stage regression shows that the dummy for livestock is negative but only significant at 10%, and it appears to capture a geographic pattern with Mbango having fewer households raising livestock than households in the other villages. On the other hand, the district price of cucumber has the expected effect on agricultural shadow wages since it is positive and highly significant. Households living in villages with a higher price of cucumber have higher shadow wages from agriculture (appendix table B.11).

[33] I have tried different measures of household's wealth such as dummy for large equipment, an asset index, a dummy for each type of equipment, regional prices of gasoline or rice, receiving a credit for medical purposes, and also different interaction terms between rainfall and size of land. However the results presented here are the best estimates I could obtain and pass successfully all tests linked to the use of IV.

Considering labour allocations to NTFP extraction and to off-farm off-forest activities, the instruments for the shadow wages in NTFP and in off-farm off-forest activities are the village wage for clearing plots and the district price of cocoa respectively. The village wage for clearing plots should have a positive effect on the NTFP shadow wages. The district price of cocoa is supposed to capture the fact that villages with higher cocoa prices tend to be wealthier with households having greater earnings from off-farm activities. Lack of correlations of these IVs to the time spent in each activity confirms that these IVs do not affect the time and that all impacts they may have go through shadow wages.[34]

I attempt to justify the use of these instruments through an ivreg2 specification. With respect to the NTFP shadow wage, the instrument is valid and identifies the endogenous variable since the Cragg-Donald statistic is above 10 in a 2SLS specification; unfortunately when controlling for censorship in an ivtobit, the instrument is not significant in the first-stage regression (table B.11 in appendix). However, I keep this IV since it is the best I could find. Other IVs were rejected due to their being correlated to the time spent in NTFP extraction or because they were giving even worse results.

In a 2SLS regression, the price of cocoa seems to weakly identify the off-farm shadow wages since the Cragg-Donald statistic is smaller than 10. However, the Wald test of exogeneity in the ivtobit regression and the significance of the instrument in the first-stage regression suggest that the IV can control for the endogeneity of the shadow wage. Contrary to what I expected the IV has a negative effect on off-farm shadow wages and villages with a higher price of cocoa such as Nyangong or Mbango tend to have lower shadow wages from off-farm activities since in these villages, households appear to participate in low earning off-farm activities.

[34] I have tried including different measures of household wealth but I could not use these instruments since either they were correlated to the dependent variables or according to the test they appear not to be valid instruments.

Moving to the second-stage regressions (table 2.20), the important result is that households do not allocate more time to NTFP extraction when shadow wages in this activity increase. However, households do allocate more time to agriculture and to off-farm activities when respectively agricultural shadow wages and off-farm shadow wages increase. In addition, when NTFP shadow wages increase, households allocate more time to hunting and they allocate more time to off-farm activities when shadow wages for agriculture increase.

The effect of NTFP shadow wages on hunting time is related to the fact that NTFP and hunting activities may be jointly performed; households can spend more time hunting since they have greater earnings from NTFP extraction. The effect of agricultural shadow wages on off-farm activities may result from the fact that with greater earnings in agriculture, households are able to invest more in self-employed off-farm activities and to spend more time in these activities.

Some household size and composition effects exist; households with more children or wives can allocate more time to agriculture, NTFPs and hunting. Children and wives are often the ones working for a greater share in agriculture and NTFP extraction and they often have small traps around their agricultural plots. Older households allocate more time to agriculture but at a decreasing rate and, if anything, older households spend less and less time in NTFP extractions. More educated households are able to spend less time in agriculture and more time in off-farm off-forest activities.

Ngoumba households tend to spend less time in agriculture while Bulu households spend more time extracting NTFPs.[35] Households with a plot further away from home tend to allocate less time to agriculture but more time to hunting activities, households checking their traps along the way to their plot.

[35]Ngoumba households live mainly in Mbango while Bulu households live mainly in Nyangong and Akom II.

Table 2.20: Estimation results for labour allocations

	Hours agriculture	Hours NTFP	Hours Off-farm	Hours hunting
Shadow wage agriculture	0.0819** (0.0335)	-0.00882 (0.0375)	0.316* (0.180)	0.0210 (0.0177)
Shadow wage NTFP	-0.00614 (0.00609)	-0.0361 (0.0361)	-0.0323 (0.0283)	0.0124* (0.00658)
Shadow wage off-farm	0.00309 (0.00307)	0.00162 (0.00412)	0.0550* (0.0307)	0.000341 (0.00127)
Child	2.776*** (0.977)	0.249 (0.970)	-0.182 (1.047)	-0.0259 (0.335)
Wives	12.93*** (3.684)	8.710*** (3.220)	3.517 (3.666)	4.445*** (1.269)
Age head	2.149*** (0.491)	0.818 (0.624)	-0.402 (0.822)	-0.214 (0.279)
Squared head age	-0.0170*** (0.00468)	-0.00992* (0.00538)	-0.00315 (0.00728)	0.000816 (0.00253)
Average grade	3.979 (2.533)	-0.617 (2.479)	1.329 (3.677)	0.402 (0.787)
Primary education	1.092 (6.230)	4.021 (10.12)	17.56 (12.35)	0.833 (2.010)
Higher education	9.782 (8.181)	11.56 (10.49)	46.86* (24.29)	2.383 (2.974)
Education head	-4.514** (2.128)	-2.727 (2.958)	-0.451 (2.655)	-0.645 (0.694)
Secondary educ head	1.504 (6.782)	1.051 (7.200)	5.703 (7.668)	2.557 (1.987)
Ngoumba	-10.57** (5.217)	3.805 (5.941)	-1.444 (9.938)	2.443 (1.902)
Bulu	12.95 (8.323)	14.50** (6.589)		-1.161 (3.673)
Distance field	-0.164** (0.0641)	0.0113 (0.0770)	-0.0678 (0.0867)	0.0497** (0.0216)
Village ethnicity	15.02* (8.259)	7.017 (10.50)	-120.5* (73.18)	-8.320 (7.326)
Village distance market	0.204 (0.137)	0.0312 (0.212)	-1.664 (1.106)	-0.136 (0.116)
More rain	1.902 (8.506)	0.357 (12.51)	66.59 (45.62)	20.82*** (7.102)
Mbango	-95.27** (46.45)	67.03 (46.46)	-323.5* (169.8)	-135.3 (0)
Ebom	-42.23*** (13.57)	-0.0402 (11.68)	-80.99* (44.43)	-9.597** (4.671)
Mekalat	-6.273 (14.05)	-2.310 (17.50)	-155.1* (86.33)	-19.14** (9.251)
Bipindi	-26.46 (18.90)	-5.242 (19.70)	-84.40* (43.41)	0.585 (4.819)
Lambi	-16.31 (18.28)			
Bidjouka	2.493 (14.59)		53.32 (39.58)	11.67** (5.417)
Ebimimbang	-12.29 (11.45)	5.967 (7.434)	19.51 (15.79)	-7.110* (4.085)
Bongwana	-0.847 (12.81)	3.300 (8.915)		-3.390 (4.232)
Mvie	10.62 (11.87)	116.6 (274.3)	-110.6* (66.79)	-10.16 (7.206)
Abiete		-13.93 (10.20)	-7.652 (24.13)	-8.279* (4.591)
Constant	-64.31** (25.41)	1.431 (29.11)	-94.38* (56.50)	-17.95* (10.45)
Observations	375	375	374	375
Cragg-Donald Wald F-stat	311			
Sargan Test P-value	0.356			

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Village effects show that households living in villages where it has rained during the last year allocate more time to hunting but this seems to capture mainly a geographic effect.

Since the residuals from agriculture and off-farm activities are respectively correlated with the residuals from NTFP extractions and hunting, I estimate labour allocations through a system, a 3SLS model (appendix table B.13) in which I control for the endogeneity of the shadow wage in agriculture.[36] Correlations between residuals are explained by the fact either that certain households with members working more than 40 hours a week are constrained in their labour supply and increase labour allocations in one activity by decreasing labour allocations in another, or that certain households participate jointly in

[36]I am not taking into account the potential endogeneity of the other shadow wages and the censorship problems which complicate the estimations without improving the results.

particular activities.

However within such a model none of the shadow wage effects found in the independent labour allocation estimations persist and there are hardly any household effects. The absence of results supports the idea that overall, correlations are not that important and households are not limited in time they work. Such results may also be due to the fact that I could not control for the censorship problem in the system. Estimating a system with an uncensored equation and three censored ones is particularly demanding.

Since the results of the estimation are poor, I prefer using the results from independently estimated labour allocations to account for the factors encouraging households to allocate labour to different activities.[37]

2.6.3 Summary of findings from labour allocation estimations

From these estimations, allocations of time to NTFP activities do not increase when the earnings from extracting these resources increase. Households decide to participate in these activities taking more into account the availability of the products and their incapacity to implement self-employed activities.

Considering that most households are not constrained in their time spent working, households with greater earnings in agriculture or in off-farm activities increase the time spent in their respective activities. In addition, increased earnings in agriculture allow households to spend more time in off-farm activities and increased earnings in NTFP extraction encourage households to hunt more. As a result, whether or not time allocations in the other activities remain unchanged households end up working more after increases in agricultural, off-farm and NTFP earnings.

[37] I looked at different estimations using control variables whether households extract palm or ndo'o, or whether households participate in self-employment activity, a wage activity, households have an old business or a wage skilled activity, and all results were the same. In the appendix table B.15, I also present labour shares in all four activities which confirm some of the results but I do not think these results are totally consistent since I am controlling neither for the endogeneity nor for the censorship problems.

Such an increase in the time spent working corroborates the findings from labour supply in which an increase in the shadow income encourages households to work more. However, time spent extracting NTFPs appears not to change when earnings increase and it seems quite likely that allocations of labour to NTFP activities does not increase when the shadow income increases. This is quite an important result because it suggests that increasing prices of NTFPs may not increase pressures on these resources since households would not spend more time extracting these resources. After an increase in NTFP prices, households engaged in NTFP extraction enjoy greater profits since without increasing their labour they would earn more.

In order to increase prices of NTFPs and resulting earnings, forest conservation practices could be implemented but better prices do not necessarily guarantee that households can improve their welfare. In order to find out whether households can improve their welfare when NTFP prices increase, the following section starts by comparing households engaged in NTFP extraction to those not participating in these activities. Then the effects of an increase in NTFP prices on household leisure and consumption are determined, analysed and compared to the effects of an increase in agricultural prices.

2.7 Using NTFP activities to improve household welfare

For households in the research area, NTFP extraction appears to be an important activity in the sense that it contributes to household total production and consumption. The literature acknowledges that households employ NTFP-related activities to manage their risks or cope with shocks (Byron and Arnold, 1999, Angelsen and Wunder, 2003). However, participating in NTFP extractions may have positive effects on household welfare; those households having greater production values may be able to enjoy greater consumption or greater leisure.

From the model and more specifically the equation (2.15), household welfare depends on both consumption and leisure that are in the left-hand side of this equation; household are better off when leisure or consumption increases.

To determine whether NTFP activities can improve household welfare or not, I first investigate if households engaged in NTFP activities and extracting certain types of NTFPs are able to consume more and work less than households engaged in other types of activities. Afterwards, I analyse the effects of changes in prices on household welfare using comparative statics and the results from the labour supply analysis. Such changes affect household consumption and leisure either directly or indirectly; the indirect effects can either go through shadow wage or shadow income, each having different effects on the various components of household welfare.

2.7.1 NTFP activities and household welfare

To determine whether participating in NTFP extractions can help households to improve their welfare, I investigate whether households extracting forest products are better off in terms of consumption and leisure than other households. I detail such analysis according to the types of NTFPs households extract and according to households' participation in hunting.

On average, comparing households engaged in NTFP activities to those not engaged in these activities, the former have greater household production. Households engaged in NTFP extraction seem to be wealthier in terms of production than those who do not participate in such activities. Furthermore, in what follows it would be seen that in the majority of cases, extracting NTFPs allows households to be better off in terms of consumption even if having less leisure.

Distinguishing households engaged in NTFP activities but not in wage work nor in self-employed activities from households engaged in wage work or from those engaged in self-employed activities, the former have greater household consumption.[38] On average, households engaged in NTFP activities work more than households engaged in wage work or engaged in self-employed activities but the values of their gains in consumption are greater than losses of leisure. Furthermore, on average, households engaged in NTFP activities but not in hunting activities are better off since they work less for the same levels of consumption.

However, if adult members of households engaged in NTFP extraction work on average more than 40 hours a week, the gains in consumption that result from working more are not high enough to compensate the loss of leisure. Households engaged in NTFP extractions whose members work more than 40 hours are worse-off than households engaged in NTFP extractions with members working on average less than 40 hours a week.

Comparing households extracting palm nuts to those extracting ndo'o, the former are better off in the sense that even if they work more, they have greater gains in consumption than households extracting ndo'o since even if palm nuts is a low-value NTFP, households extract it more than they extract ndo'o. It seems that extracting both types of NTFPs allow households to consume more but at the cost of more work, and gains in consumption do not compensate losses of leisure.

To summarise, households engaged in NTFP extractions have greater production and are able to enjoy higher consumption than households in other types of activities. Even if this result comes for most households at the cost of less leisure, all households engaged in NTFP activities are able to have greater welfare in terms of consumption.

[38] I look at household consumption and production to be able to compare values of extra-consumption to values of extra-time which are calculated at the household level. Overall, if looking at per capita consumption and production, same rankings are obtained.

2.7.2 Impacts of price changes on welfare

Knowing that participating in NTFP extraction allows households to reach higher welfare, the effects of changes in the price of NTFPs are determined and compared to the changes in the price of agricultural products.

Neglecting the impacts of changes in the price of hunting, the impacts on welfare of a change in the price of NTFPs or agricultural products can be assessed using households' maximisation problem (2.14) subject to their full budget constraint (2.15). Households maximise their welfare through their consumption of different market, agricultural, forest and hunting goods (C_m, C_a, C_f, C_u) and its leisure (l).

According to the model, consumption of good i with $i = m, a, f, u$ is a function of the price of the good i, the price of other goods j, the price of hunting goods η, the shadow wage $w^\star$ and the full income constraint $V^\star + w^\star E$; consumption can be rewritten as

$$C_i(p_i, p_j, \eta^\star, w^\star, (\sum_n (p_n Q_n - w_n^\star l_n^\star) - p_x x + Y + w^\star E)) \tag{2.25}$$

with n being the different agricultural, forest and hunting activities households are engaged in $n = a, f, u$.

Similarly, leisure is a function of the same parameters and can be rewritten as

$$l(p_i, \eta^\star, w^\star, (\sum_n (p_n Q_n - w_n^\star l_n^\star) - p_x x + Y + w^\star E)) \tag{2.26}$$

From these two equations, the effects of changes in the price of forest-products on household consumption can be decomposed as follows:

$$\frac{\partial C_i}{\partial p_f} = \left.\frac{\partial C_i}{\partial p_f}\right|_u + \frac{\partial C_i}{\partial w^\star}\frac{\partial w^\star}{\partial p_f} + (Q_f - C_f)\frac{\partial C_i}{\partial (V^\star + w^\star E)}\frac{\partial (V^\star + w^\star E)}{\partial w^\star} \tag{2.27}$$

with C_i being C_a, C_f, C_u.

Whether C_i represents the consumption of forest products or the consumption of other products, the first term is respectively negative or positive. This first term $\left.\frac{\partial C_i}{\partial p_f}\right|_u$ reports the substitution effect; to keep household utility constant, consumption of the forest-product decreases when its own price increases and the consumption of the other goods increases as long as goods are substitutes.

The second term $\frac{\partial C_i}{\partial w^\star}\frac{\partial w^\star}{\partial p_f}$ reports an additional effect through a change in the shadow wage. According to the first-order condition (2.9), everything else remaining equal, an increase in the price of the output increases the shadow wage $w^\star$. Thus, the second term has a positive effect; household consumption of different products increases when the price of NTFPs increases. However according to the data, the shadow wage does not have any significant effect on household consumption; in our research area increasing the price of NTFPs does not affect household consumption through the shadow wage.

The last-term describes the effect of an increase in the NTFP price on consumption through household full income knowing that households are net sellers ($Q_f - C_f > 0$) of NTFPs.[39] An increase in the NTFP price increases both household production of NTFPs and the shadow wage. The shadow income $V^\star$ being positively affected by household production but negatively by shadow wage, has an indeterminate effect on consumption. However, the full income constraint is a function of both $V^\star$ and $w^\star E$ and the full income constraint $\sum_i(p_iQ_i - l_iw_i^\star) - p_xx + Y + w^\star E$ increases since $\sum_i l_iw^\star < w^\star E$ with $E = l + \sum_i l_i + l_w$. As a consequence an increase in the price of NTFPs increases the household full income and, households being net sellers of NTFPs, the effect of an increase in the price of NTFPs through the full income is positive. An increase in the full income increases consumption and such an effect is confirmed by the data.

[39]Households in the research area do not buy NTFPs; they consume what they have produced.

Overall, an increase in the price of NTFPs is likely to have a positive effect on household consumption. Since the full income elasticity is presumably greater than the negative substitution effect and since it is multiplied by sales of NTFPs, the income effect would certainly outweigh the negative substitution effect on consumption of NTFPs and furthermore, adds to the positive substitution effects of other products.

The decomposition of the effects on household leisure of an increase in NTFP prices is as follows

$$\frac{\partial l}{\partial p_f} = \left.\frac{\partial l}{\partial p_f}\right|_u + \frac{\partial l}{\partial w^\star}\frac{\partial w^\star}{\partial p_f} + (Q_f - C_f)\frac{\partial l}{\partial (V^\star + w^\star E)}\frac{\partial (V^\star + w^\star E)}{\partial w^\star} \tag{2.28}$$

An increase in the price of NTFPs can have a positive effect on household leisure when utility is held fixed; households reduce consumption of NTFPs and can increase leisure in order to have a constant utility. Some households may substitute away from consumption in favour of leisure.

The second effect shows that after an increase in the NTFP price increasing shadow wage, households increase leisure. This effect is confirmed by the labour supply estimation in which the agricultural shadow wage has a negative and significant effect on labour supply (table 2.17). When shadow wage increases leisure increases.

If leisure were a normal good, an increase in household full income increase leisures; this last term $(Q_f - C_f)\frac{\partial l}{\partial (V^\star + w^\star E)}$ would be positive. But I know from the labour supply estimation that leisure is an inferior good for the Cameroonian households. Therefore, an increase in the NTFP price has a negative effect on leisure through household full income constraint. When getting wealthier, households supply more labour (table 2.17) and substitute away from leisure.

The net effect of an increase in the NTFP price on leisure is indeterminate; the first two effects are positive and the income effect is negative. Depending on whether the income effect predominates or not, a change in the NTFP price has a negative or positive effect on household leisure.

Looking now at the effects of an increase in the price of agricultural products on household consumption and leisure, the comparative statics take the following form:

$$\frac{\partial C_i}{\partial p_a} = \left.\frac{\partial C_i}{\partial p_a}\right|_u + \frac{\partial C_i}{\partial w^\star}\frac{\partial w^\star}{\partial p_a} + (Q_a - C_a)\frac{\partial C_i}{\partial (V^\star + w^\star E)}\frac{\partial (V^\star + w^\star E)}{\partial w^\star} \tag{2.29}$$

After an increase in the price of agricultural products, to keep their utility constant households decrease their consumption of agricultural products but increase their consumption of other goods. The first term has a negative sign whether C_i is consumption of agricultural products or a positive sign if C_i is consumption of other goods being substitutes to agricultural goods.

The second term is similar to the one associated with an increase in the price of NTFPs; and since the data reveal that shadow wage has no effect on consumption, an increase in the price of agricultural products has no effect on consumption through shadow wage.

The effect of an increase in agricultural prices on household consumption through full income can take different signs depending on whether households are net sellers $Q_a - C_a > 0$ ore net buyers $Q_a - C_a < 0$. For net sellers, the effect is similar to the one resulting from an increase in the price of NTFPs; households increase consumption of the different goods after an increase in agricultural prices. However if households are net buyers, the effect becomes negative since $\frac{\partial C_i}{\partial (V^\star + w^\star E)}$ is nonnegative and $(Q_a - C_a)$ is negative so the income effect is negative.

Here as well, the income effect is expected to outweigh the substitution effect. When households are net buyers of agricultural products, the net effect on consumption after an increase in agricultural prices is negative and when households are net sellers, the net effect is positive and households increase their consumption after an increase in agricultural prices.

Similarly the effects on leisure can be decomposed as follows:

$$\frac{\partial l}{\partial p_a} = \left.\frac{\partial l}{\partial p_a}\right|_u + \frac{\partial l}{\partial w^\star}\frac{\partial w^\star}{\partial p_a} + (Q_a - C_a)\frac{\partial l}{\partial (V^\star + w^\star E)}\frac{\partial (V^\star + w^\star E)}{\partial w^\star} \tag{2.30}$$

Just as with an increase in the price of NTFPs, an increase in the price of agricultural products has a positive effect on household demand for leisure. When utility is held constant, households increase leisure substituting away from consumption of agricultural products.

This substitution effect is augmented by another effect through the shadow wage; an increase in agricultural prices, increasing shadow wage, increases household leisure. According to the labour supply estimation, households in the research area increase leisure when they have higher shadow wage.

Finally, an increase in agricultural prices has an income effect that affects household leisure either positively or negatively. According to the labour supply estimation, leisure is an inferior good. Therefore, after an increase in agricultural prices, the income effect is negative for net sellers since $\frac{\partial l}{\partial (V^\star + w^\star E)}$ has a negative sign and $Q_a - C_a$ has a positive one. Net seller households decrease leisure when agricultural prices increase. On the contrary, for net buyers, an increase in agricultural prices has a nonnegative effect on leisure since $\frac{\partial l}{\partial (V^\star + w^\star E)}$ is still negative but $Q_a - C_a$ is also negative; net buyer households increase leisure after an increase in agricultural prices.

The net effect is again indeterminate for net sellers since two first terms have a positive sign if leisure is a substitute for agricultural goods but the income effect is negative. On the other hand, the effect on leisure is positive for net buyers since all three effects are positive; net buyers can improve their welfare through an increase in leisure after an increase in the price of agricultural products.

To summarise, both increases in the price of NTFPs or agricultural products have positive effects on household consumption or leisure. However an increase in the price of NTFPs appears to have less unambiguous effects on household welfare. An increase in the price of NTFPs allows household to consume more. The effect on leisure is quite indeterminate, but it is reasonable to assume that the income effect on leisure is smaller than the one for consumption. Such an assumption is supported by the fact that values of consumption are on average greater than values of labour and that the positive coefficient of the full shadow income on household consumption is greater than the one on labour supply. Overall, after an increase in the price of NTFPs, households are better off and participating in NTFP activities improve households' welfare.

2.8 Conclusion

To conclude, this study shows that households in the Province South of Cameroon generate an important part of their livelihood from forest resources, either NTFPs or hunting products. Poorer households depend more on NTFP extraction than wealthier households but on average, households engaged in NTFP extractions appear to be better off than households not engaged in such activities. The few households engaged in wage activities and not in NTFPs are worse-off in terms of production and consumption which shows that wage activities by themselves are not enough to improve household welfare in the research area.

From the labour supply estimation, it appears that household marginal shadow wages and shadow income have respectively positive and negative effects on leisure. Leisure appears to be an inferior good; households work more when their income increases. Such an increase in household shadow income according to the comparative statics has a net positive effect on household consumption if the increase in shadow income results from an increase in the price of NTFPs. It is true that the effect of an increase in NTFP prices on leisure may be indeterminate but since both consumption values and the coefficients of shadow income on consumption are greater, the effects on consumption would certainly outweigh any effects on leisure. Increase in the price of NTFPs allows households to improve their welfare.

In addition, households in the research area would not spend more time extracting NTFPs when earnings from these extractions increase, but they do spend more time in agriculture or in off-farm activities when respective earnings in these activities increase. However, the comparative statics show no clear positive effects on their consumption.

Consequently, increasing the price of NTFPs appear to allow households to improve their welfare but also, since households would tend not to spend more time extracting these resources, an increase in NTFP prices would be unlikely to have any negative impact on forest resources. Any pressures on forest resources could be reduced if increases in NTFP prices result from conservation and reforestation practices coupled with enhanced management of forest resources and the promotion of trade. Furthermore, households benefit from greater prices of NTFPs but also from improvements in agriculture through better soil conservation, better control of floods and lower levels of crop losses engendered by animals. A better management of forest resources enables forest animals to find what they need to eat in the forest and the latter need not to destroy agricultural cultivations, their natural habitats being restored. Households when hunting may find animals of bigger value.

Further research should look at how to define incentives to encourage households to participate in forest conservation. Better quality forest resources and resulting greater prices should influence households to conserve forest but households often do not take into account these effects and adopt unsustainable forest uses. As a consequence, it seems that paying households could be a rational incentive to encourage them to conserve forests. To find such payments, rigorous analysis of households' livelihood must be done prior to the implementation of a forest conservation activity.

Chapter 3

Designing forest conservation payments using a principal-agent game

Forests provide goods and services whose existence is threatened when forest users adopt unsustainable uses of forests. This loss of services decreases forest users' and the whole society's welfare, and incentives need to be defined such that forest users internalise the benefits from supplying these services. Recently, payments for environmental services have been promoted to remunerate users when adopting sustainable uses of forest that supply environmental services. The difficulty in developing such payments is to encourage forest groups to conserve forests knowing that there exist tensions between forest groups' needs of using such resources and forest conservation. Consequently, a non-governmental organisation (NGO) interested in forest conservation needs to take into account forest groups' needs when defining payments while also compensating forest groups for their conservation effort that the NGO cannot observe. Opposed utility functions and a lack of monitoring justify the use of a principal-agent game. Resulting from this game, an incentive contract ensuring the NGO that forest groups would conserve high levels of trees is such that such groups are only paid when a high outcome is observed. Any lower outcomes give zero payments since the NGO does not know the effort exerted. Payments for a high outcome include a risk-sharing element for risk-averse forest groups, and payments increase over time if forest conservation increases the value of forest resources. Pro-poor forest conservation schemes coupled with effective additionality can be achieved with low payments so as to select poor forest groups or the ones living in highly-degraded areas. The NGO defines a fine to reduce forest groups' benefits from leakage. To increase the benefits for non-participants in the scheme, the principal can either promote the development of local infrastructures or encourage the agent to hire poor workers to conserve forests.

3.1 Introduction

The Brundtland Report has underlined that conservation of natural resources, wildlife and diversity of resources has a positive effect on global society's welfare because natural resources and ecosystem in general provide free services that cannot be found anywhere else (WCED, 1987). Ten years later, Costanza et al. (1997) estimated that if 17 freely-provided ecosystems services ranging from water supply and regulation to food provision or recreation came to disappear the cost to provide these services would be equal to around US$33 trillions.

Each of these two influential studies emphasises how important and highly valuable ecosystem services are when both provided freely and taking the characteristics of externalities. Focusing on forest resources, forest users generally neglect to take into account the loss of several environmental services, e.g. biodiversity conservation, carbon sequestration, watershed protection or landscape beauty, when deciding their land uses despite the fact that these services enter the utility or production function of others. Therefore, in order to encourage land users not to destroy, or to protect, these environmental services, several policy measures have been implemented so as to push forest users to internalise the costs and benefits of providing environmental services. These policies range from subsidies and taxes, and quotas and permits, to direct payments.

Among the latter payments, Payments for Environmental Services (PES), are a market-based way of internalising the positive externalities generated when preferring sustainable land uses rather than highly-degrading ones. PES consist of payments from consumers who benefit from the existence of an environmental service, to producers of this service whose forest uses influence the provision of such service (Wunder, 2005). PES lead to the creation of a market for an environmental service in which interactions between supply and demand define the price to be paid by the consumers to the producers.

This chapter is aimed at defining payments that would incentivise forest users to conserve forest resources and areas, such payments depending on their efforts and intrinsic characteristics such as disutility, forest resources prior conservation, and poverty. Payments must be calculated such that both producers and consumers benefit from both payments and forest conservation, knowing that there exist tensions between forest groups' needs of using such resources and consumers' preference towards conserving these resources.

The payment programme here analysed consists in protecting tree biodiversity through payments from an international non-governmental organisation (NGO) to forest groups such that the latter restore and conserve trees within forests. I choose to illustrate this scheme with respect to the situation of forest groups in Cameroon; for these groups, payments for forest conservation become an alternative source of income to timber logging and agriculture. In this hypothetical case, forest restoration and conservation require that a forest group acts as an environmental service supplier, planting and taking care of the trees, while the NGO is referred to as an environmental service buyer.

The supplier and buyer do not have the same objective functions. The environmental service buyer wants a large number of trees planted and growing to maturity at least cost, while the environmental service supplier wants to spend as little time and investments as possible in planting and caring for trees, while earning more. Because the NGO cannot observe and impose the forest group's action, the NGO needs to define a contract in terms of transfers related to the outcome she will observe at the end of the contract. The NGO has for objective that the forest group produces a high level of forest conservation.

