Forging new pathways of sustainable development in resource-dependent global south regions. A discussion of related and unrelated variety

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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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Abstract

This thesis investigates how economic diversification takes place where significant regional disparities exist and there is a strong dependence on extractive industries. The context of the study will be Colombia, but this regional description is a feature of many Global South regions and therefore the framework, findings and contribution of the study will be relevant to many Global South areas beyond Colombia. A central thread of the thesis will be the global pressures for sustainable development, which render the question of how regions diversify their economies through technological innovation highly pertinent. Diversification efforts need to consider the social and environmental challenges and pressures driving new development dynamics and the views of a broad range of protagonists, in particular civil society, who are helping to shape these development pathways.

The thesis draws insights from the approach to regional diversification taken by the Evolutionary Economic Geography (EEG) literature. Traditionally, diversification has been seen as mainly driven by *related variety*, embodied in economic sectors, the technologies of which are closely related. This thesis argues that in the context of mining regions, diversification driven by related variety may continue to reproduce this highly polluting industry through unsustainable processes of technological change. Recently, in response to new environmental sustainability agendas, EEG literature has embraced *unrelated diversification*, using insights from transitions literature, as another route for diversification. This thesis argues that unrelated diversification opens a space for looking at other types of innovation and processes of regional diversification that may be relevant for cases of lagged regions with low levels of related variety or based on extractive industries.

Related and unrelated forms of diversification are examined through a mixed-method approach to assess the opportunities for diversification in twenty-eight regions in Colombia. The conditions under which unrelated diversification emerges are examined by looking at the case of Boyacá, a

resource-based region where the interaction between place-based social movements and the mining industry create forces that imprint a new direction for regional policy and create alternative strategies of economic diversification. This methodological appraoch and the extension of the EEG framework make it possible to identify important new and under-theorised trends and processes of regional economic diversification that would otherwise remain under the radar and under-conceptualised.

The contribution of this research lies in the understanding of unrelated diversification in resource-based regions as a *constructed process that requires key drivers, actors, and learning dynamics*. The thesis pins down some of the key elements of the interface between related diversification, unrelated diversification and sustainable development, and the types of new industry pathways that can be forged by these forms of diversification in Colombia. Finally, the results of this research advance the understanding of concepts in the literature of geography of transitions around path creation and bricolage in this context.

Following the introduction, chapter 2 provides a literature review, chapter 3 describes the methodology and chapter 4 subsequently presents a typology of regional diversification in Colombia based on a quantitative analysis. Chapter 5 develops the case study and chapter 6 discusses the contribution of the thesis. Conclusions are drawn in chapter 7.

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List of abbreviations

ANLA: National Authority of Environmental Licences of Colombia

CAF: Corporación Andina de Fomento (Development Bank of Latin America)

CAR: Corporación Autónoma Regional (Regional Autonomous Corporation)

CENSAT: Asociación Centro Nacional Salud, Ambiente y Trabajo (Friends of the Earth Colombia)

CEPII: Centre d'Etudes Prospectives et d'Informations Internationales (Institute for Research on the International Economy)

CINEP: Centro de Investigación y Educación Popular (Centre for Research and Popular Education)

CNRS: Colombian Institute of Anthropology and History

COLCIENCIAS: Instituto Colombiano para el Desarrollo de la Ciencia y la Tecnología Francisco José de Caldas (Institute for the development of the Science and Technology of Colombia)

CPC: Consejo Privado de Competitividad (Private Council of Competitiveness)

DANE: Departamento Nacional de Estadística (National Department of Statistics)

DAPB: Departamento Administrativo de Planeación de Boyacá (Administrative Planning Department of Boyacá)

DNP: Departamento Nacional de Planeación (National Planning Department)

EEG: Evolutionary Economic Geography

FONTUR: Fondo National de Turismo (National Tourism Fund)

GDP: Gross Domestic Product

HH: Herfindahl-Hirschman Index

HS: Harmonised System

ICANH: Instituto Colombiano de Antropología e Historia (Colombian Institute of Anthropology and History)

KET: Key Enabling Technologies

MINCIENCIAS: Ministerio de Ciencia, Tecnolog'ia e Innovación de Colombia (Ministry of Science, Technology and Innovation)

NGO: Non Government Organisation

OCYT: Observatorio Colombiano de Ciencia y Tecnología (Observatory of Science and Technology of Colombia)

OECD: Organisation for Economic Co-operation and Development

R&D: Research and Development

SENA: Servicio Nacional de Aprendizaje (National Training Service)

SIC: Standard Industry Classification

STI: Science, Technology and Innovation

TIPC: Transformative Innovation Policy Consortium

UN: United Nations

UNDP: United Nations Development Programme

UPTC: Universidad Pedagógica y Tecnológica de Colombia

WWF: World Wildlife Fund

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Chapter 1

Introduction

Why some regions are able to diversify and not others has been the backbone of the evolutionary economic geography (EEG) agenda (Boschma & Lambooy 1999, Neffke & Boschma 2011, Boschma 2017, Boschma, Coenen, Frenken & Truffer 2017) and a continuous concern in Global South. Diversified regions are deemed enclaves of technological change and virtuous market dynamics. The dominant thinking is that these regions tend to diversify into related industries (Neffke 2009, Neffke & Boschma 2011, Boschma, Minondo & Navarro 2012, Boschma 2017, Xiao, Boschma & Andersson 2018), facilitated by their technological relatedness that fuels and furthers innovation and learning. This thesis poses the question of how this conception of diversification applies to resource-based regions in the Global South. In this context, the "historical processes that [have] produce[d] the uneven economic landscape" (Boschma & Martin 2010, p. 27) need consideration. As Simmie (2012) points out, these events shape the routes and course of diversification and its associated dynamics of technological change. It can translate into path dependencies that may lock regions in to certain industries and technological trajectories (Simmie 2012). As a self-reinforcing effect and force, lock-in "steers a technology, industry, or regional economy along one 'path', rather than another" [p. 3](Martin 2010). From there, how do differentiated trajectories emerge and co-exist within a country? Sustainable development and the transitions literature can help reconstruct the understanding of regional diversification in resource-based countries in two ways: first, by embracing existing technological trajectories and their inherent constraints and, second, by

integrating wider forms of knowledge generation and innovation that take place in resource-based regions, which don't necessarily display the features of technological enclaves. This reconstruction contributes to EEG theory and constitutes the overall aim of this thesis, with a focus on the case of Colombia.

The central question that motivates this thesis is: how do sustainable pathways of diversification unfold and what conditions facilitate their emergence? The purpose is to understand patterns of diversification in the context of highly disparate regions and to assess the extent to which their existing industrial bases have shaped their evolution and created new challenges in light of sustainable development. EEG literature provides a useful framework to examine the *evolution* of regional economic configurations and growth through the geographies of technological change (Boschma & Martin 2010). The concepts of related and unrelated variety are useful theoretical devices to take stock of the technological variety of a region at certain time and to investigate patterns of change by measuring variations in their levels over time. This thesis studies both technology related and unrelated drivers of diversification to determine their role in the evolution of regional industrial bases. It also examines the existence of differentiated patterns of diversification in Colombia. A first line of enquiry asks what types of opportunities developments based on related and unrelated diversification can offer to a resource-based country? A second research question addresses the extent to which related and unrelated variety enable the adoption of principles of sustainable development in this context.

There is a growing interest in the EEG scholars to look at how existing industries and capabilities can assist regions in addressing sustainable development (Gibbs 2006, Patchell & Hayter 2013, Boschma et al. 2017, Santoalha & Boschma 2021, Montresor & Quatraro 2020). It has produced a rich response that incorporates aspects of vested interests, policy, and knowledge generation for green diversification. The context of analysis has been mainly of advanced regions, with less attention being paid to resource-based and highly economically disparate regions, where sustainable development can be even more pertinent in a discussion of regional diversification.

Sustainable Development Goals agreed at the global level have resonated at local levels (Truffer & Coenen 2012, Bridge, Bouzarovski, Bradshaw & Eyre 2013), empowering communities and civil society to explore alternative development approaches that divest away from unsustainable industries. This search for alternative pathways to economic development has been a feature of regional political dynamics in mining regions in Colombia and has reached the media spotlight. One example is the region of Boyacá, in Colombia, where communities responded to the extension of the mining industry — which was promoted by the national government as a main growth strategy — by organising social movements (Departamento Nacional de Planeación 2011). This is an example of where different actors from those traditionally considered in innovation studies, were a factor in driving economic diversification. This happened not through technology-driven change, but motivated by other social principles including sustainability.

This research agenda of incorporating institutional and social variables to understand the process of economic diversification has to some degree been taken up in the debate around related and unrelated diversification. Similarly, the geography of transitions literature had already advanced some ideas on how alternative pathways arise and the way constraining factors are overcome, particularly in high-tech contexts (Steen 2016, Binz, Truffer & Coenen 2016, Binz & Anadon 2018, Trippl, Baumgartinger-Seiringer, Frangenheim, Isaksen & Rypestøl 2020, Baumgartinger-Seiringer, Miörner & Trippl 2021). Drawing on these theoretical inputs and practical evidence, a second stream of enquiry focuses on how unrelated diversification emerges in a natural resource-dependent region through a case study analysis of Boyacá. Mining regions tend to concentrate their technological capabilities around the extractive industry and eventually lock-in. Diversification of existing technological capabilities requires a new policy direction to unlock R&D and innovation agendas and bring in the necessary resources to enable knowledge generation and learning. The thesis investigates how bricolage — a way of action by "making do with what is at hand" (Karnøe & Garud 2012*a*) — favours agency formation and resource mobilisation in this context to fulfil this need. The final question of this research concerns the conditions that enable the

emergence of unrelated diversification.

This thesis is a form of explanatory research that adopts a sequential methodology design. It first develops a quantitative analysis around related diversification, followed by qualitative research in the case study of Boyacá. A mixed methodology helps capture the complexities of the diversification process in a resource-dependent and less economically developed region, picking up on the nuances of constraining factors and knowledge generation activities pursued by heterogeneous actors and their networks. Using mixed methods enables an analysis that looks beyond the conventional understandings of diversification possibilities for resource-based regions and elucidate the reasons that make related variety a narrow approach in this context. This methodology also helps understand how more transformative pathways can be achieved.

From the quantitative analysis, a typology of regions is produced based on their regional levels of technological relatedness. This shows three groups of regions. Group 1 is formed of the most advanced regions and urban centres, with industries and diversified exports and high levels of related variety. Group 2 comprises the intermediate regions, with moderately concentrated exports and low levels of related variety. Group 3 consists of the mining and lagging regions, with very low levels of related variety and concentrated or scarce exports. The analysis shows that in the context of low related variety it is difficult to explain related diversification and the emergence of new pathways, particularly, those that emerge outside firms, for example, through niches processes, characterised by small and more experimental initiatives aimed to create more sustainable alternatives to existing industries and market dynamics. Finally, related diversification does not addresses sustainability agendas in contexts of resource-based regions, such as mining, that are highly polluting sectors. This thesis argues that these patterns of industrial dynamics, especially in mining regions, are likely to continue to reproduce unsustainable processes of technological change and economic evolution, particularly in group 2 and 3 regions. For these regions, this thesis investigates the degree to which unrelated diversification can represent an opportunity for industry diversification based on principles of sustainable development. From

these results, a more detailed investigation is undertaken for the case of Boyacá, a group 3 region. The social pressures for more sustainable pathways of development, alongside a new regional science, technology and innovation (STI) policy towards the sustainable use of biodiversity for regional development made Boyacá a case worthy of further investigation. This case study provides insights into how the concept of technological unrelated diversification can be applied to the Colombian context.

The case study of Boyacá illustrates how forces of change, emerging from the interaction between place-based social movements and the mining industry, create demands to divest away from mining. These demands can have a great effect on policy as to provide a new direction that can help overcome some of the constraining factors faced by the region, particularly unlock-in – changing the patterns driving decision making around – R&D and innovation agendas. The case study also evidences how heterogeneous actors are able to mobilise the knowledge and skills required to oppose to mining (including its negative impacts on the environment) and to create alternative strategies of economic diversification. Through these new resources and capabilities, knowledge generation focuses on local needs and displays inclusive and reflexive features. In resource-based regions, path creation is contested by the existing mining industry and situated social movements. In addition, political economy issues associated with historical patterns of industry formation can also pose further challenges to these social initiatives.

The contribution of this thesis develops the above arguments in more detail. Firstly, it shows that unrelated diversification in resource-based regions is a *constructed process that requires key drivers, actors, and learning dynamics.* Secondly, the thesis is able to pin down some of the key elements of the interface between related diversification, unrelated diversification and sustainable development. This is critical because diversification based on principles of sustainability is different to other processes of diversification. It is social change as well as industry change, that is, a socially constructed process, and therefore, is not exclusively driven by market dynamics and demand. In contrast, sustainable

pathways entail more radical changes in patterns of production, consumption and users' preferences that are strongly aligned and therefore, difficult to change market incentives and forces, for example, private transport and energy consumption. These interdependencies are fuelled and maintained by continuous innovation that makes them more efficient but do not require radical changes, as in the case of electric cars. It is in this context that social forces and policy become more relevant to envisage and enact change. The thesis also touches on the question of the types of new industry pathways that can be forged by related and unrelated forms of diversification in Colombia. Finally, the results of this research advance the understanding of concepts in the literature of geography of transitions around path creation and bricolage in this context.

The next section explains the background of the thesis. Section two introduces the research questions and the variables used in the analysis. Section three outlines the content of the thesis.

1.1 Background and research context

I began this research with the interest of understanding how regions diversify in Colombia following, in first instance, technological relatedness as the key driver of regional economic change. This is deemed to be the way in which spatial economic reconfiguration takes place (Frenken, Van Oort & Verburg 2007, Neffke 2009, Neffke & Boschma 2011, Boschma et al. 2012, Boschma 2017). Regional disparities in Colombia are well known (Moncayo 2004, Consejo Provado de Competitividad 2016), and are for some multilateral organisations a matter of concern (OECD 2014). The importance of relatedness in regional diversification was evident in the most advanced regions, but less so in the intermediate, mining and lagging regions. So, the question emerged of whether there were trends towards diversification and, if so, what was the pattern of diversification in these regions? The EEG's approach to the evolution of the regional economic landscape, as applied to the resource-dependent and lagging regions, puzzled me for some time. The results from the quantitative analysis suggested there were few possibilities of diversification in intermediate regions, whose economic activities

were predominantly agricultural and, similarly, for those regions dependent on extractive industries and the lagging regions. Based on the quantitative analysis of related variety, nothing seemed to change over time for resource-based regions: no diversification was taking place. A clear result was the *marked differences between regions in their levels of related variety.* The immediate question was how regional diversification should be understood in this context?

Alongside my PhD studies, I have been involved in the Transformative Innovation Policy Consortium (TIPC), which introduced me to the transitions literature. This literature was new to me, in contrast to some of the literature on economic geography and STI, which I became familiar with during my studies as an economist. Transitions literature puts sustainable development at the centre and explains the difficulties of change towards sustainability (Geels 2004, Grin, Rotmans, Schot, Geels & Loorbach 2010). This work offered me some insights into why the regions' industrial structures were difficult to change, and seemed useful for the case of mining regions, but it was not clear how to integrate these two bodies of literature. In February 2017, a paper by Boschma et al. (2017) was published, proposing related and unrelated diversification as routes for diversification. It opened a window to explore new forms of diversification, which could be useful in the case of Colombia. In addressing unrelated diversification, key building blocks around the drivers of change, bricolage and alignment required individual consideration, but were all important parts in the overall understanding of how the process unfolds. Still, the relation between diversification and sustainable development was not clear.

1.1.1 Social demands for change and unrelated diversification

During my work with TIPC and Colciencias (Now Minciencias), I was involved in one project interested in understanding the spatial aspects of transitions. In searching for cases that could provide evidence, I discovered news reports of communities in Boyacá holding a peaceful demonstration in defence of water resources, and in opposition to the expansion of mining titles in the region, which had been granted by the National Authority of Environmental Licences. These

events connected the dots. In this case, it was not through firms, but rather through social actors that change and a new direction towards sustainability was being enacted. The social movement was situated, opposed to unsustainable industry and, socially-driven. I thought that this fitted some of the ideas around unrelated diversification. The news reports were revealing and allowed me to connect the literature with what was happening in the territory. The case of Boyacá paved the way for a new avenue in this research to understand in detail how unrelated diversification unfolds in a resource-based region, and to examine how unrelated diversification helps to explain what is happening in this context. This turn was meaningful, because it could provide insights into how alternative trajectories of diversification could unfold in other regions in Colombia. It could highlight new factors and circumstances that are often overlooked by dominant approaches that emphasise technology-driven innovation where firms are the main actors in related diversification.

As the research progressed, it also became more evident that there was a need for a different understanding of the constraining factors faced by resource-based regions. Their industrial set-up around the exploitation of natural resources is, in the first place, unsustainable but also tends to be the main source of lock-in. This finer understanding was possible through the discussion on undone science. The science that needs to be done but gets undone because the market does not provide the incentives to be done (Hess 2007). Undone science was also relevant in the research project I was working in the TIPC. This concept helped me understand the agency behind funding of R&D agendas because it provides direction to what knowledge is generated and what isn't. Undone science made easier to explain the lock-in of research agendas in a resource-based region and why it becomes a constraining factor — something that was not fully explained by Boschma et al. (2017). Hess (2007) provided me with further insights around alternative pathways in science and industry. Hess's work on the science, technology and society fields, explains how social movements form to oppose certain industries; the role of researchers and activists; and the type of actions undertaken to oppose and facilitate alternatives to unsustainable industries. It clearly described what was happening in Boyacá. Although, for Boyacá, there was

no clear separation between opposition and path creation, as demonstrated in the cases investigated by Hess (2007).

Therefore, the coupling of sustainable development and diversification could be an entry point for new drivers of change, that can be radical but are not technological and respond to the local needs of regional inhabitants. The understanding of space was important, because it was a natural resource that was in dispute and triggered these social demands. These tensions around the control of the natural resources in local geographies, were also accompanied by the pressures from countries in the Global North, whose demands for cheap energy create opportunity for economic growth in resource-dependent regions. The "power" of social movements in Boyacá, when blocking the access of trucks to the open pits and mines, or cutting the cables for the exploration machinery, constitute examples of these new drivers. The agency of these social movements emerged in relation to the issue of controlling natural resources. That is, agency was influenced by the specific material conditions of the region. With all these different inputs, it was finally possible to form a clear argument around constraining factors and how they could enable demands for change and become drivers of unrelated diversification.

1.1.2 The importance of bricolage in constrained context

One of the most difficult aspects of creating alternatives pathways of diversification is the lack of knowledge and skills in the new field (Boschma et al. 2017, Binz & Anadon 2018). In Boyacá's case, it was not only the lack of knowledge around the new alternative, but also the knowledge needed to oppose to the mining industry, which is characterised by multinational companies that perceive local communities as obstacles in their business strategies (Garay 2013). The concept of bricolage, already coined by (Karnøe & Garud 2012*b*) to account for collective action in the transformation of the windmill industry into a wind power generation industry in Denmark, could assist in this sense. Two intertwined aspects of bricolage help to address unrelated diversification: distributed agency, which refers to actors with similar levels of influence and resources within processes of innovation, and resource mobilisation. Elements of bricolage emerged

throughout interviews in the field with local actors in Boyacá. A particular feature was that social movements were able to mobilise policy to i) legitimise their opposition to mining, ii) apply pressure for a new direction to policy, particularly STI policy, and iii) confront national government's policies and procedures fostering the expansion of the mining industry. Soon after I came across the news about social movements and communities, I found that Boyacá had formulated and was implementing a new STI policy focused on the protection of biodiversity and the creation of an alternative development pathway based on the protection of the local biodiversity: Boyacá BIO (Departamento Administrativo de Planeación de Boyacá 2017). Using the concept of bricolage, it was possible to interpret the linkages between communities, social movements and NGOs for knowledge exchange. Bricolage furthered the resourceful action of the social movements in Boyacá.

Of the four social movements researched in Boyacá, each one exhibited an alternative for regional development. The alternatives were around eco-tourism, scientific tourism, bioeconomy, and cultural tourism.

1.1.3 Alignment and the political economy of industry formation

The last part of the analysis in the case of Boyacá focused on how these alternatives evolve, and why some remain small while others grow and gain momentum. To this end, I adopted the concept of alignment in four domains: legitimacy, financial investment, market and knowledge generation (Binz et al. 2016, Boschma et al. 2017). This is the way that EEG literature addresses the emergence of new industries, and has a strong focus on market development. Alignment was incorporated to this thesis to assess the extent to which the alternatives envisaged and developed by social movements and those derived from the policy implementation of Boyacá BIO could align and give rise to a new regional industry.

Nevertheless, a criticism of this concept was around its primary market approach, which can outweigh sustainability principles and the underlying tensions within

alternatives that could hamper the process.

1.1.4 Bridging related diversification and sustainable development

Up to this point, this research had addressed the issue of resource-based regions but had not dealt with sustainable development in regions where related variety appears important. What do the levels of variety found in these regions tell us about the underlying process of diversification? It was necessary to go beyond the figures to examine the industrial dynamics that explain their patterns of technological change. In the Latin American context, industrialisation and diversification has been marked by the action and power of large economic groups and businesses (Garrido & Perez 1998, Schneider 2009, Amsden, DiCaprio & Robinson 2012) and the insertion of some regional industries into Global Value Chains of commodities. This is the case in groups 1 and 2 found in the typology of regions. Group 1 regions' economic and political power led to public investments early in the 20th century to build the infrastructure that connected the regions with the capital city of Bogotá. However, these investments did not take place in the rest of the country. Infrastructure sped up economic development and became a factor of industrial localisation in Colombia (Moncayo 2004). These "historical" events could explain to some extent, as Simmie (2012) suggests, the reasons for the uneven economic landscape. These political economy factors have been disregarded in the EEG literature under the assumption of self adaptation (Essletzbichler & Rigby 2007, Essletzbichler 2009). These factors can explain the limits of related diversification to address sustainability challenges, particularly in group 1 regions.

1.2 Research questions and methodology

The thesis is located in the interface between the literature of EEG and the geography of transitions and adopts a mixed methodology, with two streams of analysis presented in two different empirical chapters: one of quantitative nature and another qualitative, focusing on the case of Boyacá.

Chapter 4 develops the quantitative analysis that measures regional diversification levels based on Herfindahl-Hirschman indexes (UN 2016) and calculates related and unrelated variety levels for 28 regions in Colombia between 2008 and 2017. Hierarchical classification provided by the Harmonised System and the proximity method following Boschma et al. (2012) are used for these calculations. The indexes obtained are plotted against regional economic variables, such as Value Added Growth and GDP, to identify possible relations between the variables. Based on these results the analysis is elaborated with two main questions:

1. *What type of opportunities can development based on related and unrelated diversification offer to a resource-based country with highly disparate regions.*
2. *To what extent does technological relatedness and unrelatedness enable the adoption of principles of sustainable development in resource-based regions?*

Chapter 5 is based on the case study analysis of Boyacá and depicts the advocacy of four social movements for sustainable development and their actions to forge alternative pathways of development in the region. The case answers the following three questions:

1. *How do unrelated diversification alternatives emerge in resource-based regions?*
2. *How does bricolage help build agency and mobilise resources in this context?*
3. *Under what conditions might unrelated diversification paths create opportunities for sustainable development.*

1.3 Structure of the thesis

The thesis is structured in seven chapters. Chapter 2 discusses the two main bodies of literature used in this research: EEG and geography of transitions. The literature review highlights the opportunities to extend the use of EEG to address diversification in the context of resource-dependent regions facing sustainability challenges. In doing so, it points out the need for a deeper understanding of the nature of this constructed process of unrelated diversification in a resource-based region and the implications it has for the type of actors who take part in forging

sustainable pathways of diversification, particularly in this context. A second contribution derives from bridging sustainable development and regional diversification, to understand the conditions under which sustainability principles can be adopted in technologically related and unrelated pathways of diversification.

Chapter 3 depicts the methodology adopted in the research, presenting the research design and conceptual framework alongside the quantitative and qualitative data sources, finishing with the procedure followed for data analysis. Chapter 4 explores regional diversification in Colombia. A typology of regions is produced based on the levels of related variety, with three main groups. This chapter discusses the type of opportunities that related and unrelated diversification could offer to these three groups and the limitations imposed by their existing industrial bases to adopt sustainability principles.

Chapter 5 focuses on creating sustainable pathways in resource-based regions and the role of agency and bricolage in unrelated diversification. This chapter examines how the drivers of change consolidate; articulates bricolage action; and considers the extent to which alignment can be found between the diverse alternatives put forward by heterogeneous actors in four social movements and their extended networks.

The results obtained in Chapter 4 and 5 are brought together in the contribution and discussion chapter 6, where the main gaps in the literature are tackled and discussed based on the results provided by the empirical chapters. Finally, conclusions are drawn in chapter 7.

Chapter 2

Literature Review

Introduction

How regions diversify while addressing sustainability challenges has increasingly gained relevance in the EEG research agenda (Gibbs 2006, Patchell & Hayter 2013, Boschma et al. 2017, Santoalha & Boschma 2021, Montresor & Quatraro 2020). Understanding regional diversification through technological innovation has been central in the evolutionary economic geography (EEG) literature (Boschma & Frenken 2011, Boschma et al. 2012, 2017). Diversification is seen as driven by related variety, a concept that represents the "right balance between cognitive distance and proximity" (Hassink, Klaerding & Marques 2014). Innovation is fuelled by high levels of variety and economic sectors whose technologies are closely related (Boschma & Lambooy 1999, Hidalgo, Klinger, Barabási & Hausmann 2007). This means that regions tend to diversify into activities that are close to their existing regional capabilities, embodied in their regional industries. Relatedness and technological proximity make it easier for a region to move into a new industry, by facilitating learning and innovation within firms underpinned by their existing knowledge and capabilities.

Research looking at how existing industries and capabilities help regions tackle sustainability challenges and generate further opportunities for growth has produced responses from different perspectives, for example, sustainable diversification based on unrelated variety (Boschma et al. 2017, Binz & Anadon 2018, Asheim 2019), new path development (Hassink, Isaksen & Trippl 2019,

Trippl et al. 2020) and more recently green diversification mainly based on related diversification (Gibbs 2006, Santoalha & Boschma 2021, Montresor & Quatraro 2020). The context of these analyses has been predominantly of developed regions, including those dealing with old industries (Balland, Boschma, Crespo & Rigby 2019), regions with strong key enablign technologies (Montresor & Quatraro 2020) and less innovative regions (Asheim 2019). Nevertheless, how sustainable diversification unfolds in resource-based regions is noteworthy and has not yet been addressed in this literature. It could contribute to the momentum of this research agenda.

The recent interest by EEG scholars in unrelated variety and therefore, diversification into different industries to those already established in the region, opens up a space to look at other types of innovation and processes of regional diversification. These innovations may be radical and disruptive in nature, for example, responding to new environmental sustainability agendas or transformative change (Hess 2007, Coenen, Hansen & Rekers 2015, Boschma et al. 2017, Asheim 2019). This thesis will argue that unrelated diversification may also be relevant in cases of lagging regions with low levels of related variety, a point that has been made other authors but requires a great deal of development (Binz & Anadon 2018, Asheim 2019). This research explores the usefulness of unrelated variety as an explanation for processes of diversification within less developed regions and particularly those based on extractive industries.

To fully grasp the process of unrelated diversification it is necessary to understand the nature of industrial change and the forces that resist transformation, in particular path dependency, and how change is enacted and materialised in a new diversification path. The spatial element of transformation (Harvey 2006, Mitchell 2011, MacKinnon, Kempton, O'Brien, Ormerod, Pike & Tomaney 2021) is central to this research, as it captures the underlying industrial dynamics that create a need for disruptive change and the emergence of place-based forces providing directionality to that change. This is critical to understand processes of industrial diversification in mining and "lagging" regions, by actors usually not considered in innovation studies, such as civil society, and the interplay civil society and

regional innovation policy that creates the conditions for transformations. Industrial diversification in this context, is therefore likely to work with these forces, as well as other traditional factors such as market dynamics, firms and value chains. Civil society, represented in social groups and movements, has been increasingly integrated into transitions literature as a change initiator (Smith 2012, Steen 2016). Such groups and movements challenge existing routines within regional economic sectors, and trigger demand for change (Hess 2007). The agency created by social movements (Porta & Diani 2014) and its materialisation through bricolage helps mobilise resources, create narratives and pressure for change (Garud & Karnøe 2003, Karnøe & Garud 2012*b*). This can provide directionality to policy, and reconfigure research and development (R&D) priorities and investments, and the dynamics of knowledge generation and learning, through the engagement of this broader set of actors, which shapes innovation dynamics and facilitates the emergence of new pathways for diversification (Hess 2007).

This chapter comprises five sections. Relatedness and industrial change are reviewed in section 1. Section 2 discusses sectoral innovation dynamics, space and change. The role of social actors in unrelated diversification is examined in section 3. Bricolage is addressed in section 4 to explain how it enacts path creation. Section 5 reflects on the relevance of unrelated diversification for lagging regions and, its implications for the understanding of industrial change and sustainability.

2.1 Relatedness, industrial change and sustainability

EEG literature argues that regional diversification is an economic process underpinned by variety and relatedness (Boschma & Frenken 2006, Neffke & Boschma 2011, Boschma et al. 2017). Variety is constituted by the regional capabilities embedded in localised industries and sectors within a territory (Frenken & Boschma 2007). These technological capabilities are formed by routines, which are cumulative, unique and difficult to change, thereby making it more likely for firms to produce goods and services related to what they already produce (Boschma et al. 2012). Innovation takes place in the recombination of

these routines (Boschma & Frenken 2006) in a way that emphasises geographical and technological proximity, resulting in dynamic learning effects and localised economies (Boschma & Frenken 2006). Thus, it is argued that regions tend mainly to diversify into technologically related industries and sectors (Boschma & Lambooy 1999, Hidalgo et al. 2007, Wal & Boschma 2011), which means industrial change is a path dependent process (Boschma & Lambooy 1999, Iammarino & McCann 2006, Frenken & Boschma 2007, Boschma & Martin 2007, Neffke & Boschma 2011, Hassink et al. 2014, Boschma et al. 2017). Despite path dependency being a useful concept to explain "localised economic growth and self-reinforcing economic activity" (Martin 2010, p. 5), it can lead to lock-in (Martin 2010). Hence, path dependence appears to be more appropriate to explain continuity than change (Martin 2010, Steen 2016, Karnøe & Garud 2012*b*), as dominant forces for industrial change tend to be related to what is already happening within the region, making unrelated industrial change more unlikely to occur.

How regions break with path dependencies and combine efforts to continue to growth and tackle their environmental and social pressing needs has produced a wide response in two main directions. To understand how sustainability and regional diversification intertwine (Truffer & Coenen 2012, Patchell & Hayter 2013, Dawley 2014, Boschma et al. 2017, Montresor & Quatraro 2020, Trippl et al. 2020, Santoalha & Boschma 2021) and possible actions to facilitate it from the policy realm (Coenen & Truffer 2012, R & C 2014, Coenen, Hansen & Rekers 2015, Foray 2017, Tödtling, Trippl & Frangenheim 2020). An important feature of this response has been to move away from a firm and industry centric approach to embrace more complex aspects of industrial change in the light of sustainability issues such as vested interests, policy intervention and agency as shown in Dawley, (2014), Steen (2016), Hassink et al. (2019). Nevertheless, this emergent research needs careful consideration to better understand the underlying conditions giving birth to new pathways of industrial diversification and the rationale behind their emergence.

The research around green diversification has investigated how local capabilities

can produce new combinations of knowledge for greener industries. For Montresor & Quatraro (2020) green branching comes about as a hybridasation of localised non-green and green knowledge. The authors point out the relevance of key enabling technologies (KET) such as "industrial biotechnology, nanotechnology, micro and nano electronics, photonics, advanced materials, and advanced manufacturing technologies" (Montresor & Quatraro 2020, p. 1356) bridging proximity gaps between non-green and green capabilities in an industry. In this sense, non-environmental capabilities are seen to certain extent as enabler for green industrial branching. Two assumptions are important in their analysis. A clear policy directionality targeting green industries as stimulus to harness the overlap between green and non-green knowledge and secondly, the presence of strong technological capabilities embodied in KET. Two questions arise from this perspective, how does the process look like in absence of KET? Another revolves around the nature of vested interests, which substantially differs from those underlying the control of natural resources. These are central issues in resource-based and less developed regions in the global south.

A deper analysis of vested interests is provided by Santoalha & Boschma (2021), who acknowledge that power from unsustainable industries may oppose to green diversification. Neverthless, resistance from "dirty" industries may ease if firms perceive further market opportunities in becoming more sustainable. Similarly, the authors argue that in some cases the negative effects of such "dirty" sectors may foster the emergence of new technologies to mitigate its negative effect. In this case, regulation and social pressure can produce a nudge effect and enhance industrial change. Here, market opportunities is what influences decision making. As the authors pointed out, in some regions the power associated to unsustainable industries responds to more complex dynamics. This is the case of extractive industries, where the control over the natural resources may also be influenced by geopolitics of energy generation (Bridge et al. 2013). Moreover, a response to mitigate the negative impact of highly polluting industries, as in the case of mining, can promote the emergence of new business but environmental damages will not entirely resolve as some may be irreversible.

The above shows that greening existing industries is mainly influenced by market and innovation opportunities that offer new growth avenues for both firms and regions, and regulation may have a possitive effect in fostering the adoption of more sustainable technologies. The main challenges faced by firms relate to the need for new regulations and standards, upskilling, and funding for research and innovation (Balland et al. 2019, Trippl et al. 2020). Clusters of firms and entrepreneurs can use thier influence to mobilise resources and demand policy incentives to generate more favourable conditions for the new industries (Garud & Karnøe 2003, Karnøe & Garud 2012*a*). Policy response then plays an important role in facilitating rapid adjustments and continuous support to respond to these emergent opportunities. For example, as suggested by the Smart Specialisation Strategy (S3) (R & C 2014, Foray 2017, Balland et al. 2019). S3 seeks to reveal new opportunities for continuous economic growth considering the existing capabilities, their relatedness and knowledge bases. It is rooted in the concept of related diversification, and has also embraced environmental and social challenges as potential drivers for regional policy (R & C 2014, Foray 2017, Balland et al. 2019, Montresor & Quatraro 2020). As a policy framework, S3 fosters the discovery of new opportunities and their realisation through policy support. In other cases, it's the interplay between policy and networks from regional strategic actors who can bring in the capabilities to enable path development in more technologically distant industries (Asheim 2019). Less clear is the process whereby sustainable diversification is needed to halt a resource-intensive and highly-polluting industry.

Recently, some EEG authors have become more interested in unrelated diversification, in cases where regions require radical changes (Coenen, Hansen & Rekers 2015, Steen 2016, Boschma et al. 2017, Binz & Anadon 2018). For example, in places where extractive industries have deteriorated biodiversity and water sources, there exist more pressures to make a transition towards more sustainable growth (Coenen 2017, Alexandra 2017, Temper, Walter, Rodriguez, Kothari & Turhan 2018), which can represent a sharp break with previous trajectories of development. In the same vein, the Sustainable Development Goals (SDG) have focused attention on the need to overcome the most urgent societal

needs, particularly of the poorest regions (United Nations Development Program 2015). Hence, regions are trying to address these challenges in confluence with their efforts for diversification (Boschma & Gianelle 2014, Coenen, Hansen & Rekers 2015, Foray 2017). There is an increasing need for more appropriate approach to understand unrelated change, particularly in these regions, where new pathways deviate substantially from existing capabilities or in the absence of technological capabilities (Binz & Anadon 2018, MacKinnon et al. 2021). For example, MacKinnon et al. (2021) elaborate a place-based approach for left behind regions that embraces both the problems and potentialities of these places, and calls for local actors and communities to identify the opportunities and direction of development. In their view, re-framing urban and regional development implies bridging economic and social domains and alternative and conventional approaches of development (post-growth, social economy, social innovation and community development with GDP, technological innovation and infrastructure, employment and distributing the benefits of technological innovation). In this sense, diversification guided by principles of sustainability could represent an alternative approach to regional development with a "different type of growth".

To address unrelated diversification, EEG has borrowed elements from transitions literature to understand the constraining factors for radical socio-technical change (Binz et al. 2016, Steen 2016, Boschma et al. 2017). Industrial change is difficult because existing sectors embody vested interests in keeping their market and economic power (Geels 2004, Bridge et al. 2013) and sectoral interdependencies create patterns of user and consumer behaviour that hamper change (Geels 2004). Likewise, innovation responds to sectoral dynamics that focus on efficiency and further technological development, which reinforces existing production, market, user and customer relationships (Geels 2004, Hess 2007, Mitchell 2011). For example, economic activities and standards of living in the northern context are fulfilled by the energy produced from fossil fuels extracted from the Global South, where the environmental and social effects of these extractive industries are experienced (Mitchell 2011). These patterns of behaviour and the economic system associated to it are difficult to change and involve global actors and their

agency, who may be reluctant to change. In lagging regions constraining factors take the form of a lack of capabilities and an incipient industrial base (Binz & Anadon 2018), whose economic structures do not exhibit major changes over time. By considering constraining factors, EEG integrates agency to the analysis of unrelated change as a factor shaping the process of diversification (Binz et al. 2016, Steen 2016, Boschma et al. 2017).

Early on, Boschma & Frenken (2006) recognised the role of agency in the evolution of industries and places. EEG explored the concept of windows of local opportunity (WLO) (Boschma & Lambooy 1999, Boschma & Frenken 2006, Steen 2016) to explain the long-term ability of regions to develop new high-technology industries (Boschma & Lambooy 1999, p. 421). WLO were partially attributed to "triggers" such as challenges or opportunities that were conceived as "omni-present" (Boschma & Lambooy 1999, p. 422). Agency was attributed to the nascent industry, as it was able to generate the conducive environment to facilitate its emergence and consolidation over time (Boschma & Lambooy 1999). Yet, WLO relied mainly on firms and agglomeration economies to explain the emergence of unrelated industry (Boschma et al. 2017).

Recently scholars from EEG have begun to consider unrelated diversification as a constructed process driven by the interplay between agency, policy and institutional entrepreneurship – actors with interest and capacity to generate changes in the institutional framework, e.g. norms, behaviour and practices – (Binz et al. 2016, Steen 2016, Boschma et al. 2017, Binz & Anadon 2018). Boschma et al. (2017, p. 4) argue that human agency is what helps develop a "conducive milieu" which favours the subsequent evolution of a new industry. This constructed perspective opens up alternative ways to overcome constraining factors. It includes the participation of a broader set of actors, such as firms, civil society groups and NGOs who use their networks and agency to bring into the region knowledge and capabilities from elsewhere and facilitate unrelated technological change and innovation (Binz et al. 2016, Binz & Anadon 2018). An important aspect in the EEG's framing of unrelated diversification is that this process in more likely to take place in regions with strong technological

capabilities and technologically related industries (Boschma et al. 2017, Xiao et al. 2018). In those regions, varied technological capabilities, particularly in high-tech industries, foster opportunities for novel recombinations of knowledge that are taken up by entrepreneurs and firms conducing to new unrelated technologies and industries (Boschma et al. 2017). Entrepreneurs, firms and institutional entrepreneurs are decisive in providing a new direction to technological change (Boschma et al. 2017). The difficulties arise from the resistance posed by existing industries, regulations, consumers preferences and user behaviours, and institutional frameworks that may become unfit for the emergent industry.

To describe how actors mobilise resources, influence policy and drive innovation in the process of new path creation some authors refer to distributed agency (Binz et al. 2016, Binz & Anadon 2018) while others to bricolage (Garud & Karnøe 2003, Karnøe & Garud 2012*b*, Boschma et al. 2017, Feyereisen, Stassart & Mélard 2017). The underlying reason for approaching agency as distributed is that unrelated change depends on a wide range of actors to come about (Karnøe & Garud 2012*b*, Dawley 2014) and therefore it is difficult for the process to be controlled by a single type of actor (Karnøe & Garud 2012*b*, Boschma et al. 2017, Binz & Anadon 2018). It is the concurrence of policy makers, users, social actors, scientists, technicians, skilled people and firms what initiates and builds a new industry (Geels 2004). This process of co-creation (Karnøe & Garud 2012*b*) generates alternative products and technologies in the form of experiments and niches (Schot & Geels 2007), as the market, institutions and users do not yet exist or suit the nascent industry (Schot & Geels 2007, Boschma 2017). Agency is seen as distributed as it is embodied in the actors who possess or have access to key resources that can be mobilised to build an industry (Binz et al. 2016, Binz & Anadon 2018).

Similarly, the concept of bricolage, which is underpinned by distributed agency (Garud & Karnøe 2003), proves useful as it highlights the creative process by which actors manage to initiate change with what is at hand (Garud & Karnøe 2003, Baker & Nelson 2005, Karnøe & Garud 2012*b*) and therefore emphasises the experimental process that allows actors to learn, adjust and respond as the

process of change unfolds (Karnøe & Garud 2012*b*). Throughout this interactive process, actors exhibit varying levels of participation at different stages. Hence, each actor's participation may influence others' involvement (Garud & Karnøe 2003, pg. 283). As the process evolves, policy and policymakers may be one of the resources and actors that become involved (Garud & Karnøe 2003, Karnøe & Garud 2012*b*).

In unrelated diversification, policy is a facilitator that helps provide a new institutional setting, regulations, incentives to Research and Development (R&D) activities and subsidies to new product development as a result of continuous interaction with the actors involved in creating a new pathway (Karnøe & Garud 2012*b*, Steen 2016, Boschma et al. 2017, Binz & Anadon 2018). Policy supports the actions of institutional entrepreneurs who seek to "transform existing institutions" (Boschma et al. 2017, pg. 5). By doing so, policy makers stretch existing institutions, policies and policy instruments to generate an enabling context for the new industry pathway (Dawley 2014).

To sum up, EEG has opened up the possibility to understand regional unrelated diversification as a constructed process that becomes orchestrated by a wide range of actors, as well as firms, who use their agency to create the conditions and experiments for the emergence of a new industry. As the process unfolds, policy becomes relevant to support the entrepreneurial action of those experimenting with new products and niches and to consolidate further the conditions for industry formation. Nevertheless, a closer look at the sectoral forces constraining and enabling change, as well as industry specific actors, would shed light on the origin and nature of the drivers of unrelated diversification. This analysis is particularly important in mining regions in developing countries. As in this context, the drivers of change may not be technology-driven, as described by the EEG literature, but guided by principles of sustainability, in which social, developmental and technological domains converge.

2.2 Sectoral innovation dynamics, space and change

This section draws attention to the need for a sectoral perspective on the analysis of unrelated diversification so as to include a sector's inherent dynamics that become constraining and enabling factors and to consider how the demands for industrial change can emerge from within a sector (Mitchell 2011).

There exists an on-going debate on the nature of forces and actors initiating industrial change (Boschma et al. 2017, Binz & Anadon 2018) and transitions (Farla, Markard, Raven & Coenen 2012, Bridge et al. 2013, Steen 2016). On the one hand, the role of civil society has been considered in some transitions literature to represent the way in which demands for industrial and socio-technical change are put forward (Geels 2004, Hess 2007, de Haan & Rotmans 2018). But it has been less clear to what context and how civil society elaborates such demands, and the extent of its involvement through experiments in building up alternative pathways. In other cases, policy has been seen as driver of change in addressing sustainability challenges (Coenen, Hansen & Rekers 2015, Steen 2016, Boschma et al. 2017). To some extent, civil society and policy appear to be external driving forces from which demands for radical change and alternative pathways to diversification emerge.

Hess (2007) and Mitchell (2011) hold that the forces for industrial change and transformation are sector specific and therefore may emerge from within industrial sectors. For example, Mitchell (2011) explains the significance of coal in shaping the evolution of the energy industry as of today. In Mitchell's (2011) words mining workers gained agency from the extraction of coal and the subsequent amounts of energy it generated. This agency "provided [them] the means for assembling effective democratic claims" (Mitchell 2011, p. 8). This power expression shaped the configuration of the energy industry so as to define "different ways of organising the flow and concentration of energy" (Mitchell 2011, p. 8) from extraction to consumption. The way oil is produced, transported, concentrated and used significantly removed this interaction between workers and

oil. A centralised pattern of production and knowledge was put in place that removed the relational power workers could obtain from controlling production. Thus, the sectoral forces influence the social and spatial configurations of new industry formation.