Both the opposition in their objective functions and the lack of monitoring by the NGO of the supplier's action make that this forest conservation scheme can be conceptualised within a principal-agent game as developed by Laffont and Martimort (2002). In this game, the environmental service buyer becomes the principal and needs to define an incentive contract such that the supplier, i.e. the agent, participates in the game and exerts a high effort in forest conservation instead of selling concession rights to logging companies or instead of clearing all the forest area for agricultural purposes. In this game, I assume that the forest group can develop agro-forestry practices in the conserved area and can extract a fixed amount of non-timber forest products (NTFPs). The principal wants the agent to exert a high effort as opposed to a low one because there is a higher probability to have a high level of trees planted and conserved when the high effort is exerted than when the agent uses a low effort.

Considering first both principal and agent as being risk-neutral, I find that in order to have the agent performing a high effort in forest conservation, the buyer should offer a non-zero payment when the output is high and payments equal to 0 in all other cases. When the supplier becomes risk-averse, the payment associated with a high level of trees planted and conserved increases since the buyer has to bear a part of the risk. Over several periods, if the NGO always observes the high outcome, the payments linked to this outcome are in the two periods greater than if the principal observes such an outcome in one of the two periods. In this dynamic case, payments encourage the agent to create a virtuous circle in forest conservation.

If the NGO wants to contract with poor or highly-degraded forest groups as opposed to wealthier or better-preserved forest groups, she may offer lower payments. The NGO defines a fine so as to reduce forest groups' benefits from leakage when leakage results from increased facilities for adopting more degrading techniques as a result from higher payments. To increase the benefits for non-participants in the scheme, the NGO can either promote the development of local infrastructures or encourage the forest group to hire poor non-participants in the group to conserve forests.

The chapter is organised such that the following section explains both what environmental externalities are and the means by which they may be internalised. A third section focuses on PES, providing a definition, examples of existing PES, achievements and limits. Section 3.4 presents the Cameroonian situation in terms of forest policy and the limits of existing conservation practices. The game is presented in section 3.5 defining the transfers in a simple game, extending the game to characterise payments when the agent is risk-averse and when the game is repeated over time. Section 3.6 deals with the specificities of a forest conservation programme such as dealing with several agents of different types, reducing leakage created by the environmental service provider and increasing benefits for poor non-participants in a forest group. Section 3.7 gives the implications of my findings comparing these to existing PES before concluding.

3.2 Environmental externalities: review of issues and solutions

When deciding upon its production process, land use or consumption, an agent's or entity's action may have effects on another agent's or entity's production or utility function without these effects being formalised by any monetary transfers. These effects are externalities created by an agent who does not take into account the fact that its action may affect another agent or himself. More formally, *"an externality is present whenever some individual's utility or production relationship include real variables whose values are chosen by others without particular attention to the effects on the individual's welfare"* (Baumol and Oates, 1975). Externalities can be of different types and natures, positive or negative.

For instance, technological change, human capital accumulation and knowledge spillover have important positive externality elements resulting from the geographical concentration of industries. Cultural diversity, better access to services and education are positive externalities created by the concentration of population in urban areas while noise, crowds and pollution are negative externalities from such a concentration. Depletion of natural resources, erosion, loss of biodiversity, pollution are negative externalities resulting from the use and exploitation of the environment. On the other hand, when adopting land uses such as avoiding creating these negative externalities, positive externalities, e.g. control of water flows, biodiversity conservation, carbon sequestration or landscape scenery, may arise.

In my analysis, I focus only on environmental externalities and explain the different mechanisms and policies developed to internalise these externalities.

3.2.1 Definition and creation of environmental externalities

A firm or land user, here referred as the agent, before starting to produce, cultivate or use the land, proceeds to a cost-benefit analysis of its production process. It asks itself the quantity and types of inputs required to produce or how many hectares of land to convert from one use to another, and what would be the resulting outputs from these decisions.

By doing so, the agent only compares its private marginal cost to its private marginal benefit and neglects any effects its decision may have on the society. However, since the agent production process relies on environmental resources, the agent's decision creates externalities that affect society positively or negatively, either locally, nationally or globally. For instance, when a company uses large amount of water for its production, cutting down the availability of water for other users, the company clearly has only considered its own benefits and costs while deciding upon its production levels. The company creates a negative externality for the society which makes the society worse off. In this case, private net marginal benefits are higher than the society's net marginal costs; the level of output produced by the company is higher than the society's optimal level (Kolstad, 2000). Because the agent does not consider the society's marginal cost of its action that results in producing negative externalities, the agent's costs are low. Therefore, negative externalities are more likely to be over-produced (OECD, 2001).

On the contrary, a situation in which a land user decides to preserve trees on his land, which regulates water flows irrigating downstream agricultural lands, constitutes a positive externality. Such situation increases the land user's private costs while society's net marginal costs are smaller. In the end, the level of output produced by the land user is smaller than the society's desired level of output (Kolstad, 2000). The land user, not considering the social benefit of these externalities on the society when deciding upon the output to produce, has low private benefit from such a production. These positive externalities are more likely to be under-produced (OECD, 2001).

Within forest areas, negative externalities arise when forest users degrade forest resources through deforestation, over-exploitation of timber or conversion of forest land to agriculture or pasture. These degradations lead to the under-provision or loss of environmental services (ES) such as biodiversity conservation (fauna and flora), carbon sequestration by trees, watershed protection, or recreational uses of forest. Consequently, forest degradations generate negative externalities, and the loss or under-provision of these services due to forest degradations has a negative effect on other agents' utility or production functions.

On the contrary, not destroying these forest services through the conservation, protection and restoration of forest covers and resources, generate positive externalities; the aforementioned services are provided such that they enter positively into the forest user's and other agents' utility or production functions.

Such forest externalities arise because of the tensions between people's livelihoods that rely upon forest resources and the needs of providing these forest services through forest conservation. Such tensions, augmented by market failures such as unclear property rights, discourage forest users to integrate within their cost-benefit analysis the costs and benefits of their activities on society. Furthermore, the fact that forest resources are often used as a free public good makes that the agents do not pay to use the resources and does not have to compensate anyone when destroying them (Kay and Silberston, 1991). In the latter case, environmental resources have neither a price nor a market. Nonetheless, there exist situations in which a market does exist but the price of the resources on this market usually underestimate the total economic value of the resources. With respect to forest resources, their values are often limited to use values, i.e. extractive uses of forests, while forest resources also have non-extractive use values, e.g. the provision of the ES, and non-use values such as option and existence values which reflect one agent's willingness to pay for conserving the forest resources (Pearce, 2001).

As a consequence the lack of institution to pay to use the resources and when the institution does exist, the underestimation of their value have encouraged the development of different tools and policies. Such tools and policies are assumed to create the connection between the private agent and the society in order to reestablish the equality between private and social optimum.

3.2.2 Tools and policies to deal with environmental externalities

Pigou (1920), Coase (1960) and Baumol and Oates (1975) are the three most influential studies on policy responses dealing with environmental externalities. As early as the 1920s, Pigou (1920) argued that to internalise environmental externalities the agent should pay a tax when its actions negatively affect society. With such a tax it is more costly for the agent to produce and it would produce less (Kolstad, 2000). Such a tax creates property rights over the externalities, those being internalised.

Coase (1960) criticised Pigouvian tax saying that the ideal method for internalising externalities consists not in levying a tax on the originator of the externalities, rather in resolving the conflict in resource allocation so as to reach the social optimum (Cerin, 2006). Coase argued that in the absence of transaction costs, the originator of the externality and the one suffering from it can bargain in order to reestablish the optimum and the allocation of property rights over the resources does not matter. In addition, the Coase theorem specifies that if property rights are well-defined the resulting situation is efficient and any further actions would make everything worse (Medema and Zerbe, 1999). However, the limits of this theorem reside in its assumptions of the existence of clear property rights, no transaction costs or no wealth effect, these limits being an impediment of successful negotiations (Baumol and Oates, 1975, Kolstad, 2000). As a consequence, Baumol and Oates (1975) suggest that fees can be more efficient in resolving the problem of externalities but they explain that knowledge of marginal damages and marginal social costs as well as about the social optimum is required to implement efficient fees. Baumol and Oates (1975, 1988) advance three feasible tax-subsidy programmes: a charges-and-standards approach with or without direct control and taxes; subsidies; and a standards-and-permits approach.

The first policy consists of setting standards as targets in terms of environmental quality and developing taxes to reach these targets. Such policy differs from Pigou's fees in the sense that the objective is not to create taxes on the unknown value of marginal net damages but on the value of damages that is socially acceptable (Baumol and Oates, 1975).

In the second policy subsidies are used instead of taxes to reward any agent that has decreased the negative externality. The last policy consists of distributing permits according to standards and the information on baseline levels, permits being subsequently traded among permit holders on a market. The price of the permits is established through trade and so the socially acceptable levels of externalities is determined (McGartland and Oates, 1985, Baumol and Oates, 1988).

From these three mainstream schools of thought, there have arisen international programmes and policies designed to internalise the environmental externalities through the promotion of a more sustainable management of environmental resources. These policies vary from the use of environmental taxes and subsidies, as well as land acquisition, command-and-control policies, to integrated conservation and development programmes (ICDPs) and payments for environmental resources (PES). All these policies are aimed at encouraging agents to integrate the cost of using environmental resources when deciding their productions. The agents generating an externality would either be paid or taxed depending on whether the externality is positive or negative (Wunder, 2005). When using an environmental tax, a producer has to pay in order to use the production process that maximises its profit while it decreases other agents' utility or production function, while a subsidy encourages a producer to implement a production process which provides positive externalities (Kolstad, 2000).

With respect to PES within forest, a scheme consists in creating a market for an ES in which a forest user, responsible for supplying an ES when avoiding the creation of negative externality or when increasing the levels of positive externalities, and a consumer whose utility is positively affected by the ES, interact. Such interactions determine thus the value of a payment made by the consumer such that the forest user adopts forest practices that provide the amount of ES maximising the utility of the consumer.

In what follows, I focus on PES explaining how a consumer of an ES pays the supplier in order to encourage the latter to supply the ES. I want to understand whether or not such payments are able to smooth the tensions between conservation of environmental resources and the fact that people need such resources to generate their livelihood by analysing existing PES, their achievements and limits.

3.3 Payments for Environmental Services

Markets and payments for environmental services are mainly linked to forest uses and forest environments. Four main types of environmental services whose threatened provisions are in need of being secured, rely on forest resources and areas: watershed protection, consisting in regulating water flows and quality through the restoration and maintaining of forest covers; carbon storage and sequestration, achieved through both avoiding deforestation and reforestation; biodiversity conservation of endemic species (fauna and flora) whose losses and extinction are related to forest clearance; and landscape beauty and forest recreational values (Landell-Mills and Porras, 2002, Angelsen and Wunder, 2003, Wunder, 2005).

Because these services are generally free, poorly understood and taken for granted and because governments have taken insufficient actions to secure these services, there has emerged a market-based approach to their supply resulting in the creation of markets for environmental services on which buyers and suppliers of environmental services interact (Mayrand and Paquin, 2004, WRI, 2005, Duraiappah, 2006). In such a payment scheme, an ES buyer would pay an ES supplier to adopt more sustainable uses of forest resources such that the latter ensure the existence of an ES. PES schemes differ with respect to the type of ES buyers and suppliers, the nature of the ES provided and the payments.

A great number of PES schemes exists worldwide; here I present a Costa Rican case in which payments are made by a brewery to upstream land users in order to encourage them to protect a watershed, and a Nicaraguan case in which the Global Environmental Fund (GEF) pays upstream cattle ranchers to adopt silvopastoral activities such as protecting watersheds.

From these examples and the wider literature on case studies, the impacts on poverty and the provision of the ES can be analysed.

3.3.1 Definition and criteria of a PES scheme

A PES scheme relies on a user-payer principle stipulating that a user should pay when he uses an ecosystem service (Duraiappah, 2006). A PES scheme can be defined as being *"a voluntary transaction where a well defined ES (or land-use likely to secure that service) is being bought by a (minimum of one) ES buyer from a (minimum of one) ES supplier if and only if the ES provider secures ES provision (conditionality)"* (Wunder, 2005). It consists of a payment in cash or in-kind from an agent interested in, or benefiting from, conserving an environmental service, to an agent in charge of supplying this environmental service through an adaptation of his techniques or an adoption of new techniques (Pagiola et al., 2007b). PES can be an effective measure of welfare improvement in the sense that ES buyers and suppliers voluntarily participate in the scheme as long as the benefits are higher than the costs of providing ES, the payment creating an incentive to supply the ES (Mayrand and Paquin, 2004). In a PES scheme, participants want ex-ante to be better off than if they were not participating. If ex-ante they were worse off than when participating, they should not participate (Pagiola et al., 2007b). However, ex-post it could happen that the participants end up being worse off if such a payment stimulates the interest of more powerful agents in the appropriation of the lands that was pre-PES left to the poor (Grieg-Gran et al., 2005).

Actors in a PES can either be local private institutions or private agents that supply the ES and are paid by either local on-site forest residents, off-site regional (e.g. downstream water users), national (e.g. State, NGOs or urban tourists) or global beneficiaries (e.g. international community, foreign country buying certified carbon tradable offsets (CTOs), international NGO valuing biodiversity conservation) (Angelsen and Wunder, 2003, Mayrand and Paquin, 2004). Public schemes financed by the State (national or international) are assumed to affect larger areas of forest. While this may have a positive impact on the scale of forests protected, it may also multiply the number of objectives in the scheme and thereby decrease monitoring of how effectively payments have increased the provision of the ES (Wunder, 2005).

A large majority of PES schemes implemented are area-based in the sense that the payment corresponds to a specific number of forest units upon which ES suppliers must guarantee the provision of the ES to receive payments. For instance, an upstream livestock raiser would be paid to convert its pasture land back to forest in order to regulate water flows and protect watersheds for downstream users. On the other hand, some schemes are product-based. In this case, payments are made by consumers of a good manufactured through an environmentally-friendly production process and these payments are the premium linked to an agro-forestry production process of a type of coffee, ecotourism, or certified timber logging (Wunder, 2005).

Payments would be made either to protect a service against further degradation by restricting the use of some forest units to conservation (use-restricting PES) or to recuperate a lost service or create a new service by (re)building up the natural asset base of a deteriorated area (Angelsen and Wunder, 2003, Wunder, 2005).

An important requirement in a PES scheme is that the ES is effectively provided such that if there were no payments, the supply of the ES would be lower and environmental conditions would be worse. This last requirement refers to the notions of conditionality and additionality in receiving payments, both notions implying that the threat to environmental services must be credible. In the absence of payments, the loss of the ES would be the outcome, a payment ensuring that suppliers are providing more ES than without payments.

A last point worth mentioning, payments can either be in cash or in-kind though cash payments are assumed to be more flexible and more appropriate when ES supplier loses income-generating activity or factors when it has to change its forest-use income to provide an ES. On the contrary, in some rural communities, because cash payments might increase non-productive expenses in alcohol, cigarettes, or luxury goods, in-kind payments are preferred so as to increase the asset holdings of ES suppliers. While an ES buyer may prefer these payments for pro-poor motivations, some ES suppliers dislike in-kind payments that are often difficult to convert into cash and these suppliers would decide not to participate in a PES scheme if they do not receive cash payments (Wunder, 2005).

3.3.2 Existing PES schemes and achievements

Worldwide, existing PES are generally in forest areas but programmes outside of forest, such as the South African programme Working For Water, exist (Turpie et al., 2008), but because my focus is on developing PES scheme in forest areas, this section focuses on examples of well-documented PES schemes in Latin American forests.

As a general observation, PES programmes are more often implemented in Latin American than Asian or African countries. Here I select those most relevant to my purpose, emphasising those elements of a PES programme defined by Wunder (2005) and highlighting their results and limitations.

Among developing countries, Costa Rica has the largest number of PES, running for a period long enough to determine the impacts of specific payments on the provision of ES (Rojas and Aylward, 2003, Pagiola, 2008). In other Latin American countries, e.g. Nicaragua, a PES scheme has been implemented to refrain from converting forest into pasture and grassland thus improving carbon storage and protecting biodiversity (Pagiola et al., 2007a,b). Outside Latin America, recent PES projects in India and Nepal have been implemented to encourage upstream forest users to plant trees to protect watersheds, water users being as diverse as downstream communities or hydroelectric plants (Sengupta et al., 2003, Huang and Upadhyaya, 2007, Chalise, 2008).

Example of a PES in Costa Rica: Florida Ice & Farm Brewery

In Costa Rica, the first reference to PES occurs in a 1995 Forest Law in which forest protection is promoted through payments to forest owners. As a result, a programme called Pagos por Servicios Ambientales (PSA) was created encompassing several PES schemes dealing with the four types of ES mentioned above (Miranda et al., 2003, Pagiola, 2008). This programme has led to the creation of two main non-governmental organisations: a national forestry fund, FONAFIFO, and a technical organisation, FUNDECOR. The former collects payments from the ES users and redistributes them to the ES providers while the latter assists the forest users in designing management plans and monitors whether these are correctly implemented (Miranda et al., 2003, Mayrand and Paquin, 2004).

One of the projects within the PSA is a watershed protection project in the upper Rio Segundo Micro-Basin in the Virilla Watershed. While three main projects are underway in this area, I only present the payment project undertaken by Florida Ice & Farm Brewery which uses water resources for its production.

Forest degradations and deforestation in the upstream watershed due to urbanisation, poultry and livestock raising and use of chemicals in ornamental plant cultivation have led to water scarcity and water pollution, diminishing the availability of good quality groundwater to the downstream brewery production (Miranda et al., 2003). Consequently, in 2001 the brewery signed an agreement with FONAFIFO in order to promote forest conservation in the upper part of the watershed and to encourage upstream forest owners to conserve forest cover near rivers. This may involve rejecting livestock and pasture activities so as to restore quality and quantity of water available for its downstream production (Miranda et al., 2003, Rojas and Aylward, 2003).

The brewery pays FONAFIFO US$225,000 over seven years, equivalent to US$45/ha/yr, for forest owners in the upper river basin. A landowner in this area can apply to receive payments for the conservation of forest by designing a management plan incorporating elements such as the proposed land use, land tenure and topography information, proposed actions for preventing forest fires, and monitoring schedules. The landowner can ask FUNDECOR to help him in drafting their management plan but in this case, after contracting with FONAFIFO for a period of five years, the landowner must pay 12% of the US$45/ha/yr to FUNDECOR (Miranda et al., 2003).

The five-year contract between FONAFIFO and the landowner is renewable according to past performances in forest conservation and the availability of funds. The brewery gives US$1,500/month for 12 months to contract FUNDECOR to act as an intermediary in the evaluation of the management plans and to monitor within forests under contract that forest users have performed the actions corresponding to their management plan.

If new land is added to the project, the brewery pays FONAFIFO US$14 for each new hectare to cover administrative expenses and pays US$15 to FUNDECOR through FONAFIFO per new hectare to be used for legal and technical advice (Miranda et al., 2003, Rojas and Aylward, 2003). As a result of this watershed conservation project, 1,000 hectares of forest land is under conservation.

However, the results from the Florida Ice & Farm project are quite ambiguous. Only a few cases are reported in which land use has switched from pasture or livestock to forest conservation or reforestation. Most of the forest under protection was already under forest cover and forest owners report that they would have conserved the forest even without payments (Miranda et al., 2003, Pagiola, 2006). As a consequence, the ES has been provided since improvements in water quality and quantity has been achieved. However, since the implementation of the PSA programme was concomitant with the implementation of a number of related policies in Costa Rica, whether this achievement is a direct result of the payments transacted or a result from these other policies remain impossible to say; one can question about the positive impact of the PES on forest conservation (Pagiola, 2006).

The effect of payments on land users' welfare are reported to be positive. The payments are generally high and represent a large part of the households' income. In addition, participants to the PES have received environmental education and training for tree planting. The programme has allowed participants to better secure their lands against squatters and it has helped to create different tree nurseries, markets for organic products, to erect fences preventing illegal logging (Miranda et al., 2003).

Nonetheless, high transaction costs in the waiting time between applications and formal agreements prevent small landowners from participating. Miranda et al. (2003) report that the project can thus have negative effects on small land users who not only do not benefit financially from this scheme but are made unable to use forests set aside for grazing livestock.

Example of a PES in Nicaragua: Regional Integrated Silvopastoral Ecosystem Management Project (RISEMP)

Another example of PES programme is the *Regional Integrated Silvopastoral Ecosystem Management Project (RISEMP)* launched by the Global Environment Fund (GEF) in 2002 in Nicaragua, Costa Rica and Colombia. This programme consists of protecting forests against increases in pasture land in forested areas and such a payment scheme is intended to promote silvopastoral techniques to restore two environmental services: biodiversity conservation and carbon storage (Pagiola et al., 2004).

In general, silvopastoral practices consist in planting high densities of trees in pastures, feeding livestock with foliage of trees specifically planted for this purpose and using fast-growing trees for fencing and wind screens (Pagiola et al., 2007a). These practices have several positive effects on land users' welfare and production including improved pasture productivity and production diversification into fodder, fruit or fuelwood extraction, and such practices are assumed to help biodiversity conservation and carbon sequestration (Pagiola et al., 2004). However, since land users do not consider the existence of these externalities when deciding their land uses, the RISEMP has been implemented in order to pay them to adopt such silvopastoral practices.

The RISEMP pilot project in Central Nicaragua in a microwatershed called Matiguás-Río Blanco is designed such that land users are contracted for either two or four years receiving a payment based on the increase in a total environmental service index (ESI) over their entire farm area (Pagiola et al., 2007a). This index comprises two indices: an index of biodiversity conservation, giving points for each land use taking into account the number of species of plants, birds, small mammals and insects and their spatial arrangements, the plot size, and fruit production; and an index of carbon sequestration attributing points to each land use according to their capacity to store carbon in the soil and through trees (Pagiola et al., 2004).

Payments are made ex-post by the GEF. But since the GEF assumes that the improvements in productivity resulting from the adoption of more sustainable land uses would be sufficient to motivate farmers, the payments are calculated so as not to cover the whole opportunity cost of adopting silvopastoral practices (Pagiola et al., 2004, Van Hecken and Bastiaensen, 2009).

Initially, a payment is done to the land users in order to eliminate the possibility that land users recognising the potential for increased revenues as a result of a lower initial ESI, may deliberately degrade their own forest land. The forest users are discouraged from cutting trees in order to achieve lower ESI and receive higher future payments (Pagiola et al., 2004, Van Hecken and Bastiaensen, 2009). Associated with the annual payment, some land users receive technical assistance in order to improve their land uses; the existence of this technical assistance seems to have been quite an important incentive for some households towards participating in the PES programme (Van Hecken and Bastiaensen, 2009).

Impacts of this programme can felt in a stabilisation of the total pasture size, a decrease in the size of degraded pasture in favour of improved pasture with trees, and the creation of living fences and fodder banks. Most of these changes occurred during the first two years of the pilot project during which increases in the ESI compared to the 2003 baseline were more easily observed. As a result payments were higher.

However, to some extent the adoption of these silvopastoral practices have also been motivated by an increase in milk price and a better connection of the farm to milk and dairy manufactures (Van Hecken and Bastiaensen, 2009). When the price of milk increases, farmers in the region have intensified their land uses, keeping cattle in pasture adjacent to the road or to the milk production centers therefore away from river banks, and planting trees to protect livestock from sun since, apparently, milking cows are not as resistant to the sun as meat cow breeds (Van Hecken and Bastiaensen, 2009).

As a result, environmental improvements have been noticed. The ESI has increased by 48% over this 6-year period with the carbon index increasing by 47% and the biodiversity index by 50%. More specifically in the pilot area, richness and diversity of bird species have increased and water quality improved significantly.

However this project has some limitations. These include high transaction costs linked to the number of ES suppliers, the migration of poorer landless farmers to agricultural frontiers in order to sell their labour, and the lack of an ability to monitor leakage that could result in putting more pressures on land that are not in the project (Pagiola et al., 2007a, Van Hecken and Bastiaensen, 2009).

Comparing both projects, it seems that results differ both in terms of provision of environmental services and in terms of impact on participants to payments. While in Costa Rica, impacts from the programme on forest and watershed conservation are quite hard to disentangle from other policies (Miranda et al., 2003), in Nicaragua, the use of an index in order to measure the adoption of silvopastoral practices seems more suitable to the assessment of additionality from the project. In addition, in contrary to Costa Rican land users, Nicaraguan cattle ranchers report having adopted forest-friendly practices as a result of being paid to do so. In the Nicaraguan case, in the absence of such payments, it does not seem that silvopastoral practices would have been adopted while in Costa Rica, land owners answer they would have conserved forest even without payments (Miranda et al., 2003, Pagiola, 2006, Pagiola et al., 2007a, Van Hecken and Bastiaensen, 2009).
With respect to impacts on participants, the programme in Costa Rica seems to improve the welfare of wealthier households while the project in Nicaragua attempts to improve the welfare of cattle-owners with different levels of wealth and herd size. However, neither of these projects seem to have an effect on the poorest who are often excluded since they do not own the land or have higher transaction costs for participating in these projects.

3.3.3 Issues and poverty impacts

When discussing PES and their effects, a number of issues arise: lack of additionality from payments, leakage and displacement of the externalities, and exclusion of the poorest from PES schemes (Mayrand and Paquin, 2004, Wunder, 2005).
Lack of additionality is related to the fact that PES has not brought any improvements in the conservation of the ES; it is not unlikely that the status of the ES after the PES is equivalent to what would have occurred without such a scheme. Proving additionality of a PES scheme is an important requirement for demonstrating that payments have improved

the provision of an ES. In Costa Rica, households engaged in the PSA report that even without payments they would have conserved forest, which shows that little additionality may have been created (Miranda et al., 2003, Pagiola, 2006).

Leakage is also another limitation in the positive effects from PES schemes; leakage consists in displacing the negative externalities that occurred in the PES area to another area not in the PES. In a carbon project, leakage results in a loss of net carbon benefits because households that prevented from burning and degrading forests located within the PES scheme, migrate to other areas where they are not restricted from fulfilling basic needs through slash-and-burn agriculture (Brown et al., 2000, Aukland et al., 2002).

Integrating the participation of the poor in the provision of ES remains a challenge for such payments programmes. PES are not designed as a tool for poverty alleviation and even if they can have indirect positive effects, e.g. through the provision of better quality natural resources, the prevalence of negative effects on the poor are must be dealt with if one wants to use PES to alleviate poverty pressures. When a PES scheme is implemented, the poor are usually excluded from providing the ES because of high transaction costs, but they may also end up being excluded from the use of the ES on which they rely to generate their livelihood.

By nature, PES could be a powerful tool for alleviating poverty. Payments allow households to diversify their income through provision of the ES and a well-provided ES improves the productivity of land. Households can also receive technical assistance in adopting more sustainable land uses, increasing their technical skills (Wunder, 2005). However, some specificities linked to the definition of PES prevent the poor from participating in the programme. PES require the ES suppliers to have clear and secure property rights on the land used in the scheme, however many poor households do not have such rights and are de facto excluded from receiving any payments. High transaction costs, e.g. costs for applying for a PES scheme, and costs to adopt new techniques are reported to be an important burden on poorer small landholders (Miranda et al., 2003).

In Costa Rica, the PSA programme has not been developed to target the poor and if poor households have received their land from the government or have received governmental benefits and subsidies, they are non-eligible to participate in the programme. Another impediment is linked to the fact that payments in Costa Rica are not high enough to allow the poor to make all investments required to adopt land uses suitable for the provision of the ES. These low payments associated with the lack of access impede poor households to participate in the programme since they are unable to adopt land uses providing the ES (Miranda et al., 2003).

In some countries, non-participants to the ES are excluded from using the land on which the ES is supplied. These non-participants are often forced to migrate to other areas where no such scheme exists, such migration potentially creating leakage. Furthermore, PES can have indirect negative effect on the landless poor who generate their livelihoods through slash-and-burn agriculture, working for timber logging companies or cattle ranchers, and NTFP and wildlife product extractions since the implementation of a PES may prevent their accessing to these sources of goods and income, pushing them further into poverty (Angelsen and Wunder, 2003, WRI, 2005, Wunder, 2005).

Pro-poor PES are nonetheless achievable though reliant on improvements in their definition and design. PES can be more flexible in the way they define ES suppliers; an ES supplier can be defined as all land users able to secure their lands impeding outsiders from entering it and or as a group of land users. Costa Rica recently has decided to relax the stricture that ES suppliers have a title on the land so that being able to safely secure the land is enough to participate in the PES (Pagiola, 2006). In addition, FONAFIFO attempts to reduce transaction costs by allowing farmers to join collectively rather than individually, payments being made to groups rather than individuals.

The following section develops what are the requirements to target the poor more effectively. I will present these points in the context of Cameroon looking at how PES implementations are feasible in a rural forested area in the country and what are the criteria to be sure that such a PES would be efficient in protecting environmental services and alleviating poverty.

3.4 Cameroon as an hypothetical forest conservation payment scheme

To illustrate the theoretical model of payments, I opt for a forest conservation scheme that consists in planting and taking care of indigenous species of trees in threatened forest areas. Since the ES provision is undertaken by households, the latter should live within or near forest areas vulnerable to degradation through households' activities or logging by external companies.

Cameroon is potentially an interesting country where to implement such a scheme; it has large remaining forest areas representing 42% of the national territory, i.e. 20 million hectares and these forests are threatened by diverse agents, e.g. subsistence farmers and timber logging companies (Mongabay, 2010b). Although remaining forest areas appear to be large, over the last decade, the deforestation rate has remained high and continues to increase; between 2005-2010, 1.07% of forest has been lost to logging and agriculture while only 0.94% was between 1990-2000 (Global Forest Watch, 2000, Mongabay, 2010b). Both rapid population growth and devaluation of the CFA francs in the mid-1990s have pushed households to clear more forest in order to meet their agricultural needs and encouraged the government to sell more logging concession rights (Global Forest Watch, 2000, Mongabay, 2010b). Recently, in spite of presumably more frequent and systematic government controls, pressures due to timber logging have been increasing (Global Forest Watch, 2000, Mongabay, 2010b). In addition, Cameroonian households, remaining poor, have not reduced their pressures on forest resources. As a result, both unsustainable timber logging and subsistence agriculture remain the main threats to Cameroonian forests.

This loss of forest resources is increasingly disturbing given the fact that Cameroon is one of the richest country in the Congo Basin in terms of biodiversity, with more than 8,000 species of plants of which 1.9% are endemic (Mongabay, 2010a). In 2000, Cameroon had more than 2,500 species of plants, mammals and birds per 10,000 squared kilometers (Global Forest Watch, 2000). 7.2% of the birds, mammals, amphibians and reptiles are endemic to Cameroon and because of forest losses and hunting, 6.7% of these species are threatened of extinction (Mongabay, 2010b). Forest degradations are causing irreversible effects and although the government tries to create protected areas, weak monitoring on whether or not the boundaries and rules within protected areas are respected, deflates any positive effect of these protected areas (Mongabay, 2010a).

As a response to increased pressures on forests, a new legislation, supported by the World Bank, has been implemented in 1994 to promote forest management and conservation by communities.

Prior to and as a result from this reform, different types of forest regimes coexist in Cameroon: permanent forests, including among other types of forests, protected areas and natural reserves, and non-permanent forests, including communal forests, private forests, and community forests, the latter being the innovation from the 1994 Forestry Law. Such a law is aimed at encouraging communities to create community forests in order to manage themselves forest resources and derive benefits from it (Global Forest Watch, 2005, MINFOF, 2009).

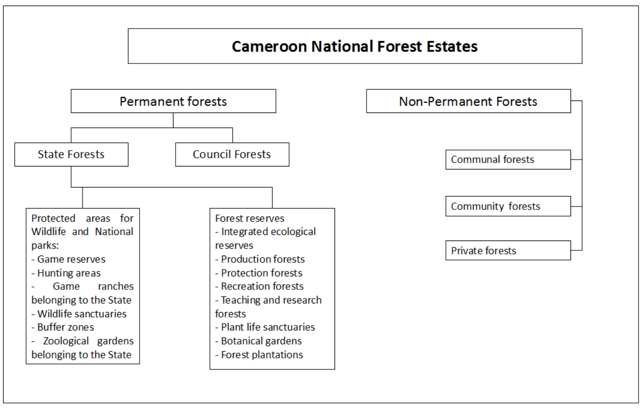
There exist moreover several previous conservation programmes, yet none of them taking the form of PES schemes for which the situation in Cameroon appears to be appropriate, the country presenting the criteria and except one case, results from these programmes are overall negative. Learning from this successful programme and failures from others, I present how a payment scheme could potentially be implemented in Cameroon so as to target poor forest households or communities.

3.4.1 Cameroonian forest estates: community forests and their limits to achieve conservation

By law 30% of the national forest are permanent forests comprising State forests including national and protected areas, production forest reserves to enable timber logging and council forests, these latter being either "artificial" or natural forests managed by municipalities (figure 3.1). The 70% of remaining forest is non-permanent encompassing private forests, owned by private agents, communal forests that are neither the property of the State nor of individuals, and community forests that are a subcomponent of communal forests upon which communities since the 1994 Forestry Law can manage, when obtaining enhanced user-rights (Egbe, 2001, Mandondo, 2003, Minang et al., 2007). Overall, while 2 million hectares of forest are protected areas (Mbilea et al., 2005), 621,245 hectares have received the legal status of community forests (MINFOF (2008) in Alemagni (2010)).

From the 1994 Forestry Law, a community forest is defined as *"a forest of the non-*

Figure 3.1: Forest estates in Cameroon



Source: Global Forest Watch (2005)

permanent state forest, object of a management agreement between a village community and the service in charge of Forestry. The management of such a forest shall be the responsibility of the village community concerned, with the technical assistance of the service in charge of Forestry"(MINFOF, 2009). With this Law, the Ministry of Forestry seeks to *"enhance the participation of the populations in the conservation and management of forest resources, in order to contribute in improving their living standards"*. In order to apply for this status, communities must delimit a forest area not exceeding 5,000 hectares and draw up a management plan describing uses of the forest area and its resources.

However after 15 years, the existence of community forests in Cameroon has not taken off, neither in terms of agreed status nor in terms of forest conservation. A large majority of the 135 community forests that have received their titles is engaged in timber logging, selling extraction permits directly to external companies and there exist no community forest engaged in conservation activities (Minang et al., 2007, Alemagni, 2010). Several factors explain the absence of conservation management plans in community forests in Cameroon.

Firstly, the Law even if promoting conservation does allow communities to contract with loggers, leading to an absence of interest in developing conservation plan. Secondly, since the costs of drawing up a management plan or traveling to Yaoundé in order to submit the application, can be extremely expensive for small communities, these latter often borrow money from logging companies to face such costs, in the end repaying their debt by granting rights to logging companies to extract timber resources from their forests (Global Forest Watch, 2000). Thirdly, uncleared on the exact status of a community, the Law grants the decision in defining such a community forest to local elites and leaders, likely to have close relationships with and/or interests in logging companies. Under such circumstances of corruption, management plans are more unlikely to withhold concession rights (Djeumo, 2001).

In the end it seems that as applied, community forests are not fulfilling their objectives of safeguarding and conserving forest heritage, and strengthening the participation of local populations in forest management. Timber logging remains the main form of management implemented within community forests, such an activity clearly decreasing forest resources.

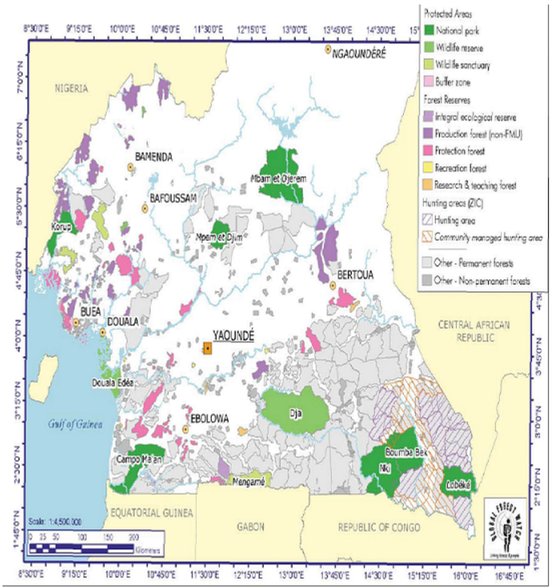
In addition, participation in community forests and related decisions seem to be restricted to a political upper-class, local populations rarely being consulted which diminishes their incentives to adopt sustainable forest practices. Both timber logging and villagers' unsustainable uses of forest lands increase pressures on forests in Cameroon.

3.4.2 Recent conservation programmes in protected areas or community forests

Besides community forests, Cameroon has created protected areas (figure 3.1 and figure 3.2) ranging from wildlife and forest reserves, protected for scientific purposes, to national parks, managed for ecosystem protection and recreational services (EarthTrends, 2003). While protected areas cover a fair scale of the Cameroonian forest estates, they are often reported as being weakly monitored, boundaries and regulations being rarely respected. In large, this is due to the fact that local populations, having been rarely consulted prior to the implementation of national parks, have been excluded either from using forest resources within the park while these resources contribute to their livelihoods, or from the management of the parks which could constitute an alternative source of revenue (Mbilea et al., 2005, Mayaka, 2002). As a consequence, poor households keep using and degrading forest resources in protected areas, the latter suffering inadequate protection.

As a response, recent efforts have been made to promote forest and biodiversity conservation by households living within or around these areas. For instance, the World Wildlife Fund (WWF) has become more and more involved in Cameroon, implementing projects

Figure 3.2: Biodiversity conservation and wildlife management



Source: Global Forest Watch (2005)

to regulate protected areas and to involve communities in the management of these areas and in the protection of biodiversity (Gardner et al., 2001, Mayaka, 2002, Mbilea et al., 2005, WWF, 2010). However, WWF programmes are too recent to judge their potential effects on forest households, while there exist other case studies that show that when local populations are involved, better results in terms of protection and respect of national parks boundaries could be expected.

For instance, in the Northern Province, a wildlife reserve has been created without any prior consultation of the local populations and as a result this reserve had ambiguous effects on wildlife conservation and negative effects on the inhabitants of poor villages surrounding the reserve (Mayaka, 2002). Indeed, villagers have lost large shares of their agricultural production due to damages caused by animals since there were no fences impeding the animals from the wildlife reserve from their plots. Presumably, even if not legally allowed to, villagers may have caught animals in the traps that often surround their plots. As a result, conservation impacts are undermined since villagers illegally kill the animals. However, such project could have offered economic measures to farmers so as to better achieve better conservation. Villagers could have been compensated for the loss of their crops and of livestock due to wildlife, and they could have been allowed to hunt game for commercial purposes. In addition, subsidies for the production of cotton near the reserve should have been cut such that farmers would have relocated their production away from the reserve, therefore diminishing their losses due to wildlife (Mayaka, 2002).

Another example deals with the Korup National Park in the Southwest Province. Attempts to extend its boundaries as to include a great number of villages within the park are in conflict with a lack of recognition that villagers use resources from the park to generate their livelihoods. Villagers are excluded from using such resources upon and not permitted to participate in the management of the park. As a consequence, villagers are pushed to use illegally forest resources, undermining the efficiency of the park in its mission of forest conservation. In order to be sure of decreasing pressures on park resources, local populations must be recognised as legal residents of the park and be able to participate in its management such that villagers keep their user-rights on forest resources and encouraged to adopt more sustainable practices (Mbilea et al., 2005).

While these two first cases show that villages are not often neglected when deciding the management of their surrounding forests, the Kilum-Ijim forest project is an example showing how communities participate in forest conservation Gardner et al. (2001). The Kilum-Ijim project was first developed to protect the forest area applying for a natural reserve status. However, the presence of 44 communities near the forest has led the conservation organisation in charge of forest conservation, to assist local communities to apply for a status of community forest with a management plan dedicated to forest conservation. This conservation organisation has helped the communities to include in their management plan a number of measures to ensure long-term biodiversity protection in the forest. In addition, this organisation has offered villages training in agriculture, livestock raising and other forest and non-forest related activities which should improve villagers' welfare while reducing pressures on the Kilum-Ijim forest.

However even if this last programme has made such efforts towards including local populations in the management of forests, doubts arise concerning the existence and persistence of net positive effects on both forest resources and forest households' welfare once the organisation has finished its training and support to the communities. In the Kilum-Ijim forests, households participate in the conservation programme because the organisation strengthens all the benefits they can derive from secured and healthy forest resources. It is true that forest households benefit greatly from forest conservation through enhanced agricultural productivity and improved availability of forest resources, but presumably villagers were aware of the existence of such benefits prior to the intervention of the organisation and this has not reduced their incentives to degrade forest areas. Within this project the communities are responsible for providing biodiversity protection through an adaptation of their forest uses without being compensated for changing their agricultural production process that was, even if more degrading, presumably giving them greater returns.

Consequently, once the organisation has gone, one can wonder what would impede villagers to use their old practices since they can feel that no one in the end is interested in the conservation of their surrounding forests. Giving payments is then expected to provide signal and incentive to encourage villagers to conserve forests. Payments show that an organisation derives its utility from the preservation and conservation of forest resources and that the actions of the villagers are meaningful and valuable. Through payments, forest households are entitled to be legitimately included in the management of the resources upon which they generate their livelihoods and to be financially compensated from providing forest conservation that increases the utility of another entity.

3.4.3 Elements of an hypothetical forest conservation payment

Following the Kilum-Ijim example, it is true that local populations in Cameroon understand the importance of conservation measures within forest areas, but it seems more reasonable to say that compensating villagers would be a more efficient way of ensuring that conservation is achieved. Looking at two provinces in Cameroon, South and East, I can define what are the threats to forests in these areas, what should be the aim of a forest conservation and who should be in charge of conserving forests against payments.

Forest covers in the South are greatly fragmented, resulting from an unsustainable expansion of subsistence agriculture which impedes forest resources to regenerate from damage caused by timber logging over the last 20 years. In the East Province, forests are less fragmented but highly-threatened by the presence of timber logging companies that harvest, either legally or illegally, valuable species of timber without caring about the regeneration process of such timber (Mongabay, 2010b).

The problem is then to conciliate forest conservation practices with households' needs of using subsistence agriculture and forest resources to generate their livelihoods. From my own research in the South Province, households living in forest areas depend upon both agriculture and forest resource extraction to meet their basic needs and generate their livelihoods. Households dedicate a non-negligible part of their labour time in forest-related activities and if anything households can improve their welfare when participating in such activities. However, the expansion of agriculture in the forest has decreased the availability of forest resources and increased the likelihood that small game destroy agricultural plots in search of food. As common, households protect their plots from such invasion with traps all around their plots, and consequently, agriculture, besides increasing degradations and impeding forest regeneration, becomes responsible for the loss of small game.

Threats to forest and biodiversity are a concrete reality and from my interviews, households acknowledge that forest conservation is possible but they also reckon that they have no incentives to do so. At the time of my research, one village in the South had obtained the status of a community forest but obtaining such status with a management plan consisting in selling concession rights to logging companies. The other villages surveyed were trying to apply for a community forest but none of them mentioned that their management plan would be directed towards forest conservation.

Incentives inducing forest conservation should be given such that payments become an alternative to timber logging payments and to revenues from agriculture for the suppliers of forest conservation. According to the Law, any association, cooperative, common initiative group or economic interest groups can apply for the status of community forest (Minang et al., 2007, MINFOF, 2009). Using this unclear definition, I assume that in this hypothetical forest conservation, women's associations should organise themselves to provide forest conservation and apply to obtain enhanced user-rights on forests. Women in Cameroon are both in charge of production of food crops and extraction of NTFPs essentially used for home-consumption but also in charge with trade of crops and NTFPs (Ruiz Perez et al., 2002, Kumase et al., 2010). As a result women have greater benefits from sustainably-managed forests with less game destroying their plots, better NTFPs and alternative sources of earnings from agriculture and NTFP extractions.

In addition, empowering women and paying them to conserve forest resources are assumed to have additional positive externalities such as children's education, such decisions being usually left to the women, and a better management of financial resources in the household to access credit and improve agricultural production or other activities. Paying women groups to ensure forest conservation could have greater impact on poverty and improve households' welfare.

In this hypothetical forest conservation payment, assuming that there exists an international NGO or any other entity, interested in conserving their forests, these groups of women, from now on referred as forest groups, need to agree with the NGO about a management plan in which payments and levels of forest conservation must be defined. With such a management plan, forest groups can apply for the status of community forest and after receiving it they can start supplying forest conservation.

However because corruption is widely spread in Cameroon, I assume that forest groups can default and after receiving their enhanced-user rights, they can still decide to sell concession rights to logging companies or use community forests for agriculture. As a consequence, the payments upon which the NGO and forest groups have agreed must take into account such alternatives. The following game examines how these payments are defined such as ensuring that a forest group participates in forest conservation, and plants and conserves high levels of trees.

3.5 Developing a forest conservation scheme using a principal-agent game

In the following payment for conservation scheme, I consider an ES buyer as being an international non-governmental organisation (NGO) interested in forest conservation and an ES supplier as being a forest group in Cameroon composed of women of a village. Both the NGO and the forest group have agreed upon a management plan consisting in planting and conserving trees within the 5,000 hectares of forest for which the group has received from the Ministry of Forestry and Wildlife enhanced-user rights.

By implementing such a forest conservation scheme, the NGO wants to curb the loss and depletion of forest resources, leading to decrease in the diversity of trees, plants and animals. Such loss and depletion are assumed to be mainly due to unsustainable agriculture and over-exploitation of forest resources through timber logging and extractions.

The forest group decides to participate in this scheme in which it supplies an environmental service, e.g. tree conservation, to an NGO paying for the supply of this service. The effort made by the forest group to provide the ES is in terms of time spent finding seeds, making cuttings, replanting small trees, pruning and caring for the trees once planted.

However, the forest group could have chosen another management plan for the forest area such as contracting with a logging company or using the forest cover for unsustainable agricultural purposes. Payments to conserve forest should compensate the community forest to forgo these options. However, I assume that within the conserved area, the forest group is allowed to develop agro-forestry practices and extract NTFPs. However, NTFP extractions are limited in terms of quantities extracted such that the forest group can ensure the sustainability of extracting these resources.

In the forest conservation scheme the two stakeholders have opposite objective functions. The NGO paying for forest conservation wants the group to spend as much time as possible finding the seeds, making cuttings or taking care of the trees at a least cost while the forest group wants to spend as little time as possible doing such tasks while receiving high payments.

Such an opposition in their objective functions sheds light on the fact that a forest conservation scheme presents the characteristics of a principal-agent game in which the principal is the ES buyer, and she delegates the provision of the ES to an agent being the ES supplier.[1] I assume that the international NGO has her offices away from the forest area and cannot observe the time the ES supplier spends providing the ES. It is too costly for her to monitor how much time the forest group spends planting and taking care of the trees. Delegation becomes problematic and a moral hazard situation arises.

[1] As in Maskin and Tirole (1990), I will refer to the principal with a female pronoun and to the agent with a male one.

However, using satellite images, the ES buyer can observe the outcome, i.e. the size of forest planted with new trees, and she remunerates the agent with payments corresponding to the observed outcome. I assume in this game, that she cannot observe the diversity of trees planted only the scale. The NGO defines transfers corresponding to the different levels of outcome so as to incentivise the ES supplier to allocate his time to planting and taking care of the trees.

When defining such transfers, the ES buyer must take into account the loss of reservation utility the ES supplier bears when he decides to participate in the provision of the ES which instead of doing something else with forest resources.

The following analysis of a forest conservation scheme using a principal-agent game applies Laffont and Martimort's models of incentives and contracts when there is a moral hazard (Laffont and Martimort, 2002). I first apply their basic model with moral hazard and a risk-neutral agent. I extend this model to relax the assumption of risk-neutrality of the agent. Since the forest group receives enhanced-user rights for a period of 10 years, I define repeated payments.

In the section 3.6, I attempt to deal with specificities linked to payments for forest conservation such as resolving the problems of contracting with several forest groups whose types in terms of alternative uses of forest areas or alternative uses of time differ. I investigate how leakage arises from such a conservation programme and I look at what are the effects of a forest conservation programme on non-members of the forest groups.

3.5.1 Basic principal-agent game for a forest conservation scheme

In this game with moral hazard, the ES buyer cannot observe the time the ES supplier spends planting and taking care of the trees but the ES buyer can observe the outcome, i.e. the size of forest planted with new trees that grow to maturity, and she pays the ES supplier according to this outcome.

When participating in the game, the ES supplier can choose whether to spend a lot of time planting and caring for newly-planted trees or not. I assume that a weather shock, either positive or negative, or tree diseases can occur making the outcome from forest conservation known only when payments are received.

Formally, the game happens in four periods (figure 3.3). At time 0, the ES buyer offers a contract with transfers corresponding to different outcomes. At time 1, the ES supplier accepts or refuses the contract; if he refuses the contract, the game stops but if he accepts it, he chooses his effort in time 2. In time 3, the stochastic event occurs and the outcome is realised. In time 4, after observing the outcome, the ES buyer pays the agent with a transfer corresponding to the observed outcome (Innes, 1990, Laffont and Martimort, 2002).

In this game, the ES supplier has to make two different choices. Firstly, he chooses whether to participate in the game and lose his reservation utility or not to participate in the game and sells concession rights to logging companies or use forest for agricultural purposes. Secondly, the ES supplier chooses whether to exert a high effort and to incur a disutility associated with the time spent working in forest conservation or to exert a low effort and not to incur any disutility.

However, I realistically assume that the forest conservation agreement is poorly enforced; a lack of control in determining whether or not the terms of the contract are respected, encourages the forest group to sign the contract with the idea of exerting a low effort and selling illegally concession rights to a logging company. As a result, the ES supplier's second choice becomes whether to exert a high effort and to have losses due to greater disutility and forgoing his reservation utility from selling concession rights to logging companies or to exert a low effort plus selling illegally concession rights to a logging company.

When designing the incentives, the principal has all the bargaining power and offers a "take-it-or-leave-it" contract to the agent who decides to participate according to his self-interest (Sappington, 1991). The ES supplier chooses whether or not to participate in the game comparing his expected utility from the payments to the utility he could have obtained by contracting with a logging company or using the forest area for agricultural purposes. In what follows, this utility is referred as a reservation utility, U_R, and is assumed to be strictly positive.

In the forest conservation scheme, the high effort, $e = 1$, consists of spending more time planting new trees and taking care of these trees, while a low effort, $e = 0$, consists of spending less time planting new trees and taking care of these trees.

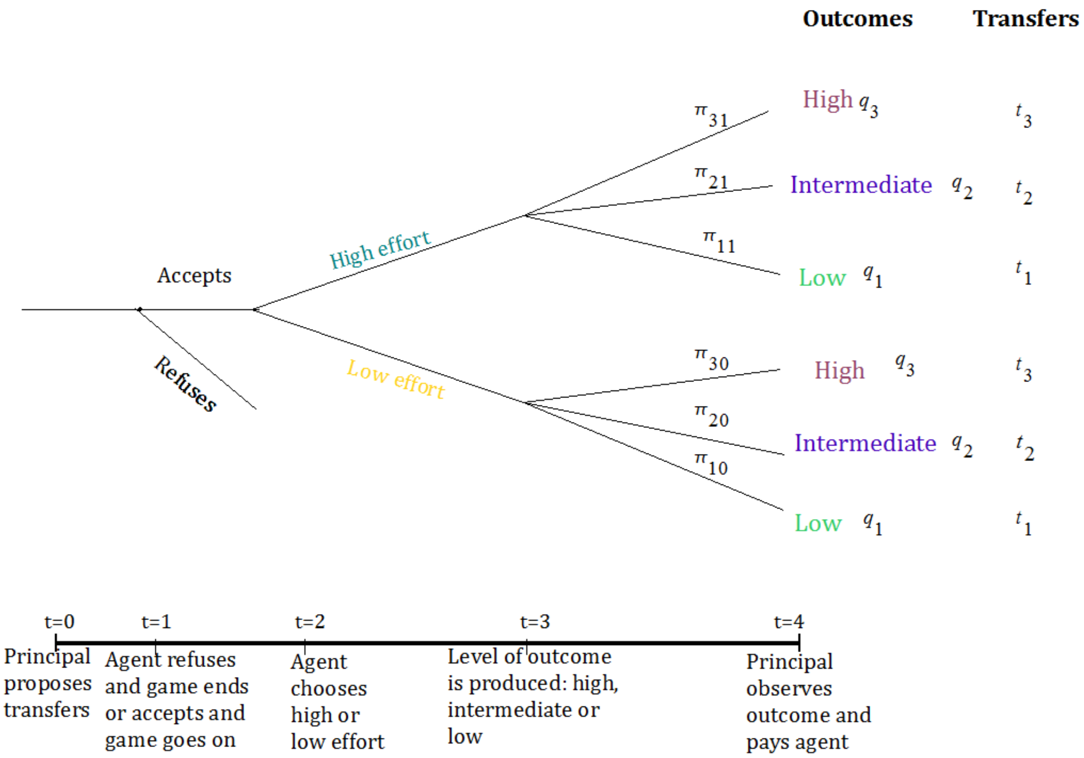
However there exist negative events, e.g. weather risks (flooding or drought), tree diseases or pests, that can prevent planted trees from showing signs of growing mature, or on the contrary, positive events facilitating tree growth and regeneration. As a consequence even when exerting a high effort, there exist a probability π_{31} that the outcome is high, q_3, with a large number of new young trees, a probability π_{21} that the outcome is intermediate, q_2, with a smaller number of such young planted trees, and a probability, π_{11}, that there are no new trees q_1. I assume that when exerting the high effort, the agent increases all chances to obtain the high outcome, negative weather can occur but it less likely to obtain the intermediate outcome and even less the low one such that $\pi_{31} > \pi_{21} > \pi_{11}$ with the latter probability tending towards 0, $\pi_{11} \to 0$.

If the agent is not taking much care and exerts a low effort, there exist probabilities π_{30} to have the high outcome, π_{20} to have the intermediate one and π_{10} to have the low outcome. However, it is quite unlikely that positive weather events favouring tree growth would be sufficient enough that the high outcome occurs and $\pi_{30} = 0$. On the other hand, positive weather conditions can make the ES supplier lucky and get the intermediate outcome. Overall, the probability to have a low outcome is higher than any other probabilities and

$\pi_{30} < \pi_{20} < \pi_{10}$.

In addition, I assume that for both efforts the sum of probabilities is equal to 1, $\sum_{i=1}^{3} \pi_{ik} = 1$ with the effort $k = 0, 1$ and I denote the difference between probabilities as $\Delta\pi_i = \pi_{i1} - \pi_{i0}$.

Figure 3.3: Sequence of game and tree of probability



The ES supplier's utility increases with the payments received through the PES but decreases with the time spent in the PES while he could have done something else; he has a separable utility function $U = u(t) - \psi(e)$, a function of the payment t received from the ES buyer and of the cost ψ of exerting one unit of effort. In this model, the unit of disutility of a low effort is null $\psi(0) = 0$ and the one of a high effort is such that $\psi(e) = \psi$. The agent's utility function $u(.)$ is increasing and concave $(u' > 0, u'' < 0)$ and the inverse function of u is $h = u^{-1}$, being increasing and convex $(h' > 0, h'' > 0)$.

The ES buyer has a utility function $v(.)$ which increases with the level of new trees planted but decreases with transfers made to the ES supplier. However, the ES buyer prefers the stochastic production distribution associated with a high effort $e = 1$ than with a low effort $e = 0$ and $\pi_{31}v(q_3) + \pi_{21}v(q_2) + \pi_{11}v(q_1) > \pi_{30}v(q_3) + \pi_{20}v(q_2) + \pi_{10}v(q_1)$.

The ES buyer needs to offer a contract with payments that encourage the agent to exert the high effort e. She offers a payment t_3 if she observes a high level of outcome q_3, t_2 if she observes an intermediate outcome q_2 and t_1 if the outcome is low q_1.

3.5.2 Incentives and transfers with moral hazard and a risk-neutral agent

In the basic model, both the buyer and supplier are risk-neutral meaning that both are indifferent to the risk linked to planting and conserving trees. To define a contract, the ES buyer offers payments to incentivise the ES supplier to participate in the game and to exert the high effort. I also assume that the ES buyer is able not to pay the agent but it may not be practical for her to tax him since the ES supplier does not have many assets and can pretend not to have cash to pay the ES supplier.

The ES buyer's maximisation programme can be written as follows

$$\max_{(t_1,t_2,t_3)} \sum_{i=1}^{3} \pi_{i1}(S_i - t_i) \tag{3.1}$$

subject to

$$\sum_{i=1}^{3} \pi_{i1}u(t_i) - \psi \geq U_R \tag{3.2}$$

$$\sum_{i=1}^{3} (\pi_{i1}u(t_i) - \pi_{i0}u(t_i)) \geq \psi + U_R \tag{3.3}$$

and

$$t_i \geq 0 \tag{3.4}$$

The first equation (3.1) refers to the ES buyer's expected utility when inducing a high effort in which S_i are the ES buyer's benefits in each state of nature and t_i are the transfers when she observes the different outcomes. The ES buyer has higher utility when she observes the high effort and consequently when maximising her utility with a high effort, she maximises her utility with a low effort.

The equation (3.2) is a participation constraint that ensures that the agent, when exerting a high effort, will receive at least his reservation utility U_R that he can obtain from selling permits to logging companies or using forest areas for unsustainable agriculture. In this forest conservation game, I assume that the utility of reservation is different from zero and positive.