Similarly, in the case of mining regions, the sector itself becomes a constraining factor for diversification, in two ways. It creates cultural expressions around the way in which people relate and create meanings around the extraction of resources. These meanings may lead to expressions of protest and demand for industrial change, particularly, when the social and environmental negative effects of economic activities are borne by local inhabitants (Bridge et al. 2013). On the other hand, R&D efforts focus to identify additional opportunities for extraction of additional materials and their potential uses but do not necessarily lead to the creation of alternative pathways (Hess 2007). Therefore, the interplay between civil society and these sectoral dynamics can unleash forces for an alternative pathway to diversification and provide new direction to R&D agendas and innovation dynamics.

Hess (2007) introduces to the analysis of alternative pathways for industry two ways in which sector specific actors within civil society advocate for new R&D agendas and industrial change. In looking at the energy, food, waste, manufacturing, and infrastructure sectors, Hess (2007) analyses the emergence of Industrial Opposition Movements (IOM) and Technology and Product-Oriented Movements (TPMs) (Hess 2007, p. 85) from within industry and shows how they complement and reinforce each other. This literature provides insights that can complement the understanding of unrelated diversification and transitions, particularly, the way in which demands for change emerge and who drives those demands.

2.3 The role of social actors on regional unrelated diversification

Science and Technology Studies STS has analysed social actors and movements to explain demands for change in R&D agendas and the way that the attention of

the public is drawn to areas of undone science (Hess 2007). Research is prioritised according to the interests of political and economic actors who posses the resources to foster knowledge generation in areas consistent with their interest, generating "pockets" of science that "does not get done" (Hess 2007, p. 22). Two elements underpin the relevance of social movements in the process of regional change and diversification, particularly in highly constrained regions and those that specialise in extractive industries. First is the agency built through social groups to demand social change (Porta & Diani 2014) or phase out an industry (Hess 2007). Social movements make it possible to develop narratives and meanings to articulate discourses to pressure for change (Porta & Diani 2014) and call for a moratorium in the case of certain technologies (Hess 2007). Second, social movements can also mobilise resources (Leahy & Mazur 1980), which is central to the process of regional diversification or path creation. This means that some social movements may adopt a proactive approach that goes beyond challenging to actually mobilise and create alternatives for the emergence of a new industrial pathway (Hess 2007).

Alongside those IOM demanding changes in industrial configuration and technology use, there exist TPOM, which focus on the creation of alternative industries and technologies that eventually "phase out the existing technology" (Hess 2007, p. 88). Social movements bring their narratives into the media spotlight, leveraging support from scientists and international non-government organisations, which can channel funds to undertake actions and build support from the public (Hess 2007). Hence, social movements, it can be argued, undertake collective action in the process of creating alternative pathways and diversification (Hess 2007). Hess (2007, p. 4) argues that "alternative pathways often take the form of social movements".

To consolidate change, social movements — in this case IOM — rely on TPMs or those movements that are able to mobilise resources, including policy coalitions that enable the emergence of a new industry or technology, but that cannot be absorbed by the existing regime – the dominant industry and its underlying linkages to regulations, users' preferences, patterns of behaviour, industrial

structure and market configurations – (Hess 2007). TPMs can be seen as reform groups within specific industries and areas of expertise. Their repertoires change from protest to institution building necessary for an alternative industry configuration (Geels 2004, Hess 2007). In building an alternative to the existing industry, TPMs engage with small firms that are able to develop technological alternatives and prototypes for the market. TPMs liaise with professional entrepreneurs, scientists and policy makers to create a narrative and envisage a new industry. This interaction with a broader set of actors is better understood through the concept of bricolage.

2.4 Bricolage as a mechanism to enable path creation

Bricolage has been treated in the literature in different, though complementary ways. It has been seen as a mode of action that emphasises the actors' capacity to work with what is at hand to create novel combinations to overcome constraints (Garud & Karnøe 2003, Faulconbridge 2013, Boschma et al. 2017). Second, it has been explained as strategy adopted by entrepreneurs (Garud & Karnøe 2001) and as a possibility to scale up niches aiming at transformation (Garud & Karnøe 2003, Feyereisen et al. 2017) that depicts the way actors interact within their constrained context to generate change. Finally, bricolage has been used to explain the nature of unpredictable and contingent outcomes within processes (Baker & Nelson 2005, Altglas 2014).

In this thesis, bricolage is defined as the experimental process by which actors interact and create an idiosyncratic resource environment from a unique recombination of existing elements to overcome institutional, economic and cultural limitations (Garud & Karnøe 2003, Baker & Nelson 2005, Altglas 2014, Boschma et al. 2017, Feyereisen et al. 2017). Literature on socio-technical change has used the concept of bricolage to explain the process by which resources and actors are mobilised and put into place to create the conditions for change (Boschma et al. 2017, Feyereisen et al. 2017).

This experimental process exhibits different features depending on the way social

movements: i) engage with civil society and other relevant actors from Science, Technology and Innovation and policymaking to change the directionality of R&D agendas and innovation; ii) respond to the use of resources and actors' involvement and develop new narratives around the emergent pathway; iii) build distributed agency with other actors (given the type of roles and levels of engagement and participation actors adopt over the process) and iv) construct a "shared collective space" (Garud & Karnøe 2001, p. 26) that facilitates the emergence of new resource arrangements, practices and policy oriented to support the emergence of a new industry.

It can be argued that social movements experiment with diverse strategies and their broad networks to accumulate the necessary resources and agency (Farla et al. 2012), through continuous micro-learning in their interaction with resources and new practices to build new collective spaces (Garud & Karnøe 2003). Participation of scientists, universities and research centres bring in knowledge and technologies to create alternative understandings and solutions to current social demands (Garud & Karnøe 2003, Boschma et al. 2017), particularly when additional knowledge is required in the process of path creation. Social movements use those inputs and results to enrich narratives and substantiate more detailed demands for change and to exert further pressure on policy. Moreover, increasing knowledge and reflection within territories opens opportunities for the emergence of new actors or institutions that are needed to facilitate the evolution towards a new industry pathway (Bathelt & Glückler 2005).

In some cases, the knowledge and technologies generated around place-specific problems enable those actors involved in the process of knowledge generation to play different roles, by supporting policy making and implementation. As shown by Garud & Karnøe (2003), continuous interaction between research centres in the development of turbines for wind energy generation and policy makers helped to shape new policy priorities, define new standards, and structure new calls to channel the funding of both research and entrepreneurial activity. Moreover, social movements can nurture expectations and maintain pressure on the need for change until an alternative industry or new socio-technical systems emerge (Penna

& Geels 2015).

Summing up, in the process of creating alternatives for unrelated diversification, actors engage in bricolage to build the resource environment that enacts industrial change (Garud & Karnøe 2003, Karnøe & Garud 2012*b*). The role of civil society has been highlighted, in the form of IOMs and TPMs, as sector-specific forces demanding social and industrial change (Hess 2007), which interact with regional actors and resources such as policy to provide directionality to R&D agendas and innovation (Hess 2007, Boschma et al. 2017). Thus, unrelated diversification is constructed by a varied set of place-based actors whose agency is distributed (Steen 2016, Boschma et al. 2017). Actors' agency is what makes it possible to generate the conditions for a new industry pathway, as it involves radical change that deviates from existing markets, institutions and users (Geels 2004, Schot & Geels 2007).

2.5 Exploring unrelated diversification in lagging regions

The argument made by this thesis is that unrelated diversification, as a constructed process, is likely to be relevant to regions facing acute sustainability challenges, and therefore, in need for alternative pathways of development, which can be framed as diversification opportunities. These are regions highly reliant on extractive industries, where the industry's negative effects risk resource depletion, pollution and represent a threat to local ecosystems. In this context, the concept of unrelated diversification offered by the EEG literature can be extended to explain the process of new path creation, underpinned by sustainability principles and the interplay of local actors' resourceful strategies, their networks and regional STI policy.

For lagging regions, where poverty, lack of capabilities and economic stagnation resemble what has been recently coined as "places that don't matter" (Rodríguez-Pose 2018), unrelated diversification could also be seen as an alternative approach, similar to what MacKinnon et al. (2021, p. 48) argue as "neo-endogenous development approach" , whereby local actors and their

expectations set the direction of regional pathways towards ones perceived as more appropriate for them and their region. Such place-based approach is gaining more relevance in the light of sustainability challenges, for example: the post-growth literature (Gudynas 2011, Escobar 2015, Jackson 2021), as a response to growth-oriented, competition and agglomeration perspectives (MacKinnon et al. 2021), that have concentrated the research agenda and policy domain (Rodríguez-Pose 2018).

EEG literature and more conventional growth-oriented approaches have argued that lagging regions have less possibilities to initiate new industrial pathways (Grillitsch & Asheim 2018, MacKinnon et al. 2021). This is because in their perspective the focus is mainly on technological drivers. And in absence of technological capabilities innovation is not possible. Some authors have started to call this a development policy paradox "whereby their [lagging regions] relative under-performance over time generates an acute perceived need for economic growth among policymakers wedded to the growth paradigm, while simultaneously making it very difficult to achieve." (MacKinnon et al. 2021, p. 48). This thesis examines how in mining regions, social forces can trigger change and mobilise resources, including regional policy to overcome the lack of capabilities and lock-in in R&D agendas, that can forge a sustainable pathway of development. To what extent this could be the case of lagging regions, is a matter of further research. A noteworthy aspect of this discussion is that increasingly the social and environmental domains are having more influence in the dynamics of regional economic change (Coenen, Hansen & Rekers 2015, Trippl et al. 2020).

In place-based approaches, innovation takes place and plays an important role, but it is seen as a mechanism to meet the social needs faced by these regions (MacKinnon et al. 2021). It could mean that the process of economic diversification driven by sustainability principles plays out as one that requires a broader understanding of industrial change, and different indicators to the conventional GDP and employment (Jackson 2021, MacKinnon et al. 2021). As industries and economic activities in these regions may not develop in the same way the more advanced regions do. This has been taken up by authors addressing

lagging regions, seeking to provide potential ways of action from the policy perspective to foster new pathways of economic development (Rodríguez-Pose 2018, MacKinnon et al. 2021). But further research is required to understand in depth the dynamics of lagging regions and the extent to which unrelated diversification could be a strategy for them. This is highly pertinent for Global South regions, where lagging regions, as well as resource-dependent regions represent a significant proportion of the country's geography, as will be shown in the empirical analysis provided by this thesis. This represents a relevant and promising area of research and policy action.

Chapter 3

Methodology

Introduction

The literature review chapter highlighted technologically related and unrelated drivers of regional diversification and their usefulness for addressing regional industrial change in resource-based contexts. This broader perspective, recently embraced by parts of the EEG literature, has opened up a window to pose new research questions, and called for a wider range of methods and indicators, which have hitherto been mainly quantitative, for example, by using mixed methods. Particularly for unrelated diversification, there is a need to engage in qualitative research to understand how it has been conceived as a constructed process, with varied actors, forms of agency and knowledge generation. This method contrasts with the quantitative analysis, in which firms are seen central actors of regional change following the natural selection process underpinned by relatedness and market conditions. This chapter offers a mixed methodology for investigating related and unrelated diversification. It specifically addresses the conditions facing resource-based regional economies. This approach allows the comparison of how related and unrelated diversification occur in the context of resource-based regions and unpacks the process of unrelated diversification through an empirical analysis.

This chapter consists of five sections. Section 1 and 2 introduce the chapter and the research questions. Section 3 elaborates on the methodological approach and research design. Section 4 details the data sources, distinguishing between

quantitative and qualitative data. Finally, section 5 describes the underpinning data analysis for each method.

3.1 Research questions

Global pressures for sustainable development render the question of how regions diversify more pertinent than ever. Colombian regions have exhibited mixed diversification results from implementing both productive development and regional innovation policies over the last twenty years (Meléndez & Perry 2009). Geopolitical pressures reinforcing extractive industries in the Global South, alongside local communities and social actors increasingly contesting such forces, characterise the landscape of resource-dependent regions in Colombia. Recently, the national STI system and some regions have proposed alternative diversification pathways towards sustainability. These proposals, along with a green growth policy formulated by the national government, emphasise the importance to investigate how diversification comes about in resource-based regions and the conditions under which related and unrelated modes of diversification unfold. The methodology outlined in this chapter seeks to help understand how regions can create opportunities for more sustainable and inclusive development. The main research question addressed by this thesis is:

How does regional economic diversification come about in a resource-dependent country?

The pertinence of this question resides in the need to understand the underlying conditions enabling differentiated patterns of diversification in this context. Subsequent questions guide the research presented in Chapter 4 and Chapter 5.

Chapter 4 answers two questions. First, *what type of opportunities can development based on related and unrelated regional diversification offer to a resource-based country with highly disparate regions.* Secondly, *to what extent does technological-relatedness and unrelatedness enable the adoption of principles of sustainable development in resource-based regions?*

Chapter 5 provides answers to three questions. First, *How do unrelated*

diversification alternatives emerge in resource-based regions? Second, *How does bricolage help build agency and mobilise resources in this context?*. Thirdly, *Under what conditions might unrelated diversification paths create opportunities for sustainable development.*

The next section describes the methodological approach and research design implemented to address these questions.

3.2 Methodological approach and research design

This research seeks to contribute to the understanding of regional diversification in Colombia, a resource-dependent, middle-income country with significant disparities between regions. As an explanatory research, it investigates the phenomenon of regional diversification in this context and the patterns and conditions under which regional technological relatedness of industrial sectors enable opportunities for sustainable paths of diversification. A mixed method underpins this analysis to expand comprehension and provide a more holistic approach to regional diversification. The quantitative and qualitative analysis offers a complementary perspective on the complexities of regional diversification in the Global South, which risk oversimplification when adopting a quantitative methodology exclusively. Nevertheless, the use of the conventional quantitative methods to measure the regional endowment of technological relatedness is noteworthy, as it sheds some light into the applicability of the analytical framework proposed by EEG in such context and hints areas where qualitative methods could assist this research to investigate the complexities and nuances of related and unrelated pathways. This is particularly important in the light of sustainability challenges as some of them involve aspects associated to environmental issues that are difficult to pick up and address by the use of quantitative methodologies.

EEG authors have increasingly advocated for mixed methods research. For example, Boschma et al. (2017) stress the importance of capturing how unrelated/related diversification develops and the need to account for different

types of actors and their agency, as well as their underlying contextual conditions. Binz et al. (2016) emphasise the challenges of understanding early stages of path creation through quantitative methods and call for qualitative approaches to overcome it. Adopting a mixed methodology is notably relevant for Colombia and resource-based countries as it also enhances the comprehension of the varied alternatives, pathways and processes that may emerge from technological and social contexts. Therefore, a mixed method approach offers complementarities and further opportunities to strengthen the conclusions of the research in a specific context (Schoonenboom & Johnson 2017, Creswell 2017).

A downside of this methodological approach is the significant work required and the need for available data for both the quantitative and qualitative analyses, compared to the use of a single method and the challenges associated with the integration of the results derived from both analyses. This integration was streamlined by adopting a sequential research design that revealed clear linkages between the results of the first and second phases of the study.

This thesis is situated in the interface between of regional diversification theory proposed by EEG and the geography of transitions literature. The underlying concepts guiding this methodology are shown in Figure 3.1. The concept of technological relatedness (Boschma et al. 2012) is utilised in Chapter 4 to assess technological variety and relatedness among industrial sectors across regions. The primary purpose is to explore the conditions under which technological relatedness creates opportunities for sustainable pathways of diversification and the extent to which relatedness has driven regional diversification. Taking into account regional industrial branching as the main processes associated to industrial diversification, the research in Chapter 4 critically assesses how does this assumption apply to resource-based regions?

Likewise, unrelated drivers of regional diversification can also be found and represent an opportunity for certain regions. Therefore, Chapter 5 incorporates four main concepts from the literature of sustainability transitions: - constraining factors, place-based social movements, bricolage and alignment - to unpack the concept of unrelated diversification proposed by EEG. Constraining factors

highlight the difficulties of change and the factors preventing diversification in the context of vested interests, lock-in (Geels 2004, Bridge et al. 2013, Boschma et al. 2017, Steen 2016) and low technological capabilities (Binz & Anadon 2018). The concept of industrial opposition movements and place-based social movements (Hess 2007, 2018, Ramirez, Garcia Estevez, Romero Goyeneche & Obando Rodriguez 2020) are incorporated to elucidate how situated demands for social change, in the form of social movements, can build agency, which can help overcome constraining factors and envisage new routes for sustainable diversification. Together, these two concepts provide a clearer picture of the drivers of unrelated diversification. The concepts of bricolage (Garud & Karnøe 2003) and alignment (Binz et al. 2016) are used to understand how these situated heterogeneous actors create shared collective spaces of action, enabling distributed agency and resource mobilisation, facilitating unrelated diversification.

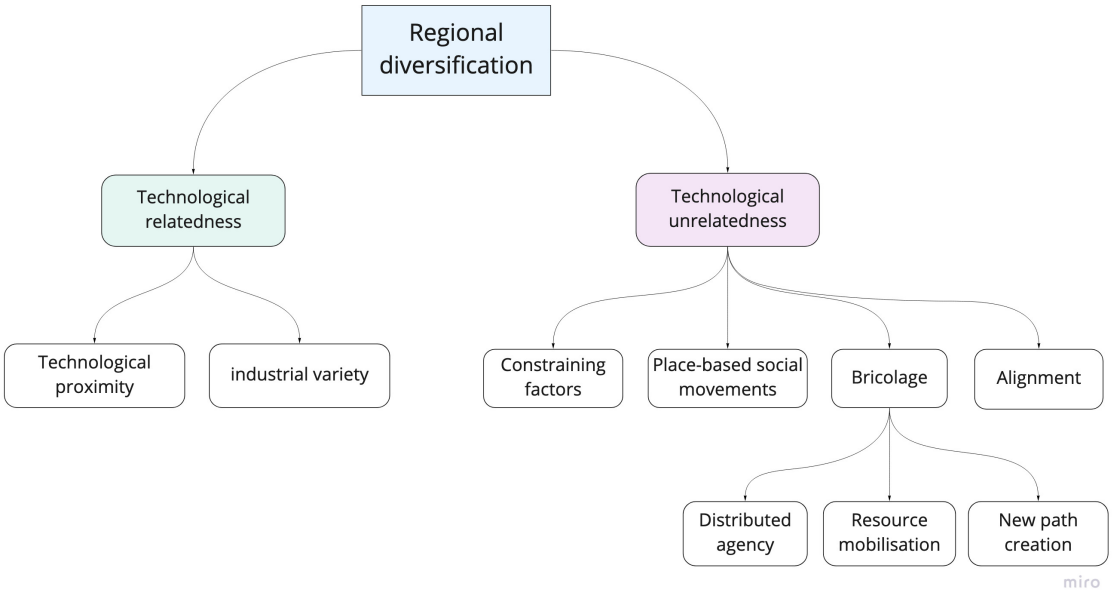

Figure 3.1: Conceptual framework

3.2.1 Research design

The empirical study of this research is situated in Colombia, with two main sources of data: panel data for the industrial and export performance of 28 regions between 2008-2017, and a single case study focused on the region of Boyacá, with semi-structured interviews and primary and secondary data.

A sequential methodology is followed, with the purpose of research development and expansion (Schoonenboom & Johnson 2017). The first stage is presented in chapter 4 and draws on quantitative methods used by the EEG literature on empirical research (Hidalgo et al. 2007, Neffke & Boschma 2011, Boschma et al. 2012) to assess the regional levels of technological relatedness based on existing industrial structures using the panel data. In this way levels of related and unrelated variety are calculated to take stock of technologically proximate industries over the period of analysis, which is pertinent considering that most of the regions are characterised by weak industrial bases and specialised in resource-intensive industries. These levels serve two purposes. They enable one, firstly, to build the Herfindahl-Hirschman indicator (UN 2016) of economic diversification and, secondly, to explore relations with regional GDP and value-added growth across regions. The relations are explored graphically by plotting related and unrelated variety levels against Value Added Growth and regional GDP. Although related and unrelated variety are static concepts, their analysis over a period of time provides a dynamic perspective of regional change that combined with the Herfindahl-Hirschman indicator can reveal whether regional diversification has taken place and if changes in the levels of relatedness occurred in those cases.

The potential relations emerging from the analysis could contribute to the definition of regional categories or typologies with distinctive patterns of diversification within which related or unrelated variety could have a more prominent role. Further analysis and expansion is needed, particularly in the case of resource-based regions with low levels of related variety. Therefore, it is necessary to use a qualitative perspective to examine these regions in a second stage, to inform and extend the regional diversification analysis.

This approach contrasts with econometric analysis assessing the entry of new technologies into cities and regions (Boschma, Balland, Kogler & Geografie 2015, Balland et al. 2019) as indication of regional diversification. Albeit the use of control variables such as GDP, population, and technological stock (Boschma et al. 2015) (Balland et al. 2019) to account for different types of regions, the

context of analysis is highly dynamic regions with strong knowledge bases, even in the case of old industries. For example, in those cases the authors adopt patents as indicator of knowledge generation and technological capabilities, which substantially differs from the Colombian context where most regions generate less than 10 patents per year and there are at least ten regions with no patents granted (de Ciencia y Tecnología 2020). For this reason, it is more appropriate to initially explore stocks of technological relatedness and to produce a typology of regions accordingly, which could yield more meaningful results than econometric models.

Chapter 5 explores the complexities in which a resource-dependent region adopts a more sustainable diversification pathways through a qualitative analysis. The case study draws on 12 semi-structured interviews with a varied group of regional actors, including leaders of social movements, activists, researchers, policy-makers, practitioners and NGOs. Participants were selected based on several criteria. First, a compilation of the demonstrations, protests and social activities advocating for sustainable development in Boyacá between 2005-2017, made by the Centro de Investigación y Educación Popular (CINEP), the Colombian centre for research and popular education, provided a geographical guide to the social actors actively pressuring for regional change. This data base provided the main reason for the protest or demonstration and based on this information, those associated with sustainability issues were geolocalised and further information was searched on internet and grey literature to triangulate information and discover whether their action could also entail efforts to create economic alternatives for diversification. Social movements or collectives that showed the articulation of a vision aimed at creating an economic diversification initiatives were interviewed. A third criteria was to interview the actors involved in the formulation and implementation of the Boyacá BIO, the regional policy changing the direction of STI aimed at sustainable development. Finally, based on these interviews, subsequent interviews were arranged with NGOs and R&D groups and centres which the initial actors identified as key in opposing mining and in creating new pathways.

The final results obtained from these two methodological approaches are brought together in chapter 6 and chapter 7 with the contribution and discussion and conclusion, to expand the understanding of regional diversification in the context of a resource-based region. Figure 3.2 synthesises the research design underpinning this thesis.

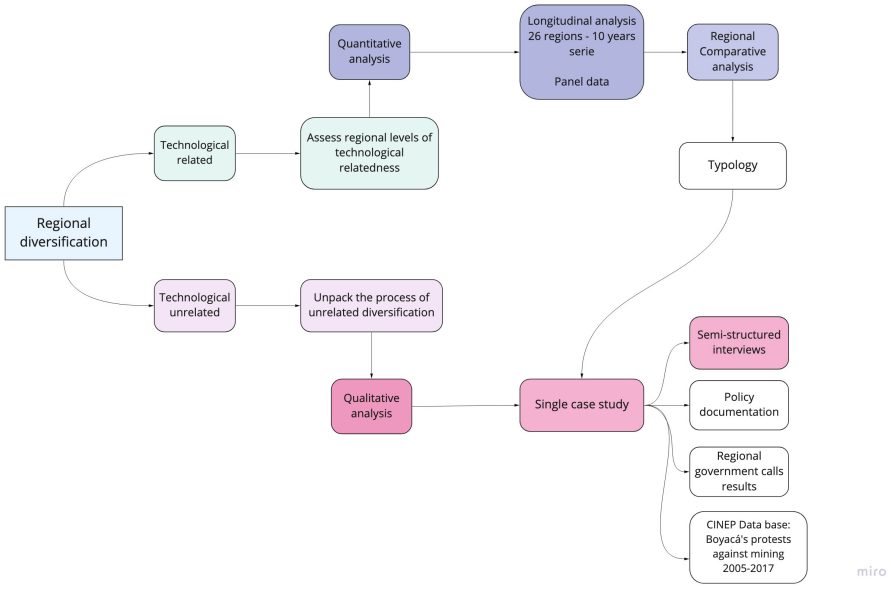

Figure 3.2: Methodological approach

3.2.2 Selection of the case study

The results from stage one provided a typology of regions within which relationships between related/unrelated variety levels and their economic performance follow certain patterns. Several questions arise from this typology, for example, do regions with high related variety outperform those with low related variety? Do regions with low related variety have poor economic performance? What opportunities could there be for regions where unrelated and related variety levels are similar? It was not clear at that time in the research, what type of technologically-related opportunities could there be for the great majority of regions, because their levels of related variety were low.

Few months before the quantitative analysis finished, Boschma et al. (2017) published a paper bridging transitions and EEG literature that opened a new way of understanding this situation found in Colombia. In their paper, the authors

acknowledge that both, related and unrelated variety offer opportunities for diversification, but in some cases, unrelated diversification could stem from grand challenges (Boschma et al. 2017, p. 32). The authors emphasised the role of policy and institutional entrepreneurs in facilitating the turn towards unrelated diversification. But, it was not entirely clear what were the situations under which unrelated diversification could be more feasible. In this line of analysis, some questions were what would unrelated variety mean for regions dominated by extractive industries? Those regions face the dilemma of whether to stay with the short and medium-term income the extractive industry generates or to make the transition towards more sustainable industries and deal with the economic, social and environmental effects that this may cause. If choosing sustainability, how could unrelated variety favour or support this change? What opportunities could this option bring? These questions made the approach of unrelated diversification relevant for a significant group of Colombian regions as will be shown in chapter 4. Yet, it was not fully clear the origin of change for resource-based regions and what could trigger it.

Increasing resistance of communities and social movements in resource-based regions in Colombia and frequent news headlines about demonstrations, road blockages, and protests against mining suggested there might be a new, previously unconsidered force in the process of regional diversification, especially in the context of resource-dependent regions, demanding a social change towards sustainability. In this case, it was not policy what initiated the process of unrelated change, but rather social forces. In the case study of Boyacá, the interplay between social movements and policy is explored through qualitative methods, to investigate the drivers and nature of unrelated diversification.

Boyacá could be a pioneering region to transition from mining to a more sustainable pathway, underpinned by STI policy. Other regions, such as Nariño and Santander, have undertaken research to identify their biodiversity stocks and compile arguments around the need for their protection. Yet, none of them has translated these results into a regional policy for diversification. This makes Boyacá's a remarkable case for understanding unrelated regional diversification

processes in a resource-based region. This case study seeks to contribute to the understanding of the *process* of unrelated diversification, recently included in the research agenda of EEG.

The following section details the process of research information gathering.

3.3 Data sources

Given the dual research method and the sequential analysis, data were collected in two stages. Firstly, databases intended for quantitative analysis were obtained from CEPII, the French centre for research on the world economy (Gaulier & Zignago 2010) and the Atlas of Economic Complexity for Colombia (*DATLAS* 2017). Table 3.1 summarises the variables of analysis, data sources and use of this information intended for quantitative analysis. Next, semi-structured interviews were conducted with 12 actors from different areas of Boyacá's region to obtain information about the mining industry, the role of social movements, the regional STI system and regional policy.

3.3.1 Quantitative datasets

Levels of technological relatedness can be calculated in two ways: one is based on the hierarchical industry classification and another is the proximity method (co-occurrence), using regional exports and employment data. As exports only account for tradable goods, exports data sets up a natural filter for those regions with fewer capabilities to plug into global trade. This is the main drawback of using exports data, making it important to consider employment data for all industrial sectors present in a region. However, formal employment in a country like Colombia comprises only about 31.9% of the total employment, which also poses questions around how well regional economic dynamics are represented by formal employment data. Despite these limitations, employment data has commonly been used by EEG literature to calculate relatedness. For example, Boschma et al. (2012) utilise employment and exports to calculate relatedness, Frenken et al. (2007) also use employment for their calculations. Some authors (Neffke 2009, Boschma et al. 2012, Fitjar & Timmermans 2017) consider

industrial classifications less accurate than proximity method at reflecting technological relatedness. The literature shows an increasing preference for the latter method as a way to establish technological linkages across different industries (Xiao et al. 2018), products (Hidalgo et al. 2007) and skills (Fitjar & Timmermans 2017).

Thus, three different datasets are used in the quantitative analysis of relatedness. One follows the hierarchical standard industrial classification (SIC). This dataset is taken from the website of the Atlas of Economic Complexity for Colombia (*DATLAS* 2017) containing regional data (for 33 regions including San Andrés and Providencia Islands; data from 5 regions was discarded due to inconsistencies) at four-digit level (product level) with employment values. This website also provided the employment data, consisting of wages, the number of employees and establishments in the same period and regions. All data was cleaned to remove zero-value and N/A entries. GDP, value-added growth and STI expenditure data are also integrated into the analysis: and their sources and use in the analysis are explained in Table 3.1.

Related and unrelated variety indexes using the proximity method were also produced for exports. This method includes world trade data, as explained in section 3.4.1. This thesis obtained the BACI dataset from CEPII. This dataset uses the Harmonised System HS at 6-digit level. This data was transformed to 4-digit level to make it comparable with Colombian data available at the 4-digit level. The CEPII world dataset uses ISO 3-digit country code.

3.3.2 Qualitative data sources

There are three main sources of primary data for the qualitative analysis. Firstly, 12 semi-structured interviews were conducted in field-work in Boyacá on April 2018 with leaders of social movements; researchers and the director of a R&D centre at Universidad Tecnológica de Tunja (UPTC), regional government officials from the planning secretariat, environmental and sewage unit; an adviser to the Governor; the former director of Boyacá BIO; and a member of the departmental assembly, as shown in section 3.3. Interviewees were contacted by email and phone

Table 3.1: Databases used for quantitative analysis

Concept	Primary source	Use
Relatedness / Unrelatedness	BACI Dataset provides worldwide disaggregated data on bilateral trade flows from the CEPII website	Calculate proximity indexes
Relatedness / Unrelatedness	Trade data from the National Tax and Customs Authority DIAN (Customs Data) that provides sectors at 6-digit level compatible with Harmonised System classification standardised by *DATLAS* (2017). HS 1992 version	Calculate relatedness indexes based on Standardise Products Classifications
Relatedness / Unrelatedness	Employment data also taken from (*DATLAS* 2017), whose source is PILA (the Integrated Report of Social Security Contributions), managed by the Ministry of Health in Colombia. This data set records monthly legal contributions made by employees and employers to the health and pension system.	Calculate relatedness indexes based on Standardise Industry Classifications
GDP	National Administrative Department of Statistics Colombia	Explore relationships with Relatedness/Unrelatedness levels
R&D	Observatory of Science, Technology and Innovation of Colombia	Explore relationships with Relatedness/Unrelatedness levels
Value-added growth	National Administrative Department of Statistics Colombia	Explore relationships with Relatedness/Unrelatedness levels

calls, using contact information obtained from internet and the social movements' websites, when this was available. In addition, former linkages between this researcher and a former civil servant in the regional government, make it possible

to contact directly the former Director of the Environment, Drinking Water and Basic Sanitation in the regional government. This contact facilitated the interviews with the other interviewees at the regional government. Interviews lasted between one and two hours, depending on the interviewee's time availability and the depth of the responses. A second source comes from a database of news articles related to regional social movements and their actions over the last 40 years, compiled by CINEP. The final source is a compilation of 23 news articles reporting regional demonstrations against mining projects from 2005-2017, also compiled by CINEP. A summary of the data used for qualitative analysis is presented in Table 3.2. These three different sources were used with the purpose of validation and reliability.

Triangulation of information was carried out through reference to blogs, NGOs websites and public information regarding social movements' participation in projects funded by NGOs and international organisations. The datasets of news articles from 2005-2017 and regional social movements' actions produced by CINEP provided valuable inputs for selecting the interviewees and understanding the context of these localised conflicts.

Interviews conducted for the case study

Table 3.3 lists the participants interviewed for the case study grouped and coded by type of organisation. Fieldwork was undertaken following the procedures and ethical approvals established by the University.

Identifier	Position	Location
G1	Former Director of the Environment, Drinking Water and Basic Sanitation - Regional Government	Tunja
G2	Manager of Boyacá BIO	Tunja
G3	Advisor to the Governor of Boyacá	Tunja

G4	Director of the Environment, Drinking Water and Basic Sanitation - Regional Government	Tunja
G5	Member of Boyacá's Department Assembly	Tunja
G6	Director of Boyacá BIO	Tunja
S1	Leader of Civil movement of Gachantivá	Arcabuco
S2	Leader of Colombia Free of Fracking and Women of Puerto Boyacá movements	Puerto Boyacá
S3	Leader of Sugamuxi Province Collective	Iza
S4	Leader of Alto Ricaurte Collective	Villa de Leyva
N1	Coordinator of the socio-environmental programme at Podion (NGO)	Bogotá
N2	Researcher - activist at CENSAT Agua Viva (NGO)	Bogotá
R1	Researcher, Instituto Von Humboldt	Villa de Leyva
R2	Researcher, Director of Biology research group at UPTC University	Tunja
R3	Researcher, Manager of Boyacá BIO's expeditions	Villa de Leyva

Table 3.3: List of interviewees for the case study

The semi-structured interviews comprised four main topics, according to the literature on unrelated diversification. First, the socio-technical system around mining; second, civil society and social movements; third, bricolage; and fourth policy. Below is the complete questionnaire used to guide the interviews.

- **Understanding the socio-technical system**
  - Describe the socio-technical system defined by the extractive industry: its characteristics, technologies and practices, main patterns of

Table 3.2: Sources used for qualitative analysis

Item	Source	Use
Main sections of the interview guide were: constraining factors, social movements, bricolage and regional policy	12 semi-structured interviews	Underpin the case study analysis
Database of social movements actions based on news articles from the last 40 years in Colombia	CINEP	Identify the main action areas of mobilised publics groups between 1978-2018
Database of actions undertaken by "mobilised publics" (students, civil society, communities, social movements) against mining between 2005-2017	CINEP	Identify social movements and their location, type of conflict, underlying reasons, parties involved.
Collective (Social movement) of Alto Ricaurte blog	https://www.escritoresyperiodistas.com/NUMERO03/colectivo03.html	Communitarian projects on tourism undertaken by the Collective of Alto Ricaurte
Entre Ojos (Digital journalist) Blog	https://entreojos.co/ambiente/conservacion/mujeres-de-puerto-boyaca-claman-por-la-cienaga-de-palagua	Women's collective of Serranía de las Quinchas
Collective (Social movement) of Sugamuxi Blog	https://sites.google.com/site/colectivosugamuxi/home/-quien-es-getulio-montana-laguna	History, legal actions and projects undertaken by the collective for the protection of Sugamuxi province

interaction with local communities.

- How have these industries gained the national government's support and consolidated their economic power.
- Are there spatial elements embedded locally that facilitate and support the consolidation of these extractive industries? To what extent have these elements hindered the regional process of diversification? How

have these spatial elements emerged and consolidated?

- **Understanding the social movement**
  - How have social movements emerged and consolidated to challenge the extractive industry?
  - Are there geographical/global connections and interactions with social actors/movements supporting these local movements?
  - Have social movements created linkages with other spheres of influence, for example, research and development, innovation activities, universities, local policy makers?
  - Have social movements built narratives around alternative paths for regional development?
  - To what extent have social movements paved the route towards unrelated diversification?
  - Is there evidence of collective learning that has contributed to destabilize the extractive industry?
  - How have roles and positions of local actors and social movements have changed over time to challenge and destabilize the extractive regime?
- **Bricolage**
  - How have social movements managed to mobilize actors and resources from other spaces (knowledge, funding, policy influence)?
  - What are the main ways of allocating and obtaining alliances and coalitions across other communities and resources?
  - What has been the process by which alternatives for regional development have been envisaged and embedded in new narratives? Who has participated and how?
  - How did these social movements become closer to Science, Technology and Innovation actors? At which point did they join? How was the connection made? Are there key actors or communities?
  - Were/are there experiments to discover alternatives paths for regional growth?
- **Policy**
  - Has policy provided support or constrained the collective action of

social movements for alternative ways of diversification? How?
- Has policy influenced the direction of STI activities towards alternatives paths for diversification/sustainable use of natural resources?
- Has policy helped consolidate a new narrative, technologies and/or knowledge to create an alternative path for unrelated diversification?
- Has regional policy faced conflict with national policies? Why? How have these conflicts been managed?

The next section explains how data was analysed to answer the research questions.

3.4 Data analysis

The analysis was carried out in two stages accordingly. The first stage involved quantitative data analysis to produce the main indexes of related and unrelated variety using the methods mentioned above. Calculations were made in R-studio following the methodology of Boschma et al. (2012). The detailed calculation process is presented in section 3.4.1. The qualitative data analysis identified the main themes emerging from the interviews. To build the case study, this primary information was then complemented with data from public calls for funding STI activities associated to the regional policy Boyacá BIO and primary information from other sources stated in Table 3.2 to build the case study. The following subsections describe how the analysis was carried out.

3.4.1 Quantitative analysis of relatedness across regions

Related variety

EEG literature argues that the more related the region's industrial base is, the higher the likelihood of diversification and economic growth (Frenken & Boschma 2007, Neffke 2009, Neffke & Boschma 2011, Boschma 2017, Boschma et al. 2017, Frenken & Boschma 2007). Thus, the analysis starts by assessing *the levels of regional related variety across industries and products.* The first step in measuring related variety is to define *the variety sets* using standardised product

classification (HS) and proximity. Under the HS method, the variety set S_r is defined by all the products within a 2-digit industry class. It is assumed that products within the same class share technologies and knowledge and, are therefore related (Frenken et al. 2007, Boschma et al. 2012, Fitjar & Timmermans 2017). Calculations to determine relatedness based on technological and knowledge proximity between products assume every product has a variety set formed by the products HS 4-digit level with a proximity level equal or higher than 0.25. Defining the proximity level that makes two products related has been a matter of discussion (Fitjar & Timmermans 2017). Nevertheless, most authors agree on 0.25 as a conservative measure of proximity (Boschma et al. 2012, p. 246).

Proximity calculation needs the revealed comparative advantage (RCA) value per product per country to generate conditional probabilities to produce relatedness indexes for Colombia. A country has a RCA for a particular product if the share of product i exports in the country's total exports is higher than it is in the world's total exports (Hidalgo et al. 2007). Having determined the products in which every country has an RCA, co-occurrence is built upon conditional probability of a region exporting product i also exporting product j (Boschma et al. 2012). Co-occurrence captures the likelihood that a region producing product i and j can move to produce another product using the know-how of producing i and j (CID 2021). Finally, the proximity matrix is formed by selecting the minimum of the pair's conditional probabilities, as shown in Equation 3.1.

$$Proximity = pmin(Px_ix_j, Px_jx_i) \tag{3.1}$$

The code in Listing A.2 calculates proximity based on world trade data as referenced in Table 3.1. Based on these proximity levels the variety sets are defined, then each variety set's entropy is calculated to measure its diversity. The equation 4.2 defines the entropy of a variety set (H_r):

$$H_r = \sum_{i \in S_r} \frac{P_i}{P_r} \log_2 \left(\frac{1}{p_i / P_r} \right) \tag{3.2}$$

p_i denotes the share of HS i product in total regional exports and P_r the share of each variety set in total regional exports (Boschma et al. 2012, p. 247).

The index of regional related variety is built as the "exports-weighted entropy in each related variety set" (Boschma et al. 2012, p. 247).

$$RELATED\ VARIETY = \sum_{r=1}^{R} P_r H_r \tag{3.3}$$

Related variety indexes based on employment data followed the same procedure, explained by the equation:

$$H_r = \sum_{i \in S_r} \frac{P_i}{P_r} \log_2 \left(\frac{1}{p_i / P_r} \right) \tag{3.4}$$

Where H_r denotes entropy for each variety set at 2-digit level. The equation describing regional related variety based on employment data is:

$$RELATED\ VARIETY\ (Employment) = \sum_{r=1}^{R} P_r H_r \tag{3.5}$$

Related variety levels are analysed against Regional GDP and Value Added Growth to explore eventual patterns of relationship between these variables. Studies have shown a positive relation between related variety and regional growth and regional GDP (Frenken et al. 2007, Boschma et al. 2012)

To complement the analysis of related and unrelated variety, regional diversification is calculated using the standard indicator Herfindahl-Hirschman (UN 2016). This indicator shows the evolution of regional economies based on their exports and employment and is defined by Equation 3.6. Albeit its static nature, by measuring it during a period of time it allows to capture variations of the regional industrial structure.

$$HH = \sum_{i=1}^{N} S_i^2 \tag{3.6}$$

S_i denotes the share of each HS group in the total regional exports or employment.

Unrelated variety

As per related variety, the analysis of unrelated variety begins with the construction of the variety sets. In contrast to the variety set of related variety formed at 2-digit level of each HS class, unrelated variety sets are formed at 1-digit level. It is assumed that, at this aggregation level, industries do not share many technological and knowledge components (Frenken et al. 2007, Boschma et al. 2012). Unrelated variety is defined by the formula:

$$Unrelated\ Variety = \sum_{j=1}^{N} P_j log_2\left(\frac{1}{P_j}\right) \tag{3.7}$$

In the case of proximity, it is assumed that industries with a proximity higher than 0.25 are not related.

3.4.2 Data analysis for qualitative research

The case study seeks to answer the question: how do technologically unrelated alternatives emerge in resource-based regions? The analysis focuses on the drivers of change through the concepts of *social movements* (Hess 2007, Smith 2012, Chilvers & Longhurst 2016); *constraining factors and demands for change* (Geels 2004, Mitchell 2011, Hess 2007, Bridge et al. 2013, Boschma et al. 2017). The concept of *bricolage* (Baker & Nelson 2005, Garud & Karnøe 2003, Boschma et al. 2017) sheds some light into how agency and resource mobilisation take place in this context. To determine the conditions under which unrelated paths create opportunities for sustainable development, the concept of *alignment* provides further elements to assess how alternatives paths can contribute to the consolidation of a new industry. Relational elements of space, such as traditions

and local narratives of sustainable development, are also highlighted in the analysis as part of the conditions enabling change and new pathways. The initial coding is presented in Figure 3.3.

Figure 3.3: Initial cluster of themes from interviews

According to the interviewees' affiliations four groups were formed: social movements, government, NGOs and R&D centres. As the analysis progressed, the themes and relationships were refined and categorised according to their occurrence and relevance for the process of change. For example, if the theme protect territories from mining is mentioned and highlighted as relevant for the emergence of social movements by the majority of interviewees, then it is categorised as an important spatial factor enabling social organisation. Individual analysis of social movements gives a rich understanding of the opposition process to mining, the strategies used to demand change and the actions undertaken to enable alternative paths. The purpose of the analysis was to capture the nature of the social movements and the key processes in which they are involved, as well as the expectations and perspectives guiding their actions. Government perceptions of social movements and the extent to which the government sets up mechanisms to align their policy and policy actions to social movements' efforts were also investigated. Other regional and national actors, such as R&D centres and NGOs, were also examined to discover the type of relationship, if any, that they have with social movements, regional government and STI actors.

Based on the interviews' responses, main themes were organised in a excel spreadsheet. Six categories are found relevant in the process of unrelated diversification, see Figure 3.3. First, situated responses from civil society become organised as social movements to address vested interests from mining firms, generate knowledge and consolidate an opposition force to halt mining projects and prevent industry expansion, particularly where strategic ecosystems are threatened. This can be understood as situated and relational sectoral dynamics between civil society and mining industry. Geopolitical dynamics that reinforce extractive industries, such as the national policy providing improved market conditions for mining, the lock-in of the R&D agenda, and vested interests reflected in the practices used by multinational companies (MNC) to apply for licences, are grouped as constraining factors. Social movements' actions and efforts to bring in the skills and knowledge required not only to oppose but also to create alternative paths to mining constitute a clear example of bricolage. Bricolage involves the use of legal tools to defend the territory, collaboration

amongst social movements, communication tools and strategies to align narratives and visions for knowledge sharing, and alliances with NGOs and R&D centres. Regional policy is a crucial factor in diverting STI activities from mining. It can also create the conditions to explore opportunities for alternative pathways with more conventional STI and regional business actors through different policy instruments such as R&D and innovation calls and scientific expeditions. In some cases, government appears as one of the resources and actors taking part in social movements' actions of bricolage, particularly in supporting agency building. Finally, alignment arises as a factor that influences the consolidation of a new industry, due to the heterogeneity of alternatives and inherent tensions of the initial process of path creation. A visual cluster of the overall themes is presented in Figure 3.4.