The equation (3.3) is the agent incentive constraint in which the ES supplier prefers exerting a high effort rather than a low one. When making a high effort, the ES buyer promises the ES supplier transfers such that his expected utility with a high effort compensates him from his disutility of making the high effort and his reservation utility of not working with a logging company. Such a constraint stipulates that the ES buyer has to offer transfers such that the ES supplier exerts a high effort instead of exerting a low effort and selling concession rights to a logging company.[2]

The last constraint, called a limited-liability constraint, stipulates that all transfers must be nonnegative but they can be equal to 0 in some cases.

Analysing the different constraints, the participation constraint (3.2) is implied by the incentive constraint (3.3) and if the incentive constraint binds so does the participation constraint. The participation constraint is dominated and the resolution of the principal's

[2]If I do not consider the case that the ES buyer compensates the ES supplier from making an effort and from not defaulting, the two constraints are not binding at the same time. The ES buyer offers contract making assumption on the value of the disutility compared to the value of the reservation utility. According to these different cases, the ES buyer offers payments considering that the ES supplier has greater reservation utility than disutility or the reverse.

problem can be resolved using only the incentive (equation (3.3)) and limited liability constraints (equation (3.4)). The principal's problem can be optimised with respect to the transfers, using the multipliers λ and μ_i for respectively (3.3) and (3.4) which gives the following first-order conditions

$$-\pi_{i1} + \lambda \Delta \pi_i + \mu_i = 0 \tag{3.5}$$

for any $i = 1, 2, 3$ and with the slackness conditions that $\mu_i t_i = 0$ for $i = 1, 2, 3$.

When the second-best transfers t_i^{SB} are positive, the slackness conditions imply that $\mu_i = 0$, and this leads to $\lambda = \frac{\pi_{i1}}{\pi_{i1} - \pi_{i0}}$. Laffont and Martimort (2002) explain that if the ratio $\frac{1}{\lambda} = \frac{\pi_{i1} - \pi_{i0}}{\pi_{i1}}$ is different for each outcome i, there exists a situation j such that this ratio is higher. In such a situation j the agent receives a positive payment t_j^{SB} such that the incentive constraint (3.3) is binding. In the other situations $i \neq j$, the agent receives a transfer equal to 0. Such a contract rewards the agent only in the situation the principal has the best information so as to whether the agent has exerted a high effort.

If the ratio is nondecreasing in i, the probabilities for the different outcomes satisfy the monotone likelihood ratio property (MLRP), implying that information about the effort exerted by the agent increases with the outcome (Laffont and Martimort, 2002). Under the MLRP a higher effort leads to a greater probability of having the high outcome and the transfers must increase with the outcome produced q_i (Innes, 1990, Laffont and Martimort, 2002).

Returning to the forest conservation scheme, I assume that the most informative situation that the agent has exerted a high effort is when the principal observes q_3. The highest outcome can only be obtained through a high effort since I assume $\pi_{30} = 0$. In addition, when observing the low outcome q_1, the principal knows that there exists a greater probability that the agent has exerted a low effort since I assume that weather conditions cannot be as bad as destroying all new trees when an agent has exerted a high effort. The probability to observe the lowest outcome with a high effort tends towards 0, $\pi_{11} \to 0$.

Considering the intermediate outcome q_2, several situations may be described. There could be the case that it is more likely that negative weather conditions such as droughts or floods destroy part of the newly planted and conserved trees than that positive weather conditions favour the natural growth of trees. In such a case, the probability of observing the intermediate outcome with a high effort is higher than the probability of observing the intermediate outcome with a low effort $\pi_{21} > \pi_{20}$. On the contrary, weather conditions can be such that there is more chance to observe the intermediate outcome when exerting a low effort than with a high effort and $\pi_{21} < \pi_{20}$.

Using these different probabilities, the MLRP does hold and the ratio increases with the level of outcome

$\frac{\pi_{11}-\pi_{10}}{\pi_{11}} \to -\infty$ if $\pi_{11} \to 0$.

On the other hand, with $\pi_{21} > \pi_{20}$, $0 < \frac{\pi_{21}-\pi_{20}}{\pi_{21}} < 1$ and with $\pi_{21} < \pi_{20}$, $\frac{\pi_{21}-\pi_{20}}{\pi_{21}} < 0$ but the latter ratio is greater than $\frac{\pi_{11}-\pi_{10}}{\pi_{11}}$ since I assume that $\pi_{21} > \pi_{11}$.

With respect to the high outcome, $\frac{\pi_{31}-\pi_{30}}{\pi_{31}} = 1$.

The MLRP implies then that the ES supplier receives a non-zero transfer when the ES buyer has the greater certainty that the high effort has been exerted. The agent is rewarded with transfers such that

$$t_3^{SB} = \frac{\psi + U_R}{\pi_{31}} \tag{3.6}$$

and

$$t_1^{SB} = t_2^{SB} = 0 \tag{3.7}$$

The principal does not reward the agent when she observes the intermediate outcome since there exists a probability that the agent has made no effort in forest conservation. This "bang-bang" contract is supposed to reduce the agent's incentives to exert a low effort and to reduce the likelihood of having an intermediate outcome that does not provide any information about the level of effort exerted by the agent.

The limited-liability constraint is binding. The principal is limited in her punishments since $t_1^{SB} = t_2^{SB} = 0$. Since she cannot effectively punish the agent when he has made a low effort, the ES buyer induces the high effort by rewarding the ES supplier when the ES buyer can observe the highest outcome. The ES supplier receives an ex-ante limited-liability rent (equation (3.8))

$$EU^{SB} = \pi_{31} t_3^{SB} - \psi = U_R \tag{3.8}$$

The ES buyer is willing to give the ES supplier a rent equal to his reservation utility because in such a case she is sure the agent has exerted the high effort.

Inducing the high effort is optimal for the ES buyer since her expected utility with the high effort is greater than her expected utility with the low effort.

$V_1 = \pi_{31}(S_3 - t_3^{SB}) + \pi_{21}S_2 + \pi_{11}S_1 \geq V_0 = \pi_{30}(S_3 - t_3^{SB}) + \pi_{20}S_2 + \pi_{10}S_1$.

This equation can be formulated such that

$$\begin{aligned} V_1 - V_0 &= (\pi_{31} - \pi_{30})(S_3 - \frac{\psi + U_R}{\pi_{31} - \pi_{30}}) + (\pi_{21} - \pi_{20})(S_2 - 0) + (\pi_{11} - \pi_{01})(S_1 - 0) \\ &= \Delta\pi_3 S_3 + \Delta\pi_2 S_2 + \Delta\pi_1 S_1 - (\psi + U_R) \geq 0 \end{aligned} \tag{3.9}$$

This equation can be rewritten such that

$$\sum_{i=1}^{3} \Delta\pi_i S_i \geq \psi + U_R \tag{3.10}$$

The expected payment of the principal through this contract, meaning the cost of inducing a high effort, is

$$C_n^{SB} = \pi_{31} t_3^{SB} = \psi + U_R \tag{3.11}$$

The strategy to induce the agent a high effort is optimal for the principal if her gain is greater than or equal to the cost

$$\sum_{i=1}^{3} \Delta\pi_i S_i \geq \psi + U_R \tag{3.12}$$

With such a contract, the ES buyer has her cost greater than, or equal to, her gain.

Such a cost with moral hazard and limited liability is greater than the cost when the ES buyer can fully observe the effort (Laffont and Martimort, 2002). If there is no moral hazard, the principal pays the agent with a payment equal to his disutility of exerting the high effort and his reservation utility. Such a payment would not be a function of the probability of observing a high outcome or not. In addition, not imposing a limited liability constraint implies that the agent can be punished with negative transfers when he exerts a low effort and sells illegally concession rights to logging companies.

The ES supplier switches from a low effort to a high one as soon as his expected gain fully covers the cost of exerting a high effort and using equation (3.3), his gain is equal to $\Delta\pi_3 t_3^{SB} + \Delta\pi_2 t_2^{SB} + \Delta\pi_1 t_1^{SB} = U_R + \psi$.

A risk-neutral ES supplier will be induced to spend a lot of time planting or taking care of new trees when his cost of doing so is less than the cost the ES buyer to induce a high effort.

But risk-neutrality is a strong hypothesis and does not seem a reasonable reflection of reality in a forest conservation scheme; the ES supplier does not want to be the only one to bear the risk.

3.5.3 Risk-averse agent and risk sharing transfer

Introducing risk aversion in the game, the ES supplier becomes risk-averse and prefers a certain payment with a logging company rather than uncertain payments. When he contracts with the ES buyer to work in forest conservation, the agent decides his effort before weather conditions happen; even if he exerts a high effort, there is a chance that the resulting and observed outcome is intermediate. As a result, payments offered by the ES buyer should cover some of the risk otherwise the ES supplier will not participate in the game if there is no element of risk-sharing.

However, the ES buyer can choose to bear part of the risk instead of giving him full insurance. With an additional payment, the agent is not the only one to bear the risk, but he shares it with the principal (Sappington, 1991, Laffont and Martimort, 2002). As before I ensure that the ES buyer receives nonnegative payments by introducing a limited-liability constraint.

To ensure concavity of the principal's programme, the following changes of variable $u_1 = u(t_1)$, $u_2 = u(t_2)$ and $u_3 = u(t_3)$ and $t_1 = h(u_1)$,$t_2 = h(u_2)$ and $t_3 = h(u_3)$ with $h(.)$ strictly convex, are performed.

The ES buyer's programme can be rewritten as follows and is strictly concave in u_i since $h(.)$ is strictly convex.

$$\max_{(u_1,u_2,u_3)} \sum \pi_{i1}(S_i - h(u_i)) \tag{3.13}$$

subject to

$$\sum_{i=1}^{3} \pi_{i1} u_i - \psi \geq U_R \tag{3.14}$$

$$\sum_{i=1}^{3} (\pi_{i1} u_i - \pi_{i0} u_i) \geq \psi + U_R \tag{3.15}$$

and

$$h(u_i) \geq 0 \tag{3.16}$$

for any $i = 1, 2, 3$

As before, using μ and λ as nonnegative multipliers associated with respectively (3.15) and (3.16), a Lagrangian function can be written as follows

$$L = \sum_{i=1}^{3} \pi_{i1}(S_i - h(u_i)) + \lambda \left[\sum_{i=1}^{3} (\pi_{i1} u_i - \pi_{i0} u_i) - \psi - U_R \right] + \sum_{i=1}^{3} \mu_i h(u_i) \tag{3.17}$$

Resolving for u_i, the first-order conditions are

$$-\pi_{i1} h'(u_i) + \lambda(\pi_{i1} - \pi_{i0}) + \mu_i h'(u_i) = 0 \tag{3.18}$$

and this equation (3.18) can be rearranged such as

$$\lambda = \frac{1}{u'(t_i^{SB})} \frac{\pi_{i1} - \mu_i}{\pi_{i1} - \pi_{10}} \tag{3.19}$$

Again I assume that there is slackness in the game with $\mu_i h(u_i) = 0$. If there exists a non-zero transfer in a situation j, the slackness conditions imply that $\mu_j = 0$; as a result λ takes the following form

$$\lambda = \frac{\pi_{i1}}{\pi_{i1} - \pi_{i0}} \frac{1}{u'(t_i^{SB})} \tag{3.20}$$

Since $\frac{1}{u'(t_i^{SB})}$ and $\frac{\pi_{i1}}{\pi_{i1} - \pi_{i0}}$ increase with i, λ are different for any i and there exists a situation j such that λ is higher and positive. In such a situation j, (3.15) is binding. In the other situations, $\mu_i \neq 0$, the two constraints are not binding and the agent receives a transfer equal to 0.

As in the case of risk neutrality, the MLRP holds and information about the effort increases with the outcome. The ES buyer knows for sure that the ES supplier has exerted the high effort when she observes the high outcome. The ES buyer has once again no information about the effort exerted when she observes the intermediate outcome q_2.

Resolving the principal's problem with (3.15), the ES supplier is rewarded when the ES buyer can observe the high outcome and he receives

$$t_3^{SB} = h(u_3^{SB}) = h\left(\frac{\psi + U_R}{\pi_{31}}\right) \tag{3.21}$$

and in the case, the ES buyer observes an intermediate or low outcome she offers

$$t_2^{SB} = h(u_2^{SB}) = h(0) = 0 \tag{3.22}$$

and

$$t_1^{SB} = h(u_1^{SB}) = h(0) = 0 \tag{3.23}$$

The transfer received by a risk-averse agent in the case of a high-outcome is greater than the one received by a risk-neutral agent since the function $h(.)$ is convex, positive and increasing.

The cost of inducing a high effort when ES supplier is risk averse C_a^{SB}

$$C_a^{SB} = \pi_{31}t_3^{SB} + \pi_{21}t_2^{SB} + \pi_{11}t_{11}^{SB} = \pi_{31}h\left(\frac{\psi + U_R}{\pi_{31}}\right) \tag{3.24}$$

is higher than when the ES supplier is risk-neutral C_n^{SB} (equation (3.11)). The ES buyer has the same probability to pay a greater transfer since $h(\frac{U_R+\psi}{\pi_{31}}) > \frac{U_R+\psi}{\pi_{31}}$. Through this greater cost, she is bearing part of the risk borne by the ES supplier, and both ES buyer and supplier are sharing this risk. The ES buyer needs to compensate for the fact that the ES supplier prefers having a secure payment from a logging company U_R rather than participating in a forest conservation scheme in which payments are uncertain.

Paying more is rational for the ES buyer when her benefit from inducing a high effort is greater than her cost

$$\sum_{i=1}^{3} \Delta\pi_i S_i \geq \pi_{31}h\left(\frac{\psi + U_R}{\pi_{31}}\right) \tag{3.25}$$

The expected benefit of the ES supplier is equal to his cost, and both the expected benefit and the cost are greater when the agent is risk-averse than when the agent is risk-neutral.

Both when the ES supplier is risk neutral or risk averse, the contract offered by the ES buyer is “bang-bang” and the ES supplier receives greater payments when he has planted, conserved and taken care of the greatest level of trees. On the other cases, the agent receives null payments.

Through such a contract, the ES buyer induces the agent to exert the high effort, increasing the probability of having a greater level of forest conservation.

3.5.4 Repeated payments in a principal-agent game

The status of a forest group is often granted for several years implying that the forest group will receive repeated payments over time. Such repeated payments can be modeled as a two-period contract offered by the ES buyer at the beginning of the first period. Payments are made at the end of each period after observing whether the outcome is high, intermediate or low. In this two-period game, I assume that transfers are defined such that in the first period, the ES supplier is paid according to the first-period outcome while in the second period the agent is paid according to first- and second-period outcomes.

Using the same model, the risk-averse agent can exert in both periods the same high $e^m = 1$ or a low effort $e^m = 0$, with m being the period in which the agent exerts effort and $m = 1, 2$. His disutility of making an effort is the same in both periods and normalised as previously with $\psi(1) = \psi$ and $\psi(0) = 0$.

With the same notations as in the static game, the agent's effort brings a stochastic output independently distributed over time. In each period $m = 1, 2$, when exerting a high effort $k = 1$ or a low effort $k = 0$, there is a probability π_{3k} that the ES buyer observes the high output q_3^m, a probability π_{2k} that she observes the intermediate output q_2^m and a same probability π_{1k} to observe the low output q_1^m and $\Delta\pi_i = \pi_{i1} - \pi_{i0}$ with $i = 1, 2, 3$, each probability of observing one outcome being identical in each period.

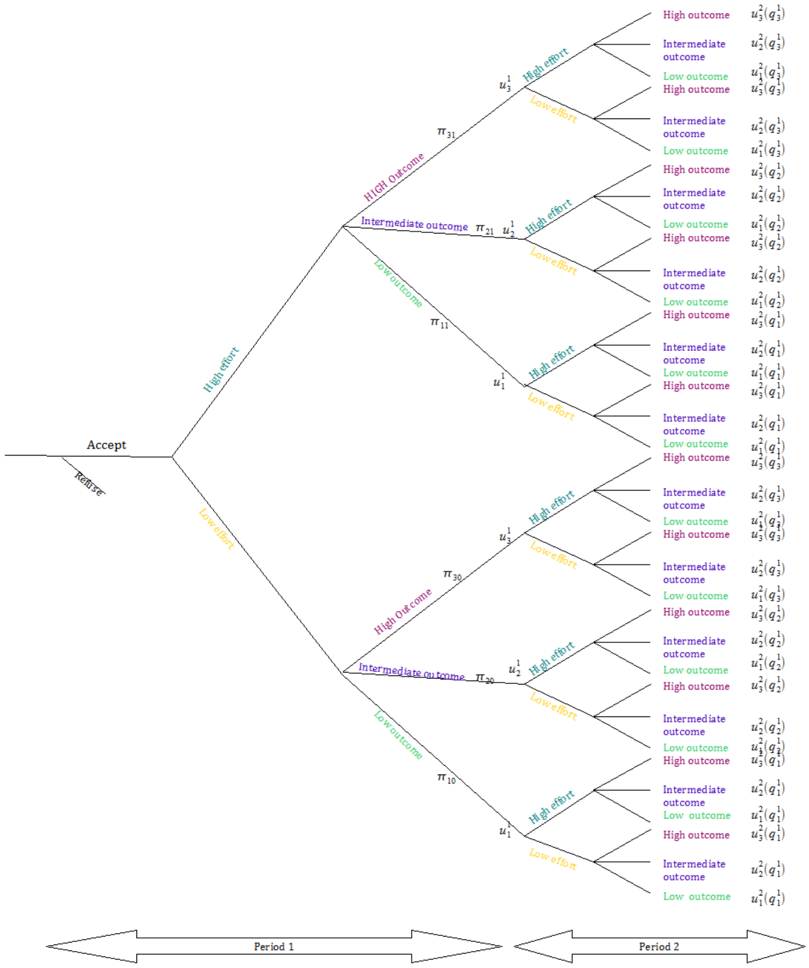
In a two-period environment, the principal offers a long-term contract which involves transfers at each date; she offers contract with payments $t^1(q_i^1)$ at the first period and payments $t_2(q_i^1, q_i^2)$ at the second period, payments in the second period being contingent on the observed first-period outcome.

In the first period, transfers can be rewritten as $t^1(q_3) = t_3^1$, $t^1(q_2) = t_2^1$ and $t^1(q_1) = t_1^1$. With the same modifications, second-period transfers are $t_3^2(q^1)$, when she observes the high outcome in the second period after any outcome in a first period, $t_2^2(q^1)$ when she observes the intermediate outcome in the second period after any outcome in a first period, and $t_1^2(q^1)$ when she observes the low outcome in the second period after any outcome in a first period, with $q^1 \epsilon \{q_3^1, q_2^1, q_1^1\}$.

As a result, the utility gains associated with each transfer are such that the agent's utility in the first period are only function of the transfers in this period, $u_3^1 = u(t_3^1))$, $u_2^1 = u(t_2^1)$ and $u_1^1 = u(t_1^1)$. The second-period utilities are functions of the transfers in the second-period contingent on the outcomes in the first-period. The utility associated with the high transfer in the second period after any outcome in the first period is $u_3^2(q^1) = u(t_3^2(q^1))$, the one when observing the intermediate outcome in the second period after any first-period outcome is $u_2^2(q^1) = u(t_2^2(q^1))$ and the one when observing the low second-period outcome after any first-period outcome is $u_1^2(q^1) = u(t_1^2(q^1))$ with $q^1 \epsilon [q_3^1, q_2^1, q_1^1]$.

The ES buyer wants to induce the high effort in the two periods; before accepting the contract, the ES supplier considers his expected second-period utilities whatever the outcomes the ES buyer has observed in the first period. The ES buyer should offer a contract

Figure 3.4: Expected payments in a repeated game



such that the ES supplier has his intertemporal incentive constraint written as follows

$$\begin{aligned}(\pi_{11}-\pi_{10})\left[u_1^1+\delta\sum_{i=1}^{3}\pi_{i1}u_i^2(q_1^1)\right]+(\pi_{21}-\pi_{20})\left[u_2^1+\delta\sum_{i=1}^{3}\pi_{i1}u_i^2(q_2^1)\right]+\\(\pi_{31}-\pi_{30})\left[u_3^1+\delta\sum_{i=1}^{3}\pi_{i1}u_i^2(q_3^1)\right]\geq(1+\delta)(\psi+U_R)\end{aligned} \tag{3.26}$$

with u_1, u_2 and u_3 being the current utility gains from each first-period transfer and $\delta\sum_{i=1}^{3}\pi_{i1}u_i^2(q^1)$ being the discounted expected utilities from the second-period transfers after any possible outcome in the first period.

The ES buyer also considers the agent's intertemporal participation constraint (equation

(3.27)) since the agent contracts before the outcomes q^1 and q^2 are observable

$$\begin{aligned}&\pi_{11}\left[u_1^1+\delta\sum_{i=1}^{3}\pi_{i1}u_i^2(q_1^1)\right]+\pi_{21}\left[u_2^1+\delta\sum_{i=1}^{3}\pi_{i1}u_i^2(q_2^1)\right]+\\&\pi_{31}\left[u_3^1+\delta\sum_{i=1}^{3}\pi_{i1}u_i^2(q_3^1)\right]\geq(1+\delta)(\psi+U_R)\end{aligned}\tag{3.27}$$

Subject to these two constraints, the ES buyer's problem is

$$\begin{aligned}&\max\pi_{11}\left[S_1-h(u_1^1)+\delta\sum_{i=1}^{3}\pi_{i1}(S_i-h(u_i^2(q_1^1)))\right]+\pi_{21}\Big[S_2-h(u_2^1)+\\&\delta\sum_{i=1}^{3}\pi_{i1}(S_i-h(u_i^2(q_2^1)))\Big]+\pi_{31}\left[S_3-h(u_3^1)+\delta\sum_{i=1}^{3}\pi_{i1}(S_i-h(u_i^2(q_3^1)))\right]\end{aligned}\tag{3.28}$$

However when the ES buyer resolves such a problem, she needs to take into account that at the end of the first period the reservation utility of the ES supplier has changed. According to the outcome observed at the end of the first period, the ES supplier knows that his reservation utility has changed and that he can expect different payments for the second period. Such a change makes the intertemporal game differ from a static problem.

Writing a continuation payoff for the second period as $\pi_{11}u_1^2(q^1)+\pi_{21}u_2^2(q^1)+\pi_{31}u_3^2(q^1)-\psi$, this is a function of the outcome at the end of the first period q^1 that the ES buyer has to consider when defining the second-period transfers. I assume that at the end of the first period, the agent can renegotiate his contract since either he has improved the quality of forest resources and knows that he can sell concession rights to logging companies for more, or he has experienced a loss at the end of the first period and prefers leaving the game and sells concession rights to logging company, even if at a lower price. As a consequence the ES buyer when defining the second-period transfers must take into account that the agent reservation utility has changed according to the outcome observed at the end of the first period. The continuation payoff must take into account this change in reservation utility. In the game such an increase in the agent's reservation utility leads to include in the participation and incentive constraint a function $g(q^1)$ which represents the change in the reservation utility the agent knows he can add to his reservation utility after the realisation of the first-period outcome.

After a high outcome, the ES supplier can sell concession rights at a higher price since he has improved the quality of forest resources and $g(q_3^1)$ is strictly positive. After an intermediate outcome, the agent may or may not have improved the quality of forest resources and his reservation utility may increase by $g(q_2^1)$ which could be positive or null. In the case of a low first-period outcome, the agent has not improved the value of forest resources and the ES buyer knows that the reservation utility has changed by $g(q_1^1)$ which is negative since the ES supplier has degraded forest resources in the first period for instance through the sales of concession rights.

The continuation contract for the second-period is such that

$$\max \sum_{i=1}^{3} \Big(S_i - h(u_i^2(q^1)) \Big) \tag{3.29}$$

subject to a second-period participation constraint

$$\sum_{i=1}^{3} \pi_{i1} u_i^2(q^1) \geq \psi + U_R + g(q^1) \tag{3.30}$$

a second-period incentive constraint

$$\sum_{i=1}^{3} (\pi_{i1} - \pi_{i0}) u_i^2(q^1) \geq \psi + U_R + g(q^1) \tag{3.31}$$

and a limited-liability constraint

$$h(u_i^2) \geq 0 \tag{3.32}$$

The second-period participation constraint (equation (3.30)) stipulates that considering the first-period outcome q_1 the ES supplier knows that his second-period transfer is going to be a function of the change $g(q_1)$ which conditions his sales of concession rights to the logging companies.

The second-period incentive constraint (equation (3.31)) stipulates that the ES buyer must define payments such that she compensates the ES supplier to make a high effort instead of a low effort and also to compensate him not to sell illegally logging concession rights which are revalued with the change in their reservation utility. The second-period limited liability constraint (equation (3.32)) implies that the ES supplier will not receive any negative payments at the end of the second period.

The second-period principal's problem is quite similar to the static problem presented in the previous subsection. The second-period participation constraint (equation (3.30)) is dominated by the second-period incentive constraint (equation (3.31)). Using the following Lagrangian multipliers λ and μ for respectively the incentive constraint (equation (3.31)) and the second-period limited liability constraint (equation (3.32)), as in the static game there exists a situation j in the second-period in which the agent receives a non-zero transfer. In this situation j, the incentive constraint is binding since λ is positive

$$\lambda = \frac{\pi_{i1}}{\pi_{i1} - \pi_{i0}} \tag{3.33}$$

if $i = 3$.

The MLRP holds; the agent receives a reward when the ES buyer observes the high outcome. The second-period utilities for each outcome are such that

$$u_3^2(q^1) = \frac{\psi + u_R + g(q^1)}{\pi_{31}} \tag{3.34}$$

and

$$u_2^2(q^1) = u_1^2(q^1) = 0 \tag{3.35}$$

The second-period cost function takes the following form

$$C^2(u^2(q^1)) = \pi_{31} h\left(\frac{\psi + U_R + g(q^1)}{\pi_{31}}\right) \tag{3.36}$$

Knowing this cost function, the continuation value payoff can be expressed as

$$V^2(u^2(q^1)) = \sum_{i=1}^{3} \pi_{i1} S_i - C^{SB}(u^2(q^1)) \tag{3.37}$$

for any $q^1 \epsilon \{q_1^1, q_2^1, q_3^1\}$. The derivative of a continuation payoff function is equal to

$$V'^2(u^2(q^1)) = -C'^{SB}(u^2(q^1)) \tag{3.38}$$

To offer a contract encompassing payments for the two periods that would keep the agent in the game after any outcome in the first period, the principal faces the following problem

$$\max \sum_{i=1}^{3} \pi_{i1}(S_i - h(u_i^1)) + \delta[\pi_{11} V^2(u^2(q_1^1)) + \pi_{21} V^2(u^2(q_2^1)) + \pi_{31} V^2(u^2(q_3^1)) \tag{3.39}$$

subject to the following constraints

$$\sum_{i=1}^{3} (\pi_{i1} - \pi_{i0})(u_i^1 + \delta u^2(q_i^1)) \geq \psi + U_R \tag{3.40}$$

$$\sum_{i=1}^{3} \pi_{i1}(u_i^1 + \delta u^2(q_i^1)) - \psi \geq U_R \tag{3.41}$$

with $u^2(q_i^1) = \pi_{31} u_3^2(q_i^1) + \pi_{21} u_2^2(q_i^1) + \pi_{11} u_1^2(q_i^1)$. The limited liability constraint is

$$h(u_i^m) \geq 0 \tag{3.42}$$

with $m = 1, 2$.

The first constraint (equation (3.40)) represents the incentive constraint through which the ES buyer offers payments such that the ES supplier is compensated from exerting the high effort in both periods and not to sell illegally permits to logging companies. The second constraint (equation (3.41)) implies that the expected utility of the agent over time when making a high effort and receiving a promised expected utility in period 2 equal to $u^2(q_i^1)$ is greater than the reservation utility. The last constraint (equation (3.42)) is a limited liability constraint for the first- and second-period transfers implying that the ES supplier receives a nonnegative transfer in the two periods whatever the outcome.

Analysing the incentive and participation constraint, the latter is again implied by the former; the ES buyer defines contract using only the incentive and limited-liability constraints. Using the multipliers λ and μ for each constraint, the problem can be optimised with respect to u_i^1 with $i = 1, 2, 3$.

The first-order conditions are

$$-\pi_{i1} h'(u_i^1) + \lambda(\pi_{i1} - \pi_{i0}) + \mu_i = 0 \tag{3.43}$$

and optimising with respect to $u_2(q_i^1)$

$$-\pi_{i1} C'^{SB}(u^2(q_i^1)) + \lambda(\pi_{i1} - \pi_{i0}) + \mu_i = 0 \tag{3.44}$$

From these first-order conditions, there exists an equality between the marginal cost of giving up some rewards in the first period following a first-period outcome q^1 and the marginal cost of giving up these rewards in the corresponding continuation of the contract in the second period

$$h'(u_i^1) = C'^2(u^2(q_i^1)) \tag{3.45}$$

Using the cost function (3.36), the first-derivatives are such

$$h'(u_i^1) = C^{'2}(u^2(q_i^1)) = \pi_{31}h'(u_3^2(q_i^1)) + \pi_{21}h'(u_2^2(q_i^1)) + \pi_{11}h'(u_1^2(q_i^1)) \tag{3.46}$$

Laffont and Martimort (2002) explain that these equations follow a martingale property and at the optimum

$$u_i^1 = u^2(q_i^1) + \psi \tag{3.47}$$

for any $q^1 \epsilon \{q_1^1, q_2^1, q_3^1\}$ and with $u^2(q_i^1) = \pi_{31}u_3^2(q_i^1) + \pi_{21}u_2^2(q_i^1) + \pi_{11}u_1^2(q_i^1) - \psi$.

Again there exists a situation j in which the agent receives non-zero transfers and $\mu_j = 0$.

$$\lambda = \frac{\pi_{i1}}{\pi_{i1} - \pi_{i0}}[h'(u_i^1)] \tag{3.48}$$

λ is positive in j and the incentive constraint is binding.

The MLRP holds in this case, and the ES buyer offers a non-zero transfer in the first period when she observes a high outcome which reveals that the ES supplier has exerted a high effort. In the other two cases, the ES buyer offers a zero transfer.

Using the binding incentive constraint (equation (3.40)), the ES supplier is rewarded in the first period when the ES buyer observes the high outcome. Resolving the problem, using the equality $u_i^1 = u^2(q_i^1) + \psi$ for $i = 1, 2, 3$

$$u_3^1 = \frac{\psi + U_R}{(1+\delta)\pi_{31}} \tag{3.49}$$

Whether the ES buyer observes an intermediate or low outcome, the reward is zero in the first-period

$$u_2^1 = u_1^1 = 0 \tag{3.50}$$

Using the relationship between the first and second period utilities (equation (3.47))

$$u^2(q_3^1) = u_3^1 - \psi = \frac{\psi + U_R}{(1+\delta)\pi_{31}} - \psi \tag{3.51}$$

and

$$u^2(q_1^1) = u_1^1 - \psi = -\psi \tag{3.52}$$

while after an intermediate outcome I assume that the ES buyer has to promise an expected utility equal to the reservation utility in order to keep the agent in the game

$$u^2(q_2^1) = U_R \tag{3.53}$$

Determining the value of the change in the utility reservation after each outcome I have

$$u^2(q_3^1) = \pi_{31} u_3^2(q_3^1) - \psi = U_R + g(q_3^1) = \frac{\psi + U_R}{(1+\delta)\pi_{31}} - \psi \tag{3.54}$$

giving $g(q_3^1) = \frac{\psi + U_R}{(1+\delta)\pi_{31}} - (\psi + U_R) > 0$

$$u^2(q_2^1) = \pi_{31} u_3^2(q_2^1) - \psi = U_R + g(q_2^1) = U_R \tag{3.55}$$

giving $g(q_2^1) = 0$ and

$$u^2(q_1^1) = \pi_{31} u_3^2(q_1^1) - \psi = U_R + g(q_1^1) = -\psi \tag{3.56}$$

giving $g(q_1^1) = \psi - U_R$ since $u_2(q_i^1) = u_1(q_i^1) = 0$ The utility associated with a high transfer in the second period after a high first-period outcome is

$$\begin{aligned} u_3^2(q_3^1) &= \frac{\psi + u_R + g^2(q_3^1)}{\pi_{31}} = \frac{U_R + \psi}{\pi_{31}} + \frac{1}{\pi_{31}}\left[\frac{U_R + \psi}{(1+\delta)\pi_{31}} - (U_R + \psi)\right] \\ &= \frac{1}{\pi_{31}}\frac{U_R + \psi}{\pi_{31}(1+\delta)} \end{aligned} \tag{3.57}$$

If she observes a high outcome in the second period, following an intermediate transfer in the first period, the transfer brings a utility equal to

$$u_3^2(q_2^1) = \frac{\psi + U_R + g^2(q_2^1)}{\pi_{31}} = \frac{\psi + U_R}{\pi_{31}} \tag{3.58}$$

and after a low outcome in the first period, she offers for a high outcome in the second period a transfer such that

$$u_3^2(q_1^1) = \frac{\psi + U_R + g^2(q_1^1)}{\pi_{31}} = \frac{\psi}{\pi_{31}} \tag{3.59}$$

The second-period payments offered when the ES buyer observes the low or intermediate outcomes are equal to zero after any outcomes in the first period and the utilities are

$$u_2(q_i^1) = u_1(q_i^1) = 0 \tag{3.60}$$

The ES buyer offers a contract in which transfers are greater in the case that the ES buyer has the greatest information that the ES supplier has exerted the high effort both periods. The ES buyer smooths the reward over time and punishes the ES supplier for not having exerted the high effort in the first period by offering a smaller transfer when observing an intermediate or low outcome in the first period and a high outcome in the second period. In this model, the contract presents some memory; if the ES supplier has in the first period planted and conserved trees such as having a larger size of area planted with trees, he is going to be compensated in the future by greater transfers. On the other hand, if the ES supplier works such that only an intermediate level of trees is conserved in a first period, the second-period transfers are smaller and he is punished for not having produced a high level of forest conservation in the first period.

Overall, this repeated game with memory appears to be more costly for the ES buyer. Payments to induce the agent to exert a high effort in both periods, are higher when she observes the high outcome in each period. Offering static payments may be a cheaper option for the ES buyer. But, with such static payments she would not take into account the fact that the reservation utility of the forest group has changed. The ES buyer needs to define incentives including the fact that over time forest resources changed and so does the forest group's reservation utility.

The ES buyer is willing to face such cost in order to have the agent to stay in the second period and she is sure that she is paying the agent only when he exerts a high effort.

Moving forward, the next section looks at the practicalities when dealing with different types of forest groups in terms of reservation utility and the disutility of making an effort. I also determine how to deal with specificities associated with a forest conservation scheme, including leakage and the effects of forest conservation payments on non-participants in a forest group.

3.6 Dealing with some specificities and limits of a forest conservation scheme

In this section, I look at some specificities and limits of a PES scheme. In order to conserve large forest areas, the ES buyer contracts with different forest groups and when doing so she must define contracts for different types of agents, i.e. agents with higher or lower reservation utility or agents with higher or lower disutility. Here I assume that the ES buyer does not know the type of the agents and that defining differentiated contracts is too costly. As a result, she needs to define an incentive contract so as to have all forest groups or to select specific forest groups.

In addition, the ES buyer does not want that the forest conservation programme increases pressures on nearby forests not included in the programme, and she must find incentives to encourage forest groups not to create leakage.

Finally I assume that there exists a selection-bias in the constitution of the forest groups since women participating in these groups may be from wealthier and more educated households while women from poorer households may be excluded from participating in the forest conservation programme. The last point of the following section presents how to increase the benefits of forest conservation for these non-participants.

3.6.1 Differentiating forest groups' reservation utilities

When contracting with several agents, the ES buyer needs to find how to conciliate the fact that all these forest groups may not have the same reservation utilities, with her objective of offering a single contract. In this case, a forest group with a high reservation utility (U_R^h) is assumed to have better forest areas than a forest group with a lower reservation utility (U_R^l). Since the transfers received by the ES suppliers are a function of their reservation utility, the transfers for the agents should differ depending on whether they have a high or low reservation utility.

Although, the ES buyer knows that there exist ES suppliers with different reservation utilities, she cannot differentiate each ES supplier according to his type. As a consequence, she decides to offer a single contract to all ES suppliers. To define such contract several options present themselves.

I consider then that when contracting with agents with a high reservation utility, the ES buyer attempts to avoid future degradations in these forest areas while when she contracts with agents with a low reservation utility, reforestation and restoration of forest cover are the expected outcomes.

If the offered contract depends upon the low reservation utility, when observing a high effort she offers

$$t_3^{SB} = h(u_3^{SB}) = h\left(\frac{\psi + U_R^l}{\pi_{31}}\right) \tag{3.61}$$

and when observing an intermediate or low outcome she offers

$$t_2^{SB} = t_1^{SB} = h(0) = 0 \tag{3.62}$$

With such a reservation utility, the transfers defined above are not high enough for the ES suppliers with a high reservation utility to participate in the scheme since their reservation utilities are higher than the expected utility from such a contract

$$\pi_{31} u_{SB}^3 - \psi = \pi_{31} \frac{\psi + U_R^l}{\pi_{31}} < U_R^h \tag{3.63}$$

These latter earn more if they sell concession rights to logging companies or use forests for agriculture and decide not to participate. If the ES buyer is not particularly keen on paying for avoided deforestation but is more interested in reforesting and replanting in highly degraded areas, such a contract would be strategic. On the contrary, if she wants to preserve and avoid deforestation or degradations in well-preserved areas, such a contract will not be efficient.

However, if the ES buyer wants to avoid deforestation in preserved forest areas, she can offer a contract in which transfers are a function of the high reservation utility.

$$t_3^{SB} = h(u_3^{SB}) = h\left(\frac{\psi + U_R^h}{\pi_{31}}\right) \tag{3.64}$$

Doing so she is certain that the ES suppliers with a high reservation utility participate in the game and so do ES suppliers with a low reservation utility.

$$\pi_{31} u_{SB}^3 - \psi = \pi_{31} \frac{\psi + U_R^h}{\pi_{31}} = U_R^h \tag{3.65}$$

However, such a contract is costly; her costs are higher than the expected costs she would have to face whether she could have differentiated between high and low reservation utility ES suppliers.

$$C_a^{SB} = \pi_{31} h\left(\frac{\psi + U_R^h}{\pi_{31}}\right) \geq v\pi_{31} h\left(\frac{\psi + U_R^h}{\pi_{31}}\right) + (1-v)\pi_{31} h\left(\frac{\psi + U_R^l}{\pi_{31}}\right) \tag{3.66}$$

with v being the probability that the agent has a high reservation and $(1-v)$ that the agent has low reservation utility. She ends up paying more the ES supplier with a low reservation utility.

The ES buyer may attempt to locate those forest groups with greater reservation utility. With respect to Cameroon, forests are highly degraded in the Province South of the country where logging has been intensive throughout the late 1990s. Logging companies are now more attracted to exploit forest areas in the East of the country where forests are well-preserved. Whether the ES buyer wants to preserve the Eastern forests or to reforest the Southern ones, she can offer differentiated contracts and locate the forest conservation scheme in one specific area.

If the ES buyer offer transfers with the lowest reservation utility to both forest groups in both Provinces, the forest groups in the East would not participate. On the other hand, if she offers transfers with the low reservation utility of the Eastern groups, forest groups with a low reservation utility in both Provinces participate. In addition, if Southern forest groups with a high reservation have a high reservation utility inferior to the low reservation utility of the Eastern forest groups, all forest groups in the Province South participate in forest conservation. However, forest groups in the East with a high reservation utility do not participate.

Defining transfers using an average reservation utility of all reservation utilities, the ES buyer can expect that all forest groups in the South participate in forest conservation while she is able to contract only with forest groups that have a low reservation utility in the East.

In the end, if the ES buyer aims at restoring forests such that carbon offsets can be traded within the Kyoto Protocol, she can offer payments with the high reservation utility of Southern forest groups to all groups and she selects only forest groups with highly-degraded areas. On the other hand, she offers greater payments such as encouraging Eastern forest groups not to increase pressures on forest areas. With such a payment she contracts with forest groups in the South and the East and even if she does not contract with forest groups with the highest reservation utility, she defines payments such that her utility is greater than it would be if contracting only with highly-degraded forest groups.

3.6.2 Forest conservation within high-return or low-return strategies

Whether the agents have diversified livelihood strategies including high-return or low-return activities their disutility to provide the ES varies. I assume that a forest group whose members are mainly involved in high-return activities, for instance cocoa production and trade, have a higher disutility (ψ_h) of providing the effort than a forest group whose members are mainly involved in low-return activities, e.g. subsistence agriculture (ψ_l). This assumption is drawn from the fact that the former households have livelihood strategies with greater returns than other agents. Supposedly, the ES supplier with a greater disutility is wealthier than the one with a lower disutility.

The problem again is that the ES buyer does not know who she is dealing with. Similarly as the case in which she does not know their reservation utility, the ES supply has different options.

She may want to have every forest groups participating in the forest conservation scheme and she has to compensate all agents with the high disutility. Doing so she is sure that the agents with more diversified livelihoods participate in the scheme.

The cost of such a contract for the ES buyer is greater than when she knows the agent's disutility. However, she is willing to pay more in order to have all agents to exert a high effort so as to have more probability to have the high outcome.

By giving higher payments for all types of agents, the ES buyer is actually rewarding more the ES suppliers with a lower disutility; this can be seen as a pro-poor mechanisms since these ES suppliers are poorer.

On the other hand, if the ES buyer is particularly keen in improving the welfare of poorer forest groups and does not mind not to have all agents to participate in the forest conservation scheme, she can define transfers employing the low disutility. The agents with a high disutility are neither willing to participate nor to exert the high effort but the ES buyer is sure that poorer forest groups participates; she is improving poorer forest groups welfare at a lower cost.

In Cameroon, my previous research reports that households living in the South Province have highly diversified livelihoods and overall, the South Province is wealthier than the

East one. As a consequence, if the ES buyer is particularly keen in implementing a pro-poor forest conservation project, she should offer contracts with transfers including the low disutility. She selects poorer forest groups in the East offering them a new strategy to generate their livelihoods. To conclude, implementing pro-poor forest conservation such as selecting forest groups with lower disutility is feasible with offering lower transfers. Such transfers are cheaper than offering greater transfers that incentivise both wealthier and poorer to participate.

3.6.3 Reducing leakage

In the previous model, the outcome is expressed only in terms of trees planted; the ES buyer is better off when more trees are planted. However, leakage may occur when the ES supplier increases forest pressures outside the forest area dedicated to a forest conservation scheme. In this case, I assume that leakage may consist in burning and clearing great size of nearby forests, and it is presumably created by the ES supplier and not by non-participants to the game. I assume that the ES buyer can perfectly observe leakage using satellite images.

In the game, leakage occurs after the ES supplier has decided to participate in the game and to exert a high effort. However, before starting the game the ES buyer can define incentives since she knows that there exists a probability β that the ES supplier does not increase pressures on a nearby forests and a probability $(1-\beta)$ that on the contrary he does so and creates leakage. The ES supplier creates leakage so as to obtain a benefit L out of it.

I assume that leakage can result from the fact that either transfers offered in the contract are not high enough so that the ES supplier must clear nearby forest in order to increase its revenue, or on the contrary, the transfers are high such as increasing the ES suppliers' demand of agricultural goods and encouraging them to adopt more degrading techniques.

Then, the ES buyer needs to redefine incentives such that the expected utility of the agent is greater when he is not creating leakage than when he is doing so.

The principal's problem is

$$\max \sum_{i=1}^{3} (S_i - h(u_i)) \tag{3.67}$$

subject to a participation constraint

$$\sum_{i=1}^{3} \pi_{i1} u_i - \psi \geq U_R + (1-\beta)L \tag{3.68}$$

to an incentive constraint

$$\sum_{i=1}^{3} (\pi_{i1} - \pi_{i0}) u_i \geq U_R + \psi + (1-\beta)L \tag{3.69}$$

and a limited liability constraint implying that the ES supplier does not receive negative payments

$$h(u_i) \geq 0 \tag{3.70}$$

Resolving this problem as previously, the utility linked to the transfer when the ES buyer observes the high outcome is a function of the probability that the agent exerts leakage.

$$u_3 = \frac{U_R + \psi + (1-\beta)L}{\pi_{31}} \tag{3.71}$$

The ES buyer offers a contract in which the transfer is greater and increases if the ES supplier is more likely to create leakage. With such a contract the ES buyer has defined appropriate incentives to be sure that the ES supplier would not exert leakage since his expected utility when not doing leakage is greater than his expected utility if he does so.

Besides the promise of greater payments, the ES buyer stipulates in the contract that if she observes leakage, she would fine the ES supplier since the above transfers are such that leakage resulting from low transfers are prevented, only leakage from greater payments remains. The ES buyer knows that leakage results from the fact that the ES supplier has been able to afford more degrading tools so as to degrade greater levels of forests.

The ES buyer can then create a fine f such that after having remunerated the ES supplier for providing a high level of forest conservation, she would punish him from creating leakage.

$$f = \frac{L}{1-\beta} \tag{3.72}$$

The principal defines a fine such that the ES supplier loses more after paying a fine than he has benefited from creating leakage.

With this contract including greater payments and a fine, the ES buyer is designing incentives such that the ES suppliers who could not fulfill their basic needs with the payments as defined in the previous section would not create leakage, while the ES suppliers that create leakage because payments allow them to adopt more degrading techniques, would pay a fine.

After paying their fine, the latter agents have a lower utility and knowing this result, they are incentivised not to create leakage.

3.6.4 Increasing benefits from forest conservation for poorer non-participants

As mentioned above, the constitution of a forest group may create a self-selection bias in favour of women from wealthier and more educated households. As a result, wealthier women benefit from an additional source of income while non-participants who are from poorer households do not receive such extra-income.

However it is interesting to acknowledge that there exist different channels through which a forest conservation scheme can create positive effects on non-participants. These latter benefit from better forest resources and better agricultural resources if they can still access some of them. Conserving forest decreases the likelihood that small game enters agricultural plots and destroy cultivations, it increases the availability of forest products in both protected and neighbouring forests through natural regeneration of forests. Non-participants can have more productive agricultural production resulting from better-quality soil and a decrease in the occurrence of floods and erosion. In addition, the forest conservation scheme can develop projects such as the construction of a school, training the community to prune trees or to treat trees against diseases, to develop trade of NTFPs...

In addition to these indirect effects, non-members of the forest group can benefit directly from the forest conservation payment if the forest group has decided to hire non-participants to provide the ES. These employees are in charge of planting and taking care of the trees while the forest group is in charge of monitoring that the employees are exerting the high effort.

Such a programme has been implemented in South Africa where the programme Working for Water consists in employing poorer households to control and clear mountain catchments of invasive alien plants so as to ensure biodiversity conservation and the protection of hydrological functions of watersheds (Turpie et al., 2008).

In the forest conservation scheme developed above, by hiring the poorest of the village to provide the ES, the forest group delegates the provision and becomes a manager for the ES buyer. Both manager and employees can exert high or low effort but while the ES buyer cannot observe the effort of the manager, the manager perfectly observes the effort of the employees if he exerts a high effort in monitoring.

When observing that employees are exerting a high effort, the manager offers a wage p_1 while if he observes the exertion of a low effort, the wage is p_0 that I assume equal to

0. Knowing that payments are strictly greater than 0 when exerting the high effort, but equal to 0 when making the low one, the employees have no incentives to exert a low effort when the manager perfectly observes their effort. On the other hand, when the manager exerts a low effort in monitoring, the employees have diminished incentives to exert the high effort since the manager does not know what effort they are making and may not compensate them accordingly if the observed outcome is intermediate or low.

I assume in this model of delegation that the employees are remunerated according to their effort while the manager is remunerated according to the outcome the ES buyer observes. Since the employees exert a high or low effort according to the effort exerted by the manager, the ES buyer needs to induce the manager to exert a high effort in monitoring.

The principal's problem can be rewritten as follows:

$$\max_{(u_3,u_2,u_1)} \sum_{i=1}^{3} \pi_{i1}(S_i - h(u_i)) \tag{3.73}$$

subject to

$$\sum_{i=1}^{3}(\pi_{i1} - \pi_{i0})u_i - (p_1 - p_0) \geq U_R + \psi \tag{3.74}$$

$$\sum_{i=1}^{3} \pi_{i1}u_i - p_1 \geq U_R + \psi \tag{3.75}$$

with

$$h(u_i) \geq 0 \tag{3.76}$$

Resolving this game as previously with the MLRP holding, the transfer is non-zero when the ES buyer is sure that the manager has done the high effort in monitoring the agents. The manager is paid only when the ES buyer observes this outcome and constraint (3.74) is binding. The utility from a high transfer when the outcome is high is

$$u_3 = \frac{U_R + \psi + p_1}{\pi_{31}} \tag{3.77}$$

and in the other cases, the utilities and transfers are zero $u_2 = u_1 = 0$.

Transfer when the ES buyer observes the high outcome is higher than previously; the ES buyer compensates the forest group for hiring out and exerting a high effort in monitoring the employees. The forest group has great incentives to exert a high effort in monitoring the employees since he knows that the latter would exert a high effort too which does increase the probability to obtain a high outcome.

With respect to the ES buyer, delegation increases costs and she is the one paying both manager and employees. Considering that the ES buyer wants to improve the welfare of the poorest, she needs to weight whether it is better for her to contract with a forest group that would hire out the poorest in order to plant and conserve trees or whether she is not better off when creating new infrastructure, training or markets besides paying the forest group to conserve forest.

3.7 Implications of this scheme in the light of existing PES and conclusion

Through logging and subsistence agriculture, households and companies heavily degrade forests in Cameroon and impede the provision of environmental services. To reduce the loss of such services and secure their provision, Cameroonian forest conservation efforts have been mainly directed towards the creation of protected areas which unfortunately appear to be inefficient in conserving forest resources, generally not taking into account that people living within or near protected areas use such resources to generate their livelihoods.

As a consequence to smooth these tensions, a 1994 Law has been promulgated in which a community can receive enhanced-user rights for managing nearby forest areas. At first the Law was unclear about the objectives of community forests but a 1995 Decree emphasises the importance of forest conservation for local communities and attempts to encourage communities to develop a management plan focusing on conservation.

However, when deciding upon their management plan, communities have greater incentives to sell concession rights to logging companies than to conserve forests. As a consequence, I consider that besides underlining the direct benefits derived from conservation, additional incentives must be defined to pay local populations for conserving forests whenever an external group consumes environmental services supplied by such an activity, e.g. biodiversity conservation, carbon sequestration, watershed protection or landscape beauty.

Since forest groups have different alternatives for their time use and their use of forest, they must be compensated such as covering their whole opportunity cost and such that the risk is shared between consumers of forest services and forest groups. Forest groups receive a non-zero payments when forest service consumers observe that high levels of forest conservation have been achieved and they receive zero-payments for all other outcomes. Over time, payments should increase if the forest groups have improved the quality of forest resources since these groups can have better alternatives than conserving forests. Although these payments seem unfair, what matters for forest-service consumers is the level of forest conservation achieved and they pay only when observing the greatest result they have agreed to pay for.

Such findings are derived from a principal-agent game in which an NGO, consuming forest services, offers an incentive contract such that she pays a forest group only when observing a high level of planted and conserved trees. In all other cases, she offers zero payments. After accepting such a contract the forest group rationally makes the high effort in conserving forests and is compensated with a payment greater than his disutility for not using his time in another activity augmented by the reservation utility he could have received if implementing another management of forests. If the forest group is risk-averse, the NGO needs to pay him more than when he is risk-neutral, this additional payment constituting a risk-sharing mechanism ensuring the risk-averse agent's conservation effort.

Over two periods, payments should differ from static payments given the fact that from forest group's past actions, forest resources have changed. If at the end of a first period high levels of forest conservation are observed, the forest group has improved the quality of forest resources and can expect greater alternative payments than if lower levels of forest conservation have resulted from his action. As a consequence, the NGO must define incentives such that the forest group is rewarded for conserving high levels of trees in each period. The incentives are such that payments increase over time when the forest group improves the quality of forest resources. The forest group is encouraged to create a virtuous circle in forest conservation.

Overall, these payments differ from the ones offered in the PES schemes in Costa Rica and Nicaragua. In Costa Rica and Nicaragua, ES suppliers are paid even if they have not effectively improved levels of forest conservation and payments received do not cover the whole opportunity of supplying the ES, respectively. In addition, payments either do not change over time or they decrease. This latter case is explained by the fact that payments, being only a function of increments in the supply of the ES, decrease following a great level of conservation in a first period since improvements in a second period may be harder to achieve and incremental points are smaller. In both cases, ES may stop participating if they realise that they could earn more from alternative options than from providing the ES.

With respect to pro-poor schemes, I find that the NGO can offer low payments such that only poorer and forest groups living in highly-degraded areas participate and provide high levels of forest conservation. Interestingly in Cameroon, poor forest groups are more likely to be in the East of the country while highly-degraded forests are in the South. As a result when offering low payments, the NGO may be able to select forest groups in both Provinces. Besides being effectively pro-poor, this scheme presents characteristics of an avoiding deforestation programme in the East and of a reforestation one in the South. Pro-poorness can also be achieved if the NGO develops a scheme including in-kind payments or encourages forest groups to hire presumably poorer non-participants to conserve forests. In the latter case, she defines greater payments so as to incentivise both the forest groups and the non-participants to exert a high effort in their respective task.

To stop leakage, the NGO defines greater payments and a fine. Consequently, forest groups creating leakage because payments were initially too low stop creating leakage while the ones still creating leakage have to pay a fine since the NGO knows that such leakage is created from the fact that forest groups could afford more expensive and more degrading techniques.

Further research should deal with analysing how to define the elements included in these payments, i.e. disutility and reservation utility, so as to value for these payments. This could be achieved with household and community surveys focusing on the activities households or forest groups are engaged in, and with environmental and satellite data to assess what are forest covers and the value of forest groups' reservation utility.

Moreover, it would be interesting to determine how indirect and direct effects from forest conservation and related payments affect participants and non-participants in the forest groups, and to understand the linkages between different environmental conservation practices within forest, e.g. effects and consequence of conserving in-land fisheries or developing biodiversity corridors.

Conclusion

Answering to my main research question, forest conservation policies can improve forest households' welfare through different channels.

In my research I demonstrate that forest households are poor and more likely to be poor over their lifetime even if there is no evidence for the existence of a poverty trap. Empirical evidence show that they accumulate assets over time but low initial levels of asset holdings associated with a slow accumulation process highlight the fact that forest households are more likely to remain in persistent poverty than to escape it. In addition, more frequent covariant and idiosyncratic shocks have adverse effects on asset accumulation, such shocks destroying households' asset holdings and degrading their living conditions. In addition, so as to cope with unexpected events, households can either sell undestroyed assets or get engaged in wage activities.

However such wage activities are often inefficient in helping households to become better off. Forest households are more likely to be wealthier when engaged in diverse activities including forest-related activities than when not engaged in such activities. Although agriculture remains their main source of production, the extraction of non-timber forest products (NTFPs) and hunting contribute to large shares of production, and households not extracting such products are overall worse off than households who do. Overall, even if a diversification into NTFP extraction pushes forest households to work more than others, they are also able to consume more. Furthermore, increasing the price of NTFPs is expected to have positive effects on households' welfare. Consequently, households are able to consume more so as to cancel out any potential negative effects of an increase in prices on their leisure. Contrary to what is stated in the literature, forest-related activities appear to allow households to improve their welfare. It appears that developing forest-related activities instead of unskilled or poorly-paid wage activities is a plausible solution to alleviate forest households' poverty.

Given these welfare results, forest conservation improving the quality of forest resources appears to be an adequate tool to improve households' welfare and protect forest resources. Furthermore, paying households to be in charge of forest conservation can decrease tensions between households' needs of using forest resources for their livelihood and forest conservation that if undertaken within protected areas impedes such uses. Thus, forest households benefit from forest conservation directly and indirectly. Direct benefits are derived from the payments that compensate households for forest conservation, such payments being made such that households are paid only if they are efficient in their levels of forest conservation. Households are only compensated for effective increments in the size of forest planted with trees. Such a contract gives households incentives to plant and conserve more trees. Households are insured against the risk of losing conserved trees with greater payments and over time, households are compensated for always improving forest conditions and for remaining in the forest conservation scheme while alternative revenues increase. A pro-poor forest conservation scheme can be implemented at a least cost when offering low payments such that wealthier agents are not willing to participate in forest conservation. Forest conservation is then used as a pro-poor mechanism.

Besides these direct effects from payments, forest conservation has indirect effects on forest households since it improves the quality of forest resources as well as the quality of other environmental services provided by forests and agricultural production. Indeed, when conserving trees within forests, water quality is improved and water flows are controlled.

This allows households to consume better quality of and greater quantities of fish, but also to have better agricultural production since small animals, able to feed themselves in forest areas, are less likely to destroy agricultural plots. Households' likelihood of selling their assets or of participating in wage activities decreases since floods are less likely to occur. As a consequence, forest conservation appears to allow households to smooth poverty pressures and to accumulate assets since households do not sell them as often as they used to. Such an asset accumulation linked to less risks and negative shocks on their consumption should enable them to escape poverty in the long run. Besides permitting households to accumulate assets, forest conservation increases prices of forest resources and if scheme allows households to extract a limited amount of better-quality forest products quantities, households can improve their welfare through the extraction of these resources and through increments in their agricultural and hunting productions caused by reduced shocks. As a result, households may have even more incentives to conserve forests and to develop forest-friendly or agro-forestry practices.

Knowing that forest conservation can improve forest households' welfare, more work can be done about forest households' livelihoods such as detailed assessment of households' participation in fisheries and hunting, the effects forest degradations have on these activities and how households can use links between forest and these sub-ecosystems so as to develop practices that can conserve both types of ecosystems. Further research could deal with how forest conservation can help households to develop new types of insurance and risk-coping mechanisms, encouraging forest groups to create microcredit organisations or to process forest or agricultural products which would allow them to store such processed products and smooth consumption. Furthermore, work still need to be done about the techniques households can use to secure their assets and develop higher-return forest-friendly activities. It would be interesting to understand what forces forest households to migrate and what are the consequences for households remaining within forests.