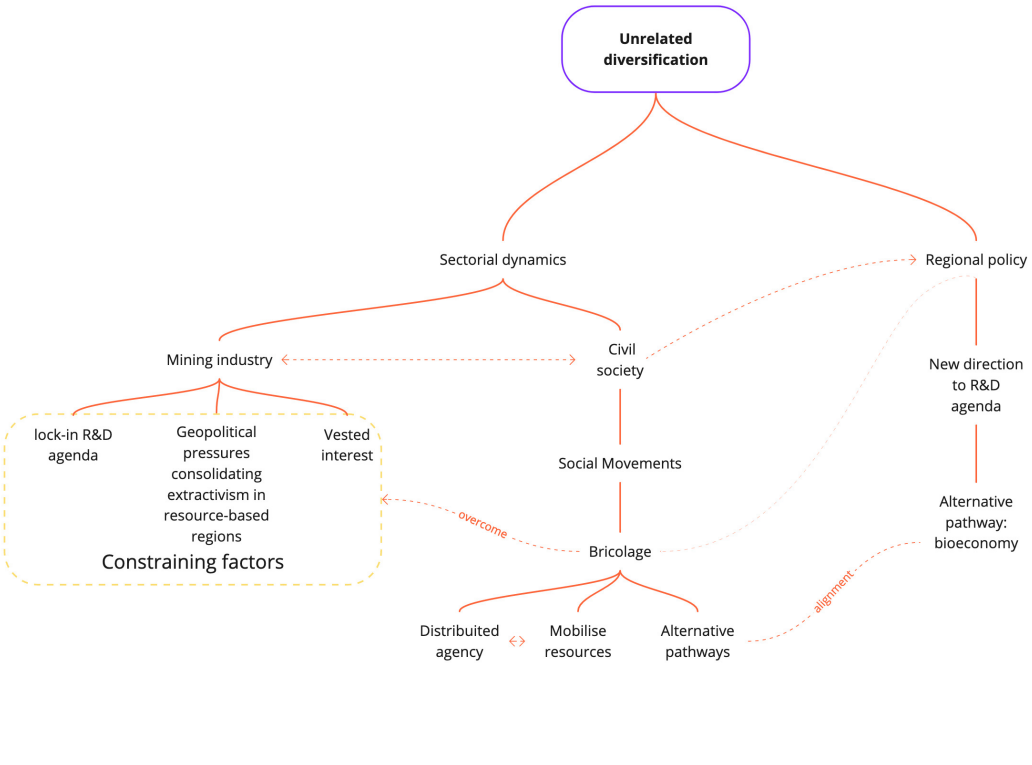

Figure 3.4: Final scheme of data analysis for the case study

Chapter 4

Exploring regional diversification in resource-dependent countries: a typology

Introduction

This chapter studies the process of regional economic diversification in Colombia. It investigates differentiated patterns of diversification amongst Colombian regions and discusses the opportunities these patterns create for sustainable development. A key feature of the study is that the economies of many regions of Colombia are based on natural resource activities - agriculture, and/or mining. The chapter studies the patterns of diversification using the EEG literature and discusses the degree to which these can be explained by the technological relatedness of their regional industrial bases.

The literature review chapter discussed the definition of regional diversification offered by EEG as an economic process enabled by the variety and relatedness of the capabilities embedded in regional industries (Boschma & Lambooy 1999, Hidalgo et al. 2007, Wal & Boschma 2011). This definition underlines the spatial element of technological change and innovation. An important question is how (and the degree to which) this analytical approach can help one to understand processes of regional economic diversification in the Colombian and beyond this, other Global South contexts, where marked geographical, economic and social differences may have shaped the regional patterns of diversification in the past

and impose new challenges in the light of sustainable development.

Recently, EEG has begun to acknowledge the importance of addressing some of the above issues. One area of growing interest has been the study of green diversification through technological relatedness (Montresor & Quatraro 2020, Santoalha & Boschma 2021) and unrelated diversification (Boschma et al. 2017, Binz & Anadon 2018, Asheim 2019) and whether this can represent a process of new industry path creation (Simmie 2012, Dawley 2014, Coenen, Moodysson & Martin 2015, Binz et al. 2016, Steen 2016, Hassink et al. 2019, Trippl et al. 2020, Tödtling et al. 2020). This approach has highlighted and acknowledged the increasing relevance of agency and multi-scalar forces in creating new diversification trajectories and has inspired a debate in terms of processes of industry formation, the role of policy and institutional entrepreneurs (MacKinnon, Dawley, Pike & Cumbers 2019, Hassink et al. 2019) in economic diversification.

This chapter advances the concepts of related and unrelated variety to study the opportunities for more sustainable pathways of diversification in the context of disparate regions in Colombia. Two main questions are posed. First, what type of development opportunities are enabled by related diversification, particularly for those regions highly reliant on extractive industries and those with less developed industrial bases? This question resonates with the increasing social demands for sustainable development, for example coming from the SDG 2030 Agenda and local responses in Colombian extractive regions whose communities have started to demand more sustainable pathways of development. The second question addresses the adoption of sustainable development principles and the extent to which related and unrelated technological variety enable the incorporation of sustainable development trajectories in regional diversification strategies and how this is done?

The chapter begins with a regional descriptive analysis using exports and employment data to evidence regional unevenness, the economic relevance of extractive industries, and the degree of regional economic diversification using the Herfindahl-Hirschman Index calculated for this dataset. Following the quantitative methodology of EEG, the chapter then measures and analyses the levels of related

and unrelated variety for 28 regions in Colombia, and relates these indexes to regional economic variables such as valued-added growth and GDP to identify patterns of change across regions. A typology of regions is offered according to the levels found, with three main groups. Group 1 is characterised by the country's most dynamic regions that present the highest levels of related variety. Group 2 is formed of the intermediate regions that show low levels of related variety, and a final group 3 made up by the lagging regions and those based on extractive industries with very low levels of related variety. A close analysis of the typology is carried out to answer the two questions outlined earlier. The argument is that, in the light of sustainable development new ways of thinking about industries and employment are required, that are not usually considered in conventional notions of economic growth. Reliance on existing capabilities may not be enough to facilitate this sort of diversification and foster sustainable development. For example, where there is a lack of diverse capabilities and dominance of unsustainable industries, such as in extractive regions. It is also discussed that in cases where there is diversity and technological relatedness, the adoption of principles of sustainability may require redirections in policy to tackle sustainability challenges, and a broader set of actors and their agency, who can bring innovative solutions to complex societal problems such as pollution, sustainable transport, bio-diversity destruction, and healthy living.

The chapter is organised in five sections. Section one sets the scene with a characterisation of Colombian regions and their patterns of diversification. Section 2 presents and discusses the role of related variety in the process of economic diversification in Colombian regions. Section 3 depicts the results of the analysis for unrelated variety and discusses in which cases this route would be more relevant. Section 4 explores the development opportunities offered by related and unrelated diversification to these three types of Colombian regions and section 5 draws the conclusions of the chapter.

4.1 Characterisation of Colombian regions and their patterns of diversification

The literature review chapter highlighted that the capabilities embedded in regional industries are cumulative, unique and difficult to change. Therefore, regions tend to diversify into technologically related industries. These capabilities emerge and consolidate from localised learning dynamics facilitated by market configurations and conditions that foster industrial development, for example, skills and labour features, infrastructure, and natural resources. In this line, this section seeks to provide a general industrial panorama of Colombian regions, and to determine to what extent these conditions are present countrywide to facilitate regional related diversification. As part of this regional characterisation, the Herfindahl-Hirschman Index is used and calculated as a regional economic diversity indicator based on employment and exports. The results of this descriptive analysis are interrogated to understand differentiated patterns of regional economic diversification over the period of analysis.

4.1.1 Regional exports: mining, resource-intensive goods and regional disparities

A first step in the process of descriptive analysis is to provide an overview of the regional performance on exports between 2008-2017. This overview describes the regional linkages with global markets and provides a dimension of the differences across regions. Figure 4.1 displays average annual regional exports. A first outstanding fact is the disparity in the exports values between regions. Indeed, the biggest exporters are predominantly mining regions. Their exports value exhibit high variance, compared, for example, to regions that export agricultural products, such as: Cundinamarca, Huila and Tolima. This variability can be explained via oil prices during 2008-2012 period. The three main oil exporters are Meta, Casanare, and Santander, which show the highest variance in exports value, compared for example, to La Guajira, a net exporter of coal. Oil producer regions become more vulnerable to this external factor due to the exports concentration on this product. Another group of regions appears in Figure 4.1 that is integrated into global trade, although to a lower degree, compared to the mining regions.

This group's exports are characterised by agricultural products, and their exports set between 0.5 and 2.5 billion USD. For these regions, some of the sustainability challenges are around fair trade, sustainable agriculture, poverty in rural areas, amongst many others. Their insertion into global value chains suppose intensive use of land to achieve high levels of productivity with low and competitive prices of food commodities, which tend to affect the soils and intensify the effects of climate change. Finally, a small group of regions exhibit a very low export value. Historically, these regions have been less connected to the rest of the country and this lack of infrastructure and connectivity has hampered their regional development, and indeed, their capacity to plug into global trade networks.

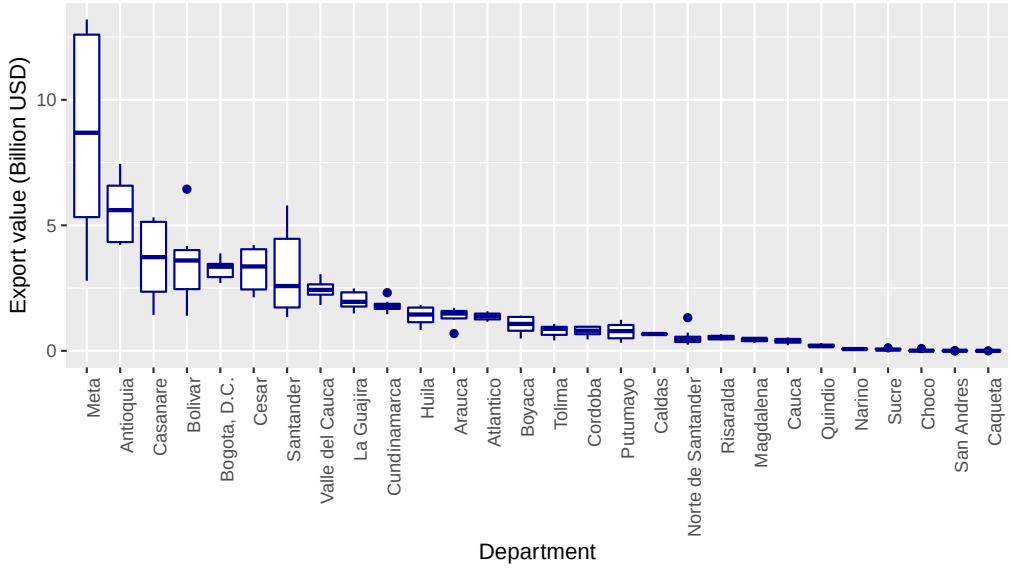

Figure 4.1: Average annual regional exports, 2008-2017. Source: Data obtained from www.datlascolombia.com

Exports composition is presented in Figure 4.2 and grouped in the main sections of the Harmonized System to facilitate visualisation. Exports in about 50% of the regions are predominantly based on mineral products. Another important section is vegetable products (02) where all food commodities are, and which is the second most important range of products after mining. Intermediate regions such as Caldas, Quindio, Risaralda, Magdalena and Nariño concentrate their exports in these products. From Figure 4.2, very few regions have diversified exports. Such composition of the exports makes the discussion of sustainability highly relevant for regional processes of diversification.

Figure 4.2: Regional exports share per sector, Colombia 2008-2017. Source: Data obtained from www.datlascolombia.com

Alongside sustainability challenges faced by most regions in Colombia, the regional composition of exports suggests low industrial diversity, which may also mean low levels of technological variety. This will be discussed later in this chapter. The implications of these results are twofold. First, the over-dependence on one or few resources can lead to monoproduction and generate negative environmental ans social externalities. Secondly, for those less connected regions, the historical conditions of which are marked by the lack of infrastructure or weak connection to the national and global markets and, a low export capability, the chances of related diversification are reduced. These implications affect the discussion of diversification and set limits to the applicability of related diversification.

4.1.2 Employment: size of regional labour markets and composition

Employment has been used as the proxy for labour mobility when looking at processes of regional branching and diversification (Neffke & Boschma 2011, Fitjar & Timmermans 2017, Xiao et al. 2018). In these analyses have shown active labour markets, where employees move between related industries. Figure 4.3 offers a first characterisation of the regional employment, that portrays the average annual size of employment per region (box-plot) between 2008-2017. As in the case of exports, employment data confirms the regional disparities. The figures show a contrast between three big cities and the rural areas. These cities are in most advanced regions and have the biggest labour markets. For example, employment in Bogotá exceeds twice the labour market of Antioquia, the second biggest employment market in the country. Intermediate regions have on average employment levels around a quarter of million people aged 15-64. For the rest of the regions, the formal labour market is very incipient. Most of the regions fall into this category. From these results, one question is to what extent low levels of employment could pose limitations to industry diversification? These labour features may have affected the conditions under which diversification comes about generating differentiated patterns of diversification that have consolidated over time and deepened regional disparities. For example, small labour markets in mining regions may reduce the opportunities for innovation and labour mobility, which could hamper related diversification. Regions having weak industrial bases, and therefore, low levels of variety may find it difficult to create the market conditions to foster continuous innovation. This situation worsens if the industrial configuration is not technologically related.

Figure 4.4 shows that compared to exports, regional employment is more diverse. Despite regional differences in size of employment, sectoral employment is evenly distributed. For example, advanced regions such as Bogotá, Atlántico, Antioquia, and Valle del Cauca, present similar employment composition to those intermediate regions like: Bolívar, Caldas, Magdalena, Quindío. Services are important for employment across the entire country, in particular, real estate,

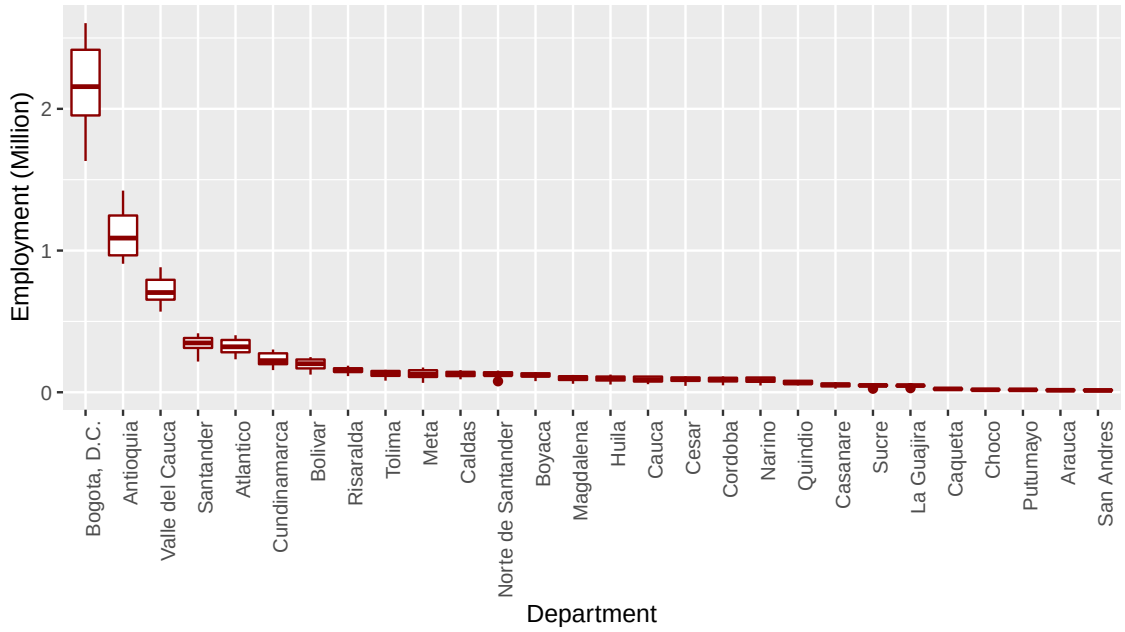

Figure 4.3: Average annual regional employment, 2008-2017. Source: Data obtained from www.datlascolombia.com

renting and business activities. Manufacturing, on the other hand, does not have a significant role, although it can be observed in most of the regions. According to Figure 4.4, the share of mining employment in the total regional employment is not notable for most of the mining regions, except for La Guajira. It shows a disconnect between the main exporting industries, where the strongest technological capabilities should be found, and the local employment composition. EEG assumes that strong technological capabilities are embodied in the workers of those exporting industries. Therefore, there is correspondence between industrial employment distribution and exports composition. In absence of such connection, the possibilities for related diversification are significantly reduced.

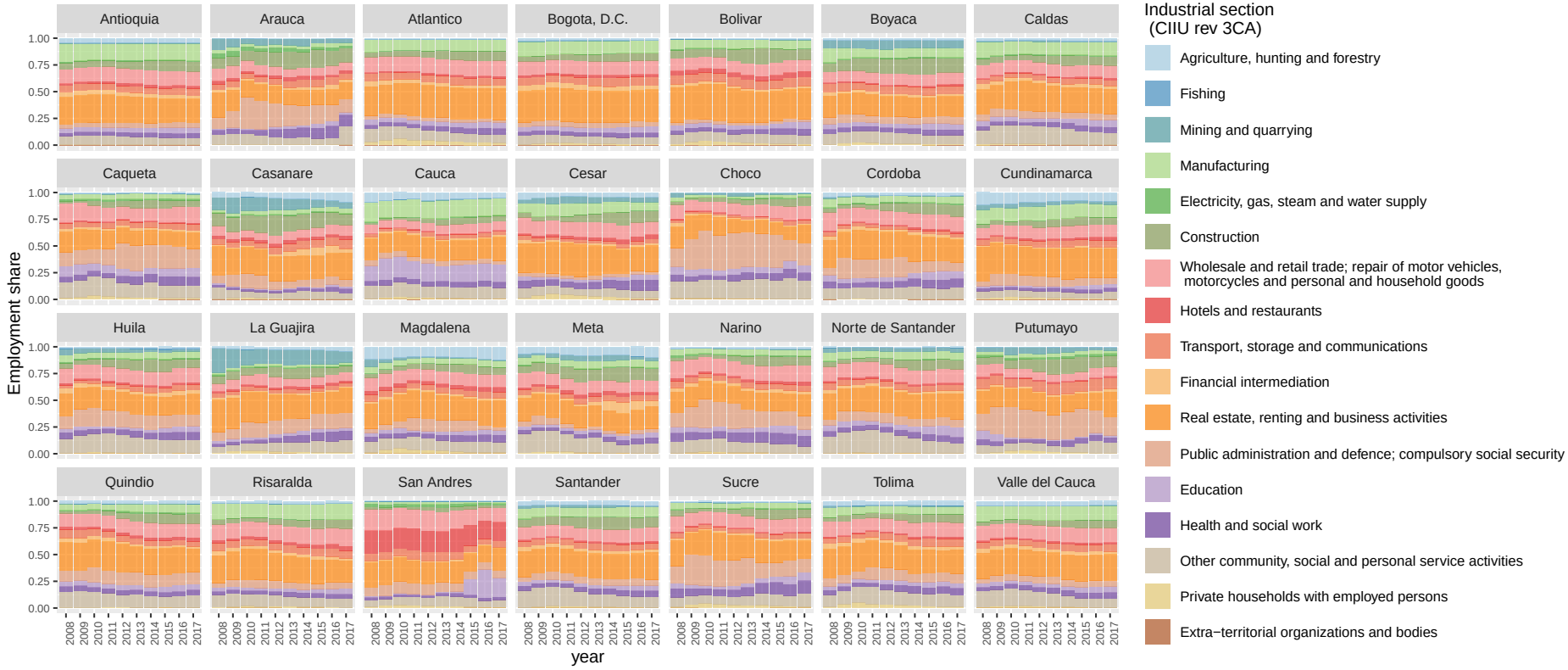

Figure 4.4: Regional employment share per sector, 2008-2017. Source: Data obtained from www.datlascolombia.com

An important conclusion of this descriptive analysis of employment is that differences in the size of employment confirms different types of regions, with similar industrial composition. The sectoral configuration of the regional economies suggests low levels of knowledge intensive industries. As a final step in the descriptive analysis is to provide a formal measure of regional economic diversity based on the calculation of the Herfindahl-Hirschman index for exports and employment.

4.1.3 Assessing regional diversity of exports and employment

To formally assess regional economic diversity, this section present the calculations of the Herfindahl-Hirschman index (HH) to determine changes in the regional economic diversity between 2008-2017 based on exports and employment. HH index has been used to measure market and industry concentration (UN 2016). The HH index provides a measure based on the share a firm has in the total regional industry or the share an industry has in the whole regional economy. This indicator complements the regional sectoral results presented earlier in this section. Changes over time in the regional values of HH are considered a signal of regional diversification, with HH index decreasing to values close to 0 and on the contrary, HH values rising towards 1 would mean concentration of industrial activities and specialisation. An HH Index below 0.15 is considered unconcentrated, between 0.15 and 0.25 moderately concentrated and above 0.25 concentrated (CFI 2021, UN 2016, Chang 2007). The HH index is calculated as follows:

$$HH = \sum_{i=1}^{N} S_i^2 \tag{4.1}$$

S_i denotes the share of each sector's exports/employment in the total regional exports/employment.

The code in Listing A.1 calculates the regional HH index based on exports and employment during the period of analysis (2008 to 2017). Figure 4.5 presents the results. A summary of the categories is presented in Table 4.1. Colours have been assigned to these categories: red unconcentrated, green moderately concentrated

Range	Classification
$HH < 0.15$	unconcentrated (diversified)
$0.15 < HH < 0.25$	moderately concentrated
$HH > 0.25$	concentrated

Table 4.1: HH Index categories

and blue concentrated.

According to Figure 4.5, most of the regional exports are concentrated, with values higher than 0.25. The resource-based regions, where extractive industries dominate, show values close to 1. In this case, more than 90% of its exports are concentrated in the mining sector. For regions having less concentrated exports and closer to moderate concentration (between 0.25 and 0.50), such as Nariño, Risaralda, Magdalena, Sucre, Norte de Santander, more than 70% of their exports fall in the agricultural sector (the main products are vegetables and fruits) (*DATLAS* 2017). Only five regions exhibit values lower than 0.15, with diversified export baskets (Bogotá, Antioquia, Valle del Cauca, Cundinamarca and Atlántico). Although for Cundinamarca and Antioquia some observations go higher than 0.15, as shown in Figure 4.5 in green triangles. For these diversified regions, their values appear more stable compared to those regions with moderate concentration. In the case of extractive regions, such as Meta, Guaviare, Casanare, La Guajira and Cesar, their values tend to be as stable as those in the diversified group. For these regions their exports are highly concentrated, and their diversity indexes do not change over time, that strongly suggest path dependency. For mining regions whose export baskets are less concentrated, such as Boyacá, Tolima and Santander, the HH index decreases after a period of concentration. This may be attributed to an oil price boom from 2008 until 2013.

Regional labour market and employment diversity

Compared with exports, diversification indexes for employment paint a different picture, with diversified labour countrywide and values below 0.15 for the 28 regions. Unlike for exports, the HH employment index also take account of

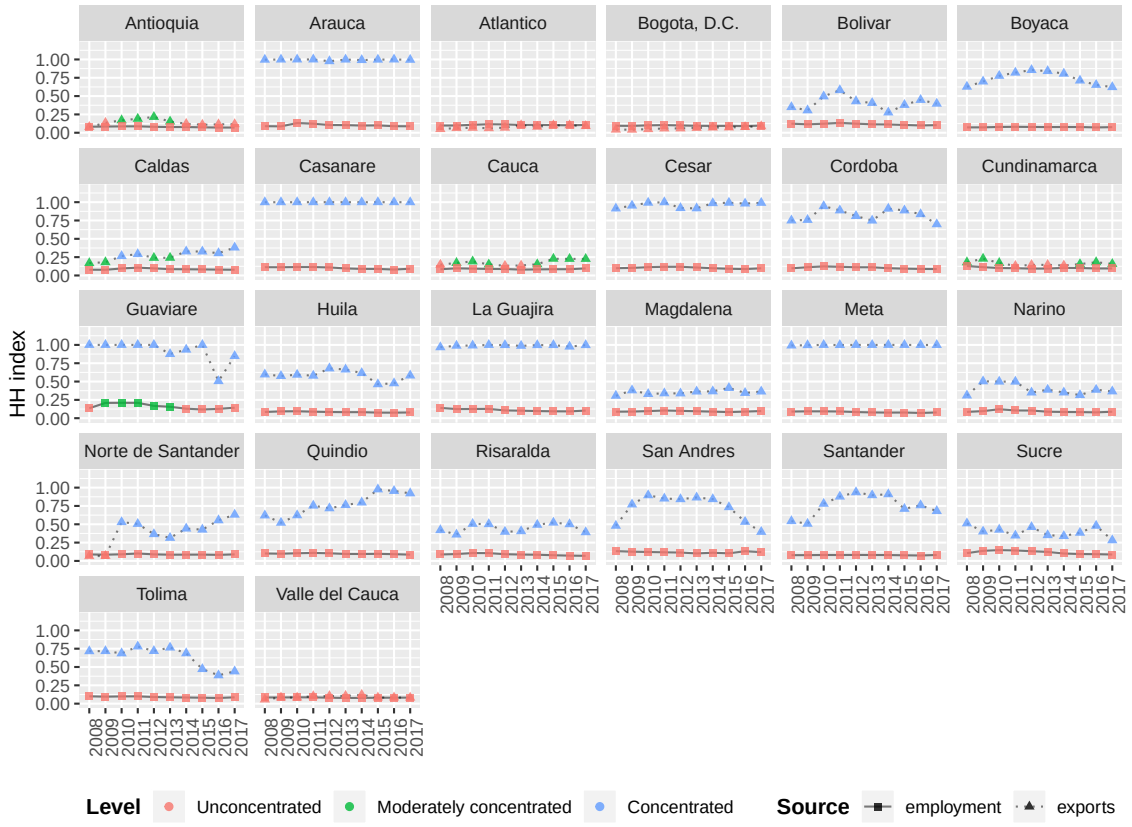

Figure 4.5: Herfindahl-Hirschman diversification index for Colombian regions based on exports and employment 2008-2017

services, which brings more diversity into the analysis, as shown earlier in Figure 4.4. The five most advanced regions in Colombia are the only ones showing diversified exports and employment. An important question to raise is what causes this dissimilarity between the diversification index of employment and exports. Low levels of sophistication of the regional industrial sectors could be one way to explain this divergence. Although these sectors generate local employment, these mature industries are unable to compete abroad and generate further opportunities for innovation and industrial diversification. The OECD (2014) highlights the maturity of industries in Colombia as a limit to industrial diversification and economic development. Low complexity of the industrial base may also explain the composition of regional exports baskets, primarily formed by agricultural and mining products.

The characteristics of the Colombian labour market may also have had an effect in regional diversification. For example, 52% of employed people are self-employees,

compared with, for example, 5% in Sweden and 27% in Mexico (OECD 2016). Neffke & Boschma (2011) highlight the importance of learning and knowledge acquisition at plant levels. Employees acquired specialised knowledge and skills that facilitated industrial renovation in Sweden between 1962 and 2002. The Swedish industrial renovation was underpinned by labour mobility and entrepreneurship from experienced workers, and captured in their analysis of regional entry and exit of firms using employment data at plant level. In Colombia, a high percentage of employees do not work within firms, but rather as individuals, this may have an effect on routine formation, learning, and innovation dynamics.

Another important aspect of the Colombian context is the labour informality. According to OECD (2016), informality amongst high-skilled workers was 53% in 2016. The OECD's report (2016) on Colombia's labour market also points out the influence of informality on low-skilled workers, particularly in traditional sectors, where the wage difference between formal and informal workers has widened up to three times during the recent years (OECD 2016). Mobility and transition from formal to informal labour market are also limited and are particularly difficult for informal workers in these sectors. According to the report, only 16% of informal workers in traditional sectors are able to transition to formal labour.

The significance of these factors is that they create unfavourable conditions for change and reinforce path dependencies. Economic diversification becomes a much more complex process, especially in extractive and lagging regions. Despite the diversity of regional employment, this has not facilitated the diversification of the regional exports. An EEG analysis suggest this disconnect may respond to the low technological relatedness of the regional industrial sectors, which does not facilitate a dynamic process of economic change. Two issues come up from this perspective. First, to what extent regional context and the nature of certain sectors have hampered the emergence and establishment of technologically related industries? For example, in the case of extractive regions, why more technology intensive industries have not developed around the extraction of minerals? Does it respond to the global configuration of the extractive industries? Secondly, in

addressing regional diversification in the Southern context, underlying features of variables such as informal employment and exports do not necessarily correspond to those of the Northern context. Thus, diversity indicators calculated from these variables are bounded by these conditions. A more holistic understanding of the conditions under which economic diversification takes place is required in the Colombian context. These two issues affect the way in which economic diversification is addressed.

4.1.4 Preliminary regional categories

As a preliminary conclusion from the diversity analysis, there appear three types of regions based on the HH indicators of exports diversity (HH indexes) shown in Figure 4.5, and summarised in Table 4.2. One group contains five Colombian regions which have been able to diversify their exports baskets. These are Bogotá, Antioquia, Atlántico, Valle del Cauca, and Cundinamarca. These regions represent important urban poles of development, and show a pattern of diversification based on the insertion into global markets and localised industries. Historical advantages in infrastructure have made these regions attractive locations for industries (Moncayo 2004), for example, due to access to transport facilities such as ports and to the international airport in Bogotá. A second group is formed of two regions with moderately concentrated exports (between 0.15 and 0.25), Caldas and Cauca. Although these regions have broadened the number of commodities in their export baskets, over 70% of their exports still belong to the agricultural sector. Group 3 consists of the main mining exporters, and also those lagging regions. Some of the less developed regions have suffered the effects of the internal conflict for decades, such as Guaviare. Regions with concentrated exports are specialised in commodities and highly reliant on their natural resources, either based on extractive industries or plugged into global value chains of agricultural products. This preliminary typology from the descriptive analysis shows that only group 1 regions has been able to diversify its local industrial bases and exports. To deepen the understanding of the reasons for these differentiated patterns of diversification, the next section assesses how technologically related the regional exports and economic activities are. In this way, it will be possible to determine

Group 1	Group 2	Group 3	
Bogotá	Caldas	Bolivar	Magdalena
Antioquia	Cauca	Boyacá	Meta
Atlántico		Casanare	Nariño
Valle del Cauca		Cesar	Norte de
Cundinamarca		Córdoba	Santander
		Guaviare	Quindio
		Huila	Risaralda
		La Guajira	Santander
			Sucre
			San
			Andrés y
			Providencia
			Tolima

Table 4.2: Classification of Colombian regions according to their HH index for exports 2008-2015. Source data obtained from www.datlascolombia.com

the extent to which related variety has played un important role in regional economic change, and which regions could rely on it to renew their economic bases.

4.2 The related variety of Colombian regions

The previous section discussed some of the patterns of diversification followed by Colombian regions given their degrees of industrial and export diversity. A typology of regions was presented based on their HH exports diversity indexes, with three main groups. A first group characterised by the most dynamic regions, with highly diversified exports. A second group consists of two regions whose exports are moderately concentrated, and a strong orientation towards agricultural products. A third group exhibits the lowest levels of exports diversity and is formed by the extractive and less develop regions. This section assesses the technological relatedness of exports and regional industrial sectors. EEG literature argues that a firms' and region's capabilities to create new sectors are shaped by the technological proximity of their existing economic activities. Therefore, technological relatedness fuels innovation, and knowledge generation in those regional sectors. Technological relatedness is captured by the concept of related variety (Boschma et al. 2012) and this section measures it for regional industries and exports. This deeper analysis will help refine the regional typology and better

understand the characteristics of each regional group and their dynamics of diversification. In doing so, this section also discusses some spatial elements underpinning these dynamics, following the argument of EEG that diversification is an idiosyncratic process, whereby place influences the way it happens and the possibilities to achieve it (Neffke & Boschma 2011).

4.2.1 Measuring regional related variety

Related variety has been mainly used as a variable to describe how diverse and technologically related are regional industries (Frenken et al. 2007, Boschma et al. 2012). Related variety can be calculated through different methods, for example, the conventional method using the hierarchical industrial classification with the Harmonised System (HS) (Boschma et al. 2012) and the proximity method (Hidalgo et al. 2007). The former deliberately assumes relatedness within industry groups classification (Boschma et al. 2012). Industry groups is an ex-ante measurement that assumes industry groups are related if they share the same two-digit class (Frenken et al. 2007, p. 245). Therefore, all industries at 4-digit level contained in the 2-digit level industry group are assumed to be technologically related. Proximity is based on co-occurrence and is an ex-post measurement that provides a refined measure of relatedness. It incorporates, apart from the technological aspect, elements such as logistics, regulatory frameworks and commercial aspects, to determine relatedness (Frenken et al. 2007, Boschma et al. 2012).

Related variety is defined as the aggregate of the weighted entropy of the regional variety sets by their share in total regional exports. Both methods define the variety sets differently. This is detailed in chapter 3. In both cases, the first step is to calculate the variety sets and their entropy, as a measure of diversity. The entropy is given by the equation:

$$H_r = \sum_{i \in S_r} \frac{P_i}{P_r} \log_2 \left(\frac{1}{p_i / P_r} \right) \tag{4.2}$$

p_i denotes the share of HS i product in total regional exports and P_r the share of each variety set in total regional exports (Boschma et al. 2012, p. 247). Once

entropies are calculated, it is possible to compute related variety through the HS method and proximity following the equation:

$$RELATED\ VARIETY = \sum_{r=1}^{R} P_r H_r \tag{4.3}$$

4.2.2 Related variety of regional industrial employment

The code in Listing A.5 calculates the related variety index based on employment by the HS method, during the period of analysis (2008 to 2017). The results are illustrated in Figure 4.6. A first conclusion is that according to this method, regional industries are technologically related. In terms of evolution, for most of the regions there is a reduction of their related variety indexes between 2008 and 2011 followed by a smooth recovery and an improvement towards 2017. This could respond to the negative effects of the mining boom in the competitiveness and performance of non-mining sectors due to appreciation of the local currency, as suggested by OECD (2014). Under this method, regional related variety indexes do not exhibit significant differences. These results complement what was found in the descriptive analysis of regional employment. A significant number of regions have diverse domestic economies and economic activities that appear technologically related.

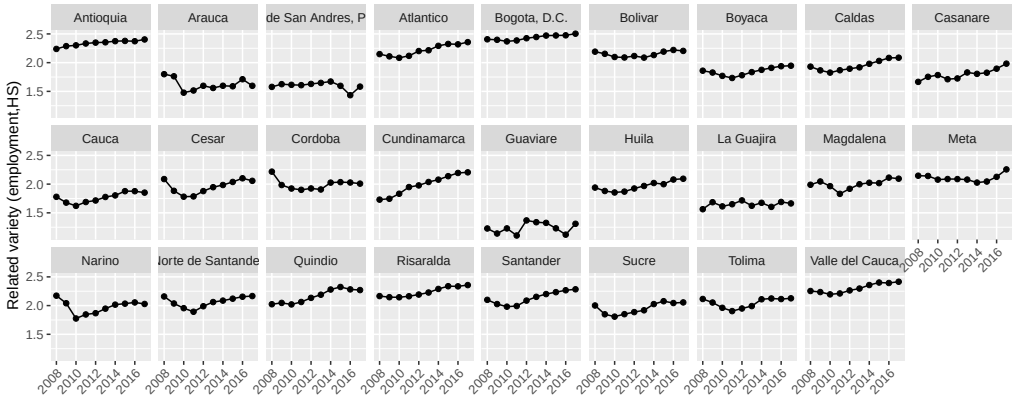

Figure 4.6: Regional related variety indexes for Colombian regions, 2008-2017, based on employment using the HS method

The small differences between regions make it difficult to distinguish the three groups described in Table 4.2. A clearer view is shown in Figure 4.7, which

compares the mean values of related variety along the period of analysis: the most advanced regions (Bogotá, Antioquia, Valle del Cauca y Atlántico) exhibit some of the highest levels of related variety (> 2.2). While less developed regions such us Sucre, Cauca and Boyacá, and some mining regions such as Casanare, Arauca, and La Guajira (Coal producer) exhibit the lowest levels of related variety (< 2.0). Most regions exhibit medium levels of related variety with values between 2 and 2.2. Among them Quindio and Cundinamarca, which have consistently increased their related variety during the period of analysis (see Figure 4.6). Some mining regions are also in the medium level of related variety, particularly the most important ones in terms of exports: Meta and Santander (oil producers).

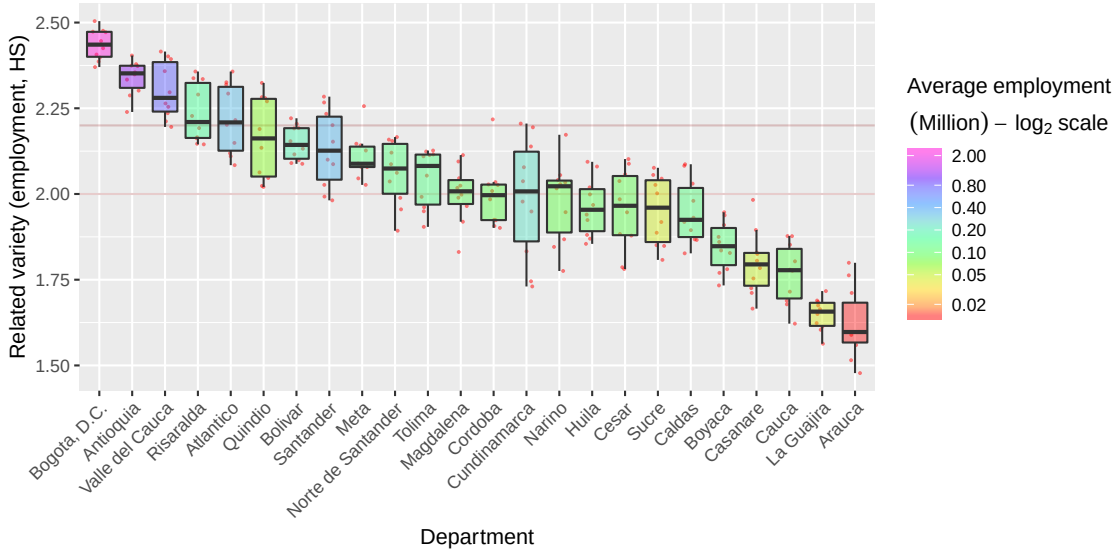

Figure 4.7: Mean related variety indexes for Colombian regions, 2008-2017, based on employment using the HS method, the colour scale represents the average employment in million jobs (log_2 scale), for reference.

A final point deals with the context in which empirical analysis of related variety have been carried out, particularly, where there is correspondence between the industrial sectors and export sectors (Boschma et al. 2012, Fitjar & Timmermans 2017). In such context, exports composition is used as a proxy of knowledge complementarities and relatedness between manufacturing sectors (Boschma et al. 2012). Earlier in this chapter, it was shown that exporting does not occur in most of the manufacturing sectors in Colombian regions. Thus, given the regional industrial composition, characterised by mature industries and low technological intensity of sectors, exports are more appropriate to assess related variety, as

argued by Hausmann, Hwang & Rodrik (2007) and Hidalgo et al. (2007). The effort required to enter in the global market competition implies higher technological intensity and related capabilities that may not be present at the domestic level (Hausmann et al. 2007, Boschma et al. 2012). This logic will be followed throughout the chapter to generate the typology of regions.

4.2.3 Related variety of regional exports by the HS method

The code in Listing A.4 calculates the related variety index by the HS method, during the period of analysis (2008 to 2017). The results are presented in Figure 4.8.

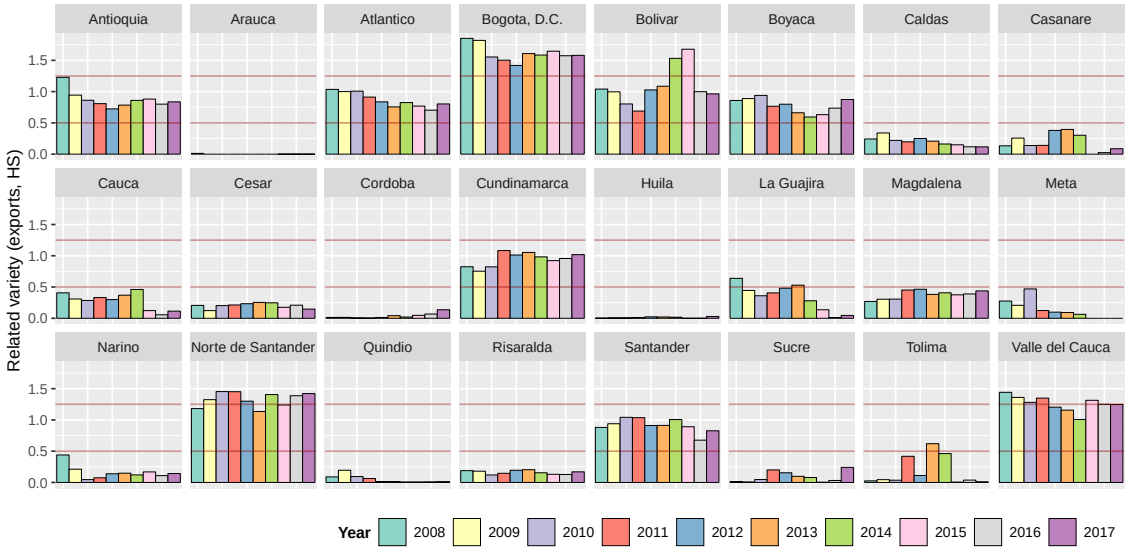

Figure 4.8: Related variety indexes for Colombian regions, 2008-2017, using HS method, based on exports.

Compared to the related variety indexes of employment, regional indexes based on exports are more differentiated. There are few outstanding regions that, according to this method, have high related variety: Bogotá, Norte de Santander and Valle del Cauca. A second group exhibits values between 0.5 and 1.2, and is formed by 5 regions: Antioquia, Atlántico, Boyacá, Cundinamarca, and Santander. While most regions' exports exhibit low levels of related variety (below 0.5), among them there are regions based on extractive industries, lagging regions and mono-production regions (agriculture). Interestingly, under this method, regions

such as Norte de Santander and Boyacá exhibit similar levels of related variety indexes that advanced regions like Atlántico and Antioquia. To put it another way, Antioquia and Atlántico are amongst the most diversified regions according to their exports —HH index for exports—, and under this calculation method, their levels of related variety are similar to those of a concentrated exports region, such as Boyacá. This type of mismatch is in line with the drawbacks identified by Boschma et al. (2012) when using the hierarchical classification to build the variety sets. As not all the products contained within a 4-digit group are strictly related, indexes obtained with this method may be less accurate than those based on proximity (Boschma et al. 2012, Fitjar & Timmermans 2017).

4.2.4 Related variety of regional exports by the proximity method

The code in Listing A.3 calculates the related variety index by the proximity method, during the period of analysis (2008 to 2017). Figure 4.9 presents the results. The co-occurrence of products is measured based on exports data (a more detailed explanation of this calculation is provided in chapter 3).

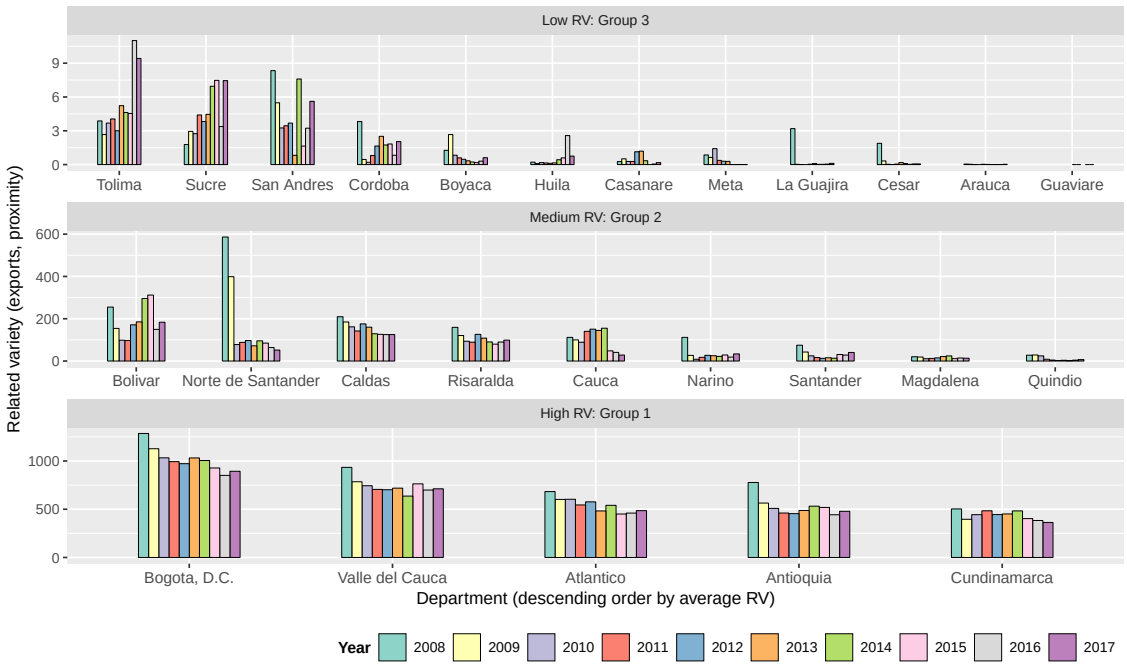

Figure 4.9: Related variety indexes for Colombian regions, 2008-2017, based on exports, using the proximity method

This method permits to clearly identify three distinct groups of regions, which are shown in different panels in Figure 4.9 (note the y axis' limits are different on each panel). The first group contains five regions with the highest level of related variety (greater than 450 and up to 1200), those regions have already appeared as outstanding in the diversification analysis presented in the previous section. A second group is formed by regions with intermediate levels of related variety (around 100, on average) and a third group is formed mostly by lagging or extractive regions, whose levels of related variety are significantly low (less than 10) due to low levels of exports, in the case of the former, and to the exports composition, in the case of the later. Table 4.3 list the regions on each group:

Group 1	Group 2	Group 3	
Bogotá	Bolivar	Sucre	Boyacá
Valle del Cauca	Norte de Santander	Tolima	Casanare
Atlántico	Caldas	Meta	Putumayo
Antioquia	Cauca	Vaupes	La Guajira
Cundinamarca	Risaralda	San Andrés	Cesar
	Santander	Cordoba	Arauca
	Nariño	Huila	Guaviare
	Magdalena		
	Quindio		

Table 4.3: Regional typology based on the analysis of related variety based on exports by the proximity method.

By considering not only the share of the different industries in the total exports, but also the entropy of variety sets (co-occurrence of products exported), the related variety index by the proximity method provides a nuanced indicator of diversity compared to the HH index (Section 4.1.3) and the index of related variety based on the HS method (section 4.2.3). As can be seen in Figure 4.9 the related variety index based on the proximity method provides a clearer distinction between the 3 groups, as the numerical values differ almost in an order of magnitude between consecutive groups. It also includes more regions on the medium level group, as compared to Table 4.2, where group 2 is formed by Caldas and Cauca only). Finally, the related variety index based on the proximity method also creates a clear and more intuitive distinction between regions like Atlántico, Antioquia and Boyacá which showed similar levels of diversification using the HS classification method (see section 4.2.3). Therefore, the groups

presented in Table 4.3 provide a more reliable classification of regions' diversification and will be used for the discussion in the next sections of this chapter.

4.2.5 Related variety and regional economic performance

This section discusses the extent to which the levels of related variety found in the previous section have a relation with regional GDP and value-added growth. Authors such as Boschma et al. (2012) and Frenken et al. (2007) have tested the relation between regional economic variables, such as economic growth, employment and value added growth, and related and unrelated variety mainly using econometric analysis. To this end, the indexes of related variety based on exports and obtained by the proximity method are used to identify the relations. The analysis will rely on a graphic representation of the regional related variety indexes and regional economic variables to determine positive or negative relations between variables, as shown in Figure 4.10.

GDP and related variety

Figure 4.10 depicts the relation between related variety and regional GDP.

Both axis in Figure 4.10 are in log_{10} scale in order to facilitate the comparison between regions, as both GDP and Related Variety span over a very wide range of values. It also highlights the big disparities across regions in terms of their GDP sizes and relatedness. Differences account for more than two orders of magnitude in related variety. For example, some regions are below the 0.1 limit, while Bogotá is above 1000. Such differences evidence important gaps between the groups, which means that significant efforts are required to move from one group to another, for instance, from group 2 to group 1: the most diversified region in Group 2 is Bolivar with an average related variety index of 190, while the least diversified region in group 2 is Cundinamarca with an average related variety index of 435, 128% larger.

The main conclusion drawn from Figure 4.10 is that it appears to be a positive relation between GDP and related variety for groups 1 and 2. In contrast, there is

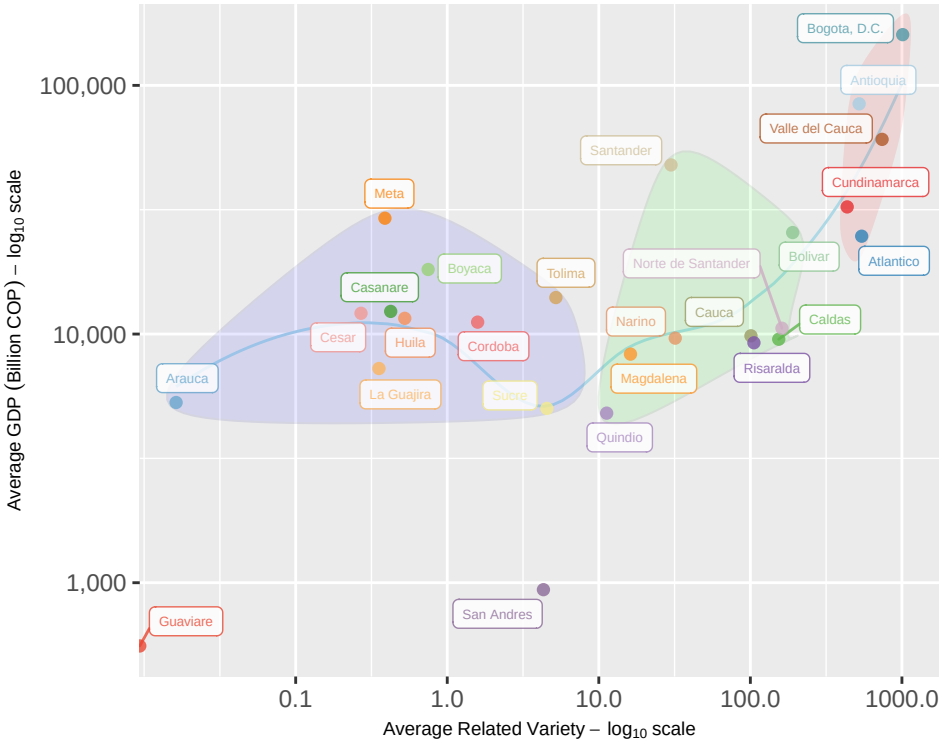

Figure 4.10: Colombian average related variety based on exports, by the proximity method, against regional GDP (Billion COP), 2008-2017. Both axis are in log_{10} scale. Encircled regions correspond to groups 1 (red), 2 (green) and 3 (blue) in Table 4.3

no clear relation between these two variables for mining and lagging regions, in group 3. This finding has important implications for the understanding of regional diversification in the group 3 type of regions. Considering the path dependencies derived from the concentration on extractive industries and the absence of an industrial base, it is difficult for these regions to create related variety, even if they manage to grow. In consequence, policy efforts that follow the logic of related diversification as the main mechanism for regional development would have a reduced impact, opposite to what could be expected for groups 1 and 2. This fact may also explain to some extent why regional disparities have maintained over time. Although more research is needed in this regard.

Related variety and regional value-added growth

A final step is to compare related variety and regional value-added growth, as another way to explain differences in regional economic performance. Figure 4.11 presents these results that follow the typology of regions introduced earlier. The

average levels of related variety can be clearly distinguished in Figure 4.11 for each group.

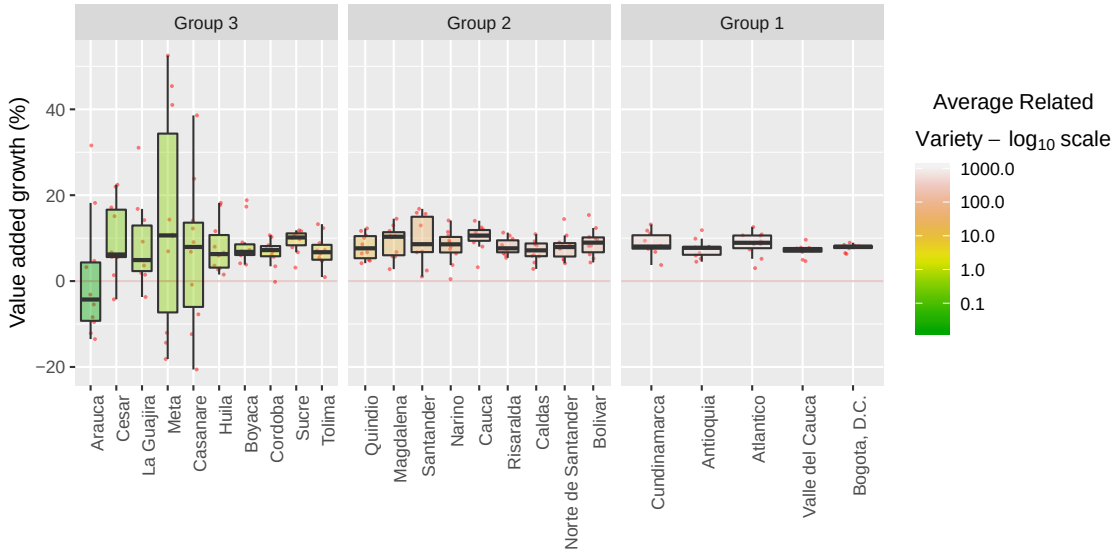

Figure 4.11: Average related variety log_{10} scale and average regional value added growth log_{10}, 2008-2017

An interesting result is that regions with lowest levels of related variety (green) - located in group 3 - have the highest variations of the value added growth rates. And this holds for lowest levels of related variety within each group, according to the sizes of the box-plots. Group two and three show similar patterns in the relation between Value Added Growth and related variety. Although, a noteworthy element is that these two variables do not exhibit a clear relation, which contrasts with results presented in the literature (Boschma et al. 2012).

4.2.6 Limits to related diversification in Colombian regions

It is important to understand the reasons behind these figures and how the history and nature of industrialisation and industrial policy have helped to create high levels of uneven development in Colombia. For the most diversified regions, significant progress in infrastructure in the 20th Century facilitated industrial localisation and their urban development (Moncayo 2004). These regions' growing economic relevance strengthened their influence on policy in terms of concentration of public investments on infrastructure (Moncayo 2004) and on trade policy (De Lombaerde 2015). This process accentuated path dependencies in

those less developed regions. For example, increasing the economic dependence and concentration on single industries and products that reduced the possibilities of diversification. This is the case of mining regions, for example, Meta, La Guajira, Boyacá and Casanare. For remote regions in group 3, the lack of investment and state abandonment created the conditions for illegal armed groups to settle and control the regional dynamics, including the provision of justice and economic activities, that were developed around illicit crops and drugs production, in regions such as: Arauca, Casanare, Cesar, Putumayo (Coca leaf) and Huila and Tolima (opium poppies) (Moncayo 2004). These path dependencies can be noted in the descriptive analysis presented earlier, in which these regions do not exhibit significant changes in the levels of diversification of their exports and their technological related variety remain almost invariable over a decade. Under these conditions, diversification needs to acknowledge these complexities that overpass the lack of technological capabilities to incorporate the challenges of sustainable development, basic infrastructure and inclusive processes of innovation like access to sanitation and energy provision, food production and inequality. Addressing these challenges could open up new routes for regional development that may divest from the existing economic dynamics.

In Colombia, as in many other countries in Latin America, the pattern of diversification has been driven by big vertically integrated economic conglomerates or business groups (Garrido & Perez 1998, Schneider 2009). Vertical economic integration was the main growth strategy in the light of reduced external competition during the Import Substitution period and, for some of these groups, their further consolidation strategy after structural reforms in the 1990's (Garrido & Perez 1998). Despite the benefits this business strategy has brought about in terms of employment, fostering urbanisation and economic progress and industrialisation, it has also shaped innovation and market dynamics that have hindered a broader diversification process in other industrial sectors. Branching processes took place within the industries owned by those groups and companies to maintain their competitive position by "generat[ing] synergies from a basic industrial core" (Garrido & Perez 1998, p. 133). For example, manufacturers of non-alcoholic beverages branched out to produce glass and cardboard. Vertical

integration facilitated labour mobility and therefore branching. Several authors (Garrido & Perez 1998, Schneider 2009) have highlighted the advantages of vertical integrated industries in facilitating related diversification, as it reduces the associated costs of entering into a new sector and flattens the workers' learning curves. These processes of sectoral diversification led by big economic groups were localised and contextual. As most of the industries were established around the extraction of natural resources (sugar cane, coffee, vegetables). Therefore, geographical proximity constituted a noteworthy localisation factor. This shaped regions' geographical and economic evolution of group 1.

Branching resulting from entrepreneurial activity has been another mechanism adopted by big economic groups to diversify. The hierarchical and ownership characteristics of big conglomerates tend to facilitate such processes (Garrido & Perez 1998). But the scope of these new products is defined by the "core" activity of the group, for example, in soft drinks or beers. To protect entrepreneurial projects from international and local competitors, the big economic groups used their political power to lobby government and shape policy (De Lombaerde 2015). These conglomerates tend to use the National Industrial Association (ANDI) to influence the trade policy and to make it more convenient for their economic interests. This made entrepreneurial activities outside the vertical integrated industries more difficult due to unfavourable conditions, for example, limited access to credit, lack of incentives, low market openness. Evidence of this is that in 2016, 22.7% of adults aged 18-64 were involved in an early-stage entrepreneurial activity, but only 5.2% of this activity became established business. Colombia has one of the highest entrepreneurial activities amongst countries observed by the General Entrepreneurship Monitor (Bosma, Hill, Ionescu-Somers, Kelley, Guerrero & Schott 2021), but both established business and Entrepreneurial Employee Activity are low, 2.3% for 2016, compared to 7.0% in the UK and 5.4% in Chile. These figures suggest that entrepreneurial activities leading to branching processes were more likely within these conglomerates and, therefore, it was a less effective mechanism of diversification for the rest of the regions.

The above discussion around industry conglomerates suggests that, as some

authors (MacKinnon et al. 2019) have pointed out, a political economy perspective on EEG literature can help discern aspects of industry configuration and capital accumulation to enrich the understanding of how economic activities change in space and time. This analysis could contribute to a better understanding of the path dependencies faced by Global South countries and how to overcome them to enable industrial change. For some regions, these complex configurations lock regions into unsustainable industrial trajectories, for example, concentrating economic activities and developing research agendas around extractive industries, and creating vested interests that can influence regional decision making. In such cases, sustainability challenges can create space for exploring very different alternatives that may be unrelated to the current industrial base that could give birth to a more socially and environmentally sustainable industries. This will be discussed in depth in the next chapter. Based on the typology presented above, the next section assesses unrelated variety in Colombian regions and discusses the results.

4.3 Assessing unrelated variety and its relevance for Colombian regions

Unrelated variety has recently gained more attention in the EEG literature as an alternative route for diversification and continuous growth (Steen 2016, Boschma et al. 2017, Binz & Anadon 2018, Xiao et al. 2018, Hassink et al. 2019). The interest stems from regions facing economic stagnation and increasing strategies of green restructuring in the light of sustainable development pressures (Trippl et al. 2020). Authors have addressed two main aspects of unrelated diversification. First, the constraining factors hampering regional economic change, for example, vested interest from incumbents that can create technological lock-in, and the institutional frameworks supporting existing economic structures (Boschma et al. 2017, Hassink et al. 2019). Second, the extent to which existing capabilities and knowledge bases enable new combinations leading to new industrial pathways. In this last point, an important factor is that unrelated diversification is argued by some authors to be more likely to occur in those regions with strong technological capabilities and high-tech industries (Boschma et al. 2017, Xiao et al. 2018).

Grillitsch & Asheim (2018) explain this recombination in terms of connecting different types of knowledge bases: analytic (science based), synthetic (engineering based) and symbolic (design based). Boschma et al. (2017) define this recombination in terms of technological breakthroughs. In both definitions, the potential of unrelated diversification lies in the knowledge and capabilities built over time in the region. To enable the conditions for unrelated diversification, institutional entrepreneurship and bricolage are key to mobilise resources and enable agency of distributed actors who bridge distant knowledge bases to create novel products with the resources at hand. In this way, unrelated diversification is seen as a "constructed" process of industrial change (Steen 2016, Boschma et al. 2017).

This thesis argues that unrelated variety could provide a way forward for understanding some diversification processes in Colombian regions. Particularly, as suggested by the EEG literature, in the presence of pressures to adopt more environmental and socially sustainable activities. Sustainable development opens new routes for exploring unrelated diversification, specifically in mining regions and those reliant on mono-production by breaking the dependence on extractive industries. Nevertheless, an adjusted interpretation of unrelated diversification is required to elucidate the lack of technological capabilities and therefore, to incorporate broader sources of knowledge and learning patterns and new types of actors who can facilitate these learning processes. This section identifies the levels of unrelated variety in Colombian regions and hints at some alternatives for the typology of regions described above. How these alternatives materialise, who drives them and how agency forms remain under researched topics (Boschma et al. 2017) and, will be developed in detail in the next chapter.

4.3.1 Measuring unrelated variety

Unrelated variety is calculated following the same logic applied to related variety, using the conventional method of industrial classification and proximity. For both, the analysis begins with the calculation of the variety sets. For the first method, the variety set is given by each 1-digit HS industry code. In the case of proximity, the variety set corresponds to all products whose proximity value is lower than

0.25. Unrelated variety is obtained by the equation:

$$UNRELATED\ VARIETY = \sum_{j=1}^{N} P_j \log_2 \left(\frac{1}{P_j}\right), \tag{4.4}$$

P_j denotes the share of each 1-digit sector in total exports.

The code in Listing A.5 calculates the unrelated variety index by the HS method based on employment, during the period of analysis (2008 to 2017). Figure 4.12 depicts the results. As previous calculations based on employment using the conventional method, regions do not differ significantly in terms of their levels of unrelated variety. Levels of unrelated variety dropped from 2008 to 2010 and recovered by 2015. This is consistent with what was discussed in terms of related variety. As variety increases and recovers, so will do the unrelated variety under this method. A final remark is that for some regions in group 3, such as San Andrés, Casanare, La Guajira, and Sucre their levels end higher by the end of the period.

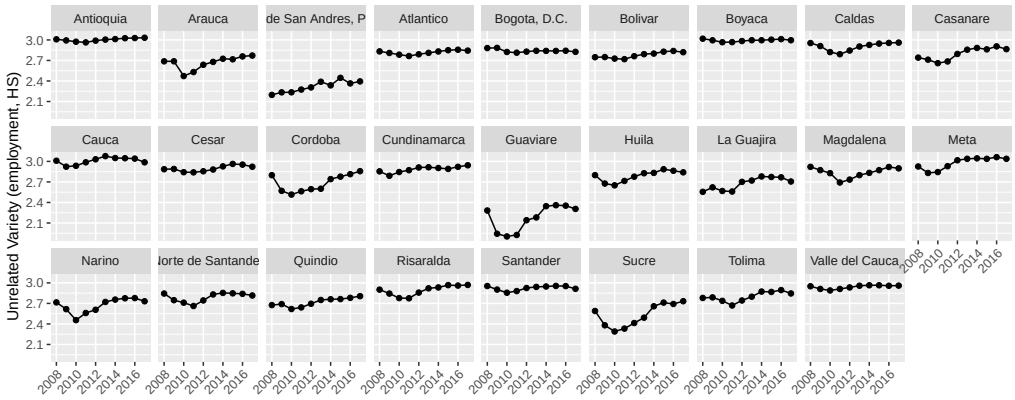

Figure 4.12: Regional unrelated variety indexes for Colombian regions, 2008-2017, based on employment using the HS method

Figure 4.13 compares the mean values of unrelated variety along the period of analysis. Only few regions from group 3 exhibit low levels of unrelated variety compared to the rest of the regions, for example, Guaviare and San Andrés.

The code in Listing A.4 calculates the unrelated variety index by the HS method, based on exports during the period of analysis (2008 to 2017). The results are presented in Figure 4.14. Big regional disparities in the levels of unrelated variety characterise the period of analysis. And this is consistent with the patterns found

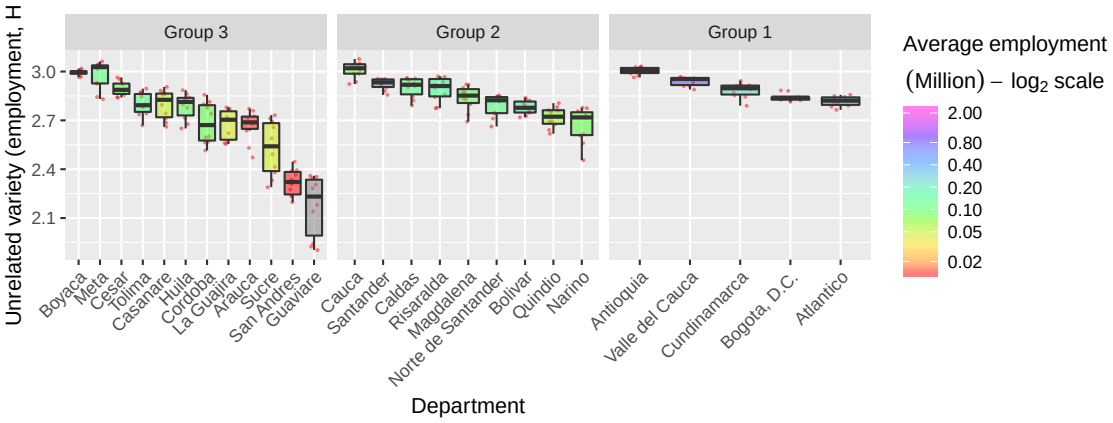

Figure 4.13: Mean unrelated variety indexes for Colombian regions, 2008-2017, based on employment using the HS method, the colour scale represents the average employment in million jobs (log_2 scale), for reference.

for relatedness based on exports under this method. Group 1 still outstands group 2 and 3. For regions in Group 3 the lack of variety, due to export concentration and mono-production model, affects unrelated variety index, generating values close to zero for most of the regions. For groups 1 and 2 unrelated variety levels reduced and, according to the reduction of related variety indexes suggests a general decrease of the regional variety, given the method of calculation. As in related variety calculations under the HS method based on exports in section 4.2.3, some lagging and mining regions such as Tolima, Sucre, San Andrés, Córdoba, Boyacá and Huila present values similar to those in group 2 (see the top panel in Figure 4.14).

The code in Listing A.4 calculates the unrelated variety index by the proximity method, based on exports during the period of analysis (2008 to 2017). The results exhibit similar patterns to those of related variety, as can be observed in Figure 4.15. In general, there is a reduction of unrelated variety levels countrywide. Compared to the hierarchical method, Figure 4.15 clearly depicts the differences between regions, and therefore, the three main groups found in the typology above. Following the literature of EEG, a first conclusion drawn from these results is that regions with the highest unrelated variety could have greater opportunities for new path creation, and to a lesser extent this could apply to regions with a lower level, like those in group 2. For the rest of the regions a less promising picture is offered by this quantitative analysis. What this thesis argues

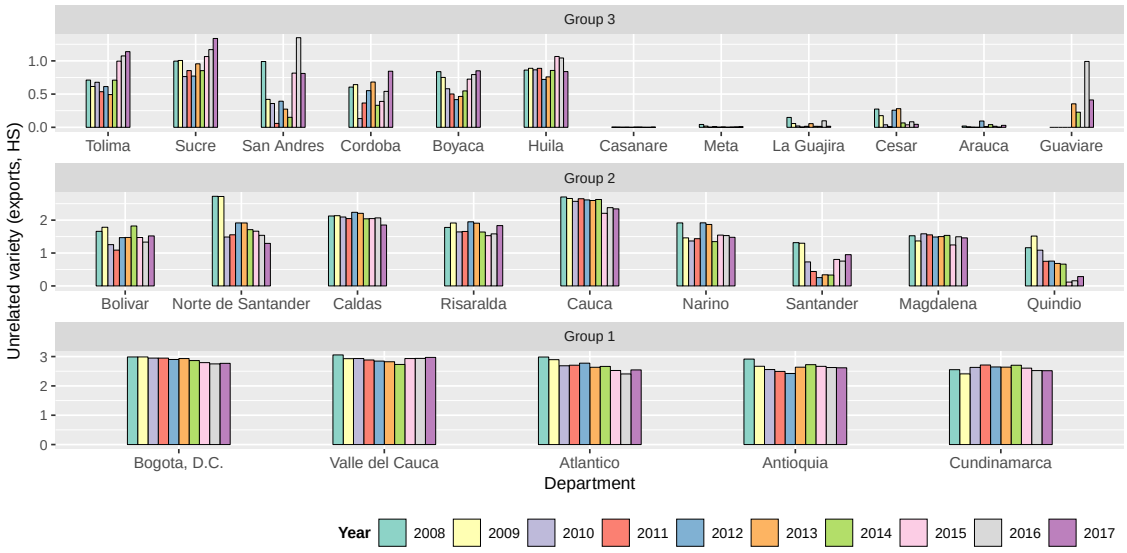

Figure 4.14: Unrelated variety indexes for Colombian regions, 2008-2017, based on exports and using the HS method

is that the concept of unrelated diversification can be useful as a "constructed process", therefore, it is the way in which the process is orchestrated what becomes meaningful for this type of regions in group 3, rather than the levels of unrelatedness *per se*. Through a constructed process it is possible to envisage that opportunities can be "built" by local actors. Their agency and networks allow them to engage in learning processes that help overcome the absence of technological capabilities required for the new industrial pathway.

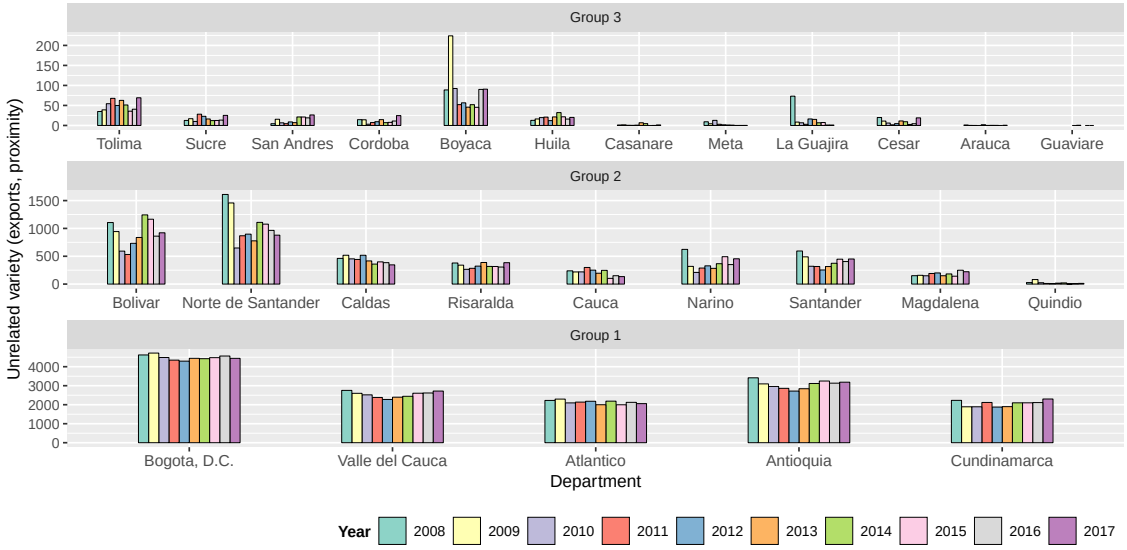

Figure 4.15: Unrelated Variety Indexes for Colombian regions 2008-2015, based on exports, using the proximity method

GDP and unrelated variety

Figure 4.16 depicts the relation between the average regional Gross Domestic Product and the average unrelated variety indexes for the period 2008-2017. To make both variables comparable, they have been transformed into their logarithmic scale. The results are consistent with the typology found in the relation between GDP and related variety and, groups 1, 2 and 3 remain unchangeable. Group 1 is represented by the red encircled area, group 2 by the green area and blue represents group 3, with the lowest levels of unrelated variety and GDP.

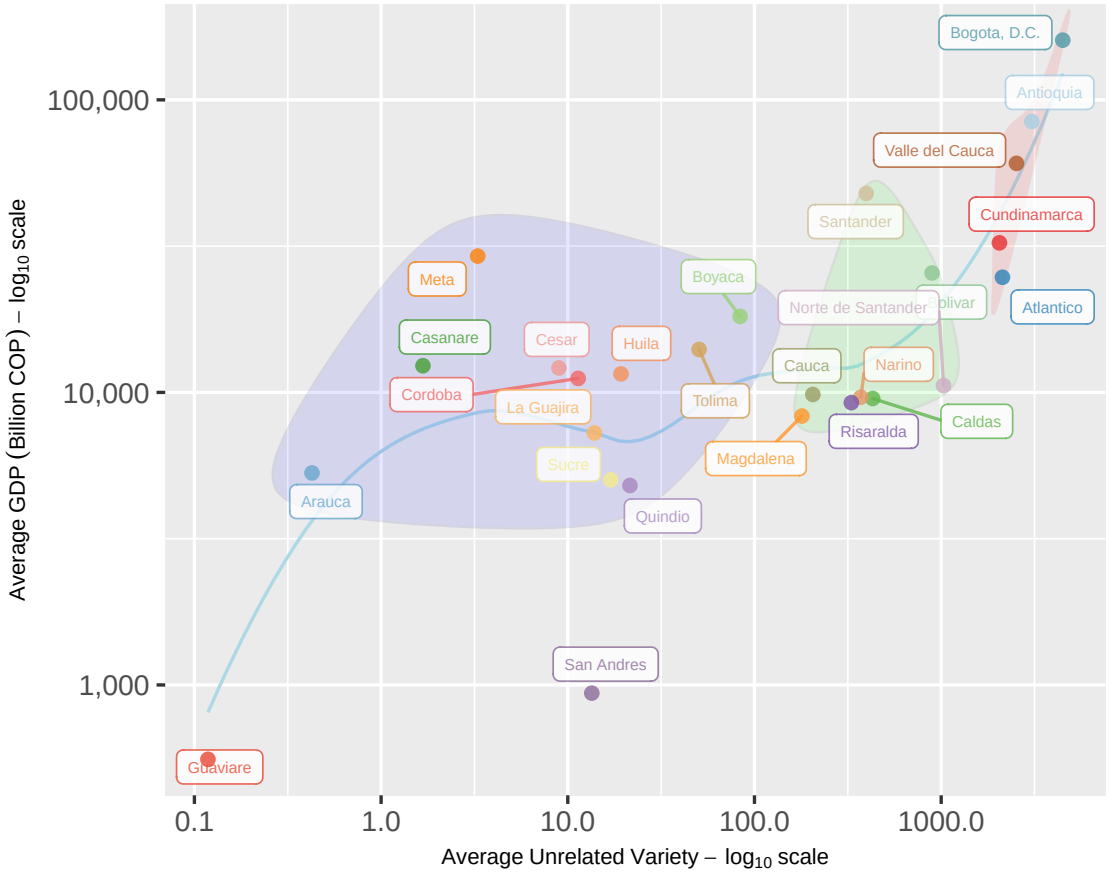

Figure 4.16: Average unrelated variety log_{10} and average regional GDP (billion COP) log_{10} 2008-2017, using proximity

In terms of the relation between GDP an unrelated variety, Figure 4.16 illustrates a positive relation for group 1, and less clear relation for groups 2 and 3. Particularly, for group 3, the economic performance of mining regions does not show relation to technological relatedness, neither unrelatedness. For example,

Meta, Casanare, and Cesar have a similar average GDP to those of group 2, but a tenth of their unrelated variety values.

4.4 Development opportunities enabled by related and unrelated diversification

The previous sections provided evidence on the differentiated patterns of diversification followed by Colombian regions and elaborated a typology to illustrate the role of technological relatedness in these diversification trajectories. The typology consists of three groups. Group 1 involves the most diversified regions of the country. The urban development and industrial localisation characteristic of these regions have been determined in greater extent by the influence of big economic conglomerates. Group 2 includes intermediate regions with a moderate diversification level, specialised in the production of food commodities. These regions tend to be placed into the low value end of Global Value Chains. Social and environmental sustainability issues arise from this pattern of economic development, for example, land degradation and pollution due to intensive agriculture. Group 3 brings together two very distinctive type of regions, those reliant on mining, that have a crucial role on revenue generation for the national economy, and the lagging regions, with the lowest capabilities and weakest economic structures of the country. From this typology is possible to develop a perspective of the sustainability challenges faced by each group. This section bridges these sustainability challenges and the possibilities offered by related and unrelated diversification to transition towards more sustainable trajectories of development that builds on the recent literature on green diversification and new path developement. In the same line, the section examines the extent to which related and unrelated diversification enable the adoption of sustainability principles.

The sustainability challenges and, especially, the opportunities for diversification emerging from greening industries have taken a more central role in the discussion of regional diversification in the EEG literature (Simmie 2012, Dawley 2014, Binz et al. 2016, MacKinnon et al. 2019, Hassink et al. 2019, Montresor & Quatraro

2020, Trippl et al. 2020, Santoalha & Boschma 2021). This literature has generated an increasing number of examples of how regions are tackling sustainability challenges and the extent to which existing frames around related and unrelated diversification can explain the underlying dynamics of change. This debate was analysed in chapter 2 and, in this section, it informs and facilitates a more general discussion around diversification and sustainability.

Following the descriptive analysis and the assessment of related and unrelated variety in the above sections, Table 4.4 builds on the literature on green diversification and new path creation presented earlier in the literature review, and summarises the sustainability challenges originated by each group's pattern of diversification and elaborates on the development opportunities that could be brought about by related and unrelated diversification to each group. It is noteworthy that the developmental history of each group makes diversification a much more complex process in Colombia.

As shown in Table 4.4, Group 1 is equipped with more capabilities, infrastructure, market dynamics and related variety, and the prominent role of economic conglomerates make more likely processes of green diversification underpinned by both related and unrelated diversification. Yet, the influence and agency of these conglomerates can also impose challenges in terms of what Boschma et al. (2017) and Santoalha & Boschma (2021) refer as vested interests. For example, the resistance of these conglomerates to adopt more sustainable forms of exploitation of natural resources and the dominant forms of investment, to give an example.

In group 2, global value chains of food commodities imposes limits to integrate sustainability practices, as high volumes and very low prices of food are key principles that leave little room to introduce more sustainable forms of production. Still, there are opportunities for more sustainable related diversification, for example, by plugging into sustainable value chains, that require higher technological capabilities to adopt sustainability practices. Group 3 regions are under explored as the lock-in around extractive industries prevents the exploration of other resources and opportunities. In this case, the opportunities offered by related diversification could, in greater extent, reinforce unsustainable

pathways and path dependencies, as illustrated in Table 4.4. The question is whether technologically unrelated pathways of development could offer a more promising perspective and the likelihood of this happening given the apparent absence of quantitative studies pointing in this direction.

Concept	Group 1	Group 2	Group 3
Sustainable development challenges from existing patterns of diversification	Greening existing industries to make them more sustainable: water consumption, waste management, pollution. Urban sustainability challenges: unsustainable provision and unequal access to basic public services such as transport, waste management, energy, sanitation. Informality, inequality and poverty. Industry and market dynamics that reproduce these problems.	Unsustainable production of food commodities due to market configuration of global value chains. Low profitability of food commodities. Informality. Low technological capabilities, poor infrastructure and communications.	Resource depletion Pollution and human health effects of extractive industries. Underdevelopment of poorer regions. Dependence on extractive industry revenues. Lock-in R&D agendas.
Development opportunities based on related diversification	Greening industries and services, Diversification towards more sophisticated industries based on existing capabilities e.g., functional and natural food, bio-cosmetics, advanced health services, technological services to tackle water management problems, energy, mobility Bogotá's diversification strategy (Invest in Bogotá 2018)	Insertion in new and more sustainable Global Value Chains of commodities, e.g., Fair trade, sustainable trade, organic. Localisation of new agro-industries to insert into sustainable value chains.	Exploration and exploitation of new minerals, optimisation of extraction and transport processes. Development of R&D portfolios aimed at mitigating the impact of extractive industries.
Development opportunities based on unrelated diversification	New recombinations of existing knowledge bases leading to new sectors and alternative pathways. e.g., bioeconomy, fintech for inclusion, sustainable energy supply, sustainable management waste. Sustainable provision of basic public services.	Anchoring: establishment of new industries through direct investment that mobilise new skills and knowledge and support resources, leading to the localisation of new sustainable industries. e.g., water recycling, energy supply, bioeconomy.	New development pathways based on the care and conservation of nature undertaken by communities. Phase out extractive industries New localised industries around abundant natural resources for sustainable use of biodiversity: scientific tourism, ecosystem services.

Table 4.4: Development opportunities offered by related and unrelated diversification

The point here is twofold. First, unrelated diversification give rise to an entirely different process of diversification that may be more relevant to group 3 type of regions, because it allows one to conceive diversification as a process that can be built through a wide range of heterogeneous actors. In doing so, it enables the participation of other types of actors such as, communities, universities, research centres, civil society, in the conception of alternatives, that make change possible in the absence of firms — for lagging regions — and lock-in of mining regions. As discussed earlier in this chapter, this approach to unrelated diversification differs from the one put forward by Boschma et al. (2017) and needs further investigation. Secondly, the opportunities explained in Table 4.4 for Group 1 and 2 aling to some of the examples recently investigated in the green diversification literature (Asheim 2019, Balland et al. 2019, Montresor & Quatraro 2020, Santoalha & Boschma 2021) in global north regions.

Thus, Table 4.4 hints some policy actions that could be taken up by local governments seeking to achieve sustainable economic diversification. In this direction, EEG literature has made an important effort to translate the insights of its research agenda into policy, particularly in the case of the Smart Specialisation Strategy S3 that has been adopted by the European Union (R & C 2014, Foray 2017, Asheim 2019, Balland et al. 2019, Montresor & Quatraro 2020, Santoalha & Boschma 2021). Such policy frame creates room for exploring different strategies aimed at sustainable development as the ones presented in Table 4.4 and also those proposed by Balland et al. (2019) and Asheim (2019). These opportunities are clear for Group 1 and 2 type of regions, but less so for Group 3, which makes unrelated diversification worth exploring.

To fully understand how the process of unrelated diversification unfolds in the context of a resource-based region, the case of the region of Boyacá, in group 3, is investigated in the next chapter.

4.4.1 Regional diversification driven by the principles of sustainability

The realisation of the opportunities described in Table 4.4 depends on the adoption of principles of sustainable development and the active role of policy, that can produce the favourable conditions for new initiatives to emerge, as discussed in the previous section. The need for this is twofold. To overcome constraining factors such as the lack of capabilities, lock-in around extractive industries and to generate the incentives for the rise of alternatives in both, sustainable industries and ways to fulfil societal needs. Secondly, to enable the participation of a broader set of actors that can bring in the resources, and networks necessary to enact change. In recent analysis of alternative pathways of diversification in the EEG literature, the role of agency and policy have been highlighted in fostering and nurturing diversification initiatives (Dawley 2014, Montresor & Quatraro 2020, Trippl et al. 2020, Tödtling et al. 2020, Santoalha & Boschma 2021), and providing a direction to the regional policy towards sustainable pathways (Coenen, Hansen & Rekers 2015, Boschma et al. 2017). Likewise, institutional entrepreneurs are deemed pivotal in processes of institutional change, as they can introduce new initiatives around sustainability and facilitate the institutional adjustments and changes required for these initiatives to flourish.

To what extent a new direction of policy towards sustainability can be leveraged by related or unrelated diversification, for group 1 and 3 requires further research. Building on the emerging literature on green diversification and path development (Balland et al. 2019, Asheim 2019, Trippl et al. 2020) and geography of transitions (Hess 2007, Farla et al. 2012, de Haan & Rotmans 2018) discussed in chapter 2 and the results of the descriptive analysis presented earlier in this chapter, some actors and policy roles that may facilitate the adoption of principles of sustainability in regional diversification processes are explored in Table 4.5. These themes as well as the opportunities that related and unrelated deversification could offer to groups 1 and 2 constitute topics for a future research agenda.

Table 4.5 explores some of the actors that can envisage and undertake actions

towards sustainable development in each group. Some questions are around the type of roles these actors could take? What could be their level of involvement? Would this change over time to follow patterns of distributed agency, like described in the literature review chapter? Which type of actors would be more likely to initiate change? How different actors engage with policy? This constitute a very relevant research agenda for Global South countries.

Table 4.5 identifies some of the policy actions that can enable the adoption of principles of sustainable development. As mentioned earlier, policy is crucial to provide a new direction and to help overcome constraining factors (Boschma et al. 2017). The significance of this for group 3 is that policy and the agency of regional actors can help overcome lock-in and create opportunities for new knowledge generation and learning that could eventually lead to a more sustainable pathways of diversification. Thus, in the context of Colombia, unrelated diversification could provide a window of opportunity to re-think how diversification strategies can help address the sustainability challenges. The next chapter advances unrelated diversification in resource-based regions, with the case study of Boyacá, a group 3 region seeking to create alternative pathways of development away from mining.

Concept	Group 1	Group 2	Group 3
Relevant actors to enact change	Civil society and sectoral associations, Activists, social movements, Activists-researchers, Entrepreneurs, start-ups, Peri-urban movements NGOs, Industry opposition movements, MNC, SMEs, Start-ups, Big companies,	Civil society and social movements, Local producers associations, Small farmers associations, International intermediaries, Communities, NGOs, Activists-researchers, International NGOs, SMEs, Start-ups, MNC	Civil society and social movements, Communities, NGOs Producers associations, Activists-researchers, Institutional entrepreneurs, International intermediaries Activists-researchers, International NGOs, Start-ups, SMEs
Role of policy	Provide a new direction for STI policy. New priority areas of private-public investment. New regulations and standards promoting the adoption of more sustainable practices and establishing higher standards to achieve environment and social sustainability. Incentives to adopt sustainable practices and for sustainable industries to emerge and consolidate.	New direction to STI policy New public investments aimed at environmental sustainability. Incentives to adopt sustainable practices and for sustainable industries to emerge and consolidate.	New direction for STI policy. New regulations aimed at social and environmental sustainability. New regulations and standards. New public investments (procurement). Incentives for sustainable industries to emerge and consolidate.

Table 4.5: Incorporating sustainability principles into regional diversification

4.5 Conclusions

This chapter has investigated differentiated patterns of diversification in Colombia. The quantitative analysis assessed the technological relatedness of existing regional industrial bases represented in the regional exports and employment from 2008-2017 and their changes over this period. The analysis showed how these patterns are the result of localised industrial dynamics and the particular conditions under which related diversification has taken place, which has helped reproduce these regional trajectories over time. As a result, a typology of regions was produced to capture these patterns in three groups. The typology depicts profound differences in the levels of diversification, and related variety and the limitations faced by resource-based regions to enable and benefit from related diversification. The argument is made that these patterns of industrial dynamics are likely to continue to reproduce unsustainable processes of technological change and economic evolution, particularly in group 2 and 3 regions.