Defining the forest groups' reservation utility required to implement a forest conservation scheme could encourage further work on how to define forest values acknowledging whether all uses and non-uses values matter for forest conservation or only revenues offered by alternative activities matter. Finding forest values can be done using forestry data but also using experiments so as to have households revealing their preferences in terms of selling concession rights or conserving forests. Encouraging research on forest households' livelihood could help to precisely define what is forest households' disutility of conserving forests. This can be estimated using household and community surveys, focusing on households' time uses and different opportunities available at the community level, so as to find in which communities households have high or low disutility of participating in forest conservation and how differences between households or communities can affect the implementation of such a programme.

As a result of forest conservation practices, assessing whether direct or indirects benefits from forest conservation for households dominate would help to understand what kind of forest conservation practices are more likely to efficiently improve their welfare.

In the end, the assessment of the effects from forest conservation could be done such as understanding from which type of programmes, either reforestation or avoided deforestation, benefits for poor forest households are greater. Knowing what is best for the poor could help to settle the debate on whether or not to include avoided deforestation within Kyoto.

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Appendix A

Appendix Chapter One

A.1 Construction of the Consumer Price Index (CPI)

To construct a Consumer Price Index (CPI) within the research area, I start first calculating the total amount spent in each food commodity during the last 7 days by all the Tsimane' households and I calculate the total amount spent in all food commodities.

For the most important food commodities consumed by the Tsimane' households in 2006 such as bread, flour, lard, noodle, rice, cassava, maize, plantain, oil and sugar, I extract weights that I use afterwards to estimate a weighted sum of prices for each village using village level prices and overall weights. According to their availability I use village selling or village buying prices; agricultural commodities are reported using village selling prices while market food commodities are reported with village buying prices.

Over time prices of these commodities have mainly increased in all communities but the rate of change is slower between 2005 and 2006 than it is between 2002 and 2006.

Finally, I use the weighted sum of prices for these 10 commodities in each year and divide it by the weighted sum of village prices in 2006 in order to determine the price index used to deflate the values to 2006 prices. I apply the price index to prices in every years between 2002 and 2005 that are reported in nominal values.

Table A.1: Weights of different food commodities used in CPI and average weighted village prices in each commodity (standard deviation)

Food commodities	Weight in 2006	Average weighted prices (std dev.) 2002	2003	2004	2005	2006
Bread	0.07	0.20 (0.04)	0.19 (0.08)	0.19 (0.07)	0.19 (0.07)	0.20 (0.10)
Flour	0.01	0.05 (0.008)	0.07 (0.03)	0.05 (0)	0.07 (0.04)	0.06 (0.02)
Lard	0.01	0.15 (0.13)	0.10 (0.02)	0.16 (0.04)	0.19 (0.09)	0.17 (0.04)
Maize	0.007	0.07 (0.01)	0.08 (0.02)	0.08 (0.02)	0.10 (0.01)	0.12 (0.03)
Cassava	0.03	0.16 (0.006)	0.16 (0.01)	0.16 (0.01)	0.18 (0.03)	0.21 (0.05)
Noodles	0.02	0.12 (0.03)	0.13 (0.02)	0.16 (0.04)	0.16 (0.08)	0.14 (0.05)
Oil	0.03	0.29 (0.16)	0.25 (0.03)	0.34 (0.06)	0.38 (0.16)	0.41 (0.17)
Plantains	0.07	0.47 (0.07)	0.47 (0.07)	0.40 (0.04)	0.49 (0.10)	0.53 (0.12)
Rice	0.05	0.54 (0.07)	0.53 (0.07)	0.58 (0.12)	0.73 (0.13)	0.69 (0.12)
Sugar	0.04	0.18 (0.06)	0.21 (0.18)	0.20 (0.06)	0.22 (0.09)	0.28 (0.11)

Table A.2: Average of sum of weighted village prices and average price index in each village (standard deviation)

Variables	2002	2003	2004	2005	2006
Sum of weighted village prices	2.25 (0.41)	2.22 (0.30)	2.37 (0.21)	2.74 (0.44)	2.84 (0.38)
Village price index	80.31 (13.68763)	80.01 (16.96)	84.94 (12.64)	97.13 (14.11)	100 (0)

Overall inflation rate is similar in 2002 and 2003, and quite small in 2005.

A.2 Households strategies according to their wealth and earnings

I assume that a household is in a high-return strategy when it has its wealth and earnings in the two upper quintiles at least three years out of five which means that they are in a high-return strategy, or whether they are not in these two upper quintiles meanings that they are in a low-return strategy.

28 households have their earnings and assets at least three years in the two upper quintiles and are engaged in a high-return strategy, and 148 households are in a low-return one.[1]

[1] I am using the 176 households for which I have deflated values of consumption and assets, and I use this same deflator to deflate earnings.

Table A.3: High and Low-return strategy according to earnings and assets

Variables	2002 High	2002 Low	2003 High	2003 Low	2004 High	2004 Low	2005 High	2005 Low	2006 High	2006 Low
Sale	216.6	85.0	164.3	114.5	403.6	51.1	590.9	125.2	354.3	99.46
Wage	250.2	93.0	261.6	109.4	247.7	152.8	294.4	111.0	311.6	146.6
Total earnings[a]	490.7	201.8	473.0	246.2	692.7	225.7	954.0	300.4	718.6	285.8
Animal wealth	1746.5	467.8	1227.8	400.7	2141.4	558.8	2201.8	455.8	1527.7	377.1
Traditional wealth	1196.0	855.9	1179.7	797.2	1126.2	741.6	1281.6	832.9	1027.1	776.7
Modern wealth	4050.7	1687.9	4262.6	1824.2	4107.7	2103.5	4316.8	2331.1	3468.8	2062.4
Total wealth	6993.3	3011.8	6670.1	3022.3	7375.5	3404.0	7800.3	3619.9	6023.6	3216.2
Beef	1.3	1.3	1.6	2.0	2.1	1.3	1.6	2.0	2.8	2.3
Chicken	1.7	0.9	1.1	1.9	0.9	1.1	1.1	1.1	1.6	1.6
Plantains	2.1	3.4	1.9	2.8	2.1	1.9	1.8	2.3	2.0	2.7
Manioc	0.9	1.6	0.5	1.3	0.5	0.9	0.9	1.5	0.8	1.1
Noodle	1.9	1.1	1.7	1.0	1.6	1.5	1.4	1.3	0.6	1.0
Game	12.2	13.0	9.4	16.0	18.9	18.7	9.4	13.9	5.7	5.0
Fish	10.6	11.6	9.3	10.9	13.5	14.9	9.2	13.2	8.6	8.3
Total Consumption	41.7	41.4	36.6	46.7	52.3	49.2	38.6	49.1	35.7	34.5
Household characteristics										
Household size	8.8	6.2	8.8	6.2	7.8	6.3	8.8	6.5	8.1	6.5
Household age	22.4	21.6	20.1	22.2	22.5	21.7	19.5	20.9	20.4	21.8
Head Age	49.7	42.2	50.2	43.4	54.3	42.8	47.7	42.9	51.5	42.2
Household education	2.0	1.8	2.0	1.8	2.2	1.5	2.7	1.8	2.7	1.8
Agricultural production										
Rice production[b]	n/a	n/a	n/a	n/a	93.2	57.7	148.2	73.7	128.9	65.6
Rice sales	44.9	23.3	n/a	n/a	57.2	30.9	83	39	61.8	26.7
Corn production[c]	n/a	n/a	n/a	n/a	129.2	61.3	104.9	72.3	47.9	37.2
Corn sales	24.0	8.8	n/a	n/a	90.7	39.1	37.1	20.4	16.8	7.1
Plot size[d]	12.3	8.8	15.2	9.2	13.1	8.4	16.6	9.4	16.4	10.1

[a] Values deflated to 2006 prices
[b] in arrobas
[c] in mancornas
[d] sum of old-growth and fallow-forest; tareas

A.3 Factor analysis and asset index

Table A.4: Factor analysis/correlation

Factor analysis/correlation				Number of obs. = 870
Method: principal factors				Retained factors = 1
Rotation: (unrotated)				Number of params = 17
Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor1	3.71410	2.70345	0.7959	0.7959
Factor2	1.01066	0.47873	0.2166	1.0125
Factor3	0.53193	0.22753	0.1140	1.1265
Factor4	0.30440	0.06685	0.0652	1.1917
Factor5	0.23755	0.11913	0.0509	1.2426
Factor6	0.11842	0.07890	0.0254	1.2680
Factor7	0.03952	0.03596	0.0085	1.2765
Factor8	0.00357	0.02701	0.0008	1.2772
Factor9	-0.02344	0.02751	-0.0050	1.2722
Factor10	-0.05095	0.02502	-0.0109	1.2613
Factor11	-0.07597	0.02074	-0.0163	1.2450
Factor12	-0.09671	0.04845	-0.0207	1.2243
Factor13	-0.14516	0.05694	-0.0311	1.1932
Factor14	-0.20210	0.00992	-0.0433	1.1499
Factor15	-0.21201	0.02055	-0.0454	1.1044
Factor16	-0.23256	0.02228	-0.0498	1.0546
Factor17	-0.25484	.	-0.0546	1.0000

LR test: independent vs. saturated: chi2(136) = 3246.72 $Prob > chi2 = 0.0000$

Table A.5: Factor loadings

Variable	Factor1	Uniqueness
axe	0.5847	0.6581
bike	0.3118	0.9028
bow	0.5488	0.6988
canoe	0.3286	0.8920
cow	0.2032	0.9587
hook	0.6264	0.6076
knife	0.6825	0.5342
machete	0.7359	0.4584
mosquito net	0.7432	0.4477
net	0.4197	0.8238
radio	0.4404	0.8061
rifle	0.2467	0.9392
shot gun	0.3764	0.8583
size plot	0.4562	0.7919
gift	0.1662	0.9724
nb speak Spanish	0.2399	0.9424
dummy math	0.0810	0.9934

Table A.6: Factor scores

Variable	Factor1
axe	0.14333
bike	0.05572
bow	0.12669
canoe	0.05943
cow	0.03420
hook	0.16634
knife	0.20611
machete	0.25900
mosquito net	0.26783
net	0.08220
radio	0.08814
rifle	0.04237
shot gun	0.07076
size plot	0.09294
gift	0.02758
nb speak Spanish	0.04107
dummy math	0.01315

Table A.7: Summary statistics of variables used in parametric regressions

Variable	Description	Mean	Std Dev.
Change asset index	Change in asset index between two years	0.12	0.84
Lagged asset index	Lagged value of the lagged asset index	-0.06	1.11
Squared lagged asset index	Squared value of the lagged asset index	1.23	2.60
Cubed lagged asset index	Cubed value of the lagged asset index	1.59	11.52
Fourth degree lagged asset index	Value of the lagged asset index at the fourth-degree power	8.29	55.35
Age household head	Age of household head over all years	43.94	16.95
Squared age household head	Squared age of household head over all years	2218.30	1689.99
Education household head	Average grade of household head over all years	2.51	2.74
Household size	Average size of household over all years	6.70	2.85
Children	Number of children in the households over all years	2.95	2.34

Appendix B

Appendix Chapter Two

B.1 Household questionnaire, code-book and village questionnaire

Enquêtes auprès des ménages

PARTIE 1 INFORMATIONS SUR LES MENAGES

1- Identification du ménage

a/ Précédent numéro du ménage ____________

b/ Nouveau numéro du ménage ____________

2-Location du ménage

a/ Arrondissement ____

b/ Village ____

c/ Quartier/Hameau ____

d/ Distance du ménage au centre du village (km et minutes)

Km	Minutes

3- Nom du chef de famille ____

4- Religion du chef de famille [ ] Utiliser code RELIGION

5- Ethnie du chef de famille [ ] Utiliser code ETHNIE

6- Enquêteur ________________________ Date ________

7- Entretien conduit en [ ] UTiliser code LANGUE

8- Grille du ménage

	1. Faites une liste de toutes les personnes dont vous avez la charge et qui ont plus de 5 ans	2. Quelle est leur relation avec le chef de ménage? Utiliser code RELATION CHEF DE MENAGE	3.Donnez-moi l'âge des personnes de votre ménage	4.Pour les personnes de plus de 16 ans, quel est leur statut marital? Utiliser code STATUT MARITAL	5.Si la personne est mariée, a un partenaire, est séparée ou divorcée, est-ce que son partenaire habite le foyer? Oui..........1 Non..........2
	Nom	CODE			
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					

PARTIE 2 EDUCATION ET SANTE

Dans cette section, je souhaiterais que nous discutions de votre niveau scolaire et de celui des membres de votre ménage. Je vais aussi vous poser des questions sur votre utilisation des services de santé.

Section 1- Éducation

	1. Reprenez la liste des personnes habitant dans la maison	2. Est-ce que [nom] est allé à l'école? Oui.........1 passer question 3 Non.........0 passer à question 4	3. Jusqu'à quel niveau est-il allé?	4. Est-ce que [nom] peut lire un journal? Oui.............................1 Non.............................0	5. Est-ce que [nom] peut écrire une lettre? Oui.............................1 Non.............................0	6. Est-ce que [nom] va toujours à l'école? *Que pour les personnes de moins de 25 ans* Oui.............................1 Non.............................0 *Si la réponse est OUI, passer question 7 et 8.* *Si la réponse est NON, passer à la personne suivante.*	7. A quel age a-t-il commencé l'école? *Que pour les personnes de moins de 25 ans*	8. Combien d'heures a-t-il passé à l'école la semaine dernière?
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								

Section 2- Santé

	1. Est-ce que dans le mois qui vient de s'écouler [nom] a été malade? Oui.............................1 Non.............................0	2. Combien de jours a [nom] été souffrant?	3. Où [nom] a été soigné? utiliser code CENTRE SANTE	4. Pour quelle maladie [nom] a été soigné? Utiliser code MALADIE	5. Est-ce que [nom] a eu d'autres maladies au cours du mois dernier? Oui.............................1 Non.............................0
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					

PARTIE 3 ACTIVITES AGRICOLES

Pendant les 12 derniers mois, avez-vous, vous-même ou un autre membre de la famille travaillé dans un champ?

Oui.............................1

Non.............................0 (aller à section 3)

Section 1- Production

	1. Est-ce que vous ou un membre de votre foyer a cultivé l'un des produits suivants dans les 12 derniers mois? Oui..........1 Non..........0		2. Combien de fois dans l'année avez-vous planté [votre produit]? Utiliser code fréquence	3. Combien de fois dans l'année les récoltez-vous? Utiliser code fréquence	4. Quelle quantité de chaque produit avez-vous ramassé à la dernière récolte? utiliser code POIDS		5. Combien de fois dans l'année allez-vous les vendre? Utiliser code fréquence	6. Quelle quantité de chaque produit avez-vous vendu lors de la dernière vente? utiliser code POIDS		7. Quel a été le revenu de la dernière vente de chaque produit?	7. Avez-vous perdu une partie de votre récolte durant les 12 derniers mois? Non..........0 Oui, un peu..........1 Oui, moyennement..........2 Oui, beaucoup..........3	8. Avez-vous gardé une partie de votre récolte afin d'avoir des graines pour les récoltes suivantes? Oui.....1 Non.....0	9. Avez-vous encore à présent une partie de votre récolte chez vous? Oui.....1 Non.....0
					quantité	CODE		quantité	CODE	FCFA			
1	Manioc												
2	Macabo												
3	Plantains												
4	Arachide												
5	Concombre												
6	Maïs												
7	Cacao												
8	Autre culture 1 (préciser)												
9	Autre culture 2 (préciser)												

Section 2- Intrants

		saison pleine	saison creuse
1	Combien d'heures dans une semaine passez-vous à travailler dans vos terrains?		
2	Combien de personnes du ménage participent à la production agricole?		
3	À combien de personnes hors ménage avez-vous fait appel?		

4. Si vous avez fait appel à une main d'oeuvre extérieure, comment l'avez-vous rémunérée?

en nature..........................1

argent..............................2

échange de travail..........3

5.Combien de champs cultivez-vous? (nombre de champs)

____

	6. Quelle est la taille des champs cultivés ? Hectares..........1 Mètres carrés..........2 Pieds..........3		7. A quelle distance de votre maison, se trouvent ces champs?		8. Avant d'être des terrains agricoles, est ce que ces champs étaient: Oui..........1 Non..........0		9. Cela fait combien de temps que vous avez ouvert chaque champ? utiliser code TEMPS		10. Quels sont les produits cultivés dans ces champs? Code PRODUITS AGRICOLES
	mesure	CODE	km	min	forêt	jachère	nombre	Unité	
1									
2									
3									
4									
5									
6									
7									

		11. Pour cultiver avez-vous utilisé: Oui……………………1 Non……………………0
1	houe	
2	machette	
3	pioche	
4	pelle	
5	brouette	
6	faucille	
7	hache	
8	coupe-coupe	
9	lime	
10	autres (préciser)	

12. Dans les 12 derniers mois pour cultiver, avez-vous Oui……………1 Non……………0		13. A combien se sont élevées ces dépenses pendant les 12 derniers mois? Francs CFA	14. Pour quels produits agricoles les avez-vous utilisés? Code PRODUITS AGRICOLES
acheté des graines?			
acheté et utilisé de l'engrais?			
acheté et utilisé des pesticides?			
loué des machines?			
utilisé des animaux?			
fait des dépenses pour transporter la récolte?			
fait des dépenses pour l'achat de sacs, de containers?			

	15. Durant les 12 derniers mois, vous ou l'un des membres du foyer a-t-il possédé l'un des équipements suivants: Oui……………………1 Non……………………0		16. Possédez-vous toujours ces équipements? Oui……………………1 Non……………………0	17. Combien en possédez-vous dans tout le foyer? Quantité	18. Si aujourd'hui vous vendiez [nom outil], combien cela vous rapporterait-il? Francs CFA
1	[illegible]				
2	Bâtiments agricoles				
3	Tronçonneuse				
4	Pulvérisateur				
5	Moto				
6	Autres équipements agricoles				

Section 3- Élevage

Pendant les 12 derniers mois, avez-vous , vous-même ou un autre membre de la famille possédé ou élevé des animaux?

Oui……………………1

Non……………………0 (aller à Partie 4)

	1. Durant les 12 derniers mois, avez-vous élevé ou possédé des animaux d'élevage? Oui……………………1 Non……………………0		2. Combien en possédez-vous en ce moment?	3. Combien en avez-vous acheté dans les 12 derniers mois?		4. Combien d'animaux avez-vous vendu au cours des 12 derniers mois?		5. Combien d'animaux avez-vous perdu au cours des 12 derniers mois?	6. Quelle a été la quantité de viande consommée? Pièce……………1 Kg……………2 Partie……………3	
			nombre	nombre	Francs CFA	nombre	Francs CFA	nombre	quantité	CODE
1	Chèvres									
2	Moutons									
3	Cochons									
4	Poules									
5	Autres (préciser)									

PARTIE 4 : ACTIVITES LIEES A L'EXTRACTION DE RESSOURCES FORESTIERES

Dans cette section, je souhaiterais vous poser quelques questions concernant l'extraction de ressources forestières, votre pratique de la chasse et de la pêche.

Section 1- Collecte de produits forestiers

Avez-vous, vous-même ou un membre de votre famille, été ramasser des produits forestiers tels que des champignons, des fruits, du bois pour cuisiner?

Oui.............................1

Non.............................0 aller à Section 2

1. Combien de personnes dans le ménage vont ramasser des produits dans la forêt?

....

		2. Dernièrement, avez-vous collecté l'un des produits forestiers suivants? Oui.........1 Non.........0	3. A quelle fréquence, allez-vous les cueillir? Utiliser code fréquence	4. Lors de votre dernière cueillette, quelle quantité avez-vous ramassée? utiliser code POIDS		5. Après votre dernière cueillette, quelle quantité avez-vous vendue? utiliser code POIDS		6. Combien cela vous a-t-il rapporté?	7. Pendant les DEUX derniers mois, quelle quantité avez-vous consommée? utiliser code POIDS		8. Quels mois cueillez-vous le plus de ces produits?	9. Combien de temps cela vous prend-il? quelques heures.............1 demi-journée.............2 jour entier.............3 plusieurs jours.............4 autres (préciser).............5	10. Est-ce que l'espace forestier où vous allez les ramasser est [loin/proche] Loin.....1 Proche...2	
				quantité	CODE	quantité	CODE	Francs CFA	quantité	CODE	Mois		de la maison	des champs
1	Ndo'o (Irvingia gabonensis: mangue sauvage)													
2	Palmier à huile (Elaeis guineensis)													
3	Ebonk (Alstonia boonei)													
4	Noisette (Coula edulis)													
5	Champignons													
6	Essok (Garcinia Lucida)													
7	Okok													
8	Autres (préciser)													

		11. Avez-vous transformé l'un de ces produits en un autre produit? Oui.............................1 Non.............................0	12. Quel produit avez-vous obtenu lors de la transformation de ces ressources forestières?	13. Avez-vous vendu le produit transformé? Oui.............................1 Non.............................0	14. Si oui, combien avez-vous reçu?
					Francs CFA
1	Ndo'o (Irvingia gabonensis: mangue sauvage)				
2	Palmier à huile (Elaeis guineensis)				
3	Ebonk (Alstonia boonei)				
4	Noisette (Coula edulis)				
5	Champignons				
6	Essok (Garcinia Lucida)				
7	Okok				
8	Autres (préciser)				

15. Pour la cueillette de ces produits avez-vous eu besoin de: Oui.............................1 Non.............................0		16. Combien en avez-vous utilisé?
a/ sac		
b/ panier		
c/ râteau		
d/ échelle		
e/ pelle		
f/ brouette		
g/ hache		
h/ autres (préciser)		

17. Combien de fois dans la semaine, allez-vous ramasser du bois pour la cuisine?

....

18. Combien de temps passez-vous dans un jour à ramasser du bois pour la cuisine? (utiliser code TEMPS)

....

Section 2- Chasse

Durant le mois dernier, avez-vous ou un autre membre de votre famille a, été chasser?

Oui.............................1

Non.............................0 aller à Section 3

1. Combien de fois dans une semaine, allez-vous chasser?

____

2. Combien de personnes dans votre ménage chassent?

____

		3. Le mois dernier, avez-vous attrapé les animaux suivants Oui..........1 Non..........0	4. Quelle a été la quantité attrapée? utiliser code POIDS		5. Quelle a été la quantité consommée? utiliser code POIDS		6. Quelle a été la quantité vendue? utiliser code POIDS		7. Combien cela vous a-t-il rapporté?	8. Où avez-vous été chasser? Forêt..........1 Jachère..........2 Champ..........3	9. Quelle technique de chasse avez-vous utilisé? piège en ligne..........1 Fusil..........2 Lance..........3 Chien..........4		10. A quelle distance (km et mn) se trouve votre zone de chasse?	
			quantité	CODE	quantité	CODE	quantité	CODE	Francs CFA				km	mn
1	Rat													
2	Lièvre													
3	Porc-épic													
4	Antilope													
5	Singe													
6	Hérisson													
7	Biche													
8	Serpent													
9	oiseaux													
10	Autres (préciser)													

Section 3- Pêche

Durant le mois dernier, avez-vous, ou un autre membre de votre famille a, été pêcher?

Oui.............................1

Non.............................0 aller à Partie 5

1. Combien de fois le mois dernier êtes-vous allé pêcher?

____

	2. Le mois dernier, avez-vous attrapé l'un des poissons suivants? Oui..........1 Non..........0		3. Pour chaque type de poissons, quelle a été la quantité attrapée? utiliser code POIDS		4. Quelle quantité de poissons a été consommée? utiliser code POIDS		5. Pour chaque type de poissons, quelle a été la quantité vendue? utiliser code POIDS		6. Combien ces ventes vous ont-elles rapporté?
			quantité	CODE	quantité	CODE	quantité	CODE	Francs CFA
1	silure								
2	goujons								
3	crabes								
4	carpes								
5	crevettes								
6	autres (préciser)								

	7. Quelles techniques de pêche utilisez-vous? Oui..........1 Non..........0	8. Quel est le matériel dont vous avez besoin pour pêcher?
Pêche à la ligne		
Barrage		
Nasse		
Autres (préciser)		

Section 4- Services forestiers et organisations locales

1. Savez-vous si votre village a des initiatives collectives liées à la forêt? Oui....1 /Non.....0

2. Si oui, pouvez-vous me dire quelles sont ces initiatives? (ex. forêt communautaire, EFA, association de conservation...) ....

....

....

3. Dans les DIX dernières années, avez-vous participé à des initiatives collectives liées à la forêt? Oui....1 /Non.....0

4. Participez-vous toujours à des initiatives collectives liées à la forêt? Oui....1 /Non.....0

5. Si non, pourquoi ne participez-vous plus à ces initiatives? ....

....

6. Si oui, à quel type d'initiatives participez-vous? ....

....

7. Comment y participez-vous? Que faites-vous?

....

....

8. Que pensez-vous qu'une initiative locale liée à la forêt doit faire dans votre communauté?

....

9. Dans les DOUZE derniers mois, est-ce que vous-même ou un autre membre de votre ménage a participé à une autre organisation locale de style tontine, association de femmes, de jeunes...?

Oui..............1 Non..............0

	2. Dans les DOUZE derniers mois, à quels types d'organisation participez-vous? utiliser code organisation	3. Décrivez moi la mission de cette organisation?	4. Dans les DOUZE derniers mois, comment avez-vous pris part à la mission de cette organisation? utiliser code participation
1			
2			
3			
4			
5			
6			
7			
8			

PARTIE 5 ACTIVITES INDIVIDUELLES

Le mois dernier, est-ce que vous même ou un autre membre de votre famille a travaillé pour quelqu'un?

Oui..............1

Non............0 (aller à section 2)

Section 1- Travail salarié

	1. Le mois dernier, en quoi consistait le travail auquel les membres de votre ménage ont participé? A quel genre de commerce, d'industrie ou de société était-il lié? Utiliser code activités		2. Combien d'heures par semaine avez-vous travaillé dans ce travail?	3. Le mois dernier, qui était votre employeur? Utiliser code employeur		4. Combien avez-vous été payé pour ce travail? A quelle fréquence le receviez-vous (par semaine, mois, année)? Utiliser code FREQUENCE		5. Pendant combien de temps avez-vous participé à cette activité l'année dernière? Utiliser code TEMPS		6. Avez-vous reçu votre paiement sous forme de nourriture, de produits agricoles? Oui..........1 Non..........0	7. Avez-vous travaillé comme salarié dans un autre emploi ce mois dernier? Oui..........1 Non..........0	8. Si oui, en quoi consistait ce travail? A quel genre de commerce, d'industrie ou de société était-il lié? Utiliser code activités		9. Combien d'heures avez-vous travaillé dans cet emploi pendant le mois dernier?	10. Combien avez-vous été payé pour ce travail? A quelle fréquence le receviez-vous? Utiliser code FREQUENCE	
	Description	CODE		Description	CODE	Francs CFA	CODE	Nombre	CODE			Description	CODE		Francs CFA	CODE
1																
2																
3																
4																
5																
6																
7																

Section 2- Activités indépendantes non agricoles

Le mois dernier, est-ce que vous même ou un autre membre de votre famille a entrepris une activité personnelle ?

Oui..............1

Non............0 (aller à section 3)

	1. Pendant le mois dernier, à quel type d'entreprise ou de travail indépendant avez-vous pris part? A quel type de commerce, d'industrie était-il lié? Utiliser code activités		2. Combien d'heures dans ce mois avez-vous travaillé dans chacune de ces entreprises?	3. Combien pensez-vous avoir gagné le mois dernier dans cette activité?	4. Depuis combien de mois avez-vous développé cette activité? Transformer les années en mois	5. Combien de personnes de votre ménage travaillent dans chaque entreprise?	6. Combien de personnes hors ménage travaillent dans chaque entreprise?	7. Faites une liste des différents outils, machines, instruments vous utilisez dans chaque entreprise
	Description	CODE		Francs CFA				
1								
2								
3								
4								
5								

Section 3- Revenu hors-travail

Durant les 12 derniers mois, avez-vous reçu un revenu venant :

			Réponse	Francs CFA
1	d'argent envoyé par des membres de la famille habitant hors du village? Combien?	Oui...........1 Non...........0		
2	de la vente d'un bien (ex. bicyclette, radio, bijoux ...) Combien avez-vous reçu?	Oui...........1 Non...........0		
3	de la vente d'une maison, d'un champ?	Oui...........1 Non...........0		
4	d'un héritage. Combien avez-vous reçu?	Oui...........1 Non...........0		
5	des intérêts d'un compte en banque, d'un compte épargne? Combien avez-vous reçu?	Oui...........1 Non...........0		
6	d'un fonds de pension ou de retraite. Combien avez-vous reçu?	Oui...........1 Non...........0		
7	de la location d'un champ? Combien avez-vous reçu?	Oui...........1 Non...........0		
8	autre: préciser	Oui...........1 Non...........0		

PARTIE 6 CREDIT

Dans cette section, je souhaiterais vous poser quelques questions concernant votre épargne et si vous recevez de l'argent à crédit de la part de différentes institutions ou individus.