Following an emerging literature in this area, an alternative could be to begin to think about sustainable development in terms of "unrelated diversification". The question is how this may exist in Colombia? This chapter has argued that the adoption of sustainable development principles will be determined to a greater extent by the role of policy and the inclusion of a broader set of actors beyond firms and their agency. Thus, sustainable development demands a broader understanding of regional diversification in which learning dynamics are guided by more desirable pathways of development. The role of related and unrelated variety responds to the local conditions and the extent to which they allow the adoption of sustainable development principles. This chapter has contributed to this debate and will take further the analysis of unrelated diversification in a resource-based region in the next chapter.

Chapter 5

Creating sustainable pathways in resource dependent regions: the role of agency and bricolage in unrelated diversification

Introduction

The previous chapter highlighted the need for a broader understanding of the process by which economic diversification takes place where significant regional disparities exist and there is strong dependence on extractive industries. The earlier analysis also suggested that a large number of regions in Colombia do not follow technological relatedness as the driver of diversification. By contrast, some regions hitherto dominated by extractive industries may follow a different route that is influenced by social pressure to divest away from mining and towards more sustainable economic activities. Therefore, unrelated diversification may be more relevant in these regions because it provides a fuller explanation of path creation through a process entailing the political and social aspects of change, that is at times overlooked by the EEG literature. This is the proposition that will be investigated in this chapter.

In the following pages, a detailed investigation takes place that seeks to understand in more depth the question of industrial diversification in resource-dependent regions (mining) seeking sustainable development pathways.

The analysis examines to what extent diversification in these regions can be seen as a socially constructed process in which mining industries and alternatives represent contested pathways. It also asks whether the new sustainable pathways can be seen as an example of unrelated diversification and if so, how agency is built? In the absence of related knowledge, another question revolves around how resources are mobilised to facilitate the emergence of sustainable pathways. To respond to these questions, a qualitative analysis of the case of the Boyacá is undertaken.

This chapter will argue that the drivers of change stem in part from the social and environmental effects of the mining industry that create tensions and conflict. These tensions emerge from the alignment between geo-political pressures from the Global North, in the form of continuous energy demand to fulfil the consumption patterns (Geels 2004, Farla et al. 2012, Bridge et al. 2013, Chilvers & Longhurst 2016), and growth strategies in resource-based countries underpinned by the extensive exploitation of fossil fuels to meet global north market demands (Mitchell 2011, Ruiz, de Herrera & Niño 2018). This alignment fosters growth of for example extractive industries in resource-rich countries, as experienced in Colombia in the last decade, due to favourable business conditions for these activities, including the ease of environmental regulations (Garay 2013). As a result, resource-dependent countries experience localised environmental and social effects of this unprecedented demand for energy (Mitchell 2011). The analysis focuses on how these tensions trigger pressures and agency for industrial change and how sectoral dynamics between the extractive industry, civil society pressures and new R&D policy create directionalities away from mining and towards new development trajectories. The social component of unrelated diversification makes it a more complex process and opens up a window to integrate these arguments into the EEG literature, which has engaged only to a limited extent with broader drivers of diversification (Hassink et al. 2019) beyond economic growth and innovation.

Through attention to place-based social actors, such as social movements, and their response to those dynamics, this chapter enquires into how sustainable

technology-unrelated pathways emerge in the region of Boyacá. To this end, the chapter examines how "constraining factors" are overcome, sustainable alternatives enabled and the conditions under which these alternatives can become a source of diversification. The analysis utilises the concept of bricolage (Boschma et al. 2017, Feyereisen et al. 2017, Garud & Karnøe 2003) to study the influence of distributed agency on resource mobilisation and path creation. The concept of alignment is used to examine areas in which the alternatives envisaged by social movements and those supported by the regional policy Boyacá BIO converge and complement to the formation of a new industry around biodiversity. In summary, the case investigates how the wider variety of actors considered can create shared collective spaces that help articulate and materialise alternative development pathways.

The chapter is organised into six sections. The geographical and place-based elements of Boyacá which underpin new drivers of industrial change are provided in section one. Section two summarises the main methodological elements of the case study. The underlying research methodology used for the case analysis is presented in Chapter 3. Section three discusses the drivers of unrelated diversification in constrained regions. Section four analyses how bricolage enables alternative pathways and their potential for unrelated diversification. The need for alignment in unfolding unrelated diversification is addressed in Section 5 and, finally, conclusions and further research opportunities are drawn in section 6.

5.1 Geographical and place-based elements of Boyacá underpinning industrial change

This section draws on place-based elements, relational dynamics and space features of Boyacá, informed by the literatures discussed in chapter 2, to facilitate the understanding of the drivers of unrelated diversification and highlight how the process is embedded in the territory. Boyacá is a biodiverse-rich region in the Eastern ranges of Colombian Andes with a unique topographical conditions and a wide variety of climates (Gómez & Antosová 2015, Arias-Gómez & Antosová 2018). Its heterogeneous geography and administrative diversity, given by its 123

municipalities, means that a place-based analysis is relevant to understand the process of diversification. Its privileged geographical condition has marked the region as one of the country's five most important agricultural producers. In 2019, the agricultural sector contributed around 11% to the regional GDP, compared to 7.3% generated by mining (MINCIT 2020). Mining constitutes 98.7% of the region's exports due to important hubs of oil, coal, construction minerals and emeralds scattered over the territory. The region has a long and complex history of a dual economy, in which, increasingly, sustainable development is expressed in social movements organised by the community against mining and towards more socially and ecologically sustainable sectors. This affects discussions of industry, space, and the relational dynamics these elements create with policy.

Smallholdings dominate the region's land tenure system, favouring and maintaining a peasant culture. This is particularly organised around small towns, where the lack of infrastructure and long distances to urban centres make agricultural output mainly available to local consumers (Arias-Gómez & Antosová 2018). Boyacá's rural economy is extensive in labour and characterised by a low adoption of technology. According to the National Agriculture Census in 2014, only 4.2% of the agriculture production units (UPA) have machinery to support their activities (Gómez & Antosová 2015). Community-run aqueducts have been one of the primary mechanisms by which communities have built strong networks and created projects to develop and protect their local natural resources (Llano-Arias 2015).

As a consequence, local inhabitants have developed a strong attachment to natural resources. For instance, biodiversity, bodies of water and, particularly, páramos have become meaningful resources, shaping the community's expectations and actions towards sustainable sources of economic growth. Páramos are "the headwater wetlands from which 70% of Colombia's water supply originates" (McIntyre, Angarita, Fernandez, Camacho, Pearse, Huguet, Restrepo Baena & Ossa-Moreno 2018, pg.4). Figure 5.1 and Figure 5.2 depict the distribution of páramos in the regional geography. Boyacá possesses 15% of the world's páramo ecosystems, whose importance lies in presence of a vast number of endemic species

(around 60% of the estimated 5,000 species are unique to these ecosystems), alongside their water production and regulation capacities (Gardens 2020, Buytaert, Célleri, De Bièvre, Cisneros, Wyseure, Deckers & Hofstede 2006). Besides páramos, a wide variety of resources and topographies includes oil reserves in the west (Puerto Boyacá - Boyacá Port) and one of the most valuables ecosystems in Colombia - Serranía de las Quinchas, a humid tropical forest characteristic of the Magdalena River (Ovalle & Arroyo 2019). The Eastern range of the Andes covers most of the region, forming an interconnected system of high-mountain springs of water, lakes and wetlands that provide most of the water supply to Eastern regions of the country and the South American continent, for example, the lowlands and arid regions in Venezuela (Buytaert et al. 2006).

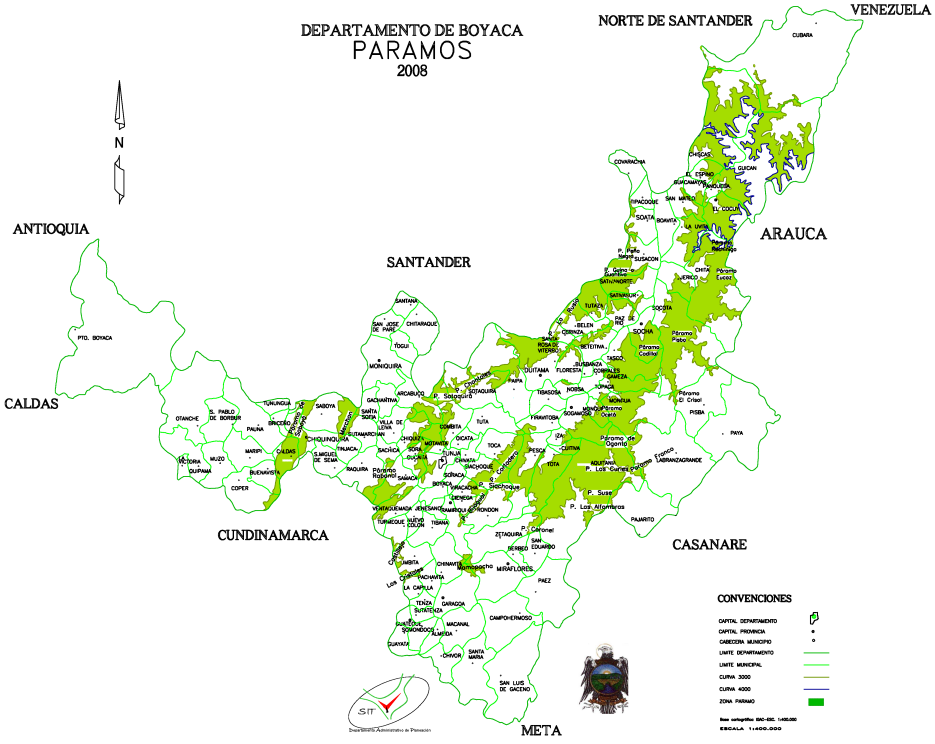

Figure 5.1: Páramos ecosystems in Boyacá

This existence of a strong export-led mining sector in a highly biodiverse region has given rise to two contested paths of economic growth, and has been the basis for the emergence of movements which oppose mining activities and wish to protect water sources (Anaya S. & Echeverri 2014) and consolidate demands for regional sustainable growth (Departamento Administrativo de Planeación de

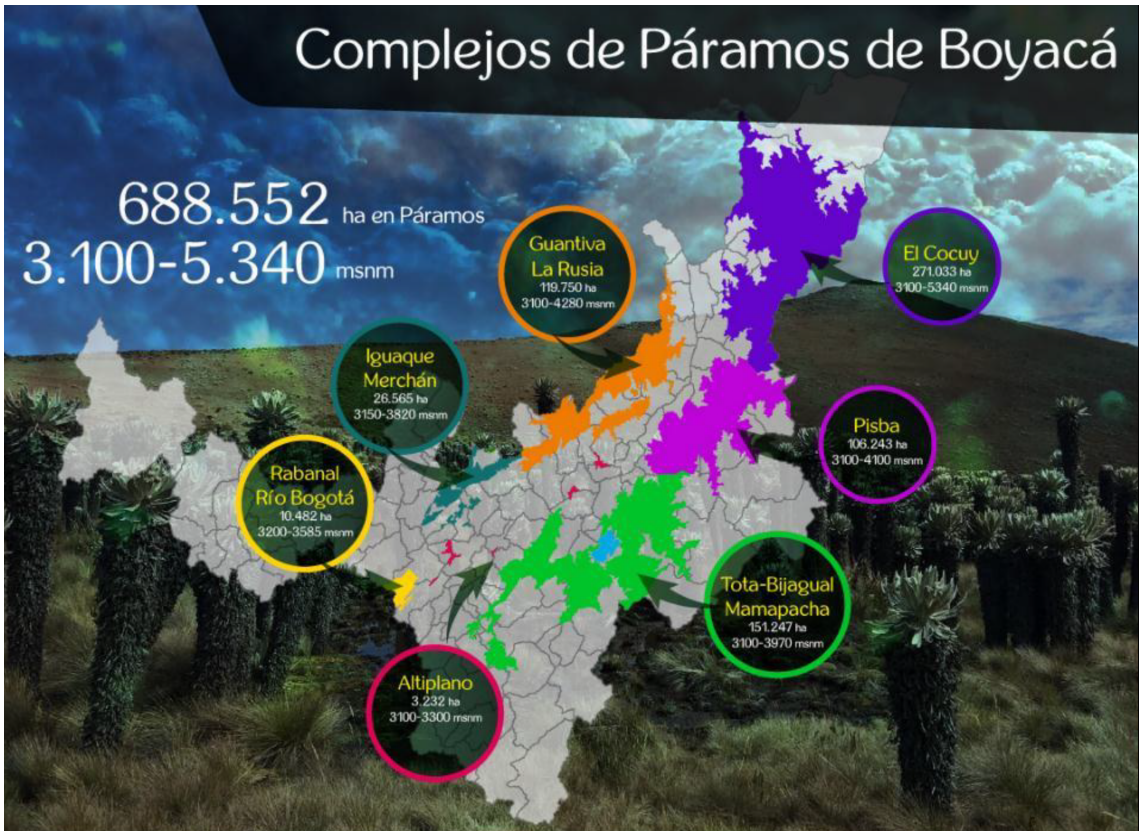

Figure 5.2: Páramos in Boyacá

Boyacá 2016). These responses from local communities make Boyacá's case special because they illustrate how the new forces of diversification partly come from the relational dynamics between civil society movements and the extractive industries.

An attempt to acknowledge non-technological drivers of diversification is made in the literature of EEG through the concept of unrelated diversification (Boschma et al. 2017). This concept provides an opportunity to enrich the understanding of regional diversification in a resource-based context and to resolve two main shortcomings of seeing industrial change only through technological drivers. First, it acknowledges the negative social and environmental effects that certain industries may have vis a vis the economic benefits. Secondly, by acknowledging not-technological drivers of industrial change, the alternatives for diversification for resource-based regions increase. A broader range of alternatives would also constitute new opportunities to break path dependencies with the unsustainable industry.

At a national level, Colombia has prioritised growth and downplayed the effects of

mining over the last two decades (Garay 2013, Ruiz et al. 2018). Thus, diversification efforts have produced mixed results, with only a few regions able to benefit from the localised dynamics of innovation associated with a strong industrial base. This leaves resource-based regions facing the pollution of water, deforestation, health problems and social conflicts derived from extractive industries (Garay 2013, Ruiz et al. 2018). These circumstances have consolidated a regional response to the environmental damage and social effects caused by mining industries in the territory. Communities have organised themselves in social movements, collectives and citizen-led initiatives to challenge the mining sector and to put a halt to mining projects that had been granted exploitation rights in strategic nature reserves and ecosystems. Along with these demands, the regional government formulated a new science, technology and innovation policy to respond to this pressure and to provide a new direction for research and innovation away from mining to focus on biodiversity and sustainable development (Departamento Administrativo de Planeación de Boyacá 2016). The interplay of this two factors has made Boyacá a noteworthy case of analysis, as argued in chapter 3. This chapter draws on interviews and secondary materials to study how these forces of unrelated diversification emerged in the case of Boyacá.

5.2 Method

A mixed method is used to research the process of regional diversification to assess related and unrelated technological development pathways. First, the thesis draws on the quantitative analysis of regional relatedness undertaken in Chapter 4 to determine the extent to which industrial variety and their technological proximity (relatedness) explain regional diversification in terms of growth and new economic pathways. Here three main groups of regions were distinguished, with significant differences in their relatedness levels. Those with the most varied and developed economic structures show high levels of relatedness and better economic performance, followed by the mid-size regions with similar performance although lower levels of technological relatedness. By contrast, lagged regions and those reliant on extractive industries did not display greater variety, neither technological relatedness. I therefore explore whether concepts of unrelated variety

provide an alternative diversification pathway for those regions. A qualitative method is adopted to investigate unrelated diversification to explore the type of actors, driving forces and process dynamics underpinning the emergence of sustainable development pathways in resource-dependent regions.

The case of Boyacá looks at three elements to understand the process of unrelated diversification, as described in Table 5.1. First, it addresses the drivers of change using the concepts of vested interests, sectoral dynamics and industrial oppositions movements to explore the difficulties of change, and how sustainability demands and social collective action are formed and triggered.

The concept of bricolage is used to understand how social movements envisage and implement alternatives around sustainability. Three main components of bricolage are explored: distributed agency, resource mobilisation and path creation. Policy is approached as another distributed force contributing to the process of unrelated diversification, as it provides potential for a new directionality to the R&D agenda, dominated hitherto by the extractive industry. Finally, the concept of alignment is introduced to examine the extent to which alternative paths can contribute to the consolidation of a new industry. The analysis draws on place-based elements, relational dynamics, and space features to highlight how unrelated diversification is embedded in the territory, and facilitate the understanding of the drivers of unrelated diversification.

The unit of analysis is the region, where an account of the situated process takes place and where place-based actors build distributed agency and undertake actions to mobilise resources and create unrelated pathways through collective action. The empirical evidence was obtained through 12 semi-structured interviews in the field, undertaken in 2018, with leaders of social movements, researchers, policy makers and civil servants. The primary information regarding the results of public calls was obtained directly from the Manager of Boyacá BIO, the new regional STI policy. The list of interviewees is presented in Table 3.3. A detailed description of the methodological approach is developed in Chapter 3.

Table 5.1: Variables of analysis of the case study

Category of analysis	Concepts and definitions	Literature
Drivers of change	*Vested interests*: the power embedded in socio-technical regimes of extractive industries that hampers diversification. *Sectoral dynamics triggering social organisation*: the interplay between the civil society and the mining industry *Social movements (industry opposition movements)*: forms of situated collective organisation through social movements, collectives, civil society organisations	(Geels 2004); (Martinez-Alier 2014) (Boschma et al. 2017) (Mitchell 2011); (Bridge et al. 2013) (Hess 2007) (Sine & Lee 2009)
Bricolage	A way of action adopted by actors to create an idiosyncratic resource environment from a unique recombination of their existing elements and resources to overcome the institutional, economic and cultural limitations - Make do with what is at hand Distributed agency Resource mobilisation Path creation Policy	(Baker & Nelson 2005, Garud & Karnøe 2003) (Boschma et al. 2017) (Suitner & Ecker 2020) (Carvalho & Vale 2018) (Feyereisen et al. 2017)
Alignment	The process by which different alternatives consolidate in stronger routes of unrelated diversification. Four domains are studied: *knowledge generation* *market formation* *legitimacy* *financial investment*	(Boschma et al. 2017) (Binz et al. 2016)

5.3 Drivers of unrelated diversification

This section elaborates on the drivers of unrelated diversification stemming from the sectoral dynamics between mining industry, civil society and policy. These dynamics are characterised by tension and contestation and are better understood through the lens of transitions theory, which allows one to re-frame "constraining

factors", in the form of vested interests, as triggers of social organisation for new STI policy directionality. Constraining factors have hitherto been framed in the discussion of unrelated diversification as the elements that hamper the consolidation of a new pathway, and which can be overcome by institutional entrepreneurs and policy (Steen 2016, Boschma et al. 2017). The reframing of constraining factors acknowledges the role of social actors in the process of enacting change. Social actors are able to build agency to demand new routes towards sustainable development and capacity to materialise alternatives around the new directionality. New forms of knowledge generation and capacity building underpin agency formation and are aided the bricolage action of social actors and their networks. This section zooms in on the conditions that trigger social organisation and creating calls for new directions of STI policy.

5.3.1 Reframing vested interests in mining regions

The first element of analysis in the drivers of diversification is "vested interests", as shown in Table 5.1. The concept of vested interests relates to the power of mining industries to control natural resources, influence policy and regulation to favour extraction, downplay the negative effects of mining in ecosystems (Martinez-Alier 2014, Smith 2012, Chilvers & Longhurst 2016) and shape R&D agendas (Hess 2007). The lens of socio-technical regimes from the transitions literature helps explain how vested interests create a strong alignment between the income and the foreign investment the extractive industry brings to the regions; the long-term control of natural resources through licences; and the limited influence that regions have in this geo-political order, where multinationals own 75% of global commerce (Ruiz et al. 2018). This alignment is expressed in the narrative of intensive exploitation of natural resources as the main source of economic growth in resource-dependent regions. In the Global North, it reflects in the acute consumption patterns enabled by the energy obtained from these mining resources (Ruiz et al. 2018).

In Colombia, growth policy has been driven by mining. During the last 20 years, the Colombian government has deployed a strong international campaign to attract foreign investment to mining projects. It has increased the area of mining

titles between 2002-2013 from 2.8 million acres to 20 million acres. Growth was particularly strong after the launch of the so-called "mining locomotive" in 2010 by President Santos (Departamento Nacional de Planeación 2011, Report 2011). Colombia possesses oil, coal, ore, emeralds, nickel, copper and construction materials, which places it in the third position after Brazil and Perú in Latin American according to its mining resources (Report 2011, McIntyre et al. 2018). As part of the strategy to make business more appealing to foreign investors, a new legislation was introduced to facilitate due diligence of licences and ease environmental and social regulations (Garay 2013, Ruiz et al. 2018). As a result, a new institutional framework was set up, with a National Environmental Licensing Authority (ANLA) and the National Mining Agency (Decree No. 4134 of 2011 and Decree No. 2041 of 2014) as independent institutions from the mining ministry. Environmental licenses were introduced and regulated by Law No. 99 of 1993, then complemented with the Decree No. 1076 of 2015, which set up the Unique Regulatory Decree for the Environment and Sustainable Development of the Sector. After these adjustments, environmental licences became a requirement for mining projects. Environmental impact assessments became an integral part of the license and a critical step in the due diligence process. These assessments are aimed to evaluate and discuss with local communities the environmental, social and economic direct and indirect effects of mining projects (Garay 2013, McIntyre et al. 2018).

Under this new selection environment, in other words, a more relaxed regulatory environmental and technical requirements, mining companies have understood the environmental impact assessments as a bureaucratic procedure that does not require scientific and technological research (Ruiz et al. 2018, Garay 2013). Despite this advantageous business environment, the mining firms' vested interests arise as attempts to co-opt the Corporaciones Autonómas Regionales (CAR) - the regional autonomous corporations, which are in charge of licensing processes for all mining resources (except oil); and the local community leaders, who are offered contracts and income opportunities to reduce their actions against mining projects and weaken social bonds with their communities. These actions are well examined in the Comptroller General of Colombia's 2013 report, in which corruption is also

highlighted as a common issue in Colombia's mining industry (Garay 2013). Moreover, "deforestation inside legal mine concessions contributed to about 3.3% of the Colombian deforestation extent from 2001 to 2018" (González-González, Clerici & Quesada 2021, p. 4) with a steep increase in the deforestation associated to legal miners from approximately 1% in 2006 to 5%-6% in 2015 approximately and 7%-10% in 2017 (González-González et al. 2021). Vicente, Martin, James, Birss, Lefebvre & Bauer (2011, p. 6) stated that "80% of the human rights violations and violations of International Humanitarian Law that have occurred in Colombia in the last 10 years were committed in these [energy-producing] places [municipalities]. Ruiz et al. (2018) researched the relationship between forced population displacement and the increase of multinational mining activities in Colombia between 1997 and 2011. The author found similar conclusions to Vicente et al. (2011), and points out that multinational firms have established alliances with paramilitary forces to gain or maintain control of territories with high mining potential. These paramilitary groups use violence as a mechanism to threaten communities and population who oppose to mining. Over time, communities have recognised the effects of mining and reflected on its "developmentalist" narrative, based on the experience of other regions such as La Guajira, where severe poverty, deep social conflicts and resource depletion resulted from more than 30 years of mining exploitation. Communities in affected regions have requested to revoke licences that would threaten collective rights and destroying the environment. In most cases the Tribunals and the Supreme Court have supported communities demands and have revoked licences previously granted by the state (Balch 2013, Garay 2013). As a summary, despite extractive industries are embedded in global value chains, they are place-specific, and so are the tensions it creates. These sectoral dynamics created by the mining industry and its interaction with the surrounding communities need further consideration.

Alongside this intricated sectoral regime is the regional STI system. Before 2016, Boyacá's STI efforts had been focused around mining, using the matching grants funding scheme of Colciencias (now Minciencias) and Royalties Fund to prioritise investment in capabilities and facilities to fulfil mining companies' requirements, as illustrated in Table 5.2. Research in biodiversity, protection and conservation

lagged behind. Despite the regional abundance of natural resources, the share of R&D in biodiversity and related areas in the total R&D is worth one-fifth of the funding for mining[1]. The UPTC (regional university) extension and enterprise services have been dominated by the strong linkages between the mining school and mining companies' interests in funding R&D projects, which leads to a continuous income for the University, enabling it to access better laboratories and equipment (*Interviewee G2*). The biology research group at UPTC carried out a six-year programme funded by the state-owned oil company Ecopetrol: "That is our main source of income, projects with external organisations. Our main allies are Ecopetrol, Colciencias, CAR and now some universities from México, Kansas and the botanic garden of New York" (Interviewee R2). In this context, R&D projects seek to compensate the environmental effects of oil extraction and transportation in surrounding areas, such as the Magdalena Medio, identifying species at risk and supporting communities in adopting more sustainable agriculture forms. Nevertheless, as Interviewee R2 states: *"Compensations are all very different, and it is difficult to assess the extent to which it repair the damage, and even more difficult when it comes to the effects on the community".* The above evidences how and why the regional R&D agenda is lock-in around the mining industry.

Table 5.2: R&D funding of projects per sector 2008-2012. Figures in Millions Colombian Pesos (COP) 2012

Sector		2008	2009	2010	2011	2012	Total
Health	No. of projects	0	0	0	0	0	0
	Funded by Colciencias	0	0	0	0	0	0
	Firm funding	0	0	0	0	0	0
	Total	0	0	0	0	0	0
Industry	No. of projects	0	0	1	0	2	3
	Funded by Colciencias	0	0	339	0	80	419
	Firm funding	0	0	6	0	37	43
	Total	0	0	345	0	117	463
ICT	No. of projects	0	0	0	0	0	0
	Funded by Colciencias	0	0	0	0	0	0

[1]229 Million COP represents 45,850 GBP (Exchange rate 1 GBP=5,000COP)

Table 5.2: (. . . continued from previous page)

Sector		2008	2009	2010	2011	2012	Total
	Firm funding	0	0	0	0	0	0
	Total	0	0	0	0	0	0
Agricultural	No. of projects	0	0	0	0	0	0
	Funded by Colciencias	0	0	0	0	0	0
	Firm funding	0	0	0	0	0	0
	Total	0	0	0	0	0	0
Energy & mining	No. of projects	2	0	2	2	0	6
	Funded by Colciencias	306	0	442	205	0	954
	Firm funding	691	0	562	176	0	1,419
	Total	998	0	1,004	381	0	2,373
Basic Sciences	No. of projects	0	2	0	0	0	2
	Funded by Colciencias	0	1,217	0	0	0	1,217
	Firm funding	0	423	0	0	0	423
	Total	0	1,640	0	0	0	1,640
Social and human sciences	No. of projects	0	0	0	2	0	2
	Funded by Colciencias	0	0	0	321	0	321
	Firm funding	0	0	0	216	0	216
	Total	0	0	0	537	0	537
Education	No. of projects	1	0	0	0	0	1
	Funded by Colciencias	163	0	0	0	0	163
	Firm funding	154	0	0	0	0	154
	Total	317	0	0	0	0	317
Biotechnology	No. of projects	0	0	0	0	0	0
	Funded by Colciencias	0	0	0	0	0	0
	Firm funding	0	0	0	0	0	0
	Total	0	0	0	0	0	0
Environment, biodiversity and habitat	No. of projects	0	0	0	0	1	1
	Funded by Colciencias	0	0	0	0	229	229
	Firm funding	0	0	0	0	104	104
	Total	0	0	0	0	333	333
Sea and hydrobiological resources	No. of projects	0	0	0	0	0	0
	Funded by Colciencias	0	0	0	0	0	0
	Firm funding	0	0	0	0	0	0
	Total	0	0	0	0	0	0
Defence	No. of projects	0	0	0	0	0	0

Table 5.2: (. . . continued from previous page)

Sector		2008	2009	2010	2011	2012	Total
	Funded by Colciencias	0	0	0	0	0	0
	Firm funding	0	0	0	0	0	0
	Total	0	0	0	0	0	0
Total	No. of projects	3	2	3	4	3	15
	Funded by Colciencias	470	1,2170	782	526	309	3,304
	Firm funding	846	423	568	392	141	2,370
	Total	1,315	1,640	1,349	918	450	5,674

Vested interests steer research agendas towards optimisation of mining over conservation and restoration. In middle-size regions like Boyacá, where the university's research income to undertake research relies on matching grants and consultancy services for the mining industry, lock-in and path dependencies become difficult to overcome.

Under such conditions, the process of diversification is crafted by social actors, who do not necessarily possess market power individually but can build political agency through demands and mobilisation for social change when dealing with the constraining factors explained in this section.

5.3.2 Sectoral dynamics triggering social organisation

The sectoral dynamics of the mining industry described above place a high burden on communities. These effects trigger social organisation and action (Mitchell 2011, Bridge et al. 2013, Garay 2013, Temper et al. 2018) that is rooted in communities of activists, social movements and civil society (Hess 2007, Smith 2012, Chilvers & Longhurst 2016) and is framed in this thesis under the concept of industrial opposition movements. In contrast to geographically distributed industrial activities, extractive industries are localised, and so are the disputes between mining firms and the communities surrounding the natural resources. These tensions enable solidarity bonds within communities that make it possible

to articulate "successful collective demands" (Mitchell 2011, pg. 18) and political agency that eventually gives back the control over the natural resources to the local communities. These expressions and demands for social change are place-based and sector-specific, as the call for the alternative use of natural resources involves the control and decision over the sectors' materiality. For example, to protect biodiversity, the industrial activities permitted are redefined and bounded by the care of environment. These social demands, similarly to markets, are forces that can define the use of mining resources.

The above argument provides essential context to the rising debate about sustainable regional diversification and, even more relevant, in resource-based countries in the southern context. These tensions are relevant to the understanding of regional diversification because they create room for change and policy directionality, something that is not clearly articulated in the EEG literature but requires engaging with political economy literature to fully capture and explain agency formation and collective action. These two aspects are crucial in expanding the understanding of unrelated diversification.

The demands for change in Boyacá form from the action of civil society and social movements to reveal mining firms' practices and narratives around the effects of these industrial activities in their territory. For example, the collectives of Sugamuxi and Gachantivá unveiled the impacts of mining projects in the adjacent ecosystems. In this process, counter-expertise is fundamental. Counter-expertise has been used in different ways by the science, technology and society literature (STI). Arancibia & Motta (2019, p. 281) define it as: "efforts to redress environmental injustice that rely on expertise, broadly construed, to contest regulatory decisions that are based on scientific knowledge". Counter-expertise was leveraged through the collectives' networks and brought into the local community to develop arguments to support the community's demands and build shared visions on how to address them (*Interviewee S3*, *Interviewee S1*). Counter-expertise therefore, has implications in the understanding of knowledge generation and more broadly participatory methods, something that has been pointed out as important on industry oppositions movements (Hess 2007), and

science and democracy (Smith 2012, Chilvers & Longhurst 2016). Social movements also utilise legal mechanisms to enforce law and protect the threatened ecosystems (Ramirez, Garcia Estevez & Romero Goyeneche 2020) or to influence policy or regulations (Smith 2012, Arancibia & Motta 2019). In doing so, social movements in Boyacá nurtured expectations and maintained pressure on the need for change until alternatives started to emerge and consolidate.

According to databases of news articles from the period between 1972 and 2018 by the Centro de Investigación y Educación Popular (CINEP, for the centre of research and popular education) (CINEP 2018), this research found that from the total events logged by CINEP, 90% of different "social expressions" - defined as protests, demonstrations and riots- in Boyacá were related to protecting natural resources, environmentalism and water protection in areas of Páramo. These protests have been organised mainly by peasants, communities and students in places where mining resources are localised. Four social movements and collectives stand out for their systematic actions to protect the territory and put forward alternative views of regional development in Boyacá: Colectivo para la protección de la Provincia de Sugamuxi (Collective for the protection of Sugamuxi Province); Colectivo Colombia Free of Fracking; Movimiento Cívico por el Agua y por la Vida de Gachantiva (civic movement for the defence of water and life in Gachantiva); and Colectivo del Alto Ricaurte (Alto Ricaurte collective). Three of them represent 26 municipalities of Boyacá (the Sugamuxy collective, the Gachantivá movement and Alto Ricaurte Collective). The Alto Ricaurte collective was formed in 2006 and has since inspired, supported and trained the other groups, according to *Interviewee S1, S2, S3, S4. "We had the support from other social movements, for example, Colectivo del Alto Ricaurte trained us and we trained Colectivo de Tasco" Interviewee S3.* Each social movement exhibits specific dynamics and organisational forms and activities, but they share forms of action and visions. The oldest, Colectivo del Alto Ricaurte has been the pioneer and supporter of others such as Colectivo de la Provincia de Sugamuxi and Movimiento Cívico de Gachantiva.

Relational elements of space, such as traditions, the community's linkages to

natural resources, and inhabitants' visions of sustainable development, underpin the emergence of these social movements. Sugamuxi collective created a comic character called Getulio Montana Laguna as a cultural expression of the relationship between peasants and their strong attachment to the territory (Sánchez, Acosta, Mahecha, Púa, Ortiz, Quiroga, Simbaqueba, Bermúdez, Ruiz, Ballén et al. 2019, Poma 2020). Boyacá's characteristic landscape is reflected in the character's surnames: the Andean ranges, surrounded by lakes (laguna) and mountains (montaña), as symbols of the rural livelihoods. Getulio wears a poncho (ruana), an idiosyncratic cloth of Boyacá, with a picture of Boyacá's landscape, drawing attention to the risks of multinational companies entering the territory to exploit its resources, and the need for the continuous defence of the territory and its heritage. The relevance of this cultural expression lies in its ability to help translate technical knowledge of mining projects' effects into informal language that anyone could easily understand. This is a critical concern when communicating with the non-literate population in rural areas in Boyacá. Thus, the collective managed to teach the community about mining risks and the need to protect the territory against extractive industries and to strengthen solidarity bonds and social organisation. Similarly, the Gachantiva movement organised a "carnival" to oppose mining and to call for the protection of water and life.

In both cases, these cultural expressions became a means to attract media attention, catapulting the collectives into the public spotlight. *"We knew we had to reach the media; otherwise, our voice would not have an impact, and so we did. We adopted some de facto strategies such as blocking main roads to call for media attention which quickly brought regional and national media press to the demonstrations. Since then, the local media have been an ally to the movement as they publish news, invitations to demonstrations and help spread the word when needed."* (Interviewee S3). The character of Getulio became an open tool used and promoted by CINEP to share the experience of communities developing tools to promote identity processes and protection of territories in Latin America (CINEP 2018). The detail of the geographical and relational factors underpinning the emergence of social movements is summarised in Table 5.3 and Figure 5.1.

Collective	Natural resources	Traditions and cultural expression
Sugamuxi Collective	Lake Tota and Paramo de Pisba	Getulio Montana Laguna and Betulia
Colombia Free of Fracking	Serranía Las Quinchas	A group of about 40 women group defending the territory from oil extraction, extensive livestock and deforestation
Gachantiva movement	River Suarez and its tributaries	Carnival for the defence of water and life
Alto Ricaurte Collective	Colonial town with archaeological and paleontology richness (biofacts and cultural landscapes)	Villa de Leyva is one Colombia's most visited places due to its beautiful landscapes, cultural activities and colonial architecture. This area is on a tentative list of properties under consideration for World Heritage status by UNESCO [2].

Table 5.3: Place-based social movements in Boyacá

5.3.3 Elaborating successful collectives demands for change: industry opposition movements

Attempts made by the literature of transitions to introduce the role of civil society in transitions remain timid and underdeveloped (Farla et al. 2012, Chilvers & Longhurst 2016). However, authors such as Hess offers a clearer view and points out the importance of civil society, especially when "innovation is linked to community control and social justice within industries" (Hess 2007, p. 85). In Boyacá, communities and members of these four social movements have learned to recognise the mining firms' strategies, deal with their practices, assess the environmental effects of mining, use legal tools to revoke environmental licences, applications and modifications to titles, and create a network of observers to examine the process of awarding of mining licences, as described in Table 5.4. Revealing firms' narratives has been a critical process undertaken by place-based social movements. This involves knowledge generation and learning, collective action and networking, and can result in successfully halting mining projects within their localities. These groups resemble what Hess (2007) calls "industry opposition movements". Through opposition, social movements build agency and create substantial demands for local change.

Table 5.4: Examples of how social movements reveal and address mining firms' strategies

Collectives	Narratives and actions
Sugamuxi collective	"We started to analyse the Environmental Impact Assessment document submitted by the company (Mauren & Proom) as a requirement to obtain the licence. We realised the plan was out of context. The ecosystems described by the company did not correspond with the characteristics of the place. For example, only six water springs were recognised in six municipalities where the licence was granted. This number can be easily found in one farm only. The plan also talked about rice crops, yet there is no possibility to grow rice because of the climate and land conditions" (Interviewee S3)
Alto Ricaurte collective	As sociologists, "we have experience and know people who can help figure out the risks of certain economic activities in the territory. We have developed a methodology to deal with multinational companies (MNC) to protect communities and their territories from firms' strategies". (Interviewee S4)
Colombia Free of Fracking	"MNC ally with paramilitary groups to seek security and protection within the territory. Companies offer community leaders and political figures contracts to provide transport and private security to their employees. The criminalisation of social leaders opposing mining is a common and well-documented practice." "MNC use technical terms when sharing environment impact assessment documents and mitigation plans with communities. These firms mock communities and confuse them. Their purpose is to thick the box of "community consultation", without actually caring about communities and their views on their projects."
Gachantiva movement	"We asked the comptroller's office to train us as environmental observers together with Alto Ricaurte collective so that we could develop the skills to have a pair dialogue with mining firms." (Interviewee S1)

When communities do not possess the knowledge required to confront multinational companies (MNC), they use what is at hand to identify and assess threats and to understand technical documents associated with licences and modifications already granted. Interviewee S3 argues: "There are two main ways to address the problem of mining and path creation. One is based on technical knowledge, the other is through the community, in which knowledge comes later".

In mobilising resources and building constituency, the Sugamuxi movement used their acquaintances to reach out to a Senator from Boyacá, to call for a public hearing at the Congress, in which the Minister of Mining had to present a strategy to deal with the impact of mining in protected zones such as páramos and Lake Tota. The Senator aligned himself with the social movement's vision of protecting the territory from mining, and this vision has remained central to the Regional Development Plan since this representative became the Governor of Boyacá in 2016.

New technical knowledge enables collectives to use a broader set of legal instruments: "We started using legal tools such as the right to petition (derechos de peticion), we sent letters to different institutions at the regional and national level, to Regional Autonomous Corporations (CAR), ANLA and the Environmental Ministry" (Interviewee S3). Then, the movement called two public hearings -one at the Congress and another in the region - where they reached more than a thousand people from different municipalities. They brought along regional and national authorities to present the counter-expertise findings from communities on the Mauren & Prom's request for a modification to a licence granted surrounding the Tota Lake. As a result, the environmental authorities rejected the request. It was a lawyer, who had been involved in a similar processes in other regions and had the experience on this issue, who helped analyse the request from the company, and other geologists, both associated with the collective, who provided the required knowledge. This joint work reveals how the Sugamuxi collective acts under bricolage, by making do with what is at hand. In the absence of strong public institutions and when rights are threatened, social movements play a key role in re-establishing rights and enforcing the law using legal mechanisms in bricolage. "We can achieve things through juridical means" (Interviewee S3) and "all our actions are supported legally" (Interviewee S4). Juridical actions are also used to influence policy and decision-making, mainly when dealing with the CAR, which are easily co-opted and captured by mining companies. "We organise a Green Council to enforce environmental protection and call for action to CAR." (Interviewee S1). To influence decision-making, the collective of Gachantiva created the "Municipal Council of Environment, a

consultative body that has a seat in the municipal cabinet. Members of the collective with experience and knowledge in agriculture, soil treatments and tourism have come together to support the new path creation through this mechanism" (Interviewee S1).

The experience accumulated by these social movements has enabled the oldest collective, Alto Ricaurte, to produce a manual to guide other initiatives and movements in Boyacá and elsewhere. It summarises as a five-steps strategy, according to *Interviewee S4*:

- Research and understand the problem
- Planning: meetings, strategies and activities
- Legally support all the actions undertaken
- Lean on government officials' watchdogs to obtain support and help with demands and requests.
- Social mobilisation as the main force to build a narrative around our causes and against the adversary, through different mechanisms:
  - Gain support from Leading environmental figures
  - Nurture allies and support from public institutions and watchdogs
  - Rely on media and social media to communicate progress and strategy
  - Organise meetings, cabildos, public hearings and forums,
  - Organise demonstrations, protests and mass meetings to build up support, legitimacy and visibility

Today, the collectives still respond to any threat to the territory. The technical analysis of each issue is documented in websites and translated into comics to make it easier for the public to understand, as shown in Figure 5.3 below. This is an example of how comics are used to inform the public on real-time news regarding mining. In Figure 5.3 Getulio tells his neighbour that the ANLA has launched a mobile app to keep track in real-time of all licences granted and says that maybe kids and young people at home can help their parents to use it and stay alert. He carries on saying that the Maurel & Prom (French Multinational Mining firm) application for a licence in the COR-15 block - including 4 municipalities Tasco, Beteitiva, Busbanzá and Corrales - has been archived due to

insufficient information on the project's environmental assessment. This comic's purpose is threefold. It keeps the community informed, builds social bonds and keeps the social movement's identity alive.

Figure 5.3: Communications strategy to keep communities informed about mining threatens in Sugamuxi province

Thus, collective action consolidated as legal actions have become successes, and sustainability narratives have been enriched by the knowledge and participation of a wider variety of actors. The previous section has highlighted the role of social movements as opposition agents to mining. In contrast to industry opposition examples investigated by Hess (2007), where social movements possessed the necessary resources to instigate change, the Boyacá's case depicts a resourceful and bottom-up process that allowed the movement to overcome its lack of technical knowledge and, at the same time, facilitated network formation to consolidate a constituency. Opposition has been made possible by bricolage action that remains important when envisaging alternatives for sustainable development.

The following section discusses how social movements can also be sources of development of alternative pathways (Hess 2007). It discusses how alternatives are conceived and created through distributed agency, resource mobilisation and collective action.

5.4 Bricolage and sources of alternative pathways for diversification

Hess (2007) stresses the importance of technology and product-oriented movements in materialising alternative sustainable industries. These movements work closely with and complement industry opposition movements. Yet, more attention is needed to understand the process by which favourable conditions are created to enable the emergence of a new pathway, specifically in the context of low technological capabilities and resource-based regions.

In Boyacá, social movements may not exhibit such division of labour and in contrast fulfil both opposition and the creation of new paths. The concept of bricolage helps to show how Boyacá's social movements engage with a broader set of local actors to imprint directionality towards sustainable development and how the existing and required resources are mobilised to build alternatives, including STI policy. Finally, this section explains how agency configures throughout the process to enable path creation.

5.4.1 New directionality to regional development

The shared narrative and vision constructed by social movements is underpinned by sustainability and "buen vivir" concepts (Gudynas 2011), wherein quality of life and well-being are achieved only within a community and cohabitation with nature (Gudynas 2011, Escobar 2015). To realise these visions, social movements focus on providing a new directionality to policy by initiating their own paths and bringing in support from local (municipality) and regional government. As in opposition activities, they lean on creative communication processes using local radio stations and information and communication technologies to keep expectations and visions aligned across heterogeneous constituencies (Red

Desarrollo Sostenible 2016). The richness of the path creation process resides in the differentiated options undertaken by social movements according to their networks and the resources mobilised. From this, place-based interactions result that shape the design and experimental deployment of alternatives for local economic activities, such as eco-tourism, community-led organic agriculture and environmental services. Manifold initiatives co-exist and evidence the idiosyncratic nature of bricolage, enabling innovation and knowledge generation. For example, in Gachantiva's collective, one of its members works for the Instituto Von Humboldt. His role and activism has allowed him to work closely with the community and activists to generate scientific knowledge around several private civil society nature reserves (Córdoba-Córdoba, Borja, Medina, Mendoza-Cifuentes, Robles, Robles, Sierra, Diaz-Pulido, Arbeláez-Cortés, Acosta-Galvis, Bautista, Parrales, Torres, González, Castro, Espitia-Reina, Torres & Amat 2017). Interviewee S1: "The Institute in the last year has investigated 18 reserves". By identifying unique and valuable flora and faura, protection becomes a valid argument against new mining exploration projects in the area and its surroundings. Such knowledge can be seen as a way of shielding the reserves and therefore, the alternative pathway, from potential mining threats "It has legitimised our demands and the new paths for development" (Interviewee S1).

In contrast, Sugamuxi collective has taken a divergent path by joining in the national strategy of clusters. The Red Cluster Colombia is the national initiative to foster business networks in related industries through cluster formation. "Boyacá Turismo Sugamuxi" cluster is the strategy to bring together different actors and resources to consolidate eco-tourism in the province (Cluster 2021). Through this network new opportunities are opened, as it makes it possible for the the collective to apply for STI and competitiveness grants from ministries and other funding bodies, and participate in the national tourism programme of the Ministry of commerce, industry and tourism that promotes nature tourism. A first grant from the National Tourism Fund FONTUR allowed the collective to design a tourism package. These two examples illustrate how bricolage enables multiple responses in the process of unrelated diversification.

5.4.2 Resource mobilisation

Almost every collective has relied on NGOs to acquire knowledge, skills, and in some cases, access to funds to undertake small projects. NGOs have a central role in supporting social movements to develop sustainability narratives, define strategies to defend the territory, and mobilise resources. Moreover, NGOs can have particular views on pathways, favouring some alternatives against others, as described in Table 5.5. According to Interviewee O2, their main action focusses on "support[ing] communities and social movements to undertake legal actions (for example, the 'tutela': "This action allows an individual to access the courts in an expedited manner to seek protection against current or imminent violations of 'fundamental rights' protected by the Constitution." (Corte Constitucional 2015, p. 26); popular actions; right to petition) by helping to gather information, understand and use it; supporting the organisation of meetings, forums and photos; and exerting pressure on public institutions to meet those communities' demands". However, NGOs' role goes beyond pressuring the mining industry to open up opportunities for alternatives, as argued by *Interviewee R1*: "We rely on NGOs more than on public organisations. They support us and dynamise certain initiatives". As *Interviewee O1* summarises: "We help them [social movements] to creatively discover alternative economic activities such as communitarian tourism, biodiversity tourism, agroecology, crafts. We help them to develop a sensibility for these activities and recover ancient knowledge in order to achieve a decent living standard".

In the absence of technological capabilities and knowledge, social movements learn and generate knowledge through continuous micro-learning processes from the interaction with resources and new practices that help build collective spaces. Besides, increasing knowledge and reflection on the visions and pathways to follow within territories favours the emergence of new actors and institutions required for the new industrial path. This reflexive character of learning contrasts with the learning approach proposed by EEG, which is aimed mainly at providing new skills but also questioning and reflecting on change possibilities. In this case study,

Table 5.5: NGOs as part of the strategy of resource mobilisation by social movements

Process supported by NGOs	Description
Building narratives	• Help communities to strengthen their narratives against mining and protect their territories. • Help communities to uncover firms' strategies and develop means to stay together and address the entrance of such companies. • Help develop a reflexive approach towards development and alternative path creation processes.
Develop strategies to defend the territory	• Support communities throughout the process of banning mining projects. • Organise trips and agendas for policymakers to show the real effects of mining in other regions, so that their decisions are more informed and based on evidence. • Lease with Defensoria del Pueblo and the Attorney General Office to enforce local environmental authorities' action and speed up decisions on the communities demands.
Mobilise resources	• Help communities to gather information, understand it, organise meetings, forums and how to put pressure on public institutions for the demands of the community (Interviewee O1) • Support communities to formulate projects or apply for funding to support their actions against a mining firm or project. • Support communities in demonstrations. • Build networks and linkages with other institutions and social movements. – Facilitate the exchange of experiences with other social movements and collectives. This is the most critical element; every social movement has relied on another to learn how to deal with threatens. – Bring technical experts to the communities to provide specific knowledge on certain topics. – Cover transport costs for the community to vote and participate in Popular Actions (vote). – Fund workshops. – Look to strengthen collective leadership across social movements, like the Sustainability School - offered by CENSAT AGUA VIVA. – In some cases, NGOs have linkages with researchers whose agendas are linked to communities' problems. The knowledge they generate is fundamental to the social movement.

learning appears as a salient outcome from the interaction between social movements and NGOs. It comes about in multiple ways and empowers social movements and communities to achieve change and implement their visions on economic diversification. As Interviewee N1 states "We accompany them [social movements], and as we do so, communities develop a reflexive approach towards the implications of extractive industries. We facilitate the exchange of experiences and learning between them, with technical experts who know how to do this type of processes. We cover experts' transport costs to get to the community, and the expert delivers a workshop or supports formulation of projects. These activities are normally done ad honorem. We build bridges".

Another NGO whose role has been central to the regional social movements actions is CENSAT Agua Viva. Interviewee N2 mentions: "Our role during the last 30 years has been to articulate actors, create opportunities for actors to meet up, encourage reflection within communities. Nowadays, our work is more territorialised. It seeks to strengthen collective leadership across social movements and is the main purpose of the *Sustainability School*". This school utilises political ecology concepts and methodologies to provide training and an analytic framework to communities to help them address sustainability issues. Therefore, the school is bespoked designed for a territory, according to the problems faced by communities, for example, the women school and mining in Puerto Boyacá. This school led to the formation of the Women of Puerto Boyacá's movements; among others. Interviewee N2 mentioned: " The women school has also become stronger in Boyacá, where I have created a strong bond with Interviewee S2 to consolidate women's roles in decision-making, to empower women to participate and speak up, particularly in regions where women discrimination is culturally embedded".

In these ways, knowledge generation is a more participative process, which brings together communities to share their approaches and understandings of nature and to envisage alternatives, as shown in Figure 5.10. This is expressed by Interviewee N2: "We rely on participative methodologies and popular environmental education, which acknowledges popular knowledge from communities, so we treat them as peers even though they have not received formal education. We also rely

on political ecology frames to understand conflict and disputes.". NGOs are determinant in the opposition stage and in providing practical knowledge around sustainability.

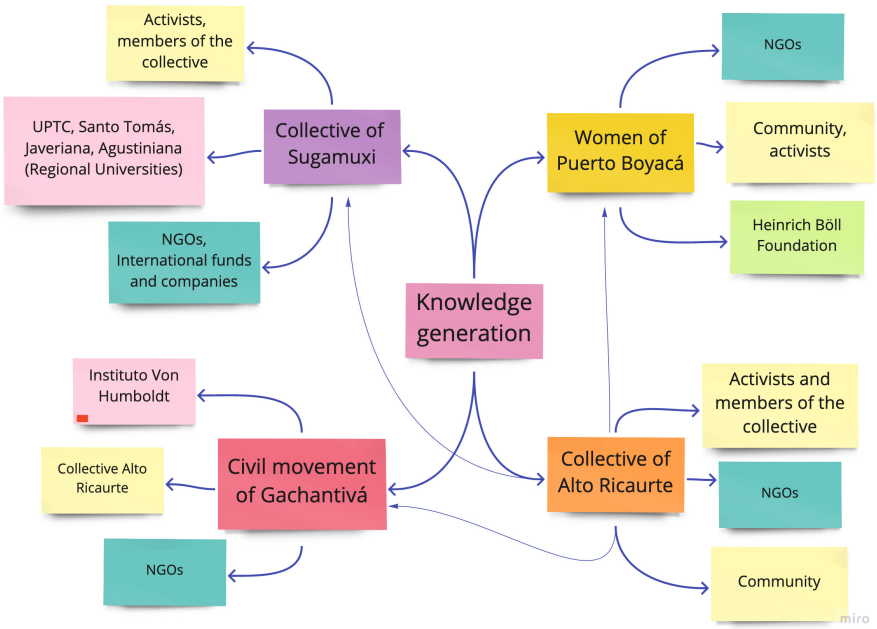

Figure 5.4: Knowledge generation dynamics of social actors under bricolage

Another source of knowledge comes from the social movements members' networks. In some cases, members have linkages with research centres to identify the potential of biodiversity, to back up conservation requests, and to identify the potential for economic activities derived from biodiversity, as in Gachantivá. In other cases, knowledge is more distributed across the movement's networks. Hence, individuals bring their experience and connections to the social movement, enabling bricolage and strengthening the social movement's agency, as in the Sugamuxi and Alto Ricaurte collectives. Their strong and strategic networks reach civil servants within watchdogs, government institutions such as the Comptroller General, or even employees within MNC, who can possess privileged information and knowledge regarding mining projects. Inhabitants of Iza use their networks to obtain the technical knowledge and experience to understand and reveal the effects of mining and the environmental management plans of licences in the process of being granted exploitation. In the words of Interviewee S3, "An environmental engineer joined and created Getulio Montana Laguna. Afterwards a

lawyer got involved, he knew a civil servant in ANLA, who had all the knowledge about licences. He shared with us the details of the procedures, practices and so on."

Funding comes from heterogeneous actors in different geographies, including national and international NGOs, foundations, the Governor's office, funding agencies at various levels, activists, and members of the social movements. Media coverage and communication strategy constitute a third critical resource, with local community radio stations underpinning the consolidation of narratives and forming part of the social movements' communication strategy. Using radio stations reduces diffusion costs, allowing social movmeents to overcome distances and connectivity problems in rural areas. Information and communication technologies, including websites, WhatsApp groups and community radio stations, are used to flag up concerns and follow up events, which constitutes a systematic action in the social movements analysed. A detailed description of resource mobilisation for each collective is presented in Table 5.6.

Table 5.6: Resource mobilisation and path creation by social movements

Collective	Actors and networks	Resources mobilised	Visions and alternatives for diversification
Sugamuxi collective	Community: environmental engineers, lawyer - ex-worker from ANLA, anthropologist, artists, farmers, traders.	Technical knowledge to assess the impact of mining: Master's thesis, technical documents and research projects. Social media content [3]	Eco-tourism - nature-based tourism A grant from the national tourism agency FONTUR will allow the collective to design a new service package to identify the tourism potential of the destination including: • Sogamoso - Paramo de Siscunsi • Aquitania (Lago de tota) • Cuitiva (Lago de Tota y Playa Blanca) • Mongua (Paramo de San Ignacio, Paramo de Ocetá y Laguna negra) • Monguí(Paramo de Oceta), Pajarito (Selva húmeda tropical y salto de candelas) • Firavitoba(Bosque alto andino), • Iza(Aguas termales y bosque alto andino). Within the ring of páramos there is an Important Bird Area (IBA). The diagnostic includes: • accessibility assessment, • activities, • potential services related to tourism, • basic services and tourism attractiveness, • demand and supply analysis members of the community who are involved with tourism will play a key role in developing the new package.
	Lush Fresh handmade cosmetics,	Funding to carry out technical studies and work with communities	
	Colombian Institute of Anthropology and History (ICAHN)	Research on fossils and inputs to oppose mining and to protect potential archaeological sources	
	Veeduría Ecológica y Protección del Agua Citizen Ecological Oversight and water protection [4]	Organisational and technical knowledge to undertake legal actions.	
	Alto Ricaurte Collective		
	Tasco Collective	Inspiration for Getulio comic	

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[3] https://www.facebook.com/Colectivo-por-la-Protecci%C3%B3n-de-la-Provincia-de-Sugamuxi-354171434628733/
[4] https://repositorio.flacsoandes.edu.ec/bitstream/10469/13621/14/TFLACSO-2017VAVP.pdf Pg. 127

Table 5.6: (. . . continued from previous page)

Collective	Actors and networks	Resources mobilised	Visions and alternatives for diversification
	CINEP	Visibility, legitimacy, convening power	
	Global Greengrants Fund	Funding to produce two guides to help defend the territory (2017-2020) and to engage artists and communities in designing a communication strategy to highlight the problems around mining in the region	
	Chamber of Commerce Sogamoso	Support and participation in a project to design a programme of nature-based tourism	
	FONTUR	Funding for eco-tourism project	
	Students from UPTC, Universidad Santo Tomas, Universidad Agustiniana	Technical knowledge about mining, DOFA analysis for Eco-tourism	

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Table 5.6: (. . . continued from previous page)

Collective	Actors and networks	Resources mobilised	Visions and alternatives for diversification
Colombia Free of fracking	United Communities Foundation COUNCO	Support and visibility to the campaigns against MNC and the configuration of alternative pathways	People need is to see further opportunities for development such as the civil society nature reserves. The collective has given birth to alternative ways of organising economic and social activities, such as eco-aldeas, barter, etc.
	CENSAT Agua Viva	Mentoring, visibility and empowerment of the social movement. Training and activism	
	Governor's office	Funding, venue for a women's forum on 8th March 2018 ("How women protect their territory and create sustainable alternatives")	
	Community radio stations	Diffusion of campaigns and narratives across communities	
	Heinrich Boll Foundation	Technical support and funding	

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Table 5.6: (. . . continued from previous page)

Collective	Actors and networks	Resources mobilised	Visions and alternatives for diversification
Gachantiva movement	Governor's adviser to social issues	Support to organise the carnival and attract media attention to the problem	• Support and develop civil society nature reserves within the region and to follow the path of other social movements to protect their local ecosystems. In this way, the movement can also work with some national government agencies such as National Parks Institute, Institute Von Humboldt and Secretariat of Economic Development in Villa de Leyva. • Eco-tourism supported by international NGOs Travolution • Scientific tourism - bird watching • Community production of blackberries by a new community association that secure a grant to pay for fruit-processing equipment • Environmental management, eco-tourism and organic agriculture with further capabilities and training provided by SENA (Technical Training Service of the Country)
	NGOs: • Miserior • Bread for the world • ITA-CHO • Podion: most of the training has come from them • WWF	Funding, environmental schools, skills on georeferentiation, how to use legal tools against mining, technical knowledge, training.	
	Community and activists	Funding, community trade, fairs.	
	Colectivo Alto Ricaurte	Training to become environmental observers	
	Travolution	Organise Latin American Meeting for Sustainable Tourism (about 450 attendees) to analyse and discuss a new perspective and vision of local farmers around eco-tourism	

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Table 5.6: (. . . continued from previous page)

Collective	Actors and networks	Resources mobilised	Visions and alternatives for diversification
	Instituto Von Humboldt	Scientific knowledge to characterise the first three civil society nature reserves in Gachantivá. Currently, 18 reserves have been characterised in the region.	
	Regional Autonomous Corporation - Area: Regional Division of protected areas	Legitimacy and visibility for their participation in the Regional System of Protected areas	

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Table 5.6: (. . . continued from previous page)

Collective	Actors and networks	Resources mobilised	Visions and alternatives for diversification
Alto Ricaurte Collective	Government's official watchdogs	Support and help with demands and requirements	/A liveable region, underpinned by the tranquillity, harmony, sustainability and cultural richness.
	Community radio stations	• Enhancing community's literacy, • Diffusion of information, • Updates on procedures, • Campaigns • Leverage community support for causes and amplify the collective's voice to gain the public support	
	Celebrities	Support collective's causes, amplify the collective's voice and help align a narrative around sustainable development	
	Comptroller's office	Training to become environmental observers	

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Table 5.6: (. . . continued from previous page)

Collective	Actors and networks	Resources mobilised	Visions and alternatives for diversification
	Activists and members of the collective	As highly educated people with strong backgrounds and careers, they possess the knowledge and networks to understand problems and leverage support and resources even within the MNC. Fund campaigns, demonstrations and legal actions with own resources.	

end of table.

Each collective's dynamics of work are relational to their territories. For example, Sugamuxi builds on its thermal waters resources and beautiful landscapes to envisage a path for eco-tourism and sustainable well-being tourism. The collective has looked to strengthen networks with business-related actors who have the capital and influence to position the province as a tourism destination. In doing so, it has partnered with the local Chamber of Commerce and local mayoralties to promote the initiative. At the same time, research around the benefits of thermal waters is gaining attention at different regional universities (Beltrán, Montoya & Sandoval 2017, Gómez 2019).

Every member brings in invaluable resources that stem from their expertise and careers. In the Interviewee S3's words: "We weave relationships with other collectives, research centres, etc. From everyone's professional activities, we all contribute with relationships and networks to the collective... We have an anthropologist who works at the UPTC university, in charge of the UPTC Museum. We also work with the Colombian Institute of Anthropology and History (ICANH) as the province is an archaeologically important site".

Actors and resources mobilised under bricolage render agency distributed, which means decision-making and influence are not concentrated in a single actor. This facilitates the emergence of shared collective spaces. As Interviewee S3 puts it, "I studied with them [activists and members of the collective and the Governor's cabinet] all. We [Governor, advisers, leaders of social movements] went together to the university in Tunja. We all were part of the student movement, and we joined forces with the peasant movement to fight for free education and other social causes." These shared traditions and a past as activists are important relational factors that contribute to the building of collective spaces. Interviewee S3 sees this regional process as "a golden opportunity".

The next section deepens the understanding of distributed agency in the case of Boyacá, to recognise how social movements realise spaces of collective action through bricolage. The process described is defined by Garud & Karnøe (2001, p. 26) as "shared collective spaces"

5.4.3 Distributed agency in the process of path creation

Along the process of path creation, actors exhibit different roles to influence directionality. For example, the leader of Colombia Free of Fracking began playing a role as a young leader and activist. Later, she was asked to join the regional administration to strengthen the social organisation in defence of the territory. In doing so, she kept connecting communities and people. She drew the attention of international organisations such as Foundation Böll and United Nations and obtained their support and protection in her endeavours. In an event related to the peace process organised by the United Nations Development Programme (UNDP) she met the people from Alto Ricaurte collective. She built a close relationship with them, which helped her better understand social movements and their work. Throughout her career, she has strengthened her ties to CENSAT Agua Viva and Amigos de la Tierra Colombia, which later allowed her to become the sustainable school leader in Puerto Boyaca and organise the Women's of Puerto Boyacá group. In parallel, she has led the Colombia Free of Fracking collective, which has been very visible in the news and has recently played an important role in confronting exploration projects of fracking in Colombia.

Similarly, *Interviewee S3* played a vital role in the configuration of the collective of Sugamuxi during its first five years. Later, he was appointed by the Mayor to design the development plan for tourism in Iza, a municipality surrounding the Lake of Tota. He stated that the main reason to participate in local government is to influence planning, allocate resources to strategic initiatives and influence policy.

In Gachantivá, one of the leaders of the civil society nature reserves works for the Institute Von Humboldt. He has been crucial in establishing a bridge with the National Parks and the National Network of Nature Reserves of Civil Society. He has worked actively in the characterisation of 18 nature reserves in the region. He has also helped organise regular meetings where a civil servant from National Parks presents to the community how to join the civil society's nature reserves, as part of an ongoing strategy to protect the territory. In his words: "I have some research from the Institute I can use to attract the National Natural Parks. What

National Parks provides is very limited, but enough to help us consolidate this initiative. I used the inventories [from private nature reserves] we have done at the Institute to attract the agency's attention regarding biodiversity. These are not part of National Parks' protected areas, so it is important to protect them through a different mechanism. It is not something coming top-down from [National] Parks. It is the other way around, we propose to National Parks, we asked and looked for it and finally got it." (Interviewee R1).

Thus, the distributed agency emerges as a contingent feature of bricolage during early stages of path creation, particularly when challenging existing conditions and lock-in. Communities, NGOs, research centres, civil servants and specific national institutions, such as the Comptroller's General office, take part and contribute to agency formation. Within communities, the role of lawyers and practitioners is crucial to provide the technical knowledge required to support social movements' responses to the mining industry. Their participation varies along the process and so do their roles, as explained earlier in the section. A time-line of the process is synthetisised in Figure 5.5 and Figure 5.6.

A key finding is that opposition to mining overlaps with path creation. The early stage of *path creation* is reactive and contingent, as illustrated earlier. Afterwards, the process becomes more strategic, and agency is used in a more conscious and planned way to build networks and overcome shortcomings on their way to create alternatives. These networks involve different types of actors, ranging from government agencies at the local, regional and national levels, chambers of commerce, NGOs and local businesses. See Figures 5.5 and 5.6. These new linkages are aimed at strengthening market opportunities, influencing policy and institutionalisation of alternatives as a means to protect and legitimise them. For instance, the Alto Ricaurte collective, Gachantivá collective and civil society nature reserves partnered to participate in the national programme, "A ciencia cierta", run by Minciencias (the Ministry of Science, Technology and Innovation). "When considering biodiversity and tourism as an alternative, regional integration is important, as it enables more appealing journeys for tourists" (Interviewee S4). Through their participation in this national programme, these three social

movements obtained a grant equivalent to £12.000 to invest in strengthening the network, undertaking research on conservation of local biodiversity within the reserves, and deepening the scientific knowledge of flora and fauna. As part of the project, the movements produced material to diffuse the Alto Ricaurte nature reserves. The project was developed between 2018-2020 and helped consolidate a network of 25 civil society nature reserves in the region, which gives birth to a new pathway in Boyacá. It has brought together Institute Von Humboldt, UPTC, Universidad Juan Corpas and the three social movements mentioned earlier, illustrating how social movements can partner to create new opportunities and explore different avenues to integrate science and technology components into their daily actions.

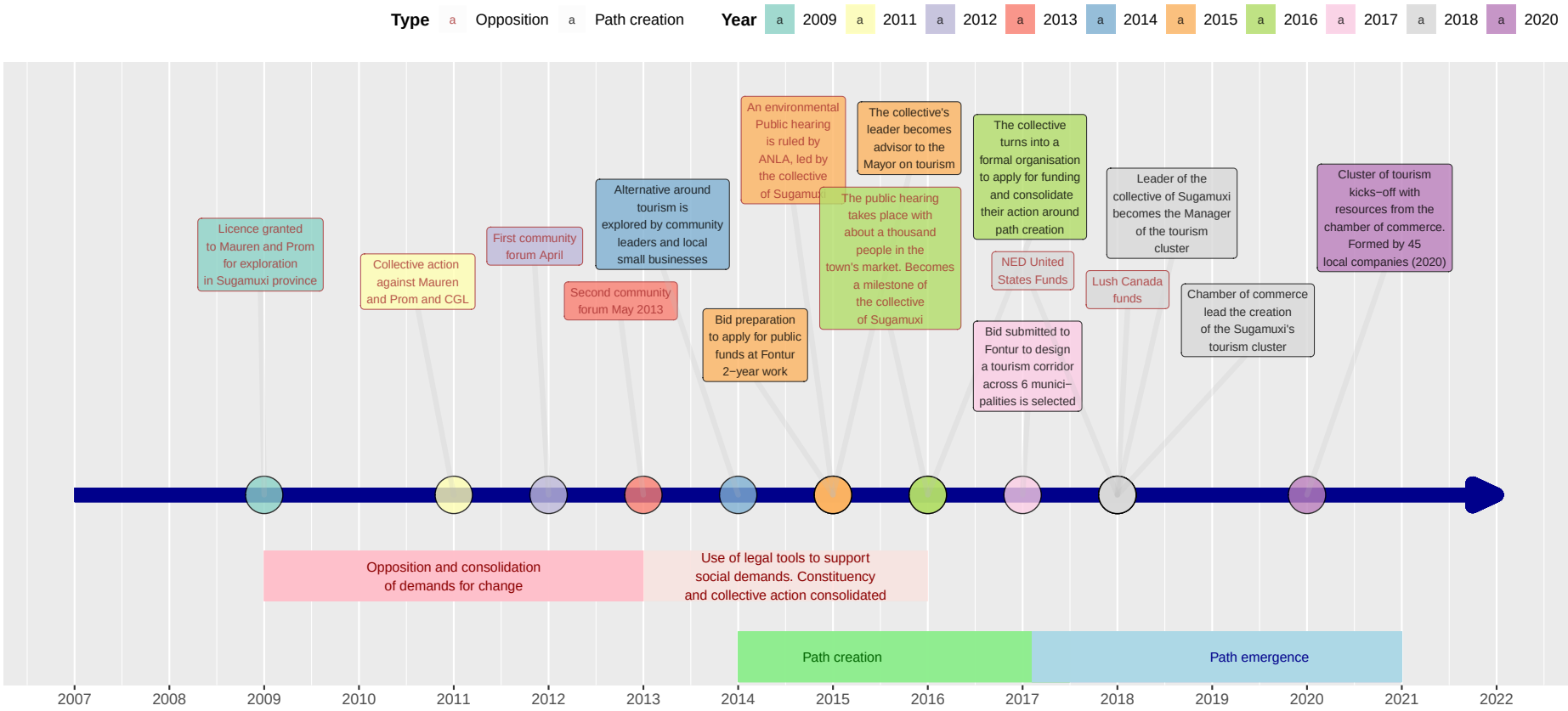

Figure 5.5: Industry formation led by Sugamuxi Collective

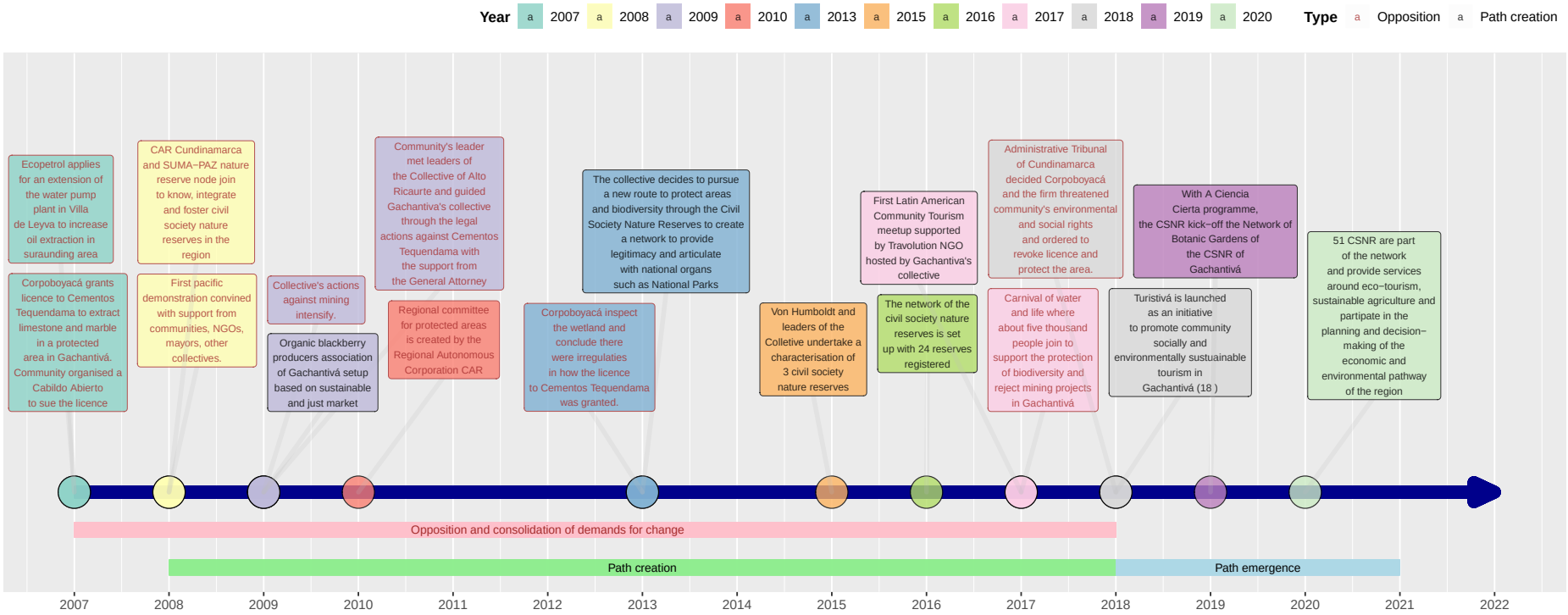

Figure 5.6: Industry formation led by Gachantivá collective

In Boyacá's process of path generation, local initiatives diverge due to their varied perspectives on the use of natural resources, which shape their narratives, repertoires of action and strategies to growth and consolidate. Policy plays an important role in creating benevolent conditions for these pathways to evolve and become a new economic sector. Moreover, alignment across initiatives plays an important part in consolidating industry formation. EEG and geography of transitions literature has elaborated on the concept of alignment, which will be examined later in the chapter in section 5.5.

5.4.4 Regional policy and social actors working under bricolage

The influence of Boyacá's social movements in policymaking has not been incidental. In the first instance, most of the government board members shared a past as activists advocating for free and high-quality education and social justice in the 1990s, during their time at the UPTC. This facilitated the alignment with existing social movements' demands around the development of a new vision leading to a new directionality for the STI policy for the region. This alignment has also favoured the place-based bricolage of social movements and the process of creating new development paths in several ways. First, it legitimised social actions against mining MNCs. Second, it mobilised essential resources and engaged with key actors in the process to halt mining and create the required institutional setting for an alternative pathway. Third, it unlocked new R&D agendas, by fostering a new portfolio of STI initiatives to explore new markets around the sustainable use of biodiversity through Boyacá BIO. The role of policy is determinant in the process of unrelated diversification to facilitate change and enable the conditions for new paths to arise, as will be explained in this section.

In the initial stage, the government directly and indirectly supported the actions of social movements against mining. A prominent role in the cabinet is the Adviser to the Governor on peace and social affairs, who defines himself as an "intermediary and facilitator in some cases with institutions from the national level, such as the Ministry of environment". *Interviewee G3* was a councillor in Tunja, the capital city of Boyacá, for ten years. He became a public political

figure, well known by most of the collectives. Two main aspects of his role can be highlighted. His involvement in the causes of social movements provided legitimacy to social movements' initiatives, particularly those associated with protests and social expression against mining. Second, due to his networks and the fact that he was part of the cabinet, he could mobilise resources, and draw the media attention and the Governor's attention to urgent matters, such as the Carnival for Life in Arcabuco, led by the collectives of Gachantivá and Alto Ricaurte.

Regional government plays a role as an intermediary to help overcome institutional weakness, bureaucratic procedures, and the co-opting of the national mining agencies function by vested interests. Regional government empowered social action and legitimized demands, for example, by putting pressure on the institutions responsible to deal with rights to petition and collective actions filed by the communities and social movements. In this way, collectives in Boyacá promptly obtain official responses from their enquires (normally within 10 business days). Regional government can also help overcome the knowledge and skills gaps of social movements: "I received instruction to provide support to them [collective of Sugamuxi], so my team, with a lawyer, sat down with them to review the "Accion popular" [popular action] against Maurel & Prom and to provide enough evidence to the ANLA to ban mining in the lake and its surrounding area." (Interviewee G1).

Similarly, the regional government can foster social organisation, as can be noted in the Regional Development Plan 2016-2020. A project called "Strengthen processes of defence of nature" was included in the Plan, and the former Director of Environment and Sewage hired *Interviewee S2* to lead it. As Interviewee S2 explained: "It was atypical that a governor wanted to foster social organisation and movements. I used to be told by the collectives, you are being paid to come to tell us what to do, so at the beginning, they saw me as an infiltrator. Indeed, I was being paid to go into the field to speak with activists to help them strengthen their collective action and organise to defend nature. My role was to raise awareness about the need for them to organise as a social movement or

collective.". During her role, Interviewee S2 made an inventory of most of the social movements and collectives of the region and established a dialogue between them and the regional government: "I used regional forums and the support from the Governor's office to show what the social movements [for example, the forum of women in defence of the territory in Boyaca] were doing. I also have friends in local radio stations so I asked them to invite activists to share their experiences, to call for more support from the community and so on. What I do is that I pass on the contact details of people with emblematic cases to them." (Interviewee S2)

Advancing opposition to mining, there has been policy intervention to support the new pathway towards sustainable use of biodiversity through a new institutional setting. Previously, environmental matters were under the Secretariat of Infrastructure, led by a first-level director of environment, sewage and clean water, with limited budget and no seat in the regional cabinet. To address this, the government submitted a request to the Departamental Assembly to create a new Secretariat of Environment in 2016 (by the Ordenanza RG-CO-02-007). The Secretariat would design an environmental sustainability policy to preserve ecosystems and tackle poverty through the sustainable use of natural resources. This Secretariat was created in 2019 and has been active in the design of programmes and strategies to deliver on these objectives. Previously, two main points were made around the alignment of policy with the bricolage action of social movements. One point was related to the joint effort against mining, and another around the support provided to social movements for resource mobilisation, that includes changes in the regional institutional setting. The third aspect deals with unlocking R&D agendas.

To unlock R&D agenda from mining and set up a new agenda around biodiversity and water protection, the government adopted a more entrepreneurial role. Through face-to-face meetings with research groups, it made an inventoried of capabilities, researchers' interests and the extent to which these could match its policy agenda. From the planning perspective, the contrast with the previous administration was evident: "I have been in charge of this fund [the Royalties Fund - the primary regional source of STI funding] for the past and current

administration, and I can notice the difference. In the past plan, mining was a key sector, and STI sought to strengthen it through applied research on minerals and setting up a technological park in the corridor of Sugamuxi province". Her perception of the new administration is: "Our current vision is different because we want an ecosystem of [bio]diversity and water. Boyacá BIO is the first program that has a base in applied research, technological development and innovation working in the territory of Boyaca for biodiversity and ecosystem services." (Interviewee G2)

Two factors kept the STI agenda locked-in on mining in the past. First, the INCITEMA, the research institute of mining and corrosion was led by the UPTC's Vice-Chancellor (2017-2018), and the Deputy Vice-chancellor was also a member, so they were keen to continue to work with the government if the research was focused on coke, clays, limestone and corrosion. Second, one of the university's main income streams came from consultancy and training services for mining companies. The Secretariat of Planning was aware of this: (Interviewee G2) "So, we [regional governmnet] said we do not want to work on that, and we will cancel the project of the technological mining park, which had been prepared to submit to the Royalties Fund. We mentioned to them [Vice-chancellor and board of the university] that we wanted to work with biologists, the herbarium, the natural history museum and the biology groups that have been working on biodiversity." In this way, the regional government lay the conditions for a new STI agenda with a substantial shift in the use of the Royalties fund, the primary regional source of STI funding. Policy directionality has become a key factor in enabling change and creating the environment for unrelated diversification.

5.4.5 Policy directionality and experimentation for unrelated diversification

Activism and the demands for social change permeated and strongly influenced this new policy directionality in Boyacá, that underpinned the shared desire of social movements and the regional government to protect the environment and embrace the concept of "good living" (Departamento Administrativo de Planeación de Boyacá 2017). The background of the Boyacá BIO's founder

illustrates the new approach, as Interviewee G6 comments: “I used the first-hand experience of activism, as my father has been one of the representatives of the community aqueducts for Boyacá at the national level and is also a member of the regional aqueduct network. He has defended paramos all his life and fought against the army and antiriot troops in the past.”.

Boyacá BIO builds on the national programme Colombia BIO, the main axes of which are to protect ecosystems that provide essential services to the country and to understand how to promote actions that lead to new business models and income streams based on STI for people in the region. Colombia BIO constitutes one of the country’s efforts to meet the commitments under the COP21. Interviewee G2 commented: “We identified ourselves with the programme. We felt it contained most of the drivers of our Regional Development Plan, so we moved ahead”. Boyacá was a pioner, as Interviewee G2 states: “Boyacá became the first region to adopt this policy to the regional domain and to operationalise it in public calls. After that, other regions have followed their path and used Boyacá’s experience to design their own, such as Santander Bio and Nariño”. Colciencias (nowadays the Ministry of Science, Technology and Innovation) manages the national programme. The Ministry acted as an intermediary between the regional government and international cooperation agencies who had been allies in the national programme, including the British Council and Kew Gardens. Although beneficial in terms of knowledge generation, this partnership between the regional government and Kew Gardens faced significant resistance from some social movements and research groups at the regional university, as the collaboration is for bioprospection activities. Social movements and the biology research group at UPTC disagree with an international research organisation undertaking bioprospection in their territory. They perceive it as a threat, in which the region may loose rights over the species Kew Gardens can identify, patent and exploit commercially. Kew Gardens worked along the Instituto Von Humboldt to generate knowledge on seed banks and identify new species in the páramo ecosystem[5].

Boyacá BIO consists of nine components summarised in Figure 5.7. Three main

[5]https://www.kew.org/science/our-science/projects/kew-colombia-bio-programme

Figure 5.7: Composition of Boyacá BIO programme.
1. Bio Expeditions,
2. Call for R&D project,
3. Call for Innovation projects,
4. Impact analysis in the National Natural Park el Cocuy,
5. Science Centre,
6. Conservation and restoration actions in páramos,
7. Vulnerability and threaten studies on regional biodiversity,
8. Strengthening regional STI system,
9. Protection, conservation and restoration of strategic ecosystems

items are analysed in this section: the BIO Expeditions, the call for R&D projects and the call for innovation projects. The objective of BIO expeditions is to generate tools to facilitate the management of biodiversity and ecosystem services for regional planning and decision making. The aim is to generate knowledge on the region's biodiversity, identify scientific products that use and preserve biodiversity, and foster knowledge generation around nature through the participation of communities. Expeditions focus on the strategic páramo ecosystems as shown in Figure 5.8. A second component is the call for R&D projects, which seeks to produce further knowledge and technological development to address the region's biological challenges. The call is structured around three themes. The first theme, the effect of climate change in the regional biodiversity and adaptation and resilience of the biodiversity under the existing conditions, seeks to fund at least two R&D projects. The conservation of strategic ecosystems is the second theme, which aims to fund at least five projects. The sustainable use of biodiversity theme funds another five projects. This last theme aims at exploring commercial use of biodiversity and understanding multiple criteria for valuation of ecosystem services. The third component is the call for innovation projects, which seeks to strengthen regional innovation capabilities for sustainable use of agroecology and biodiversity. This component is strategic due to its experimental character. One objective is to strengthen institutional capabilities to design and implement support schemes for innovative products in Boyacá. It also promotes the development of early-stage products (prototypes) derived from

regional agroecological diversity and fosters linkages between universities, firms and NGOs. Finally, this call supports organisations already working in biocommerce, and interested in alternative uses of flora and fauna. It provides support to these organisations in experimenting with new uses of biodiversity while protecting for strategic ecosystems.

Figure 5.8: Geographical distribution of the BIO Expeditions across Boyacá

Boyacá BIO adopts a participatory approach to allow communities and their knowledge to take part in the policy implementation process. It provides opportunities to integrate different types of knowledge and new knowledge producers. As Interviewee G2 comments *"For us, the call for R&D has to be a bridge between university, civil society, environmental movements. Civil society and environmental movements know the territory as nobody else. Their knowledge is empiric and still very relevant, as they look after their territories and have sustainability as a core element of the daily activities. They remain in the territory; projects do not, that is the only way to ensure continuity."* The government partnered with Instituto Von Humboldt and worked with the regional branch in Villa de Leyva, Boyacá. The Institute had experience in participatory

science, which supported policy implementation, so was particularly relevant for the expeditions. In the process of policy design, walks were undertaken by the team, who established a relationship with some environmental groups and social groups, including Caminantes "Juanetes" (Juanetes Walkers), which organises visits and walks to acknowledge ancient paths within the region; Corporation TIBAIRA, which offers restoration and sustainable eco-tourism and apiculture; Nature reserve Pueblito Antiguo (old town), which focuses on fostering environmental education, bird watching and sustainable eco-tourism; the Ornithologic association of Boyacá; and Foundation IRAMACHA, amongst others. Some of them managed to receive funding for Research and Development R&D and innovation projects through the Boyacá BIO's calls, as can be observed in Table 5.7 and Table 5.8. The government's purpose was to "create bridges and teams to formulate projects that could apply for the calls" (Interviewee G2). Through a dialogue, the government tried to match the priorities of local governments (mayors) with the objectives of Boyacá BIO, facilitating the participation of municipalities throughout the process. This process of bringing new actors and their knowledge constitutes a central element in the process of *unrelated diversification*.

However, this participatory purpose faces significant challenges in the other two components of Boyacá BIO - the R&D and innovation call. Despite the interest of social movements to participate and the will of the regional government, legal requirements established by the national government for participation in public calls for funding STI activities did not allow the social movements' participation. This issue hindered experimentation and alignment within pathways. This point will be discussed in more detail later in the analysis.

Experimenting with a new directionality in the R&D agenda

In general terms, these calls can be seen as part of an effort to experiment with new policy instruments and a new regional development vision. In the words of *Interviewee G2*: "To see if there was a demand for funding in biodiversity and those scientific fields, we opened two calls one for R&D projects and one for innovation projects. By talking to every [research] group, we tried to identify

commonalities and opportunities for linkages. Once groups and research themes were identified, we wrote proposals for the Royalties Fund's fast track. Three projects were awarded, one to carry out scientific expeditions around biodiversity, the second one of R&D and a final one on innovation (prototyping, market discovery)".

This experimental process by which the regional policy translates into specific calls to drive knowledge generation around biodiversity provides insights into key elements of unrelated diversification. First is the intermediary role of the regional government in facilitating policy alignment between municipal and regional government to build expectations around sustainability and alternative trajectories of development. The fact that most of the municipalities involved are rural highlights the relevance of the regional government's role in bringing together local authorities towards this common objective for local development. For example, by mobilising actors in traditional sectors such as agriculture, to explore alternatives for more sustainable production. With 48 entries recorded for the R&D call, and 12 proposals approved, this can be seen as a first step in nurturing alternatives envisaged by local actors.

The total grant figure was far higher compared to the allocations made for the period 2008-2012 and shown in Table 5.2. A total figure of 931,628.48 GBP was awarded in grants for this call to strengthen scientific and technological capabilities across the region, in partnerships with national and international universities such as Universidad Nacional de Colombia and Universidad de los Andes, two of the top universities in the country. The UPTC plays a leader role in most of the projects. Partners abroad are the Centre National de la Recherche Scientifique - CNRS, Institute Prime and Universidad Católica de Valparaiso. The protagonist role of the UPTC confirms the government's interest in capacity-building. It also sets out the challenges facing the university due to the changes in the research agenda, and the new type of interactions and interlocutors, which contrast with the consultancy and research type of relationships with mining MNC. Hence, in the process of unrelated diversification, a more inclusive approach to knowledge generation and innovation implies

Table 5.7: Summary of R&D projects approved by Boyacá BIO 2018 (Call 794-2017)

Theme	Projects approved	Leading institution	Funding (GBP)	Municipalities involved
STI for conservation of strategic ecosystems	2	UPTC - UNIVERSIDAD SANTO TOMAS	139,595.17	None
STI for mitigating climate change and increasing resiliency	2	Universidad de Boyacá - UPTC	163,887.62	Paipa
Bioprospecting - STI for sustainable use of biodiversity	5	UPTC Universidad de Boyacá Universidad Antonio Nariño	383,865.23	Chiscas Sotaquirá Tibana
Implementation of multi-criteria systems of valuation of biodiversity and ecosystem services	3	UPTC	244,280.47	San Mateo Pachavita Santamaría Macanal La Capilla

adjustments in the practices of regional universities. Their role includes creating spaces for learning, across projects and with different actors, and engaging actively in providing insights to the policymakers to encourage the adjustment of policy instruments and incentives to assure the continuity of the process of market development and path creation.

Another important result of the regional government's involvement is the configuration of wider and more diverse networks for R&D projects. Projects, which predominantly involved academic institutions, have been broadened out to include a range of allies from local development agencies, CAR, local associations of producers, and regional public services companies. This variety of actors is salient in the bioprospection and valuation themes, as shown in Table 5.7. In some cases, these new actors can be pivotal elements for radical change and act as facilitators of knowledge transfer as they provide a bridge between communities,

government and components of the STI system. Their role is crucial in the process of changing practices and establishing dialogues to tailor policy interventions to the unfolding conditions of path creation. Nevertheless, these new networks do not necessarily reach social movements, who have in most cases built their networks with actors outside the STI domain.

Building prototypes and exploring new markets for biodiversity

The innovation call funded 12 projects in two main themes: developing new products from biodiversity and the sustainable extraction of new products from biodiversity. As in the R&D call, the UPTC participates and leads most of the projects. Doing so strengthens the university's technological capabilities around biodiversity and allows it to explore the market opportunities to exploit those capabilities and knowledge. Interviewee G2 commented: *"We accepted proposals with national actors, but, again, the regional organisation had to keep the leadership to assure they get transferred some technical capabilities get transferred by the end of the project."*. A similar amount (935,038.38 GBP) was awarded in this call, with national and regional actors as partners in the projects' execution. Interestingly, local associations are concentrated in the second theme, where market opportunities are expected to be identified more quickly in the short term. The convergence of proposals in this theme may also indicate that the narrative of biodiversity as a new pathway and the need for sustainable use of natural resources are appealing to a broader set of regional actors, even in traditional sectors such as agriculture. This can be seen as an initial sign of alignment of narratives and resource mobilisation across heterogeneous actors towards a more sustainable trajectory, led by the regional policy. Bearing in mind that the initiatives from the social movements have been left out due to legal impediments, a question that emerges is whether there will be opportunity for those initiatives to align and benefit from the regional policy and how this could be possible? Further research is needed in this point.