1. Est-ce que vous avez emprunté de l'argent ou reçu un prêt (argent ou nature) de la part d'un individu ou d'institutions durant les deux derniers mois?

Oui...........1 Non...........0

2. Quelle est l'institution/l'individu qui vous a prêté le plus?

utiliser code INSTITUTION DE PRET

3. Combien avez-vous reçu de la part de cette institution/individu? (Francs CFA)

----

4. Qu'avez-vous fait avec cet argent?

----

5. Est-ce que vous avez repayé cet emprunt?

Oui...........1 Non...........0

6. Comment avez-vous repayé cet emprunt?

utiliser code REMBOURSEMENT

PARTIE 7 CONSOMMATION ET DEPENSES

Dans cette section, je souhaiterais vous soumettre quelques questions relatives à votre consommation alimentaire et vos dépenses non alimentaires.

Section 1- Consommation

		1. Dans les deux dernières semaines, avez-vous consommé: Oui..........1 Non..........0	2. Avez-vous PRODUIT/ELEVE/CHASSE ce que vous avez mangé? Oui..........1 Non..........0	utiliser code POIDS		3. Avez-vous ACHETE ce que vous avez mangé? Oui..........1 Non..........0	utiliser code POIDS		4. Combien avez-vous dépensé pour les aliments achetés?
				quantité	CODE		quantité	CODE	Francs CFA
1	igname								
2	tomate								
3	oignon								
4	manioc								
5	macabo								
6	arachide								
7	maïs								
8	plantain								
9	banane								
10	aubergine								
11	concombre								
12	riz								
13	lait								
14	sucre								
15	café								
16	huile								
17	poisson								
18	sardines en boîte								
19	poulet								
20	viande								
21	oeufs								
22	gibier								
23	miel								
24	Autres (préciser)								

Section 2- Autres dépenses

	1. Dans le mois qui vient de se terminer, avez-vous acheté l'un des articles suivants? Oui..........1 Non..........0	2. A combien se sont élevées vos dépenses dans chacun des produits?
1/ médicaments		
2/ moustiquaire		
3/ savon		
4/ brosse à dents		
5/ vêtements		
6/ bijoux et montre		
7/ scolarité		
8/ bois de chauffe		
9/ piles		
10/pétrole		
11/ instruments de cuisine		
12/ meuble		
13/ transport		
14/alcool		
15/ cigarette		
16/envoi d'argent/dons/prêt		
17/ Autres (préciser)		

Code RELIGION

Catholique	1
Protestante	2
Musulmane	3
Autre Chrétienne	4
Traditionnelle	5
Autre: préciser	6

Code ETHNIE

Bulu	1
Bagyeli	2
Ngoumba	3
Fang	4
Bassa	5
Autre: préciser	6

Code LANGUE

Francais	1
Bulu	2
Autre: préciser	3

Code RELATION CHEF DE MENAGE

Chef de ménage	1
Époux/Épouse	2
Fils/Fille	3
Petit-enfant	4
Père/Mère	5
Frère/Sœur	6
Neveu/Nièce	7
Beau-fils/Belle-fille	8
Beau-frère/Belle-sœur	9
Autre relation: préciser	10
Invité	11
Employé de maison	12

Code STATUT MARITAL

Marié (e) légalement	1
Partenaire	2
Divorcé(e)/Séparé(e)	3
Veuf/Veuve	4
Jamais marié(e)	5

Code EDUCATION

Section d'initiation	1
CP/CE1/CE2	2
CM1/CM2/Certifié	3
Collège général	4
BEPC	5
Collège technique	6
CAP	7
Lycée/BAC	8
Université	9
Autre: préciser	10

Code CENTRE SANTE

Hôpital public	1
Dispensaire religieux	2
Médecin	3
Soin à domicile	4
Médecine traditionnelle	5
Autre: préciser	6

Code MALADIE

Paludisme	1
Grippe/Fièvre	2
Accident	3
SIDA/ITS	4
Rhumatisme/Mal de dos	5
Autre: préciser	6

Code FREQUENCE

Tous les jours	1
Toutes les semaines	2
Une fois par mois	3
Deux fois par an	4
Une fois par an	5
Autre: préciser	6

Code POIDS

Kilogrammes	1
Sac	2
Régime	3
Filet	4
Pièce	5
Autre: préciser	6

Code TEMPS

Heure	1
Jour	2
Semaine	3
Mois	4
Année	5
Autre: préciser	6

Code PRODUITS AGRICOLES

Manioc	1
Macabo	2
Plantains	3
Arachide	4
Concombre	5
Maïs	6
Cacao	7
Autre 1: préciser	8
Autre 2: préciser	9

Code ORGANISATION

Agricole	1
Chrétienne	2
Tontine	3
Forestière	4
Développement	5
Autre: préciser	6

Code PARTICIPATION

Don d'argent	1
Travail	2
Prêts d'outils	3
Autre: préciser	4

Code INSTITUTION DE PRÊT

Banque commerciale	1
Gouvernement	2
Membre de la famille	3
Autre personne	4
Tontine	5
Société de microcrédit	6
Entreprise	7
Autre: préciser	8

Code REMBOURSEMENT

Argent	1
Nature	2
Déduction de la récolte	3
Autre: préciser	4

Code ACTIVITES

Agriculteur	1
Pêcheur	2
Chasseur	3
Scieur	4
Commerçant	5
Chauffeur	6
Ouvrier	7
Éducation	8
Santé	9
Secrétaire/Clerc	10
Hôtel/Restaurant	11
Autre: préciser	12

Code EMPLOYEUR

Gouvernement	1
Entreprise privée	2
Autre ménage	3
Société coopérative	4
Institution religieuse	5
Autre: préciser	6

QUESTIONNAIRE POUR LES VILLAGES

Données démographiques

1. Quel est le nom du village?	nom et code	
2. En quelle année le village a-t-il été établi?		
3. Quelle est la population actuelle du village?	nombres	
4. Combien de ménages vivent actuellement dans ce village?	nombres	
5. Quel était l'effectif total de la population du village il y a 10 ans?	nombres	
6. Combien de ménages vivaient dans le village il y a 10 ans?	nombres	
7. Combien de personnes (approx.) se sont installées dans le village durant les 10 dernières années?	nombres	
8. Combien de personnes (approx.) ont quitté le village durant les 10 dernières années?	nombres	
9. Combien de groupes (ethniques, tribus ou castes) vivent dans le village ?	nombres	

Infrastructure

1.Combien de ménages dans le village ont accès à l'électricité ?		nombres		
2.Combien de ménages dans le village ont accès à l'eau du robinet (= utilisation)?		nombres		
3.Combien de ménages ont accès à un crédit formel (gouvernement ou banque privée intervenant dans le village)?		nombres		
4.Y a-t-il des institutions de crédit informel comme des mutuelles d'épargne et de crédit dans le village?		Oui 1 Non 2		
5. Y a-t-il une école dans le village?		Oui 1 Non 2		
6. Y a-t-il un centre de santé dans le village?		Oui 1 Non 2		
7. Le village a-t-il une route praticable par des voitures durant toutes les saisons?		Oui 1 Non 2		
8. Si 'non': Quelle est (en kilomètres) la distance la plus proche de la route praticable à toutes les saisons?		km		
9. Dans les limites du village y a-t-il des rivières navigables à toutes les saisons?		Oui 1 Non 2		
10. Si non : Quelle est la distance qui vous sépare de la rivière la plus proche navigable à toutes les saisons ?		km		
11. Quel est la distance qui sépare le centre du village ... (en km et en minutes par le moyen de transport commun)		km	min	transport
	du marché de l'arrondissement			
	du marché des produits agricoles			
	du marché des produits forestiers			

Utilisation des terres

Catégories de terres	Superficie totale (ha)	Propriété			
		État	Village	Privée	Libre accès
1. Surface agricole cultivable					
2. Forêt naturelle					
3. Forêt aménagée					
4. Plantations					
5. Agroforesterie					
6. Jachère					
7. Autres (préciser)					

Données générales

1. Quelle a été la quantité totale de précipitations dans les 12 mois passés?		
2. Est ce que le village a subi une crise durant les 12 derniers mois?	Sécheresse	
	Inondations	
	Feux de forêt	
	Attaques d'insectes, maladies de plantes ou d'animaux	
	Épidémies humaines	
	Changement de chefferie	
	Changement des prix alimentaires	
	Vagues de réfugiés ou de migrants	
	Autres (préciser)	

Prix et salaires

	Temporaires		Permanents	
1. Suivant la saison, quel a été le salaire journalier des travailleurs agricoles temporaires ou permanents?	Saison pleine	Saison creuse	Saison pleine	Saison Creuse
2. Quel est l'aliment de base dans le village				
3. Quel est le prix de l'aliment de base du village?				
4. Quel est le prix d'un hectare de terrain propice à l'agriculture dans le village?				

Services forestiers

1. Le village a-t-il reçu un paiement direct relatif à des services forestiers?
Oui...1
Non...0

	2. Est-ce que le village a reçu des paiements relatifs à: Oui............................ Non............................	3. A combien se sont élevés ces paiements? 1 Francs CFA	4. Combien de personnes du village ont rendu ces services?
1. Tourisme			
2. Séquestration du Carbone			
3. Captage d'eau			
4. Conservation de la biodiversité			
5. Compensation des sociétés forestières			
6. Compensation de sociétés d'exploitations			
9. Autres, spécifiez:			

B.2 Summary descriptive, first-stage, OLS, reduced-forms and labour shares regressions

Table B.1: Summary statistics of variables used in section2.5

Variable	Description	Mean	Std Dev.
Dependent variables			
Log Agric. prod	Log of total household agricultural output value per week in CFA Francs	9.78	1.12
Log NTFP prod	Log of total household NTFP output value per week in CFA Francs	7.62	1.38
Log of hunting production	Log of total household hunting output per week in CFA Francs	7.6	1.3
Log total time	Log of weekly total time spent working in agriculture, NTFP, off-farm and hunting	4.15	0.62
Explanatory variables in production functions			
Log hours agriculture	Log of total hours devoted to agriculture by households in a week	3.75	0.61
Log hours NTFPs	Log of total hours devoted to NTFP by households in a week	2.18	1.21
Log of hours hunting	Log of total hours devoted to hunting by households in a week	0.62	1.36
Log input expenditures	Log of total input expenditures used in agricultural production in CFA Francs	1.80	2.77
Log seed expenditures	Log of expenditures in seeds in CFA Francs	5.84	4.14
Log land area	Total area in hectares used for agricultural production	0.45	1.35
Ekouk	Dummy if household collects ekouk	0.61	0.48
Ndo'o	Dummy if household collects ndo'o	0.30	0.46
Distance to ndo'o	Interaction term ndo'o and distance to ndo'o site; 1 if far and 0 otherwise	.26	0.44
Palm	Dummy if household extracts palm nuts	0.73	0.44
Distance to palm	Interaction term palm and distance to palm site; 1 if far and 0 otherwise	0.32	0.46
Equipment index	Index of dummy variables for whether household has a large equipment (chainsaw, motorbike, spray ...)	0.0075	0.66
Hunt with rifle	Dummy if household hunts with a rifle	0.11	0.31

Variable	Description	Mean	Std Dev.
Interaction terms for translog			
Log squared hours	Log of squared hours in agriculture	14.43	4.64
Log squared input expenditures	Log of total input expenditures used in agriculture	10.88	18.15
Log squared land size	Log of squared of land agricultural area	2.04	6.01
Log square seed expenditures	Log of squared value of seed expenditures	51.26	38.88
Log hours*expenditures	Log of interaction terms between hours and input expenditures	7.00	11.13
Log seed*land	Log of interaction terms between seed and land area	2.96	9.22
Shadow wages and income			
Log shadow wage (1)	Log of predicted shadow wage in agriculture using regression (3)	5.04	0.64
Log shadow wage (2)	Log of predicted shadow wage in agriculture using regression (4)	5.07	0.64
Log shadow income (1)	Log of shadow income using regression (3)	9.73	0.72
Log shadow income (2)	Log of shadow income using regression (4)	9.70	0.76
Household characteristics			
Household size	Number of household members	5.02	2.81
Wives	Number of wives in household	0.83	0.55
Child	Number of household members less than 15 years old	2.05	2.09
Ill adults	Number of adult members ill during the last week	0.85	0.83
Age head	Age of household head	50.30	15.33
Squared age head	Squared age of household head	2765.10	1592.93
Bulu	Dummy if household is Bulu	0.45	0.49
Ngoumba	Dummy if household is Ngoumba	0.20	0.40
Average grade	Average grade attained by all household members aged 15 or above	3.81	1.19
Maximum grade	Maximum grade attained by all household members aged 15 or above	4.69	1.89
Primary education	Dummy if household average grade is primary school	0.30	0.46
Higher education	Dummy if household average grade is higher education	0.18	0.39
Education head	Average education of household head	3.87	1.91
Secondary education head	Dummy if household head has secondary education	0.50	0.50
Distance field	Distance between house and plot (minutes)	32.44	25.13
Non-labour income	Dummy if household receives non-labour income	0.39	0.49

Variable	Description	Mean	Std Dev.
Total expenditures	Household average expenditures in durable goods	40355.99	59911.64
Number sheep	Number of sheep owned by households	0.12	1.13
Village control variables			
Price cocoa	District price of a bag of cocoa	44204.24	7111.70
Village input	Village average value of input expenditures	10708.59	7245.87
Wage clearing	Village average wage for clearing plot	1899.17	1857.88
Village ethnicity	Dummy if village has more than 2 ethnicities	0.70	0.45
Village distance market	Distance between village and market (km)	14.26	17.88
Village palm	Dummy if village has more than 70% households extracting palm	0.59	0.49
More rain	Dummy if village has more rain the last year	0.64	0.48
Mbango	Dummy if household lives in Mbango-Bitouer	0.06	0.24
Ebom	Dummy if household lives in Ebom	0.07	0.26
Mekalat	Dummy if household lives in Mekalat	0.04	0.20
Bipindi	Dummy if household lives in the village of Bipindi	0.17	0.38
Bidjouka	Dummy if household lives in Bidjouka	0.09	0.29
Lambi	Dummy if household lives in Lambi	0.05	0.22
Ebimimbang	Dummy if household lives in Ebimimbang	0.10	0.30
Bongwana	Dummy if household lives in Bongwana	0.04	0.19
Akom	Dummy if household lives in the village of Akom II	0.11	0.31
Nkomakak	Dummy if household lives in Nkomakak	0.04	0.20
Abiete	Dummy if household lives in Abiete	0.05	0.22
Mvie	Dummy if household lives in Mvie	0.04	0.20
Nyangong	Dummy if household lives in Nyangong	0.11	0.32

Table B.2: First-stage estimates of agricultural production function

Variables	log hours agriculture (1)	log input expenditures (1)	log hours agriculture (2)	log input expenditures (2)
Household size	0.0682*** (0.0109)	0.0164 (0.0462)	0.0653*** (0.0110)	0.0216 (0.0466)
Equipment index	0.0173 (0.0501)	1.144*** (0.212)	0.0110 (0.0501)	1.154*** (0.213)
Log seed expenditures	0.00152 (0.00742)	0.127*** (0.0314)	0.00327 (0.00745)	0.122*** (0.0317)
Log land area	0.0668*** (0.0233)	0.277*** (0.0985)	0.0663*** (0.0232)	0.276*** (0.0985)
Age household head			0.00445** (0.00211)	-0.0107 (0.00895)
Secondary education head			0.0327 (0.0642)	0.103 (0.273)
Mbango	-0.102 (0.153)	-0.000826 (0.650)	-0.146 (0.154)	0.116 (0.656)
Ebom	0.00614 (0.142)	1.096* (0.602)	-0.0143 (0.142)	1.152* (0.603)
Mekalat	0.00833 (0.171)	1.312* (0.724)	-0.00173 (0.171)	1.373* (0.726)
Bipindi	-0.0742 (0.118)	0.452 (0.498)	-0.0908 (0.118)	0.462 (0.501)
Bidjouka	-0.0801 (0.133)	-0.187 (0.565)	-0.0965 (0.133)	-0.156 (0.566)
Lambi	-0.279* (0.157)	-0.771 (0.667)	-0.303* (0.158)	-0.737 (0.669)
Ebimimbang	-0.0330 (0.130)	-0.345 (0.550)	-0.0456 (0.130)	-0.300 (0.551)
Bongwana	-0.0715 (0.176)	-0.876 (0.744)	-0.0698 (0.175)	-0.873 (0.744)
Akom	0.0467 (0.128)	-0.304 (0.541)	0.0225 (0.129)	-0.288 (0.546)
Nkomakak	-0.0835 (0.169)	-1.255* (0.718)	-0.163 (0.174)	-1.123 (0.741)
Abiete	-0.102 (0.161)	-1.027 (0.682)	-0.115 (0.161)	-0.995 (0.683)
Mvie	0.224 (0.166)	-1.292* (0.704)	0.173 (0.167)	-1.175* (0.712)
Constant	3.409*** (0.106)	0.954** (0.450)	3.194*** (0.149)	1.405** (0.634)
Observations	384	384	384	384
R-squared	0.144	0.243	0.154	0.247

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table B.3: First-stage estimates of NTFP production function

	Household time in NTFP extraction	
Household size	0.0880*** (0.0190)	0.0864*** (0.0192)
Ill adults	0.182*** (0.0643)	0.189*** (0.0649)
Ekouk	0.274** (0.118)	0.291** (0.119)
Ndo'o	0.911*** (0.244)	0.915*** (0.244)
Age household head		-0.000137 (0.00379)
Secondary education head		0.105 (0.115)
Distance ndo'o	0.560** (0.242)	0.550** (0.243)
Mbango	-0.938*** (0.282)	-0.916*** (0.287)
Ebom	0.760*** (0.258)	0.772*** (0.259)
Mekalat	-0.137 (0.365)	-0.137 (0.367)
Bipindi	0.313 (0.206)	0.296 (0.207)
Bidjouka	0.298 (0.231)	0.300 (0.232)
Lambi	-0.298 (0.269)	-0.296 (0.270)
Ebimimbang	0.253 (0.215)	0.265 (0.216)
Bongwana	0.0602 (0.291)	0.0662 (0.292)
Akom	0.0919 (0.209)	0.0622 (0.213)
Nkomakak	-0.109 (0.298)	-0.135 (0.310)
Abiete	-0.249 (0.277)	-0.235 (0.278)
Mvie	0.439 (0.271)	0.434 (0.275)
Constant	0.807*** (0.197)	0.755*** (0.275)
Observations	304	304
R-squared	0.478	0.480

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table B.4: Hunting production function OLS

	Log of hunting production
Hours hunting	0.600*** 0.0721)
Rifle hunt	0.685*** (0.215)
Palm	0.542* (0.286)
Distance to palm	0.361* (0.192)
Ebom	0.826 (0.540)
Mekalat	0.412 (0.565)
Bipindi	0.565 (0.553)
Bidjouka	0.490 (0.542)
Ebimimbang	1.078** (0.523)
Bongwana	0.735 (0.614)
Akom	0.723 (0.544)
Nkomakak	1.629* (0.897)
Abiete	0.0732 (0.571)
Mvie	0.962 (0.586)
Nyangong	0.121 (0.519)
Constant	5.859*** (0.514)
Observations	150
R-squared	0.484

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure B.1: Total time and time spent in different activities (hours per adult)

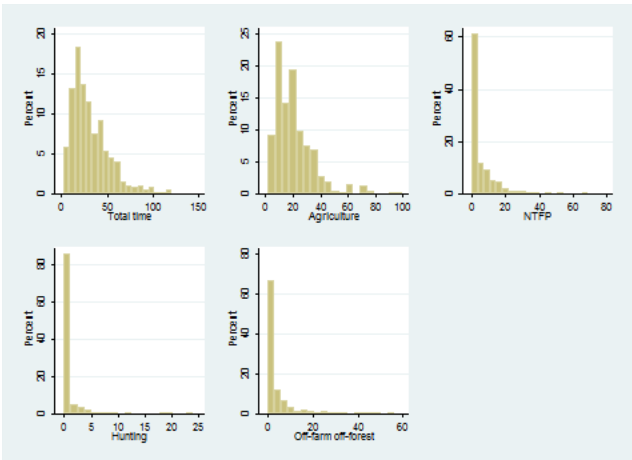

Table B.5: First-stage of total labour supply estimations

	Regression (2)		Regression (3)		Regression (4)		Regression (5)	
Variables	Log shadow wage	Log shadow income	Log shadow wage	Log shadow income	Log shadow wage	Log shadow income	Log shadow wage	Log shadow income
Rifle hunt	-0.0195(0.070)	0.316***(0.11)	-0.0085(0.070)	0.285**(0.11)				
Village input	-2.19e-06(1.1e-05)	4.90e-05***(1.79e-05)	3.73e-05***(9.1e-06)	5.61e-06(1.4e-05)				
Non-labour income	-0.0983**(0.044)	0.233***(0.070)	-0.0906**(0.043)	0.230***(0.070)	-0.102**(0.043)	0.273***(0.074)	-0.0890**(0.042)	0.274***(0.074)
Total expenditures	5.31e-07(3.8e-07)	2.75e-06***(6.1e-07)	5.62e-07(3.8e-07)	2.70e-06***(6.1e-07)	5.97e-07(3.89e-07)	2.38e-06***(6.6e-07)	6.14e-07(3.8e-07)	2.34e-06***(6.64e-07)
Price cocoa	-8.07e-05***(2.5e-05)	6.36e-05(3.96e-05)	0.00011***(3.7e-05)	0.00011*(5.9e-05)	0.00035***(6.7e-05)	0.00016(0.00011)	0.00035***(6.52e-05)	0.00017(0.00011)
Number sheep					-0.0178(0.019)	0.0846**(0.033)	-0.0142(0.019)	0.0776**(0.034)
Wage clearing					0.0002***(7.56e-05)	0.0003***(0.0001)	0.0003***(7.53e-05)	0.0003***(0.0001)
Child	-0.0354***(0.010)	0.00505(0.016)	-0.0254**(0.010)	-0.0075(0.017)	-0.036***(0.010)	0.0095(0.017)	-0.249**(0.010)	-0.0026(0.018)
Wives			-0.103** (0.034)	0.165**(0.064)			-0.097**(0.039)	0.177***(0.068)
Age head	-0.0177**(0.0071)	0.00358(0.011)	-0.0196***(0.0071)	0.0022(0.011)	-0.0226***(0.0073)	0.0076(0.012)	-0.0237***(0.007)	0.00593(0.012)
Squared age head	0.00013*(6.9e-05)	-5.04e-05(0.00011)	0.00015**(6.87e-05)	-4.95e-05(0.00011)	0.00015**(7.21e-05)	-0.00013(0.00012)	0.00016**(7.09e-05)	-0.00012(0.00012)
Bulu			-0.201**(0.089)	0.0065(0.144)			-0.200**(0.088)	-0.0034(0.154)
Ngoumba			0.052(0.083)	-0.080(0.134)			0.047(0.082)	-0.059(0.142)
Maximum grade			-0.0613**(0.030)	0.0802*(0.048)			-0.0615**(0.029)	0.089*(0.0516)
Average grade	-0.0184(0.025)	0.100**(0.040)	-0.022(0.025)	0.092**(0.043)				
Primary education			-0.0613(0.083)	0.016(0.133)			-0.0643(0.082)	0.0453(0.143)
Higher education			0.109(0.111)	-0.0697(0.178)			0.117(0.110)	-0.146(0.192)
Education head	0.0166(0.017)	-0.0389(0.0266)	0.0458*(0.023)	-0.0408(0.0375)	-0.0040(0.016)	-0.0471*(0.0284)	0.0444*(0.023)	-0.0317(0.040)
Secondary edu head			-0.052(0.081)	-0.051(0.130)			-0.172**(0.079)	-0.130(0.139)
Distance field	0.0027***(0.0008)	-0.0033**(0.0013)	0.0026***(0.00086)	-0.003**(0.0014)	0.0027***(0.00086)	-0.0034**(0.0014)	0.0026***(0.00085)	-0.0029**(0.0015)
Village ethnicity	1.266***(0.342)	-0.818(0.543)	-1.404***(0.520)	-0.920(0.835)	-4.993***(1.056)	-2.696(1.796)	-5.205***(1.038)	-2.884(1.808)
Village distance market	0.0413***(0.0135)	-0.0353*(0.021)	-0.0471***(0.0097)	-0.0226(0.0156)	-0.121***(0.0231)	-0.0571(0.039)	-0.121***(0.022)	-0.0615(0.0392)
Village palm	-0.993***(0.239)	0.460(0.379)	0.471***(0.0928)	0.241(0.149)	0.835***(0.154)	0.358(0.262)	0.847***(0.151)	0.340(0.262)
More rain	-1.037***(0.266)	0.694(0.422)	0.382***(0.130)	-0.0513(0.209)	1.383***(0.328)	1.477***(0.558)	1.382***(0.322)	1.591***(0.561)
Mbango	1.136***(0.176)	1.495***(0.279)	1.979***(0.203)	1.818***(0.327)	3.332***(0.371)	2.133***(0.631)	3.334***(0.368)	2.173***(0.641)
Ebom			1.207*(0.706)	1.635(1.136)	4.940***(0.891)	2.182(1.516)	5.162***(0.875)	2.269(1.524)
Mekalat			0.430**(0.217)	0.885**(0.349)	0.509***(0.180)	-0.379(0.306)	0.507***(0.179)	-0.429(0.312)
Akom	-0.0633(0.122)	0.214(0.193)	0.639(0.511)	1.461*(0.822)	3.231***(0.694)	1.562(1.179)	3.422***(0.685)	1.705(1.192)
Mvie	0.942***(0.221)	-0.0168(0.350)	-0.0602(0.223)	1.092***(0.359)				
Abiete			-0.347(0.218)	0.870**(0.351)				
Lambi	0.602***(0.161)	0.488*(0.254)			-0.0673(0.165)	0.979***(0.281)	-0.0532(0.177)	1.075***(0.309)
Bidjouka	-1.196***(0.235)	0.469(0.373)						
Ebimimbang	1.071***(0.205)	-0.196(0.325)						
Bipindi					-0.385*(0.233)	-0.223(0.397)	-0.336(0.233)	-0.287(0.405)
Constant	8.796***(1.114)	6.203***(1.766)	1.565(1.290)	4.702**(2.074)	-7.293***(2.380)	2.850(4.047)	-6.937***(2.325)	2.307(4.049)
Observations	372	372	372	372	372	372	372	372
R-squared	0.634	0.277	0.652	0.293	0.641	0.262	0.666	0.279

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table B.6: Reduced form for total labour supply estimations

Variables	Log total time	Log total time
Child	0.0480** (0.0235)	0.0148 (0.0285)
Wives	0.225*** (0.0578)	0.211*** (0.0576)
Ill adults		0.0838** (0.0380)
Dependency ratio	-0.186 (0.176)	-0.0665 (0.201)
Average age		-0.000921 (0.0152)
Squared age		-6.13e-05 (0.000165)
Age head	0.0345*** (0.0109)	0.0345*** (0.0123)
Squared age head	-0.000329*** (0.000107)	-0.000304*** (0.000113)
Maximum grade	0.115*** (0.0430)	0.105** (0.0437)
Primary education	0.0835 (0.120)	0.107 (0.121)
High education	-0.0967 (0.158)	-0.0888 (0.158)
Education head	-0.0779** (0.0337)	-0.0686** (0.0340)
Secondary education head	0.0659 (0.117)	0.0903 (0.117)
Ngoumba	-0.0166 (0.120)	-0.0243 (0.119)
Bulu	0.277** (0.129)	0.272** (0.129)
Distance field	-0.00237* (0.00124)	-0.00230* (0.00124)
Village ethnicity	-0.0385 (0.218)	0.00703 (0.219)
Village distance market	-0.00224 (0.00360)	-0.00204 (0.00360)
Village palm	0.0402 (0.168)	0.0925 (0.169)
Village road	-0.378** (0.168)	-0.398** (0.169)
District price manioc	8.32e-05 (0.000192)	8.19e-05 (0.000193)
Ebom	0.203 (0.265)	0.176 (0.265)
Bipindi	0.124 (0.188)	0.123 (0.188)
Bidjouka	0.250 (0.211)	0.262 (0.211)
Ebimimbang	0.0224 (0.175)	-0.0256 (0.175)
Nkomakak	-0.198 (0.222)	-0.171 (0.221)
Akom	0.205 (0.221)	0.186 (0.220)
Abiete	-0.235 (0.179)	-0.211 (0.180)
Constant	2.706*** (0.806)	2.647*** (0.839)
Observations	374	374
R-squared	0.233	0.251