The government was aware of the need to change the institutional setting to support the new pathway. In doing so, the Departmental Assembly approved an institutional reform to create the Secretariat of Environment to provide autonomy

Table 5.8: Summary of Innovation projects approved by Boyacá BIO 2018 (Call 795-2017)

Theme	Projects approved	Leading institution	Funding (GBP)	Municipalities involved
Development of new products and processes from biodiversity with potential for biocommerce	5	Universidad de Boyacá UPTC (4)	390,506	Arcabuco
Development of products and processes with native species under sustainable process of extraction and production	7	* UPTC (5) Centro Regional para la Gesti'on para la productividad y la innovaci'on de Boyacá (CREPIB) * Fundación Universitaria Juan de Castellanos	544,531	Jenesano

for decision making and to put it at the same hierarchical level as secretariats of those of Planning, Mining and Agriculture. The adoption of a new policy directionality also triggers the need for adjustments to institutional domains and can create new channels of dialogue between new networks and actors involved in the experimental process and policy making. Institutional change has been considered a critical component in unrelated diversification (Boschma et al. 2017) because it legitimises the needs for change and materialises the opportunities for sectoral policy intervention, which would be unfeasible otherwise. Nevertheless, the EEG literature has not engaged further in questions about how policy and a new institutional settings can nurture and protect those initiatives in the practice. EEG literature has referred only to the three main processes of nurturing, shielding and empowering niches (Boschma et al. 2017, p. 37) but has not elaborated on how these processes look like in practical terms. In Boyacá's case, questions arise on the ways in which this new Secretariat can deploy further mechanisms to shield and nurture the ongoing experimental process and how it feeds into other areas to consolidate a new development pathway. Through the calls described earlier, the case study provides evidence of the initial stage of path creation, when institutional requirements are outlined, institutional changes attained and first policy interventions are made.

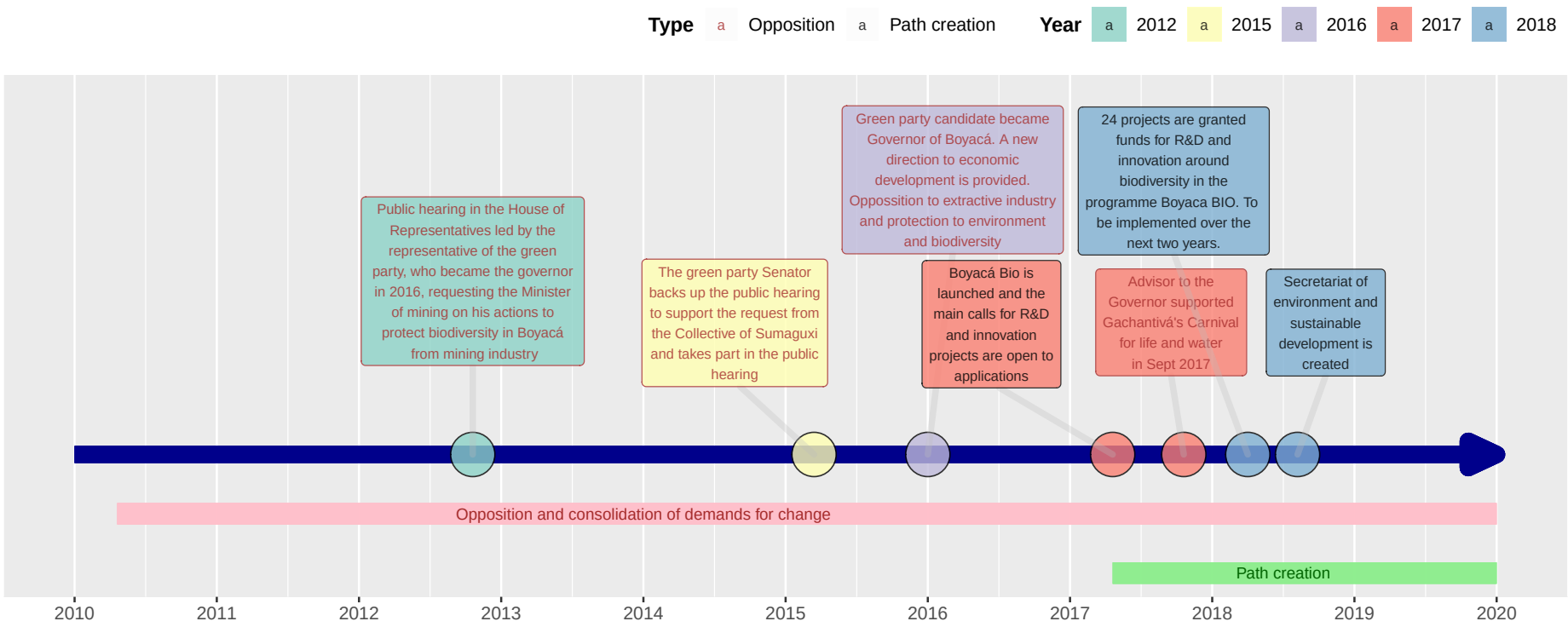

Figure 5.9: Policy actions contributing to new industry formation in Boyacá

It is still not entirely clear from the evidence how this new institutional setting is equipped and empowered to overcome the dominant regulations and practices in the STI system that could hamper experimentation in later stages of path development. For example, to what extent can regional institutions build enough agency to influence and/or adapt to the needs of the new pathways? And how can regional policy embrace initiatives from civil society, social movements and collectives, which have been under the radar due to weak or non-existent links with the STI system? The requirements for R&D and innovation calls in Colombia undermine inclusion, as highlighted by Interviewee S2: "We could not participate in Boyacá BIO's call due to its legal requirements, whereby social movements needed to be recognised actors of the STI system, with clear research fields, which is very unlikely for social movements in Boyacá. The university is still far away from the problems of the communities and social groups. The social movement does not trust Instituto Von Humboldt as it has partnered with MNC, so we doubt its objectivity. The institute is meant to protect biodiversity, but now in the search for alternatives to exploit natural resources."

5.5 The importance of alignment in the unfolding of unrelated diversification

Alignment constitutes the final category of analysis used to examine unrelated diversification in Boyacá. Previous sections analysed the drivers of industrial change and the bricolage action of social movements and policy, which represented the other two categories. The sectoral dynamics created by the interplay of MNC's vested interests and industry opposition movements triggered social demands for change, and put pressure on policymakers for a new direction, initiating industrial change. In this context, heterogeneous actors with distributed agency mobilised the necessary resources to create the conditions for new pathways of sustainable development. Several results came out of this regional process: a shared vision on sustainable development by regional actors and the policymakers, reflected in five initiatives developed by social movements and a new R&D and innovation agenda and its subsequent experiments led by Boyacá BIO. To support these alternatives, a new regional institutional setting has been

put in place. These findings manifest the complexity of the process of unrelated diversification. A final aspect to be addressed in this section, is the opportunities for alignment between these five alternatives emerging from Boyacá BIO and those put forward by the social movements. This section's purpose is to understand the opportunities for industry formation.

Some authors have looked at unrelated diversification and new pathways of diversification and have highlighted the coupling of bricolage and alignment in facilitating transitions and the rise of new industries (Garud & Karnøe 2003, Binz et al. 2016, Feyereisen et al. 2017, Suitner & Ecker 2020). However, more attention is needed to the underlying tensions between "competing" alternatives. New path creation has captured significant attention from the EEG as a way of addressing unrelated diversification. It has also been a point of confluence with the Geography of Transitions literature (Simmie 2012, Dawley 2014, Steen 2016, Carvalho & Vale 2018, MacKinnon et al. 2019, Hassink et al. 2019, Suitner & Ecker 2020, Trippl et al. 2020, Baumgartinger-Seiringer et al. 2021). This emergent literature has mainly focused on successful initiatives that do not face major contestation, and therefore consolidate rapidly through collective action and alignment across four main domains: knowledge generation, legitimacy, market formation and investment mobilisation (Binz et al. 2016, Garud & Karnøe 2003, Binz et al. 2016, Binz & Anadon 2018). Boyacá's case advances the understanding of path creation in an extractive industry context. It uses these four domains that have been proposed by the EEG literature and geography of transitions literature to show that, in this context, the process of path creation is contested and depends on technological and social factors. Therefore, it is necessary to incorporate other indicators to account for successful industry formation that put sustainability at the centre.

Figure 5.10 summarises five different initiatives aimed at alternative path creation undertaken by regional actors, including Boyacá BIO. Every social movement has mobilised the resources at hand to build a market prospect, with some initiatives more developed than others, exhibiting differentiated networks and strategies, as mentioned in Table 5.6. Sustainable tourism is one of the main pathways, that

beneficiates from some existing capabilities around tourism already present in the region, but that have not been upgraded to fulfil sustainable development. Although initiatives present variations because of the location of the natural resources. For example, the variety of ecosystems and nature landscapes makes eco-tourism the path to consolidate in Sugamuxi Province, whereas sustainable cultural tourism is the main route followed by Alto Ricaurte collective as it is already a well-established sector in this province. The civil society nature reserves collective has developed a more flexible approach with two potential economic activities: scientific tourism and eco-tourism on the one hand and ecosystem services on the other. This flexibility has been purposefully kept by the members of the Civil movement of Gachantivá as a mechanism to interact and explore partnerships with regional government and sectoral agencies. Another initiative exhibits more grassroots features with the development of eco-aldeas and seed banks by the Women of Puerto Boyacá group, supported by the Heinrich Böll Foundation (Germany). Finally, Boyacá BIO seeks to create the conditions for both the sustainable tourism trajectories and sustainable use of products and services from biodiversity.

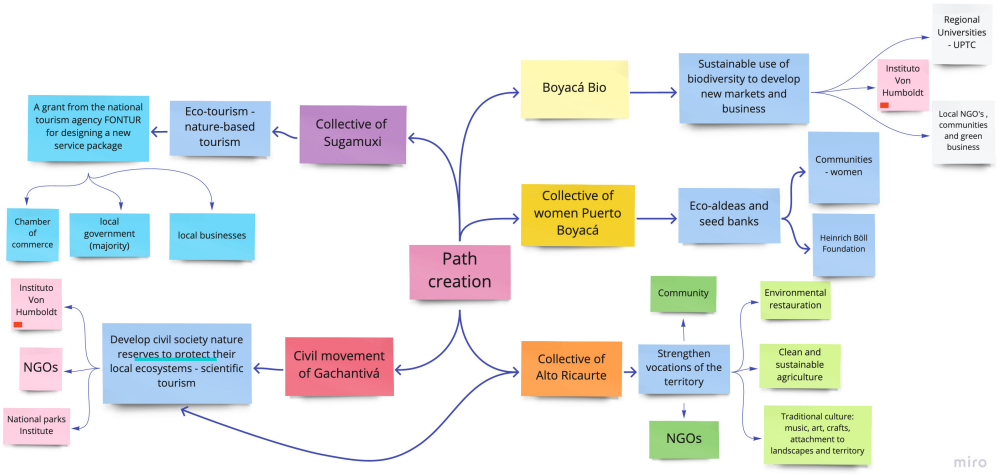

Figure 5.10: Alternatives in the process of unrelated diversification in Boyacá

As can be seen, these alternative have common elements, but the process of unrelated diversification is still unfolding. Table 5.9 depicts the areas in which these alternatives align and the opportunities for deepening collective action and policy intervention to strengthen new industries. The chance of a new industry emerging depends on the actors' capacity to align their expectations, resources

and to achieve collective action towards a new regional trajectory of development. In maturing these alternatives, some will remain small and local, such as the seed banks and eco-aldeas of the women of Puerto Boyacá. Others can develop and grow stronger, such as the eco-tourism in Sugamuxi, due to their strategy to develop deeper and broader networks, legitimacy and mobilisation of financial investment and partnering with regional business networks. Gachantiva collective (nature reserves) is closer to Boyacá BIO in the knowledge generation domain. This closeness can also facilitate financial investment for the civil society nature reserves initiative, which could benefit from strategies of market formation adopted by the regional government. In the case of Boyacá BIO, there is significant contestation from social movements responding to the bioprospection, financialisaton and marketisation of nature. These tensions reveal the contested nature of sustainable pathways and affect discussions of industry formation and growth.

Table 5.9: Alignment across different alternatives in Boyacá

Domain	**Collective of Sugamuxi**	**Women of Puerto Boyacá**	**Civil movement Gachantiva - nature reserves**	**Collective Alto Ricaurte**	**Boyacá BIO**
Legitimacy	+++ Support from local government and Alto Ricaurte Collective. Sceptical about Boyacá BIO.	Advocacy for conservation and opposition to marketisation of nature. Support from Alto Ricaurte. Critical view of Boyacá BIO	+++ Alignment with National, Regional and Local environmental authorities to support civil society nature reserves. Exploring partnership with regional government for scientific tourism. Support Boyacá BIO.	+ Local legitimacy around sustainable tourism and defence of nature. Critical view of Boyacá BIO.	++ Policy has inspired other regional governments to formulate their own regional bio-policies. Supported by local NGOs and emerging business and firms around ecosystem services. Supported by Instituto Von Humboldt and Civil Movement of Gachantivá.
Financial Investment	++ Grant from national and local government. Private Investments of local businesses.	Small grants from Heinrich Bóll Foundation.	++ Private funding for setting up civil society nature reserves. Resources from the Instituto Von Humboldt to undertake research. Private funding for setting up nurseries.	++ Private funding for strengthening existing local business. Private funding for training and expanding cultural offer of local businesses.	+++ Public resources from the Royalties Fund to sponsor regional calls by Boyacá BIO Public resources to fund complementary investments.

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Table 5.9: Alignment across different alternatives in Boyacá

Domain	**Collective of Sugamuxi**	**Women of Puerto Boyacá**	**Civil movement Gachantiva - nature reserves**	**Collective Alto Ricaurte**	**Boyacá BIO**
Knowledge generation	+ Community and business related know-how.	+ Indigenous knowledge and grassroots practices for knowledge sharing.	+++ R&D for characterisation of nature reserves and scientific tourism.	++ R&D for characterisation of nature, cultural & sustainable tourism.	+++ R&D for characterisation of nature and sustainable use of biodiversity through new business.
Market formation	+++ Alliances with Chamber of commerce, local hotels and industry-related business	Not interested in developing a market. Their vision is that nature is mainly for conservation and must not be marketed.	++ Partnering with National Parks to position ecosystem services out of civil society nature reserves Scientific tourism - bird watching	++ Local businesses	+++ Prototyping of new products from biodiversity Researching valuation methods for biodiversity and ecosystem services

end of table.

Despite the participation of social leaders in policy, their perception is that "there is little room for manoeuvring within public administration" (Interviewee S4). This perception draws the attention to the underlying tensions between social movements and regional government, and the limitations of policy action due to bureaucracy, existing institutional arrangements and economic pressures. This perception has roots in the institutional limitations which hinder a broader participation of regional social organisations in the design and implementation of STI policy (as explained in the previous section) and in the divergent approaches around the use of biodiversity. Diversity in the expectations and actions around the use of nature facilitates alignment between some social movements' and the regional policy. Therefore, some social movements' initiatives can be supported and favoured by the policymakers whereas others become excluded. For example, initiatives around bio-economy are closer to the government priorities than those initiatives that are more aligned to agroecology, promoted by national NGOs such as CENSAT Agua Viva and the Heinrich Bóll Foundation in the case of Women of Puerto Boyacá. The initiatives that are more relevant to the government's agenda, such as Gachantivá and the civil society nature reserves, are easily supported and integrated into the regional priorities and boosted through policy instruments. Such as the case of Gachantivá and the Civil Society Nature Reserves.

These tensions between the social movements and the regional policy transcend the policy domain to the knowledge generation domain. For example, there are tensions between social movements and Instituto Von Humboldt (R&D centre of biodiversity) around the alternative pathways and their underlying development principles. Regarding biocommerce, Interviewee S2 argues: "We, social movements, are concerned about the approach to ecosystems and green economy, because it may be the opportunity for business to take over nature and worsen the existing situation around unsustainable development. Similarly, we are worried about privatisation, R&D to discover new uses of biodiversity that will lead to new companies. We are sceptical about foreign researchers who are coming to research our ecosystems. They can patent and protect resources that we have not been able to study. Then the resources will be owned by the UK." It is the viewpoint of some social movements about the partnership between Instituto Von

Humboldt and Kew Gardens in the UK in BIO expeditions and the bioprospection theme included in Boyacá BIO.

Likewise, Interviewee R1 from Instituto Von Humboldt points out that: "Collectives have ideologies, take a side on politics, and they have strong positions that we do not see as constructive. The Institute's reason to join the civil society reserves is that it does not represent a political option but rather one of preservation and conservation of environment." He also argues: "We try to remain neutral in the demands from social movements, as we are in a grey area. As a research institute, we are not an environmental authority, but yes, we receive "rights to petitions" from social movements that require our technical concept on certain environmental disputes. We need to keep strategic. If we take a position on specific topics, it will have consequences in funding and projects availability. That is why I see the civil society nature reserves initiative as more appealing to us. We are 'legal'; the Institute's support is neutral. The initiative aims at environmental improvement, without politics involved, in contrast to other social movements and initiatives". This viewpoint is the same for the biology R&D group at UPTC: 'We do not work with social movements; we rather work with communities." Interviewee R2.

This approach mentioned by Interviewee R1 is closer to the government's, and, therefore, it can easily gain policy support. For example, there is an emergent initiative at Iguaque, in the Province of Gachantivá. In the words of the regional government, Interviewee G2: *"We are also working on structuring a proposal around scientific tourism, with the people from Iguaque, as they are very well organised and have taken steps forward. It would be excellent to implement it with the local people, and they provide the science to tourists".* This initiative is envisaged by Gachantivá collective, and reflects how the collective has moved from a radical opposition to mining towards the consolidation of nature reserves of civil society and scientific tourism to enable further opportunities to work and fit in the regional's government agenda.

These tensions around the use of biodiversity influence market formation dynamics and legitimacy. They can shape the scale of businesses and hinder

collective action, that hamper alignment in the market domain and, therefore, affect the initial stage of industry formation. Inclusion and removing existing institutional barriers that reduce social participation in R&D calls can be seen as mechanisms to embrace more variety in the sustainable use of biodiversity. To what extent the regional government manages to achieve alignment across those initiatives is part of what needs further research.

5.6 Conclusions

This chapter has answered the question of how unrelated diversification alternatives emerge in resource-based regions. It also aimed to extend the understanding of unrelated diversification provided by the EEG literature. The case of Boyacá elaborates on the drivers of industrial change, looking at the sectoral dynamics created by the interaction between civil society, in the form of industrial opposition movements, the mining industry and policy. The study of the drivers of change also casts some light on the difficulties of divesting R&D agendas away from mining, due to vested interests of MNCs in the extractive industry. These sectoral dynamics triggered social demands which in turn put pressure on regional policy bodies to provide a new direction to the STI agenda. This resulted in a new regional policy: Boyacá BIO.

The chapter explained how four social movements have adopted bricolage action to halt mining in their territories and to drive alternative pathways for sustainable development. Their collective action allows them to overcome their lack of technological capabilities in the field and to enable new forms of knowledge generation and skill formation through heterogeneous networks, including NGOs, communities and research centres. Alongside this process, the development of the regional policy agenda creates opportunities for exploring and experimenting with initiatives for the sustainable use of biodiversity. In reviewing alternatives and industry formation, it is found that sustainability brings in more complexities and challenges to the alignment across initiatives.

The analysis of the case of Boyacá undertaken in this chapter makes three main contributions to unrelated diversification in the literature of EEG. The first relates

to how the drivers of change form and unfold, coming from within the dominant sector, in the form of social movements and their collective action. This study highlights the wide spectrum of actors driving change, and provides a finer perspective of what "civil society" participation in sustainable development and regional diversification entails, and how it can shape the direction of diversification.

Another contribution lies in understanding the process of change and path creation. These results provide insights into the constructed nature of unrelated diversification, something that is still under-investigated by the EEG literature. The findings also highlight the importance of bricolage in realising change and materialising alternatives. EEG has only marginally engaged with the concepts of bricolage and alignment. The case brings to light how agency is formed and distributed across networks that facilitate resource mobilisation. In orchestrating unrelated diversification, policy plays an important role throughout, which brings one to the final contribution of the thesis.

The case study illustrates the role of policy in unrelated diversification. Policy appears essential to legitimise demands for change and to provide a new direction to R&D agendas. It plays a salient role in adjusting the institutional settings to create more favourable conditions for the emergent path. In supporting the emergent sector, government funding is crucial to mobilise resources and create additional capabilities. But policy support takes different forms at different stages of the process, including direct and indirect interventions, particularly as the process evolves from opposition to path creation. Within path creation, policy intervention is necessary to support experimentation and shield the emergent alternatives. More research on how policy continues to be implemented is needed to assess whether broader social participation and access to public funding of R&D activities is allowed, for example, for social movements. The current national institutional framework of STI, which sets the ground rules for accessing STI funding, impedes their involvement. This fact significantly limits the opportunities for alignment between alternatives and the subsequent process of industry formation.

Chapter 6

Discussion and contribution

This thesis has investigated how regional diversification comes about in a resource-dependent country, like Colombia. Economic diversification as commonly understood and measured, as a source of innovation and economic growth has occurred in very few regions of Colombia. These results question the relevance of diversification as an industrial strategy for most of the regions in the country. This thesis has made a case to the contrary, that regional diversification can, under certain conditions, represent an effective means of developing new industrial pathways for resource-dependent regions. But that implies re-thinking of concepts, particularly, unrelated diversification.

This research sought to understand the conditions under which these differentiated patterns of diversification emerged in the Colombian context. Following the argument of the EEG literature that regions tend to diversify into related industries (Frenken et al. 2007, Neffke & Boschma 2011), a first approach was to study the type of opportunities that development based on related diversification offer to a resource-dependent country. Increasing contestation and social demands for more sustainable development in regions highly reliant on extractive industries, led me to ask to what extent technological relatedness enables the adoption of some principles of sustainable development in those regions? In that case, technological relatedness would imply to continue within the trajectory of an unsustainable industry, that would deepen the negative effects of the extractive industries. Unrelated diversification appears more relevant for

this regions, as opportunities for sustainable alternatives could be conceived. How the process of unrelated diversification unfolds in this context, what are the actors driving the process and how resources are mobilised in the absence of technological capabilities are questions that guide this study. Only recently has sustainability begun to appear in the debate of regional diversification (Coenen & Truffer 2012, Patchell & Hayter 2013, Tödtling et al. 2020, Trippl et al. 2020), with scholars bridging literatures from the EEG and Sustainability Transitions to explain how sustainability is shaping regional diversification. This thesis provides some arguments and evidence on whether these regional sustainable alternatives could be an example of unrelated diversification.

This research agrees that related and unrelated diversification are useful lenses with which to understand how new regional development pathways emerge. However, the thesis also finds that, when applied to some processes of diversification such as divestment from mining or new sustainable pathways, the frame of analysis needs to incorporate important features associated with agency, policy and resource mobilisation to overcome constraining factors. Some authors in the EEG literature already highlight this gap (Boschma et al. 2017). This thesis advances that call and provides a framework by which studies of this nature can do this that include: drivers of change, determined by sectoral dynamics of change and social movements; new directions to the regional policy; bricolage and alignment. By paying particular attention to the constructed nature of unrelated diversification, this thesis develops the existing literature about how unrelated diversification takes place in a resource-based region and offers insights into the way sustainability principles can be introduced into processes of regional diversification.

The chapter is organised in six sections. It begins with a brief synthesis of the findings from Chapters 4 and 5 and a discussion of the opportunities offered by related and unrelated diversification to sustainable development. Section 2 reflects on the drivers of diversification. Section 3 elaborates on the need for a more inclusive approach to innovation and learning dynamics in the light of these new drivers. In forging new pathways of sustainable development, section 4 looks at

the processes of industry formation, emphasising the importance of sectoral political economy for the understanding of industry formation and diversification as well as the lack of alternative indicators to capture early dynamics of path creation and industry formation. Section 5 discusses how policy can facilitate the integration of sustainable principles in processes of regional diversification and create the conditions for the formation of sustainable pathways. Section 6 puts forward some propositions for a future research agenda.

6.1 Sustainable development and the alternatives offered by related and unrelated technological variety

Chapter 4 examined the extent to which technological relatedness has driven regional diversification and elaborated on the opportunities for sustainable development according to different levels of the technological variety in Colombian regions. The analysis measured diversity following the EEG method. A first finding builds on a typology of regions constructed on the basis on their levels of related variety. The first group is formed of five regions with the most advanced capital cities, whose diverse industrial bases and exports embody the country's highest levels of related variety. The second cluster consists of five intermediate regions exhibiting some degree of diversification (Herfindahl Hirschman HH indicators around 0.75, being 0 a diversified economy and 1 a concentrated economy) and related variety. This group follows a related diversification pathway, and is specialised in agricultural products - as shown by their regional exports - that have facilitated their insertion into the global market. A final group entails seventeen regions with the lowest levels of related variety. Here are included the smallest regions in economic size and those that are based on extractive economies. This last group has GDPs that are comparable to the size of the first group due to oil and mining exports. In the light of these results and a close reading of the literature it found that a number of authors suggest that regions facing serious challenges of sustainability such as those imposed by extractive industries can follow opportunities for alternative pathways through unrelated diversification strategies. As discussed in the literature review and chapters 4 and

5, this is quite different from high-skilled unrelated diversification discussed in some of the literature, principally in that it is a much more socially constructed processes. In this sense, although the conventional quantitative analysis described in chapter 4 allowed the thesis to gain an interesting take on the relationship between employment, growth and exports, and diversification in Colombia, it was the qualitative study of Boyacá that picked up on the hitherto unseen dynamics of diversification that, in my opinion, have remained in the shadows.

In terms of diversification, the first group entails the most diversified regions, with steady value-added growth levels throughout the period analysed. This value-added growth pattern is the same for the second group, despite their less diverse exports. For the third group, their levels of diversification are low, with HH indexes close to 1 and highly volatile value-added growth rates.

Another finding relates to the reduction of the related variety indexes for the advanced and middle-size economies during the period 2008-2018. The most diverse regions are the ones exhibiting the biggest reduction in their technological relatedness across industries and exports.

From the levels of unrelated variety, it is possible to distinguish the same three groups found for the analysis of related variety in Table 4.15 and Figure 4.16. Nevertheless, the first group exceeds the other two in greater proportion compared to what was found for related variety calculations. As in the case of related variety, there is a lessening of unrelated variety indexes, which confirms a lowering of the industrial and exports variety over the last two decades identified by OECD/UN/UNIDO (2019), while services have been taking over the economy.

The results confirm that regions with high levels of related variety tend to outperform in terms of GDP and value-added growth. Nevertheless, in the context of unsustainable pathways, this poses a problem because these industries create negative externalities and social problems, and therefore as discussed policy, efforts need to be directed towards industry transformation, change in direction, which overlaps with unrelated diversification agenda. How new directions can be introduced is central to the discussion and contribution of the thesis.

For the group 3, regional economies with low value added and low diversification, strategies of related variety appears to offer limited options to explore sustainable development, because, as discussed in Chapter 4, the absence of sources of innovation, lock-ins around the exploitation of natural resources and weak market dynamics that foster alternative entrepreneurial activity in these regions.

As argued earlier, a more promising approach to study the development of sustainability pathways in the light of scarce technological relatedness can be offered by analysis of patterns of unrelated diversification. This builds on the work of Boschma et al. (2017) and Steen (2016) around alternative pathways of development, that emphasise the difficulty of change due to regional lock-in, the role of bricolage to mobilise the necessary resources for enabling path creation, that are new to the region, and policy. EEG literature focusses on firms and institutional entrepreneurs as central actors creating the conditions for unrelated diversification to come about. Less attention has been paid to the role of civil society and social movements, who can be key players in this process. Chapter 5 found that opportunities for radical changes come from alternative forces, such as social movements opposing to existing industries, which are not necessarily technology-driven, but rather respond to local user demands for industry diversification underlined by different principles of social and ecological sustainability. In the case of resource-based regions, the agency generated by sectoral dynamics from the extractive industries, civil society and policy originate a new policy directionality that puts at the centre sustainability and mobilises a new set of actors who can engage in experimentation to unleash change and materialise alternatives for sustainable development and diversification. This chapter discusses how these findings converse with the existing literature from the EEG and the opportunities this raises to extend the analytical potential of this literature.

6.2 Drivers of diversification

Chapter 4 sets up the discussion of diversification around new development pathways allowing the incorporation of sustainability principles. Several factors

underpin the importance of linking questions of economic and environmental sustainability to regional diversification. Above all, regional disparities have reinforced social problems, such as exclusion and inequality, making Colombia one of the most unequal in the continent and worldwide (OECD/UN/UNIDO 2019). In the first group of regions, where the largest cities are found, environmental pollution, mobility problems and growing social unrest (Parkin 2021, Tobar, Vargas & Lombard 2021, Watch 2021, Turkewitz 2021) have become critical. For resource-based regions, their reliance on extractive industries has provided economic growth, but at high and for many unacceptable environmental costs. The intensive exploitation of mining resources in Colombia has produced negative externalities ranging from human displacement to massive loss of biodiversity and resource depletion (Garay 2013, Ruiz et al. 2018, Sánchez et al. 2019). Technological relatedness as a strategy of development extending the capabilities embodied in extractive industries, even if they were effective, are unlikely to suffice to address these negative effects. For example, between 7%-10% of the deforestation is related to legal mining in 2017, compared to a 1% in 2006 (González-González et al. 2021), population displacement and linkages between multinational mining activities and paramilitary forces to gain control of territories with high mining potential (Vicente et al. 2011, Ruiz et al. 2018) and 80% of the Human Right violations between 2001-2011 have occurred in energy-producing municipalities (Vicente et al. 2011). Moreover, lagged regions are often confronted with building sustainable pathways with local capabilities and resources "at hand", given their limited capacities and geographical isolation. Under such circumstances, a new direction to policy is needed to channel diversification efforts into sustainability. In doing so, it acknowledges that these issues will not be solved and overcome by consumer demand, market and conventional innovation dynamics. This is what transitions literature defines as policy "directionality" (Schot & Steinmueller 2018).

The above brings to the fore the discussion of drivers of industrial change in different contexts to discern processes of diversification underpinned by the dynamics of local actors seeking to unlock existing technological trajectories and overcome path dependencies. This thesis has argued that localised industries can

also be the root for transformative change and unrelated diversification. Existing industries may become incompatible with civil society's visions and aspirations towards sustainability, which can resonate with innovation policy steering its directionality to sustainable development.

This proposition suggests that the analytical framework offered by EEG could be extended to explain how new economic activities and technological change come about in both related and unrelated diversification in the context described above. According to the EEG literature, related diversification is driven by routine recombination, which drives learning and innovation and therefore, economic and technological change (Boschma & Martin 2007). This takes place through workers' mobility from one firm to another and entrepreneurial activity responding to market opportunities, resulting in new branches of related economic activities (Neffke & Boschma 2011). Firms interaction takes place in the market, where localised economies and industrial agglomeration characterise spatial configurations. This analysis provides a highly useful explanation of the dynamics of knowledge construction for new industrial activity. However, there appears to be a gap where the process occurs less through conventional market and market related forces (for example labour markets, finance and investment, research and development). And through other processes, such as the demands from civil society. This can come in the form of social movements, citizen movements and organised communities or from institutional or political pressure. This may impose limits to the branching process or alter its direction. Hence, demands from social actors also create opportunities and pressures for diversification. Previous studies (Sine & Lee 2009, Hess 2007) have investigated the role of social actors in the emergence of more sustainable industries, and some discussion of this process has begun within the EEG literature by for example Patchell & Hayter (2013) (Trippl et al. 2020) and recent efforts concerning path development (Coenen, Hansen & Rekers 2015, Binz et al. 2016, Boschma et al. 2017, Trippl et al. 2020, Tödtling et al. 2020). Nevertheless, the central interest has tended to be in the process of early industry formation, with the main assumptions regarding industrial change tending to remain unchallenged.

This discussion has evolved in this thesis through an exploration of the potential of unrelated diversification. Chapter 5 extended the understanding of the type of actors initiating change and the conditions under which new drivers of change emerge and consolidate in the absence of related technological capabilities. It explains how demands for change form outside the market domain and the way these demands influence regional STI policy. In this sense, an important contribution of this thesis is that, in addition to policy and institutional entrepreneurs, which the EEG literature argues are key drivers of unrelated diversification, this role can also be undertaken by the collective action of social actors through their networks and the impact of their actions on policy. This thesis argued that in the context of regions dominated by extractivist industries, this can enable the conditions for the building of alternative pathways of development.

Building on the EEG literature and extending this to embrace challenges from sustainability, the thesis embraces elements of sectoral political economy to understand the underlying tensions emerging from the interaction between firms and civil society. To do so, sustainability transitions provided a first entry to this discussion through the concept of socio technical regime, which allows an explanation of the geopolitical dynamics of extractive industries and the resistance to change due to strongly aligned components of the energy socio-technical system, which responds to the consumption patterns in the global north and sets up the conditions under which inputs to meet those energy demands are produced, for example, low cost oil and coal. It positions the analysis of economic diversification in a more complex domain interfacing market and societal dynamics. Sectoral political economy also acknowledges the difficulties of change, highly relevant for resource-based regions experiencing lock-in of science and technology agendas around extractive industries. The political economy of sectors illuminates the process of industry formation, relevant for those cases in which market power is concentrated in economic conglomerates. It has been a characteristic of industrial change in Latin America (Moncayo 2004). Therefore, this thesis enriches both the understanding of unrelated diversification and the adoption of principles of sustainability in related diversification by introducing

theoretical elements of sectoral political economy and empirically illustrating how to capture them through the concepts of constraining factors and vested interests.

6.2.1 Space and the configuration of new drivers of diversification

To fully incorporate sectoral dynamics into the diversification analysis requires a relational understanding of space to explain agency formation and non-technological drivers of diversification. Relational space makes it possible to acknowledge the fact that firms do not only interact with other firms in the market, but also with civil society and, this interaction takes place in a physical space, where environmental and social effects of extractivist industries become tangible. Negative externalities are experienced by communities and society (Bridge et al. 2013) creating relational responses calling for change.

EEG addresses space in terms of the localised conditions offered to industries that can shape their emergence and consolidation. Such perspective also reflects a relative understanding of space (Harvey 2006, Bridge et al. 2013), where regions have or do not have those advantages. This framing explains why deep path dependencies around extractive industries exist and narrows the prospects for alternative more sustainable pathways. Hassink et al. (2014) have advocated for the "multi-scalar interrelatedness and embeddedness of firms" to account for these interactions, calling for a pluralistic EEG. This call reflects in a rising strand of literature about Geography of Transitions to account for the relevance of place-based and relational dynamics of more radical industrial change (Coenen, Benneworth & Truffer 2012, Truffer & Coenen 2012, Coenen, Hansen & Rekers 2015, Binz et al. 2016, Hassink et al. 2019).

On the other hand, these localised dynamics are stimulated and legitimised by multi-scalar pressures and changes in the global landscape, such as the set up of the SDG agenda 2030. As a new global endeavour, it has met ongoing actions and encouraged new responses from communities and civil society all over the world, encouraging civil society and governments, mainly at the local scale, to take action to address sustainability problems (Truffer & Coenen 2012, Bridge et al.

2013).

A schematic representation of the process of unrelated diversification in Boyacá is presented in Figure 6.1. In the base, communities and social movements confront and halt strategic projects of the extractive industry, and create alternative pathways through bricolage. Through their collective action under bricolage, social movements and policy create the conditions for new pathways to emerge, although mining and these new alternatives co-exist and contest one another. In creating new pathways, social movements and their heterogeneous networks mobilise resources and capabilities to enable these alternatives. Figure 6.1 depicts the variety and differentiated sizes of these alternatives and highlights that not all receive support from policy.

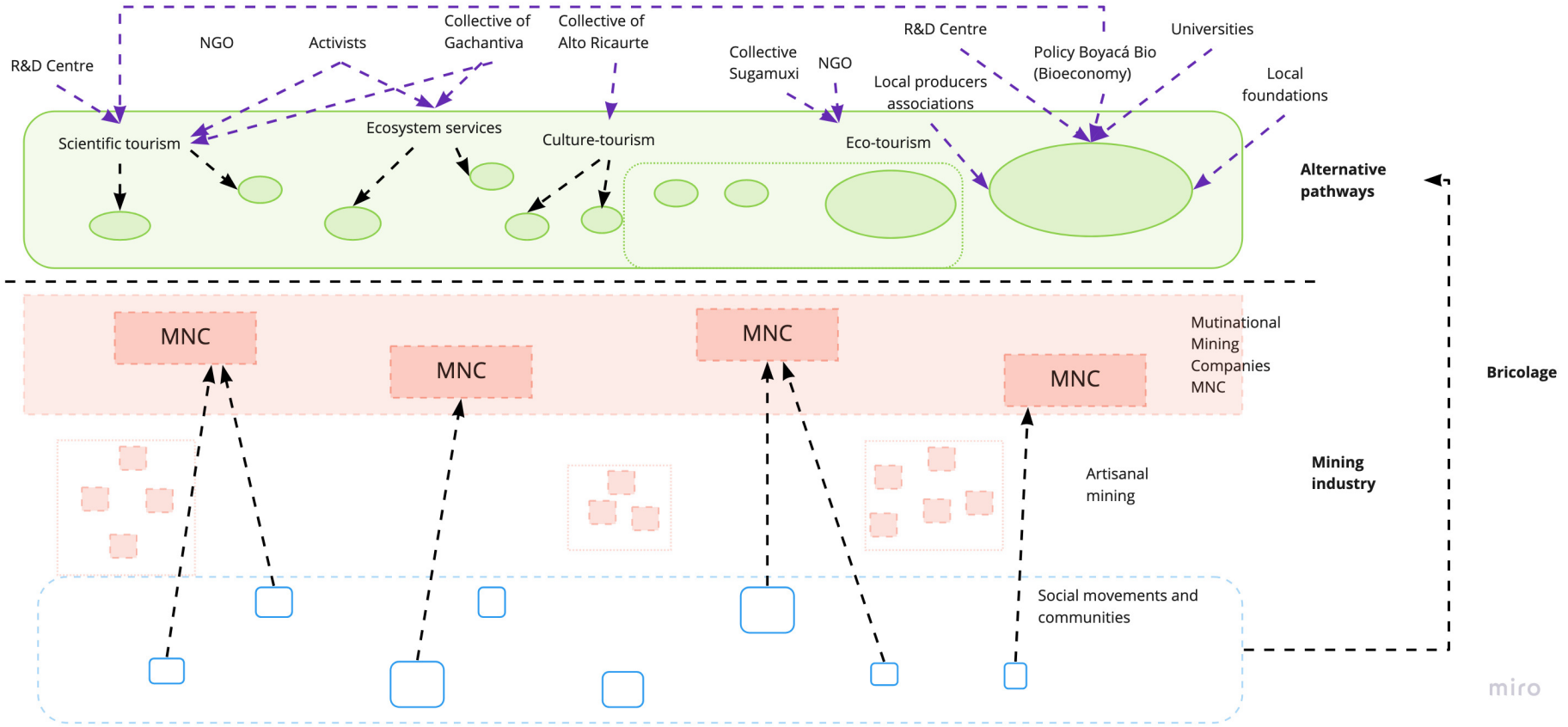

Figure 6.1: Unrelated diversification in Boyacá

To sum up, in the context of resource-based regions in the global south, drivers of diversification can also emerge from the local needs and challenges faced by the local population in close interaction with existing industries. These can create pressures that unrelated diversification (through for example sustainable tourism and agriculture) provides a more appropriate frame to understand this process, in which social actors and their demands can become the main drivers of economic and technological change. This turn marries economic and social aspects of diversification that also require revisiting the nature of the innovation and learning dynamics displayed by these new sets of actors involved.

6.3 Nature of innovation and learning dynamics

In resource-based regions where extractive industries are established, innovation dynamics are defined by their sectoral agenda and the financial resources they put into R&D activities, setting the direction of research and innovation. Chapter 5 discussed how such sectoral agency deepens path dependencies resulting in a STI lock-in. This situation becomes a constraining factor and creates obstacles to the emergence of alternative sustainable pathways of diversification. These pressures are generally not resolved by the market forces of demands. However, two complementary and, to a certain extent, contested ways of knowledge generation and innovation can be distinguished in this context. One is led by the regional policy which, in response to social demands, can enabling change by diverting the R&D agenda towards new sectors. An example of this was "Boyacá BIO", in which STI opens up a new development trajectory that incorporates principles of sustainable development, therefore defining a direction for development, out of several technological trajectories, inclusion, sustainable use of the natural resources amongst others. Boyacá BIO funded a new pipeline of R&D and innovation projects aimed at exploring alternative pathways around the Bioeconomy, bringing in new actors, initiatives and opportunities for research and innovation, seeking to explore the potential for a new industry formation. A second source of knowledge generation comes from the bricolage action of social actors, where distributed agency and resource mobilisation are key to leveraging the skills and knowledge required to pave the way for alternative development

routes. As knowledge is not in place or is fragmented, social actors and their linkages to less conventional actors, such as NGOs, play an important role in facilitating new skills formation and learning. Learning and innovation in this context are relational, situated and reflexive, which highlights the importance of place-based elements, social actors and their bricolage action, as well as the role of reflexive learning in enabling a new collective vision around sustainable development and opening up new forms of learning and knowledge transfer.

In creating sustainable pathways of diversification in resource-based regions, learning dynamics and innovation are more complex and require a more deliberative, socially constructed and inclusive perspective that acknowledges the agency of social actors and their networks. Policy and social actors demonstrate a wider engagement with diverse actors, for example, communities, associations of small producers, NGOs and local foundations with strong local ties that are situated, whose shared agendas can feed into the process of new path creation. This variety of actors also implies variegated types of knowledge, such as indigenous, place-based, analytic and symbolic knowledge used resourcefully through bricolage. Moreover, learning becomes more holistic, involving technology at some point. These practices support the formation of a collective vision and action. This perspective extends the usual process of knowledge generation proposed by EEG either in the branching process of related diversification or examples of new path development and unrelated diversification mainly explained in terms of transplantation – the development of new unrelated industries (Binz & Anadon 2018) and anchoring (Binz et al. 2016). Although in some of them a similar process of resource mobilisation has been outlined, the role of civil society has not been developed and the inclusive nature of the process is not sufficiently analysed or problematised. The reflexive learning that challenges existing unsustainable industries and its underlying effects is overlooked because learning is framed in terms of firms and market dynamics.

Another contribution discussed by this thesis is that knowledge generation and innovation dynamics in this context are not circumscribed just by market opportunities, but rather are considered through a relational perspective and

linked to place-based necessities and challenges, thereby fostering wider responses and participation from diverse actors. EEG sees formal institutions such as research centres, universities, training centres and firms as the main places where new knowledge is generated, and innovation comes about. However, in the light of disparate knowledge bases from these diverse actors, learning can also be underpinned by highly creative forms of knowledge conveyance, to overcome barriers such as illiteracy and the civil society's lack of sectoral knowledge. These creative forms of knowledge transfer and learning that may also serve the purpose of strengthening social bonds and building shared identities to envisage and materialise collective visions and action. Such dynamics are well captured in the concept of bricolage, where actors "make do with what is at hand", in contrast to the innovation responding exclusively to market opportunities.

These more inclusive and idiosyncratic learning dynamics defy traditional policy approaches, instruments and regulations related to the funding of STI activities. To allow wider participation, actors beyond the STI sphere need recognition and agency, to be able to propose, lead and participate in STI bids with projects and experiments that can nurture alternatives and entrepreneurial activity for diversification. Although in the case of Boyacá, national STI funding regulations prevented social actors from participating in its calls for proposals, their bricolage action overcame it by leveraging funding from international NGOs and sectoral programmes from the industry and Ministry of commerce, industry and tourism. The above is a clear example of the need for institutional change in processes of industry formation in unrelated diversification.