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table B.7: Summary statistics of variables used in section 2.6

Variable	Description	Mean	Std Dev.
Dependent variables			
Agri - Log (earnings/hours)	Quotient of agricultural production over hours worked	6.03	1.15
NTFP - Log (earnings/hours)	Quotient of NTFP production over hours worked	5.44	1.47
Off-farm - Log (earnings/hours)	Quotient of off-farm earnings over hours worked	6.60	1.39
Hunting - Log (earnings/hours)	Quotient of hunting earnings over hours worked	6.98	1.31
NTFP - Participation	Participation to NTFP extraction	0.79	0.40
Off-farm -Participation	Participation to off-farm activities	0.48	0.50
Hunting -Participation	Participation to hunting activities	0.42	0.49
Hours agriculture	Total of household weekly hours spent in agriculture	51.26	33.67
Hours NTFP	Total of household weekly hours spent in NTFPs activities	14.43	25.61
Hours Off-farm	Total of household weekly hours spent in off-farm off-forest activities	9.37	16.2
Hours hunting	Total of household weekly hours spent in hunting activities	1.78	5.29
Agriculture share (w1)	Share of time spent in agriculture over total time spent working in a week	0.71	0.21
NTFP share (w2)	Share of time spent in NTFPs activities over total time spent working in a week	0.15	0.16
Off-farm share (w3)	Share of time spent in off-farm off-forest activities over total time spent working in a week	0.11	0.17
Hunting share (w4)	Share of time spent in hunting over total time spent working in a week	0.02	0.05
Shadow wages			
Agricultural shadow wage (2)	Predicted shadow wage in agriculture using regression (4)	482.09	326.47
NTFP shadow wage (1)	Predicted shadow wage in NTFP using Heckman model (1)	510.00	544.61
NTFP shadow wage (2)	Predicted shadow wage in NTFP using Heckman model (3)	475.15	482.80
Shadow wage off-farm (1)	Predicted shadow wage in off-farm off-forest activities using Heckman model (2)	1381.96	966.73

Variable	Description	Mean	Std Dev.
Shadow wage off-farm (2)	Predicted shadow wage in off-farm off-forest activities using Heckman model (4)	1807.15	1139.45
Log of agriculture shadow wage	Log of shadow wage in agriculture using regression (4)	6.02	0.50
Log of NTFP shadow wage	Log of shadow wage in NTFP using Heckman model (1)	5.95	0.67
Log of off-farm shadow wage	Log of shadow wage in off-farm off-forest using Heckman model (2)	7.01	0.67
Log of hunting shadow wage	Log of shadow wage in hunting using Heckman model (5)	7.78	0.66
Explanatory factors			
Children at school	Number of children still at school	1.49	1.74
Wives	Number of wives in household	0.83	0.55
Child	Number of household members less than 15 years old	2.05	2.09
Dependency ratio	Ratio of children and elder on household size	0.38	0.27
Ill adults	Number of adult members ill during the last week	0.85	0.83
Age head	Age of household head	50.30	15.33
Squared age head	Squared age of household head	2765.10	1592.93
Head aged less than 30	Dummy if household head is less than 30 years old	0.09	0.29
Head aged [31;55]	Dummy if household head is between 31 and 55 years old	0.53	0.50
Household age less than 20	Dummy if household average age is less than 20 years old	0.28	0.45
Household age [21;40]	Dummy if household average age is between 21 and 40 years old	0.48	0.50
Education head	Average education of household head	3.87	1.91
Secondary education head	Dummy if household head has secondary education	0.50	0.50
Literacy head	Dummy if household head can read and write	0.90	0.29
Average grade	Average grade attained by all household members aged 15 or above	3.81	1.19
Primary education	Dummy if household average grade is primary school	0.30	0.46
Secondary education	Dummy if household average grade is secondary school	0.51	0.50
Higher education	Dummy if household average grade is higher education	0.18	0.39
Bulu	Dummy if household is Bulu	0.45	0.49
Ngoumba	Dummy if household is Ngoumba	0.20	0.40
Area	Size of agricultural land	2.50	2.19

Variable	Description	Mean	Std Dev.
Livestock dummy	Dummy if household has dummy from animal raising	0.69	0.46
Non-labour income	Ratio of non-labour income over total production	0.02	0.09
Tontine	Dummy if household participates to a tontine	0.55	0.49
Palm	Dummy if household extracts palm nuts	0.73	0.44
Self employment	Dummy if household is self-employed	0.33	0.47
Wage skilled	Interaction term between participating in a wage activity and activity is skilled activity	0.04	0.19
Distance field	Distance between house and plot (minutes)	32.44	25.13
Household asset	Value of household assets and expenditures in durable goods	113063.3	390474.8
Village variables			
District price cocoa	District price of a bag of cocoa	44204.24	7111.70
Village wage clearing	Village average wage for clearing plot	1899.17	1857.88
District price manioc	District price of a filet of manioc	3628.12	403.37
District price cucumber	District price of a bag of cucumber	17340.28	6303.96
Village electricity	Dummy if village has more than 5 households with electricity	0.56	0.49
Village ethnicity	Dummy if village has more than 2 ethnicities	0.70	0.45
Village distance market	Distance between village and market (km)	14.26	17.88
Village palm	Dummy if village has more than 70% households extracting palm	0.59	0.49
More rain	Dummy if village has more rain the last year	0.64	0.48
Mbango	Dummy if household lives in Mbango-Bitouer	0.06	0.24
Ebom	Dummy if household lives in Ebom	0.07	0.26
Mekalat	Dummy if household lives in Mekalat	0.04	0.20
Bipindi	Dummy if household lives in the village of Bipindi	0.17	0.38
Bidjouka	Dummy if household lives in Bidjouka	0.09	0.29
Lambi	Dummy if household lives in Lambi	0.05	0.22
Ebimimbang	Dummy if household lives in Ebimimbang	0.10	0.30
Bongwana	Dummy if household lives in Bongwana	0.04	0.19
Akom	Dummy if household lives in the village of Akom II	0.11	0.31
Nkomakak	Dummy if household lives in Nkomakak	0.04	0.20
Abiete	Dummy if household lives in Abiete	0.05	0.22
Mvie	Dummy if household lives in Mvie	0.04	0.20
Nyangong	Dummy if household lives in Nyangong	0.11	0.32

Table B.8: Estimation of participation and shadow wage in NTFP extraction, off-farm off-forest activities and hunting

	NTFP (3)		Off-farm off-forest (4)		Hunting (5)	
	Log (earnings/hours)	Participation	Log (earnings/hours)	Participation	Log (earnings/hours)	Participation
Ill adults		-0.0762 (0.0929)		0.245*** (0.0788)		0.306*** (0.104)
Children at school		-0.108** (0.0447)		-0.0947** (0.0477)		-0.108** (0.0532)
Area		-0.0162 (0.0338)		-0.0506 (0.0330)		0.0836** (0.0394)
Livestock dummy		0.139 (0.154)		0.0119 (0.150)		0.197 (0.169)
Self employment		-0.362** (0.165)				
Non-labour income		-1.205 (0.769)		-7.044*** (2.131)		0.263 (0.837)
Tontine		-0.178 (0.152)		0.124 (0.143)		0.257 (0.170)
Palm				-0.406** (0.159)		0.837*** (0.192)
Head aged less than 30	0.583 (0.385)	-0.996*** (0.336)	-0.925** (0.425)	0.339 (0.317)	-0.634 (0.496)	1.383*** (0.361)
Head aged [31;55]	0.478** (0.230)	-0.432** (0.204)	-0.464* (0.271)	0.128 (0.185)	-0.216 (0.309)	0.703*** (0.197)
Household age	0.0143** (0.00724)	-0.0190*** (0.00733)	-0.0177** (0.00885)	-0.00843 (0.00685)		
Household age less than 20					0.168 (0.350)	0.0811 (0.301)
Household age [21;40]					-0.105 (0.304)	0.117 (0.229)
Literacy head	-0.440 (0.324)	0.357 (0.258)	-0.632 (0.405)	0.157 (0.246)	-0.554 (0.458)	0.361 (0.292)
Primary education					-0.0470 (0.384)	0.518** (0.246)
Secondary education					0.155 (0.327)	0.242 (0.218)
Village electricity	-0.660 (0.421)	0.200 (0.303)	0.0277 (0.474)	0.176 (0.286)	0.203 (0.449)	-0.887*** (0.327)
Village distance market	0.0172 (0.0109)	-0.0172* (0.00973)	-0.00218 (0.0123)	-0.00502 (0.00793)	-0.0383*** (0.0115)	0.0201** (0.00856)
Village palm	-1.082* (0.598)	1.615*** (0.533)	-0.535 (0.665)	0.853** (0.422)	0.737 (0.521)	-0.124 (0.442)
Mbango	1.171** (0.575)	0.0533 (0.399)	-1.445 (1.377)	-1.617*** (0.587)		-7.757 (47588)
Ebom	1.206** (0.547)	-1.207*** (0.464)	0.665 (0.642)	-0.605 (0.393)	-0.00426 (0.543)	1.000** (0.435)
Lambi	1.690** (0.694)	-0.883 (0.630)	0.135 (0.773)	0.0325 (0.512)	-1.092 (0.776)	0.401 (0.549)
Bidjouka	-0.514 (0.540)	0.763** (0.385)	0.0175 (0.587)	0.754** (0.369)	0.341 (0.492)	-0.424 (0.415)
Ebimimbang	0.820 (0.530)	-0.387 (0.532)	-0.757 (0.618)	-0.523 (0.394)	0.102 (0.555)	0.534 (0.427)
Bongwana	-0.927 (0.637)	0.969* (0.499)	-0.595 (0.719)	0.445 (0.446)	-0.149 (0.596)	-0.278 (0.490)
Akom	-0.0880 (0.548)	-0.586 (0.665)	-0.00119 (0.648)	0.211 (0.456)	-0.902 (0.598)	-0.101 (0.445)
Nkomakak	1.369* (0.725)	-1.473**(0.619)	-0.817 (0.865)	-0.405 (0.550)	0.313 (1.006)	0.328 (0.616)
Abiete	0.277 (0.537)	-0.692 (0.579)	-0.274 (0.605)	0.387 (0.449)	-0.980* (0.575)	-0.134 (0.420)
Constant	6.002*** (0.592)	1.336** (0.543)	9.289*** (0.751)	-0.124 (0.502)	8.561*** (0.866)	-2.492*** (0.539)
athrho	-1.113*** (0.307)		-0.869*** (0.321)		-0.816* (0.421)	
lnsigma	0.469*** (0.0644)		0.406*** (0.109)		0.270** (0.121)	
Observations	383	383	384	384	371	371

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table B.9: NTFP, off-farm and hunting shadow wages by quintiles of total time

Quintiles	NTFP shadow wage (3)	Off-farm off-forest shadow wage (4)	Hunting shadow wage (5)
Lowest	692.1	1780.8	12153.3
2nd	493.7	1730.3	8456.9
3rd	463.8	1909.6	8851.7
4th	408.5	1751.3	8929.9
Highest	312.7	1852.2	7230.8
Total	475.1	1807.1	9137.2

Table B.10: OLS and Tobit regressions for labour allocations

Variables	Hours Agriculture	Hours NTFP	Hours off-farm
Shadow wage agriculture	0.00489 (0.0220)	-0.0152 (0.0262)	0.0306 (0.0353)
Shadow wage NTFP	-0.00512 (0.00556)	-0.00406 (0.00671)	-0.00682 (0.0126)
Shadow wage off-farm	-0.001000 (0.00275)	-0.000553 (0.00222)	0.00318 (0.00275)
Children	2.349** (0.976)	0.889 (1.005)	-0.897 (0.746)
Wives	13.05*** (3.810)	7.953** (3.156)	2.488 (2.355)
Age head	2.190*** (0.494)	0.760 (0.646)	0.469 (0.547)
Squared age head	-0.0183*** (0.00465)	-0.00807 (0.00570)	-0.00903 (0.00572)
Average grade	3.782(2.633)	-0.0345 (2.387)	2.734 (1.998)
Primary education	0.542 (6.442)	-3.012 (5.451)	1.927 (4.815)
Higher education	4.615 (8.314)	12.92 (10.97)	11.16* (5.944)
Education head	-4.103* (2.232)	-2.520 (2.849)	-3.169** (1.425)
Secondary educ head	1.104 (6.961)	1.590 (7.332)	1.851 (5.099)
Ngoumba	-7.935 (5.165)	6.448 (5.048)	3.440 (5.783)
Bulu	11.82 (8.798)	11.01** (5.453)	1.657 (5.205)
Distance field	-0.151** (0.0662)	0.0146 (0.0758)	-0.0571 (0.0588)
Village ethnicity	17.82 (16.99)	0.493 (12.43)	1.164 (14.68)
Village distance market	0.239 (0.310)	-0.111 (0.269)	0.115 (0.255)
More rain	2.906 (14.86)	17.10 (12.17)	-0.282 (11.68)
Mbango	-4.408 (35.07)	4.702 (33.55)	-72.46 (45.58)
Ebom	-19.65** (9.748)	-2.118 (11.97)	-15.24 (10.26)
Mekalat	9.279 (20.57)	-24.59 (17.29)	-17.54 (18.32)
Bipindi	2.870 (9.353)	8.355 (8.489)	-20.09* (11.57)
Bidjouka	3.238 (12.59)	8.981 (8.903)	-5.875 (10.57)
Ebimimbang	-4.387 (8.962)	3.426 (7.790)	-5.175 (7.690)
Bongwana	1.131 (12.04)	1.373 (8.911)	-13.29* (7.598)
Mvie	8.415 (15.87)	6.298 (13.29)	-4.274 (14.73)
Abiete	-6.984 (12.75)	-21.88** (11.09)	22.79* (12.03)
Constant	-37.73 (24.66)	-13.52 (24.77)	-10.12 (22.75)
Observations	375	375	374

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table B.11: First-stage results for labour allocations

Variables	Shadow wage Agriculture	Shadow wage NTFP	Shadow wage off-farm
Shadow wage agriculture		0.200 (0.702)	-5.508*** (0.958)
Shadow wage NTFP	0.0150 (0.0543)		0.491 (0.396)
Shadow wage off-farm	-0.0531*** (0.00509)	0.0678** (0.0320)	
Livestock dummy	-10.67* (6.202)		
Village price of cucumber	0.0969*** (0.00401)		
Village wage clearing		-0.0664 (0.0467)	
Price of cocoa			-0.0265*** (0.00883)
Child	-5.365*** (1.413)	-19.98*** (7.693)	-13.70 (12.74)
Wives	1.700 (3.779)	23.61 (16.40)	-20.22 (50.62)
Age head	0.536 (0.960)	1.820 (3.098)	16.51** (7.365)
Squared age head	-0.0170* (0.00986)	-0.0578* (0.0317)	-0.111 (0.0788)
Average grade	-1.872 (5.296)	-18.17 (13.58)	25.86 (58.23)
Primary education	-6.599 (17.79)	219.5*** (35.29)	-301.0** (132.4)
Higher education	-65.87*** (13.33)	-42.44 (43.78)	-686.1*** (130.2)
Education head	4.933 (3.128)	-6.468 (9.078)	-52.89 (33.14)
Secondary education head	-4.293 (12.78)	-16.83 (34.36)	-70.84 (97.87)
Ngoumba	34.99** (16.19)	-82.49 (67.80)	91.75 (130.7)
Bulu	-14.91 (10.11)	108.9 (97.32)	
Distance field	0.173 (0.144)	-0.102 (0.405)	0.232 (1.151)
Village ethnicity	-511.4*** (20.77)	195.3 (295.3)	2743*** (343.6)
Village distance market	-35.33*** (1.486)	3.549 (4.039)	47.98*** (7.100)
More rain	454.1*** (26.75)	-517.0* (264.2)	-1645*** (324.4)
Mbango	-401.5** (162.4)	1886* (1013)	4993*** (1137)
Ebom	-269.5*** (34.43)	160.3 (175.4)	1072*** (270.2)
Mekalat	-907.8*** (70.25)	782.6** (361.3)	2857*** (412.1)
Bipindi	415.9*** (15.20)	-166.9 (242.5)	1282*** (301.6)
Lambi	351.6*** (22.90)		
Bidjouka	404.0*** (26.05)		-1237*** (312.5)
Ebimimbang	235.5*** (13.20)	62.90 (79.30)	-287.3** (122.2)
Mvie		116.6 (274.3)	289*** (324.2)
Abiete		235.2** (114.5)	739.9*** (207.1)
Bongwana	-21.66* (12.50)	23.48 (52.52)	
Constant	-592.4*** (67.38)	535.7* (313.3)	2529*** (549.5)
Observations	375	375	374

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table B.12: Reduced form for labour allocation estimations

Variables	Hours Agriculture	Hours NTFP	Hours off-farm	Hours hunting
Child	2.612* (1.493)	1.501 (1.353)	-0.202 (1.084)	0.442 (0.498)
Wives	12.56*** (3.736)	7.937** (3.173)	1.702 (2.360)	4.148*** (1.199)
Dependency ratio	-4.127 (9.165)	-6.239 (7.315)	-7.543 (8.508)	-7.509** (3.610)
Age head	1.950*** (0.493)	0.565 (0.722)	0.126 (0.555)	-0.444 (0.296)
Squared age head	-0.0164*** (0.00481)	-0.00589 (0.00641)	-0.00575 (0.00581)	0.00256 (0.00272)
Maximum grade	6.358*** (2.420)	4.385* (2.304)	0.906 (1.976)	0.499 (0.803)
Primary education	7.244 (6.756)	3.903 (6.242)	-0.335 (5.191)	3.781* (2.060)
Higher education	-6.781 (9.030)	3.093 (10.34)	7.813 (7.117)	-1.695 (3.191)
Education head	-4.803** (2.363)	-3.703 (2.877)	-2.450* (1.459)	-0.557 (0.695)
Secondary education head	3.793 (7.091)	3.774 (7.613)	1.231 (4.980)	2.368 (1.973)
Ngoumba	-6.992 (5.178)	6.071 (4.821)	3.508 (5.419)	1.878 (1.932)
Bulu	12.76 (8.436)	13.05** (5.895)	0.433 (5.063)	-1.333 (3.695)
Distance field	-0.159** (0.0654)	0.000260 (0.0741)	-0.0625 (0.0575)	0.0537** (0.0226)
Wage skilled	-14.68* (7.979)	-14.72**(6.100)		-0.140 (2.324)
Tontine	4.968 (3.562)	3.779 (2.547)	5.703* (3.116)	2.962** (1.310)
Village ethnicity	3.381 (13.07)	7.864 (9.342)	-19.78* (11.58)	1.202 (2.043)
Village distance market	0.0173 (0.166)	-0.256* (0.147)	0.164 (0.164)	0.0103 (0.0549)
Village palm	-4.389 (9.502)	6.846 (6.790)	7.410 (7.479)	-1.977 (2.096)
Village road	-4.625 (9.954)	-31.30*** (7.282)	11.40 (7.633)	-8.897** (3.701)
District price manioc	0.00353 (0.00999)	-0.00674 (0.00811)	0.0337*** (0.0125)	-0.0117** (0.00583)
Mbango	0 (0)			-60.95 (0)
Ebom	-6.746 (13.48)	9.581 (12.78)	23.94 (14.70)	
Bipindi	1.818 (11.46)	13.85* (7.364)	-4.295 (8.755)	1.387 (4.282)
Lambi	0 (0)			4.166 (5.129)
Bidjouka	2.243 (12.11)	22.03** (9.137)	-3.391 (9.046)	4.610 (4.849)
Ebimimbang	2.542 (9.549)	-4.387 (6.372)	1.909 (8.525)	-0.111 (2.782)
Nkomakak	-9.508 (12.23)	8.434 (11.01)	-11.85 (10.63)	
Akom	4.801 (12.39)	15.31 (9.713)	12.08 (10.33)	8.040** (3.669)
Abiete	-15.66** (6.746)	-24.22*** (6.398)	17.22* (9.394)	-3.695 (2.507)
Constant	-40.36 (43.12)	5.623 (40.94)	-114.6** (47.70)	52.20** (25.57)
Observations	375	375	374	375

Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table B.13: Estimation results for labour allocations in a 3sls

Variables	Hours agriculture	Hours NTFP	Hours Off-farm	Hours hunting
Shadow wage agriculture	0.356 (0.418)	-0.322 (0.333)	0.423 (0.315)	0.0145 (0.0571)
Shadow wage NTFP	-0.00958 (0.0109)	0.00388 (0.00866)	-0.00789 (0.00819)	0.000540 (0.00148)
Shadow wage off-farm	0.0173 (0.0222)	-0.0175 (0.0177)	0.0223 (0.0168)	0.000531 (0.00304)
Children	4.293* (2.487)	-0.653 (1.980)	1.788 (1.874)	0.133 (0.339)
Wives	12.48*** (3.731)	6.979** (2.972)	0.633 (2.812)	1.303** (0.509)
Age head	1.948*** (0.697)	0.613 (0.555)	-0.0832 (0.525)	-0.251*** (0.0951)
Squared age head	-0.0115 (0.00975)	-0.0104 (0.00776)	0.00377 (0.00735)	0.00203 (0.00133)
Average grade	4.699 (3.171)	-1.477 (2.525)	2.376 (2.390)	0.364 (0.433)
Primary education	2.274 (7.396)	-6.665 (5.890)	4.587 (5.574)	0.603 (1.009)
Higher education	27.58 (28.80)	-8.017 (22.94)	31.90 (21.71)	0.674 (3.931)
Education head	-5.908** (3.008)	-0.793 (2.395)	-4.015* (2.267)	-0.381 (0.410)
Secondary educ head	2.223 (7.514)	-0.210 (5.984)	4.193 (5.663)	0.872 (1.025)
Ngoumba	-20.22 (16.39)	15.53 (13.05)	-14.65 (12.35)	-0.0644 (2.237)
Bulu	17.03 (10.36)	5.956 (8.252)	7.098 (7.809)	-1.203 (1.414)
Distance field	-0.216** (0.109)	0.110 (0.0868)	-0.111 (0.0821)	0.0343** (0.0149)
Village ethnicity	-282.4 (318.6)	114.4 (114.0)	-221.8 (178.9)	-5.990 (43.48)
Village distance market	-4.716 (5.251)	1.730 (1.853)	-3.559 (2.938)	-0.0936 (0.717)
More rain	128.3 (153.6)	23.06 (20.53)	66.90 (55.10)	10.12 (20.96)
Mbango	-381.2 (453.8)	352.7 (380.1)	-474.1 (350.1)	-23.50 (61.93)
Ebom	-26.59 (24.30)	56.80 (64.54)	-55.47 (37.72)	-5.125 (3.316)
Mekalat	-252.9 (286.6)	114.0 (135.0)	-229.4 (175.2)	-8.958 (39.11)
Bipindi	0 (0)	132.0 (140.5)	-89.56 (62.08)	0 (0)
Lambi	70.33 (86.50)	62.64 (79.60)	0 (0)	2.068 (11.80)
Bidjouka	178.3 (205.8)	0 (0)	101.0 (83.69)	6.775 (28.09)
Ebimimbang	31.24 (35.35)	7.243 (13.61)	9.291 (13.57)	-4.518 (4.824)
Bongwana	40.06 (42.38)	-7.748 (14.03)	18.14 (22.52)	-2.086 (5.784)
Nkomakak	-143.7 (131.4)	102.0 (111.6)	-122.2 (102.1)	1.509 (17.94)
Mvie	-262.6 (291.6)	122.7 (120.4)	-215.2 (170.8)	-8.352 (39.79)
Abiete	-174.2 (172.1)	21.69 (40.41)	-89.00 (87.11)	-5.295 (23.49)
Observations	374	374	374	374

Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table B.14: Reduced forms for labour allocations in a 3sls

Variables	Hours agriculture	Hours NTFP	Hours Off-farm	Hours hunting
Child	2.641** (1.266)	1.814* (0.946)	-0.517 (0.625)	0.360* (0.199)
Wives	12.55*** (3.121)	6.649*** (2.331)	1.132 (1.538)	1.165** (0.491)
Dependency ratio	-4.263 (9.534)	-8.396 (7.121)	0.123 (4.702)	-3.330** (1.501)
Age head	1.908*** (0.596)	0.247 (0.445)	0.0775 (0.294)	-0.348*** (0.0938)
Squared age head	-0.0159*** (0.00585)	-0.00305 (0.00437)	-0.00295 (0.00289)	0.00276*** (0.000921)
Maximum grade	6.376*** (2.329)	3.038* (1.739)	0.866 (1.147)	0.292 (0.367)
Primary education	7.002 (6.469)	1.873 (4.832)	1.765 (3.192)	1.100 (1.018)
Higher education	-7.121 (8.539)	5.331 (6.378)	2.741 (4.207)	-1.073 (1.344)
Education head	-4.767*** (1.835)	-3.355** (1.370)	-1.641* (0.904)	-0.211 (0.289)
Secondary education head	3.497 (6.333)	3.111 (4.730)	2.401 (3.125)	0.856 (0.997)
Ngoumba	-7.105 (6.493)	4.292 (4.850)	-0.112 (3.204)	0.343 (1.022)
Bulu	12.69* (7.021)	12.52** (5.244)	-0.0585 (3.457)	-1.349 (1.105)
Distance field	-0.160** (0.0674)	0.0421 (0.0504)	-0.0365 (0.0331)	0.0358*** (0.0106)
Wage skilled	-13.73 (8.465)	-14.15** (6.314)		-0.593 (1.333)
Tontine	4.864 (3.448)	3.184 (2.576)	2.929* (1.699)	1.179** (0.543)
Village ethnicity	7.384 (7.552)	13.27** (5.641)	0.812 (3.728)	-1.333 (1.189)
Village distance market	0.218 (0.246)	-0.0310 (0.184)	0.106 (0.122)	0.0226 (0.0388)
Village palm	-15.26** (7.410)	3.398 (5.534)	6.711* (3.657)	1.127 (1.166)
Village road	-11.60 (8.868)	-12.94* (6.624)	1.394 (4.376)	0.771 (1.396)
District price manioc	-0.00552 (0.00485)	-0.00133 (0.00362)	0.00166 (0.00239)	0.00199*** (0.000764)
More rain	-9.282 (8.311)	-7.121 (6.208)	-1.663 (4.081)	2.544* (1.308)
Mbango	-3.926 (10.55)	-4.074 (7.879)	0.917 (5.207)	-1.021 (1.660)
Bipindi	1.842 (7.007)	-4.683 (5.234)	2.042 (3.448)	-0.331 (1.103)
Lambi	10.05 (11.17)	-17.97** (8.342)	1.829 (5.494)	-1.907 (1.758)
Ebimimbang	12.36 (11.01)	-4.057 (8.224)	-0.0764 (5.430)	-2.937* (1.733)
Akom	20.39** (9.463)	5.109 (7.068)	-0.543 (4.671)	1.485 (1.489)
Mvie	10.20 (13.47)	9.165 (10.06)	1.042 (6.643)	-1.235 (2.120)
Abiete	-6.699 (12.07)	-13.25 (9.012)	14.70** (5.951)	-2.313 (1.899)

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table B.15: Estimations of labour shares in all four activities using template by Urzúa (2010)

	Agriculture (w1)	NTFPs (w2)	Off-forest (w3)	Hunting (w4)
Log shadow wage agriculture	0.0154 (0.0281)	-0.0017 (0.00131)	-0.0111 (0.0373)	-0.0025 (0.0233)
Log shadow wage NTFP	0.0229 (0.0215)	0.0040*** (0.0007)	-0.0305 (0.0226)	0.00350 (0.0076)
Log shadow wage off-farm	-0.0002 (0.0069)	-0.0001 (0.0006)	0.00066 (0.007)	-0.00028 (0.0004)
Log shadow wage hunting[a]	-0.0381* (0.02272)	-0.0021 (0.0014)	-0.0385 (0.0240)	-0.0006 (0.0246)
Children	-0.0609*** (0.0183)	0.0526 (0.0411)	0.0078 (0.0486)	0.0004*** (0.0001)
Age head	0.0001 (0.0059)	-0.0026 (0.0314)	0.0047 (0.0319)	-0.0021*** (0.0006)
Primary education	-0.0104 (0.0138)	0.0077 (0.0102)	0.0014 (0.0173)	0.0012** (0.0005)
Secondary education	0.0040 (0.0105)	0.0371 (0.0301)	-0.0416 (0.0332)	0.0004*** (0.0001)
Secondary educ head	0.0040 (0.0034)	0.0004 (0.0230)	-0.00442 (0.0232)	
Distance field	0.0043 (0.0052)	0.0053 (0.007)	-0.0097 (0.0091)	
Village distance market	0.0005 (0.004)	0.0244 (0.0305)	-0.025 (0.0309)	
Constant	0.5835*** (0.0655)	0.0611 (0.0500)	0.3070*** (0.0529)	0.0482***(0.0162)

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

[a]Shadow wage for hunting has been calculated following the same Heckman model as used to estimate the shadow wage in NTFPs and off-farm off-forest activities.