6.4 Agency and industry formation

Chapter 5 emphasises the process by which change is enabled and the ground is prepared for new path emergence, based on the care and sustainable use of biodiversity, as an alternative to mining. Three main stages are highlighted in this process according to the actions of the collectives of Sugamuxi and Gachantivá: opposition stage, path creation and path emergence. These two social movements alternatives exhibit stronger elements of industry formation, compared to the

other two collectives analysed, because of their actions to influence policy (at the local and regional level) and progress on developing a market for their alternatives. In a similar line, Boyacá BIO presents policy actions to promote research and development, product innovation, prototyping and market development around biodiversity, but compared to social movements' process, the execution of Boyacá BIO and the bioeconomy sector it seeks to create, is still in the stage of path creation, as there is not yet a network of actors providing services and a market emerging, as for collectives of Gachantivá and Sugamuxi. The discussion centres on two main aspects of industry formation. First, the intricate dynamics and inherent tensions and contestation that characterise a resource-based industry, in this case, between mining and the emergent sustainable pathways. Second, how bricolage features evolve over the three stages. How these factors shape agency to facilitate or block industry formation is discussed in this section.

The literature of EEG has outlined path creation and path emergence (Dawley 2014, Binz et al. 2016, Steen 2016, Baumgartinger-Seiringer et al. 2021) as the initial stages of industry formation for paths unrelated to the existing local industry. These processes are driven my market dynamics and highlight the importance of alignment in four main domains, market, financial investments, legitimacy and knowledge generation. For regions facing acute sustainability challenges (perhaps not just in the Global South), the discussion can add an "opposition" or "contestation" stage, to account for the response and at times conflict and social process that drives change. Chapter 5 presented the support and interaction between the collective action of social movements and policy during the opposition stage and how Boyacá BIO emerges as a response to these actions and to create more favourable conditions for path creation that could also benefit those pathways already undertaken by these social movements.

Creating a new development pathway based on the use of natural resources encompasses continuous contestation between mining and sustainable alternatives and even between sustainable alternatives themselves, as discussed in the previous chapter. These tensions become more visible where institutional and legal settings

are susceptible to vested interests, which can easily co-opt enforcement agencies and control bodies, as shown in the case of Boyacá. In this context, the conflicting and intertwined nature of opposition and path creation has implications for the understanding of regional diversification. It makes it more difficult to draw a line between the stages of opposition to the extractive industry and path creation as the processes overlap and feed one another. For example, the adoption of the legal figure of Civil Society Nature Reserves serves the purpose of "shielding" biodiversity in surrounding areas where mining titles can be granted or have already been granted. Moreover, it enables opportunities for new scientific and economic activities around the protection and care of nature as illustrated in Chapter 5.

Contestation is partially addressed by EEG in the recent literature on green diversification and the concept of alignment, particularly in the "legitimacy" domain. But this is analysed in terms of market and users' acceptance rather than in the control over the natural resources which is central to industry formation dynamics. Hence, EEG framework for understanding unrelated diversification needs careful consideration of the underlying sectoral and spatial nuances entailed in path creation across different contexts and industries which appear barely debated in the cases suggesting stage-models of diversification (Dawley 2014, MacKinnon et al. 2019, Baumgartinger-Seiringer et al. 2021). The contribution of this thesis in the understanding of contestation and opposition is twofold. On the one hand, it offers a more granular insight into contestation in processes of sustainable regional diversification in this context. As elements of bricolage play out during the opposition stage, a contribution is made in terms of the explanation on how it builds on the bricolage action of heterogenous actors. Thus, this research enriches the knowledge on new path creation dynamics in highly contested industries.

Likewise, important sectoral political interests in Colombia shore up activity that relies on exploitation in natural resources. Industrial diversification in Colombia is characterised by vertical integration and consolidation of economic conglomerates owned by powerful economic groups that have also political power to influence

policy at their convenience (Moncayo 2004, Helmsing 1990). Some of these groups have already shown interest in nature reserves to exploit them through commercial tourism. This places significant threats to just and sustainable market configurations, as well as diversification efforts pursued by social actors. Given the early stage of these emergent initiatives, vested interest and powerful actors can easily suffocate attempts of social actors to bring about sustainable regional diversification. As shown in Chapter 5, in the case of the Collective of Alto Ricaurte, continuous monitoring of big commercial platforms and economic groups seeking to establish branches of their business in their municipality contributed to banning a commercial project that could hamper small local businesses in Villa de Leyva, one of the most important tourist destinations in Colombia, struggling to keep tourism at sustainable levels.

This thesis also enriches the understanding of bricolage in terms of its role in the process of unrelated diversification. Contributions made by empirical cases to the transitions literature (Faulconbridge 2013, Feyereisen et al. 2017) have pointed out the strategic nature of bricolage. The Boyacá case provides a broader understanding of bricolage, following Karnøe & Garud (2012*b*), in the context of resource-based regions in the Global South.

This thesis offers a perspective of bricolage underpinning the entire process of change, from opposition to path emergence characterising the social response to the lack of resources and agency faced by social movements. In the initial stage, social movements' bricolage action is more contingent, responding to threats and utilising legal tools to protect their ecosystems and ban the dominant industry. In the stage of path creation, it becomes more strategic, broadening their networks and liaising with government institutions that allow them to leverage enough agency to achieve the institutional changes needed for their alternatives. In this way, collectives craft alternatives through small changes enabling more benevolent conditions for industry formation. For example, the Collective of Sugamuxi leveraged multi-scalar support combining resources from the central government and local government, setting up a new agenda around eco-tourism. Whereas the Collective of Gachantivá strategically adjusts its activities to benefit from the

regional policy, adopting existing legal mechanisms to consolidate its agency to gain control over the natural resources and influence local policy decision making, through new legal mechanisms such as the Cabildo. These two different ways of opening up avenues for sustainable diversification highlight the idiosyncratic and relational character of diversification, where a distributed agency is key to allow room for strategic action from different actors, including policy. These results contrast with emerging literature on path creation where the role of institutional entrepreneurs is conceived as the drivers of institutional change fulfilling the needs of local actors to facilitate path creation as argued by MacKinnon et al. (2019).

A synthesis of the process of bricolage is drawn in Figure 6.2. Bricolage is characterised by networks of heterogeneous actors who create new narratives and mobilise resources to overcome their existing limitations. At actors adopt a "make do with what is at hand" approach, creativity and experimentation are two key features of their collective action that enhances learning and network formation. This collective action builds agency as resources are mobilised, and collective narratives consolidate to create a new resource environment that enables alternative pathways emerging. As the process builds up and gains momentum, conditions for unrelated diversification emerge and consolidate.

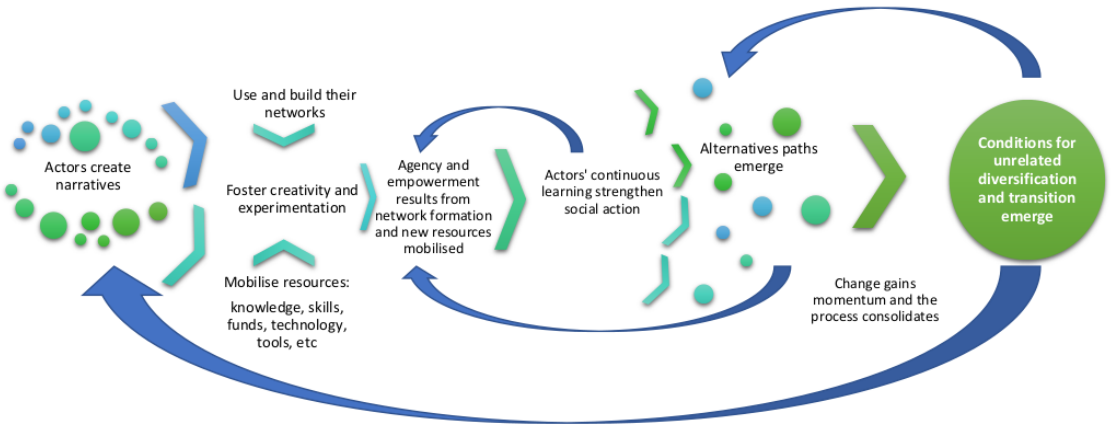

Figure 6.2: A schematic definition of bricolage for unrelated diversification and path creation

A final point of discussion addresses how a sustainability agenda can impose limits on conventional process of industry formation. In the context discussed in the

thesis, sustainability strategies challenge industry's growth patterns. Some alternatives may wish to remain local and do not develop to become a new industry, like the case of Collective Alto Ricaurte and its cultural eco-tourism initiative. Its grassroot nature implies that market dynamics do not take over the sense of community and its internal dynamics. When diversification is driven by principles based on environmental and social sustainability principles, new forms of organisation and market formation appear in which social justice is pivotal, such as community businesses, not-for-profit organisations and associations and short value chains. These forms of organisation include collective forms of ownership and business based on shared responsibilities may be more likely to emerge to ensure fairer distribution of economic benefits. Consequently, formal industry may not be reflected entirely by the number of new firms created. The case of the Civil Society Nature Reserves constitutes a good example, because each reserve can provide ecosystem services or take part on a tourism route without becoming a new company. The provision of the services may lead to the set up of an business and therefore a company consisting of several nature reserves. In caring for the environment, fast growth is not necessarily prioritised to avoid extensive use of resources. Policy can play a prominent role in preparing the ground for changes in processes of industry formation and fostering new indicators that can capture these emerging dynamics of diversification.

6.5 The role of policy and its implications for policymaking

In Boyacá, policy played different but pivotal roles in the process of unrelated diversification. First, public policy has played a role legitimising opposition of social movements to mining industry, by facilitating the conditions and supporting social movements in substantiating their demands for change. As referred in Chapter 5, the regional policy put at service of social collectives legal support and lawyers to undertake legal actions, to overcome the lack of legal knowledge. Moreover, public policy provided visibility and mobilised media to call the public's attention to these causes. Those actions are clear examples of shielding and legitimisation, as highlighted in sustainability transitions perspectives, represented

in a new directionality and the spirit of change through actions against MNCs and the national government. This constituted a significant new direction for the regional STI agenda and towards the conservation of natural resources. Such synchrony is relational and builds on broad and deep networks that are locally embedded, who share expectations and visions about sustainable development. That is what makes it possible to translate these social demands into policy action. This is evident in the opposition stage but becomes contested as policy defines its agenda around the bioeconomy and mechanisms for continuous social participation do not evolve accordingly.

Policy prepares the ground for experimentation around alternative uses of biodiversity signalling a new route and making funding available for exploring new knowledge, technologies and commercial opportunities around biodiversity, initiating a path creation stage, in which more alternatives arise in response to these policy instruments. As discussed in Chapter 5, some of these initiatives may align with those developed by social movements. How they evolve to consolidate a new industry is framed around four key factors, knowledge generation, market formation, legitimacy and financial investment, as elaborated in Chapter 5, following the method proposed by EEG and geography of transitions literature (Binz et al. 2016, Boschma et al. 2017). Due to alignment across different initiatives undertaken by social movements and the policy around a sustainable development vision, legitimacy is more easily achieved. Although tensions persist regarding the marketisation of nature, the policy can create spaces for dialogue around different options and facilitate experimentation that can provide insights into the limits of sustainable use of biodiversity. These could be done by funding activities of nature reserves and Sugamuxi to allow growth and consolidation but keeping close monitoring of the effects on natural ecosystem dynamics. For nature reserves and scientific tourism, finance mobilisation appears as a barrier, therefore, the policy can offer stage-gate funding, joint ventures and guarantors mechanisms to fulfil their investment needs. To facilitate deeper alignment across initiatives, close interaction and channels of communication are required to re-establish synchrony and collective action.

But collective action along with different forms of intervention at different stages becomes a real challenge to policymaking, where standard interventions in the form of funding dominate policy agenda. To fully support the process of path creation and generation, elements of niche formation and institutionalisation from the transitions literature (Ghosh, Kivimaa, Ramirez, Schot & Torrens 2021) could enrich the analysis provided by EEG literature in the process of unrelated diversification, particularly at industry formation. Interventions in the form of experimental engagements (Schot, Kivimaa & Torrens 2019) can open up the policy perspective to more varied and effective forms of support to sustainable development. This means further coordination between government areas to put into place policy instruments aimed at facilitating entrepreneurial activity, funding, visibility, networking and learning. As well as interactions with key actors involved in the process of path creation to tune instruments, spaces and resources to consolidate path generation and industry formation.

This thesis enriches the existing literature of EEG and sustainability transitions by providing evidence on how policy can be part of a collective action opening up alternatives for more radical change eventually leading to more systemic change. In the context of resource-based regions, unrelated diversification encompasses a new development pathway that requires new institutional settings, industries, markets, values, knowledge and users, which appear and consolidate as the alternative pathways come about. Such understanding is still embryonic in the EEG and more developed in the literature of Geography of Transitions and Sustainability Transitions (Coenen & Truffer 2012, Coenen et al. 2012, Coenen, Hansen & Rekers 2015, Binz et al. 2016).

6.6 Methodological contribution

This research adopted a mixed method to address the complexity of highly disparate regions and embrace the challenges imposed by sustainable development in a resource-based country. The methodological approach responds to the call for more mixed methods in the analysis of regional diversification in the EEG literature (Binz et al. 2016, Boschma et al. 2017), particularly in the light of

sustainable development. There are three main areas within which the thesis' methodological approach contributes. First, the sequential research design sheds some light on how to expand on the use of analytical frameworks such as the EEG in other contexts, and assess their advantages and disadvantages accordingly. The combination of qualitative and quantitative analysis widens the audience of this research including policymakers, NGOs, social movements and civil society, apart from the natural audience of the research community, for whom this thesis provides practical recommendations in the above sections. Finally, this approach also enabled this research to bridge the bodies of literature on the EEG and the geography of transitions, which constitute a relevant contribution to their research agendas.

6.7 Future research

Forging alternative sustainable pathways of development in the Global South is an emerging topic. The work of the EEG literature on processes of path creation and geography of transitions on new sustainability pathways in the Global North context has begun to approach questions of industry diversification and in particular the concept of unrelated diversification from new perspectives. More research in the policy domain is required to reveal how new spaces for experimental engagement with social actors are designed to facilitate the alignment across knowledge generation, market formation, investment mobilisation and legitimacy that can realise a new industry and development pathway. Much of the current research focuses mainly on the interplay between firms, policy and STI actors. However, in the global south in particular (though not exclusively) more efforts should be devoted to understanding (and developing indicators to trace) path creation and industry formation that emerge from new forms of social organisation, sustainable environmental practices and economic progress. Particularly, indicators to account for the initial process of path creation and capture learning dynamics that tend to be more reflexive at this stage, and involve a wider variety of actors, like new users, communities, etc., which are not normally considered under conventional measures of entrepreneurial activity such as income or new products/services/firms. How these processes unfold and the

policy contribution to it also demands further consideration, to fully understand distributed agency and its influence on networks formation and policymaking. Finally, the multi-scalar aspect of unrelated diversification also deserves deeper understanding, especially in resource-based regions seeking sustainable development, as social actors integrate into global trends and networks to leverage agency, resources and legitimacy for their local strategies of path creation.

Chapter 7

Conclusion

This thesis investigated how sustainable pathways of diversification emerge in resource-based countries. The research focused on the case of Colombia and sought to explain the existence of differentiated patterns of diversification across regions based on their industrial bases. In the context of disparate regions and high dependence on natural resources, this question brings together two outstanding issues in the Global South: sustainable development and the emergence of new sources of economic development. The EEG literature has provided a useful framework to address this question, helping to explain how these patterns respond to localised learning and innovation dynamics. This body of literature offers two useful ways to approach diversification based on technological innovation: related and unrelated variety. The literature argues that regions tend to diversify into technology-related sectors as technological and geographical proximity of the industrial sectors based in the region facilitate learning and innovation.

Recently, EEG has begun to focus more on unrelated variety as an alternative process by which new routes of diversification emerge. These routes are crafted by firms and institutional entrepreneurs and, in some cases, civil society, who overcome existing constraining factors for more transformative change. Unrelated diversification incorporates some elements of transitions literature, such as the concept of regime, to account for the resistance to change, and path creation. This thesis is situated in the interface of regional diversification theory and geography

of transitions literature. Related and unrelated variety provide the theoretical scaffolding to address Colombian regions and the different paths followed by them, which have created very distinctive outcomes. This theoretical framework is stretched by the incorporation of further elements from geography of transitions literature, including bricolage and alignment. Five subsequent questions guided this research to investigate what type of opportunities development based on related and unrelated regional diversification can offer to a resource-based country with highly disparate regions, and, secondly, to what extent technological relatedness and unrelatedness enable the adoption of principles of sustainable development in resource-based regions. These two questions are addressed in chapter 4. Three more questions relate to the nature of unrelated diversification. First, how do unrelated diversification alternatives emerge in resource-based regions? Second, how does bricolage help build agency and mobilise resources in this context? Third, under what conditions might unrelated diversification paths create opportunities for sustainable development. These questions guided the analysis of Chapter 5.

The analysis of related and unrelated diversification utilise distinctive research methods: a quantitative method for the former and a qualitative one for the latter. This thesis adopted a mixed method approach to respond the main and subsequent questions and to fully capture the complexities of Colombian regions: differentiated pathways and processes that characterise their varied technological and social contexts. The analysis followed a sequential methodology that started with the quantitative analysis that generated first insights into the general conditions of Colombia in terms of related variety, and posed questions about the alternatives available to resource-based regions. The quantitative analysis was carried out for 28 regions for the period 2008-2017 using two main methods to calculate relatedness — hierarchical (conventional) and proximity, as explained in chapter 3.

In the light of these results, together with insights provided by the EEG literature about unrelated diversification, the thesis began to explore the societal demands of communities in Boyacá which demonstrated against mining projects in their

region. These demonstrations were part of a general strategy of regional actors demanding sustainable development pathways and opposing mining. The protests and demands in Boyacá fed into this research and opened a new perspective, bringing a rich case study that followed the earlier analysis. Semi-structured interviews with twelve regional and national actors (social movements leaders, policy-makers, researchers, NGOs) and primary data from public funding calls derived from the regional policy of Boyacá BIO provided the inputs for the qualitative analysis that composes Chapter 5.

The evidence obtained from this sequential research design was, in the first instance, a typology of regions whose differentiated patterns of diversification responded to distinctive levels of related variety. The typology comprises three groups: group 1, 2 and 3, with high, medium and low levels of related variety accordingly. Each group exhibits an idiosyncratic industrial base, although for Group 2 and 3 their exports demonstrate their dependence on natural resources, with more than 70% of their exports concentrated in these industries. A final result derived from this quantitative study was that the regional levels of related variety have reduced countrywide for the period of analysis. This decrease in variety highlights the importance of the main research question of this thesis, as new sources of sustainable development need further investigation and understanding to provide insights for policymaking.

The case study evidenced the role of civil society, particularly social movements, in generating demands for change and enabling alternative pathways of diversification through their bricolage action. The increasing tensions between communities and social movements and the mining sector gave rise to pressure for change and the consolidation of these demands. These local demands triggered a new direction in regional STI policy towards sustainable development, which banned some important mining projects granted by the national government in regional strategic ecosystems. The confluence of these heterogeneous actors created opportunities for localised learning and new knowledge generation around the sustainable use of natural resources and against mining. However, these alternative and diverse approaches to the use of natural resources are contested

permanently. This reduces the chances of alignment between the local initiatives put forward by the social movements and those supported by the regional policy. At this point, institutional settings and existing STI regulations can accentuate these tensions and contestation. Finally, the actions of two social movements revealed three different stages that account for different processes in industry formation in this context: opposition, path creation, and path emergence. Given the fact that mining and the sustainable use of natural resources are contested paths, opposition overlaps with the other two stages.

Based on the evidence collected by this research, it is possible to conclude that sustainable pathways of diversification in resource-based countries respond to spatial configurations of heterogeneous actors that can be enabled by related and unrelated variety. However, unrelated variety offers a more appropriate alternative for those resource-based regions, where sustainable pathways can be crafted by local actors, their networks and the agency they build to mobilise resources and materialise these pathways. In the case of pathways underpinned by related variety, the endogenous market and innovation dynamics impose limits to incorporate principles of sustainable development. This is due to industrial regimes and their highly aligned components. To overcome these barriers, policy and agency from a wider range of actors are required to enact underlying system changes in order to achieve sustainable development. These new system configurations are spatially defined and relational. In creating related and unrelated pathways, the role of policy is crucial in signalling and providing a new direction towards sustainability, as deviation from path dependencies is difficult otherwise. A new policy direction legitimises alternatives and creates opportunities for experimentation and the further engagement of actors from different domains. Moreover, the process of path creation towards sustainable development is characterised by tensions and uncertainties that require support from policy.

This thesis contributes to the understanding of regional diversification in resource-based countries in the light of sustainable development. The EEG literature has focused mainly in the Global North and has recently bridged some

concepts from the geography of transitions literature with interest in understanding how regions are increasingly marrying sustainable development and diversification efforts using unrelated diversification and new path creation as devices of analysis. Three main contributions are made by this thesis to these two bodies of literature. First is around the drivers of diversification, which, in resource-based regions, may not be just technology-driven, but rather a response to alternative forces, such as social movements opposing existing industries. Existing industries may become incompatible with civil society's visions and aspirations towards sustainability. These views can resonate with innovation policy, thereby steering its directionality to sustainable development. These tensions are best explained by political economy, as actors and forces beyond conventional market and innovation dynamics can influence innovation dynamics and industry formation. In this line, this thesis unveils the role of civil society and the forms it takes in creating demands for change and driving alternatives for sustainable development. Transitions literature has invoked the inclusion of civil society as a relevant actor in initiating change but it has not been clearly articulated what this entails or how civil society engagement bring about industrial change in this context. Efforts in this sense have been made by the science, technology and society strand of literature, which considers industry oppositions movements and 'undone science'. The hope is that, this thesis has enriched both the understanding of unrelated diversification and the adoption of principles of sustainability in related diversification. It has done so by introducing theoretical elements of sectoral political economy and empirically illustrating how civil society responds to constraining factors and vested interests and uses them to build agency and drive regional change.

The configuration of these new drivers is relational and spatially defined. This is crucial in the understanding of agency formation and the sectoral dynamics created by the interaction between civil society and unsustainable sectors in resource-based regions. Moreover, space shapes learning and innovation dynamics, by making them socially constructed and inclusive. Thus, learning results from the engagement of different actors and their variegated types of knowledge that are resourcefully used through bricolage to address local problems. This process is

what enables the formation of a collective vision and action that initiates change. It sheds light on forms of knowledge generation that are not driven by technology and the market, and thus differ from the EEG's current perspective. As mentioned above, this broader approach to learning and knowledge generation affects industry formation and acknowledges the agency and capacity of social actors to mobilise resources and overcome lack of capabilities.

There is a question of agency and industry formation and the role of policy. In the context of sustainable diversification in resource-dependent regions, contestation is an inherent factor. Thus, opposition phase — when sustainable alternatives oppose and advocates for phasing out the unsustainable ones, it overlaps processes of path creation and emergence. This is because the use and control of natural resources, either by mining industries or big economic groups to exploit them — as in tourism, can threaten and bypass sustainability principles as market and business interests grow. Therefore, civil society and the actors involved in sustainable alternatives are continuously vigilant to unsustainable practices that can threaten their territories, while trying to develop their own pathways. This is particularly relevant in the context of large economic groups and patterns of diversification driven by practices of vertical integration by economic conglomerates. As their interests and agency can also destroy the efforts of social actors for creating alternatives for sustainable development. This situation justifies policy intervention. A final point constitutes a deeper understanding of bricolage action. This concept has become more used in the transitions literature and is considered from different angles, for example, its strategic character or resourceful nature. This thesis showed that bricolage is present throughout the three stages: opposition, path creation and path emergence, and makes it possible to overcome the lack of resources and capabilities faced by regional actors. Networks formation and resource mobilisation are central in enabling learning and knowledge generation, thus supporting opposition actions and also path creation. This understanding enriches the approach of bricolage.

Finally, this thesis has provided some policy insights and corresponding policy implications. In the first place, policy plays an important role in providing

legitimacy to demands for change. A central argument made by this thesis is that policy is not the driver of the process. Instead, its intervention comes as a result of the demands from social actors. In legitimising these demands, policy can also signal a new direction for R&D agendas and innovation. Policy can shield nascent initiatives aimed at diversification and facilitate the conditions for experimentation. Such interventions are crucial in the context of vested interests and highly contested processes. Moreover, policy can be part of collective action through interactive processes of resource mobilisation, institutional change and policy incentives. These combinations and the use of new forms of policy intervention constitute an important topic for future research on the creation of sustainable pathways of diversification in resource-based countries.

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Appendix A

Code listings

A.1 R code to calculate HH indexes for regional export and employment

Listing A.1: Code to calculate HH indexes for regional export and employment

```
#!/mnt/ebinstall/software/R/3.5.1-foss-2018b/bin/Rscript
#
# Code to calculate the Herfindahl-Hirschmann index for regional
# exports and employment
#
# Author:  Claudia Elizabeth Obando Rodriguez
#
# usage:
#
# ./Regional_diversification-cl.R
#
library(ggplot2)
library(anytime)
library(Hmisc)
library(reshape)
library(dplyr)


# Calculating HH for regional exports
file = "products_department-2008-2017.csv"
C <- read.csv(file, header = TRUE, sep = ",")

DF <- as.data.frame.matrix(C)

DF$product_name_es <- NULL
DF["HS92_1"] <- floor(DF["product_code"]/1000)
DF["HS92_2"] <- floor(DF["product_code"]/100)


DF <- filter(DF, export_value >0)

sx_agg <- as.data.frame(aggregate(list(export_value=DF$export_value),
                                  by=list(location_code=DF$location_code,location_name=
                                      DF$location_name,
                                          year=DF$year,HS92_2=DF$HS92_2),
                                  FUN = sum))


columns = c("year", "location_code")
sx_agg <- sx_agg %>% group_by_(.dots= columns) %>%
  mutate(reg_xs= sum(export_value))

```

```
head(sx_agg)
sx_agg <- sx_agg %>% mutate(Si=export_value/reg_xs)

head(sx_agg)
sx_agg <- sx_agg  %>% mutate(Si2=Si^2)

plot(sx_agg$Si2)

HH_regional <- as.data.frame(aggregate(list(Si2=sx_agg$Si2),
                                by=list(location_code=sx_agg$location_code,location_
                                    name=sx_agg$location_name,
                                        year=sx_agg$year),
                                FUN = sum))

plot(HH_regional$Si2)
HH_regional$year=as.factor(HH_regional$year)

head(HH_regional)

#printint out results
write.table(HH_regional, "HH_regional_exports.csv", sep=",",quote = TRUE, row.names
    =TRUE,append=FALSE)


# Calculating HH for regional employment
file = "industries_department-2008-2017.csv"
C <- read.csv(file, header = TRUE, sep = ",")

DF <- as.data.frame.matrix(C)

DF$product_name_es <- NULL
DF["SIC_1"] <- floor(DF["industry_code"]/1000)
DF["SIC_2"] <- floor(DF["industry_code"]/100)


DF <- filter(DF, employment > 0)

se_agg <- as.data.frame(aggregate(list(employment=DF$employment),
                                by=list(location_code=DF$location_code,location_name=
                                    DF$location_name,
                                        year=DF$year,SIC_2=DF$SIC_2),
                                FUN = sum))

columns = c("year", "location_code")
se_agg <- se_agg %>% group_by_(.dots= columns) %>%
  mutate(reg_employ= sum(employment))

head(se_agg)
se_agg <- se_agg %>% mutate(Si_employ = employment/reg_employ)

head(se_agg)
se_agg <- se_agg  %>% mutate(Si_employ2=Si_employ^2)

plot(se_agg$Si_employ2)

HH_employ_regional <- as.data.frame(aggregate(list(Si_employ2=se_agg$Si_employ2),
                                by=list(location_code=se_agg$location_code,location_
                                    name=se_agg$location_name,
                                        year=se_agg$year),
                                FUN = sum))

plot(HH_regional$Si2)
HH_regional$year=as.factor(HH_regional$year)

head(HH_regional)

#write output results
write.table(HH_employ_regional, "HH_regional_employ.csv", sep=",",quote = TRUE, row
    .names=TRUE,append=FALSE)
```

A.2 R code to calculate proximity based on RCA

Listing A.2: Code to calculate Proximity based on RCA

```
#!/mnt/ebinstall/software/R/3.5.1-foss-2018b/bin/Rscript
#
# Aggregate to BACI HS92_4 and calculate Proximity between rpoducts
# based Revealed Comparative Advantage
#
# Author:  Claudia Elizabeth Obando Rodriguez
#
# usage
#
# ./RCA-cl.R [DATA_DIR] [YEAR]
#
# DATABASES
#
# http://www.cepii.fr/CEPII/en/bdd_modele/bdd_modele.asp
#
# TRADE UNIT VALUES
#
# http://www.cepii.fr/CEPII/en/bdd_modele/presentation.asp?id=2
#
# BACI
#
#
# BACI: International Trade Database at the Product-Level.  The 1994-2007 Version
# CEPII Working Paper, N°2010-23, Octobre 2010
# Guillaume Gaulier, Soledad Zignago
#
# http://www.cepii.fr/CEPII/en/bdd_modele/presentation.asp?id=37
#
# download page
#
# http://www.cepii.fr/CEPII/en/bdd_modele/download.asp?id=37
#
# BACI92 data links
#
# http://www.cepii.fr/DATA_DOWNLOAD/baci/trade_flows/BACI_HS92_V202102.zip
# http://www.cepii.fr/DATA_DOWNLOAD/baci/nomenclatures/country_codes_V202102.csv
# http://www.cepii.fr/DATA_DOWNLOAD/baci/nomenclatures/product_codes_HS92_V202102.csv
#
#
# Docs
#
# http://www.cepii.fr/DATA_DOWNLOAD/baci/doc/DescriptionBACI.html

library(ggplot2)
library(anytime)
library(Hmisc)
library(reshape)
library(dplyr)

options <- commandArgs(trailingOnly = T)
options(digits=12)
options(max.print = 99999999)

#option to call all files of baci
print(options[1])
DIR <-  options[1]
year <-  options[2]

file <- paste(DIR,"BACI_HS92_Y",year,"_V202102.csv",sep="")

DF <- read.csv(file, header = TRUE, sep = ",")

#create a data.frame
DF <- as.data.frame.matrix(DF)

#convert column hs6 into HS92_4 reducing it to 4-digit
```

```
DF["HS92_4"] <- floor(DF["k"]/100)


#Aggregate value by 4-digit product and exporter
DF <- as.data.frame(aggregate(list(v=DF$v),
                              by=list(i=DF$i,t=DF$t,HS92_4=DF$HS92_4),
                              FUN = sum))

#creating columns to speed up coding for year and country group it by
#year and country, then create a new column with exports per country
#Ec (by summing up exports per product per country (v)), and creating
#a new column with the Share of exports from each product (Scp) in the
#total exports of the country
columns = c("t", "i")
DF <- DF %>% group_by_(.dots= columns) %>% mutate(Ec= sum(v), Scp=v/sum(v))

#Count total number of countries
Nc <- length(unique(DF$i))
#sum up total world exports
WT <- sum(DF$v)

#creating columns to speed up coding for year and product
#creating new columns for world exports per product and
#creating the share of products exports in the world total exports
columns = c("t", "HS92_4")
DF <- DF %>% group_by_(.dots= columns) %>%
  mutate(Epw= sum(v), Spw=sum(v)/WT)

#calculating RCA
DF <- DF %>% mutate(RCA=Scp/Spw)

#filtering out RCA < 1, leaving only the products with Revealed
#Comparative Advantage
DF <- filter(DF, RCA >1)

#create a new data.frame counting the number of countries having RCA >1
#by HS92_4
DF_Pi <- data.frame(table(DF$HS92_4))

#changing names of columns
colnames(DF_Pi) <- c("pi","FreqPi")


#Aggregating a new column with the probability of a country having RCA in product i
DF_Pi <- DF_Pi %>% mutate(Pi=FreqPi/Nc)

#converting pi and pj into numeric values
pi <- numeric(0)
pj <- numeric(0)

#listing unique countries in the DF
countries <- unique(DF$i)

#for (c in countries[c(5,6,7)])

#Form up the pair of products with their exports
#using the lenght of the products HS92_4 exported by the countries listed
#creating the pairs for each product i and then associate as many products j to each product i
for (c in countries){

    c_x <- filter(DF, i==c)
    np <- length(c_x$HS92_4)

    c_pi <- rep(c_x$HS92_4,np)
    c_pj <- rep(c_x$HS92_4,each=np)

    pi <- append(pi, c_pi)
    pj <- append(pj, c_pj)
}

#Create the unique list of world products
WP <- unique(DF_Pi$pi)

```

```
#Number of total products at 4-digit level
Np <- length(WP)

# create all possible pairs
w_pi <- rep(WP,Np)
w_pj <- rep(WP,each=Np)

# create data frame to include all possible pairs.  Changing columns'
# names to make it possible for them to merge
DF_WP <- data.frame(w_pi,w_pj)
colnames(DF_WP) <- c("pi","pj")



#create a DF with the pairs with RCA>1
pij <- data.frame(pi,pj)

#Grouping up products by product i and j and them count them up
#replace table function as it allows to count by pairs of variables
Pij <- pij %>% group_by(pi,pj) %>%
  summarize(Count = n())

#Finding joint probability by creating a new column that divides
#the number of countries having RCA>1 in product i and j
Pij <- Pij %>% mutate(Pij=Count/Nc)

#Merging the data frames with Pi and Pij
Pij <- merge(DF_Pi,Pij)

#change columns' names in DF_Pi to remerge as DF_Pj, as Pj is also
#necessary
colnames(DF_Pi) <- c("pj","FreqPj","Pj")

#merge Pij and DF_Pi to form the table to use for calculating proximity
Pij <- merge(DF_Pi,Pij)

#Finding conditional probabilities for i and j
#calculating the probability of having RCA
#in product i given that the country has comparative adavantage in product j
#then select the minimum value between the two conditional probabilities
Pij <- Pij %>% mutate(Pxixj=Pij/Pj)

Pij <- Pij %>% mutate(Pxjxi=Pij/Pi)

Pij <- Pij %>% mutate(Proxi=pmin(Pxixj,Pxjxi))



#plot promixity for BACCI
p1 <- ggplot(Pij, aes(x=Proxi))+
    geom_histogram(colour="black",fill="red")

#reducing the DF to the columns of interest:  pi, pj, Proxi
keep <-c("pi", "pj", "Proxi")

#New data.frame using the columns selected
Proximity <- Pij[keep]

#Merging two DF from Proximity and DF_WP
Proximity_w <- merge(Proximity,DF_WP, all = TRUE)

#changing N.A in the Proximity_w DF for 0
Proximity_w[is.na(Proximity_w)] <- 0

#histogram showing the distribution of Promixity amongst world's products
p2 <- ggplot(Proximity_w, aes(x=Proxi))+
    geom_histogram(colour="black",fill="red", binwidth=0.016)


pdf_file <- paste (DIR,year,".pdf",sep='');
pdf(pdf_file,width=8,height=5)
p1
```

```
p2
dev.off()


#create the output table with the data to
#build up the related variety sets for Colombia
proximity_output <- paste(DIR,"proximity_Y",year,".csv",sep='')
write.table(Proximity_w,
            file=proximity_output, sep=",",
            row.names=FALSE, col.names=TRUE)
```

A.3 R code to calculate related/unrelated variety by the proximity method

Listing A.3: Code to calculate related/unrelated variety by the proximity method

```
#!/mnt/ebinstall/software/R/3.5.1-foss-2018b/bin/Rscript
#
# R code to calculate related/unrelated variety with the proximity method
#
# Author:  Claudia Elizabeth Obando Rodriguez
#
# Usage:
#
# ./variety_prox_2.R [YEAR]
#
# Data paths are hardcoded (based on year)

library(ggplot2)
library(anytime)
library(Hmisc)
library(reshape)
library(dplyr)

#CALCULATING RELATED VARIETY

options <- commandArgs(trailingOnly = T)
options(digits=12)
#print(options)
options(max.print = 99999999)

input_year=options[1]
print("calculating RV for year ")
print(input_year)


print("getting colombian data...")

#calling the file of exports for Colombia
file = "/mnt/lustre/users/bmec/co64/DATLAS/products_department-2008-2017.csv"
C <- read.csv(file, header = TRUE, sep = ",")

#creating the data frame
DF <- as.data.frame.matrix(C)

#filtering out <=0 exports
DF <- filter(DF, DF$export_value >0)


print("getting proximity table...")
#reading the data frame from proximity (world)

prox_file <- paste("/mnt/lustre/users/bmec/co64/BACI/proximity_Y", input_year, ".
    csv", sep = "")


P <- read.csv(prox_file, header = TRUE, sep = ",")

```

```
#converting proximity data into a data frame
DF_P <- as.data.frame.matrix(P)

#reducing the data frame to main variables:
#year, exports, product code and location
#and filtering for 2014 to match proximity data
keep <-c("year", "export_value","product_code", "location_code", "location_name")
DF <- DF[keep]
DF <- filter(DF, year == input_year)


print("first merge, pi...")
#changing column names to fit proximity data frame
#merging proximity and colombian data to associate to each product i
#its proximity value
colnames(DF) <- c("year","xi","pi","location_code","location_name")
DF_prox <- merge(DF_P, DF, all= TRUE)

head(DF_prox)

print("second merge, pj...")
#changing column names to merge proximity DF
#with the data from Colombia to build up the data for product pj
colnames(DF) <- c("year", "xj","pj","location_code","location_name")
DF_prox <- merge(DF_prox, DF)

#filtering out proximity values lower than 0.25
DF_prox_rv <- filter(DF_prox, Proxi >0.25)

#group by regions to obtain regional exports and the
#share of product xj into the regional exports
columns = c("location_code")
DF <- DF %>% group_by_(.dots= columns) %>%
  mutate(reg_xs= sum(xj), sj=xj/sum(xj))

#change column names for product pi
#create a new column with total exports for product i (Xi),
#the share of the product in the variety set and the entropy fo the product i
columns = c("year", "location_code", "pi")
DF_prox_rv <- DF_prox_rv %>% group_by_(.dots= columns) %>%
  mutate(Xi= sum(xj), si_var=xj/Xi, hi=(si_var*log2(1/si_var)))


print("calculating entropies...")
#aggregate by location and product, bringing in exports value
#for j to a new data frame to obtain regional entropy Hr
DF_var <- as.data.frame(aggregate(list(Hj=DF_prox_rv$hi),
                                  by=list(location_code=DF_prox_rv$location_code,
                                          location_name=DF_prox_rv$location_name,
                                           year=DF_prox_rv$year, pj=DF_prox_rv$pi,
                                               Xj=DF_prox_rv$Xi),
                                   FUN = sum))

#bring together regional exports and proximity grouped by region, year and product.
DF_var <- merge(DF_var, DF)

#calculate share of xj exports in regional exports and then related variety per product
DF_var <- DF_var %>% mutate(SXj=Xj/reg_xs, Rv_r=SXj*Hj)

print("calculating related variety...")
#obtain related variety per year,region and product
Rel_var <- as.data.frame(aggregate(list(RV=DF_var$Rv_r),
                                   by=list(location_code=DF_var$location_code,
                                           location_name=DF_var$location_name,
                                    year=DF_var$year),
                                    FUN = sum))

pdffile <- paste ("RV-proxi-",input_year,".pdf", sep = "")

pdf(file=pdffile, height=7, width=7, onefile=TRUE, family='Helvetica', paper='a4',
    pointsize=12)

```

```
123
125
#CALCULATING UNRELATED VARIETY
127
#filtering out proximity values higher than 0.25
129 DF_prox_urv <- filter(DF_prox, Proxi <=0.25)
131 #group by regions to obtain regional exports and the
#share of product xj into the regional exports
133 columns = c("location_code")
DF <- DF %>% group_by_(.dots= columns) %>%
135   mutate(reg_xs= sum(xj), sj=xj/sum(xj))
137 #change column names for product pi
#create a new column with total exports for product i (Xi),
139 #the share of the product in the variety set and the entropy fo the product i
columns = c("year", "location_code", "pi")
141 DF_prox_urv <- DF_prox_urv %>% group_by_(.dots= columns) %>%
  mutate(Xi= sum(xj), si_var=xj/Xi, hi=(si_var*log2(1/si_var)))
143
145 print("calculating entropies...")
#aggregate by location and product, bringing in exports value
147 #for j to a new data frame to obtain regional entropy Hr
DF_uvar <- as.data.frame(aggregate(list(Hj=DF_prox_urv$hi),
149                                  by=list(location_code=DF_prox_urv$location_code,
                                             location_name=DF_prox_urv$location_name,
151                                          year=DF_prox_urv$year, pj=DF_prox_urv$pi,
                                                 Xj=DF_prox_urv$Xi),
                                  FUN = sum))
153
#bring together regional exports and proximity grouped by region, year and product.
155 DF_uvar <- merge(DF_uvar, DF)
157 #calculate share of xj exports in regional exports and then related variety per product
DF_uvar <- DF_uvar %>% mutate(SXj=Xj/reg_xs, URv_r=SXj*Hj)
159
print("calculating unrelated variety...")
161 #obtain unrelated variety per year,region and product
URel_var <- as.data.frame(aggregate(list(URV=DF_uvar$URv_r),
163                                   by=list(location_code=DF_uvar$location_code,
                                              location_name=DF_uvar$location_name,
165                                           year=DF_uvar$year),
                                   FUN = sum))
167
DF_res <- merge(Rel_var,URel_var)
169 out_file <- paste("variety-proxi-results_",input_year,".csv",sep="")
171 #print output table
write.table(DF_res, out_file, sep=",",quote = TRUE, row.names=TRUE,append=TRUE)
```

A.4 R code to calculate related/unrelated variety based on exports by the HS classification method

Listing A.4: Code to calculate related/unrelated variety by the HS classification method

```
1 #!/mnt/ebinstall/software/R/3.5.1-foss-2018b/bin/Rscript
#
3 # Code to calculate related/unrelated variety based on the HS
# classification method
5 #
# Author:  Claudia Elizabeth Obando Rodriguez
7 #
```

```
# usage:
#
# ./variety.R
#
library(ggplot2)
library(anytime)
library(Hmisc)
library(reshape)
library(dplyr)

file = "products_department-2008-2017.csv"
C <- read.csv(file, header = TRUE, sep = ",")

DF <- as.data.frame.matrix(C)

DF["HS92_1"] <- floor(DF["product_code"]/1000)
DF["HS92_2"] <- floor(DF["product_code"]/100)

#Drop regions with insufficient and/or erratic data
drop <- c("Vichada", "Amazonas", "Caqueta","Choco", "Guainia",  "Putumayo", "Vaupes
    ")
`%ni%` = Negate(`%in%`)
DF <- filter(DF, location_name %ni% drop)

#convert location and into factor
DF$location_code <-as.factor(DF$location_code)

#eliminate from the DF export_values=0 to avoid NAN values
#create vector with the three factors
#create regional exports and pi
DF <- filter(DF, export_value >0)
columns = c("year", "location_code")
DF <- DF %>% group_by_(.dots= columns) %>%
  mutate(reg_xs= sum(export_value), pi=export_value/sum(export_value))

#create a new vector with the three main factors to calculate regional
#exports per year per variety set
columns = c("year", "location_code", "HS92_2")
DF <- DF %>% group_by_(.dots= columns) %>% mutate(Sr_xs=sum(export_value))

#calculate Pr
DF <- DF %>% mutate(Pr=Sr_xs/reg_xs)

#calculate entropy per product
DF <- DF %>% mutate(hi=(pi/Pr)*log2(Pr/pi))

#aggregate hi by variety set to obtain entropy per variety set
Hr <- as.data.frame(aggregate(list(hi=DF$hi),
                              by=list(location_code=DF$location_code,location_name=
                                  DF$location_name,
                                      year=DF$year,HS92_2=DF$HS92_2,Pr=DF$Pr),
                              FUN = sum))

#Obtain related variety per variety set
Hr <- Hr %>% mutate(RV_r=Pr*hi)

#Obtain related variety per region per year
Rel_var <- as.data.frame(aggregate(list(RV_r=Hr$RV_r),
                                   by=list(location_code=Hr$location_code,
                                           location_name=Hr$location_name,
                                           year=Hr$year),
                                   FUN = sum))

Rel_var$year <- as.factor(Rel_var$year)

#OBTAIN UNRELATED VARIETY

#calculate Pj

DF_HS1 <- as.data.frame(aggregate(list(export_value=DF$export_value),
                                  by=list(location_code=DF$location_code,
                                          location_name=DF$location_name,
                                          year=DF$year, HS92_1=DF$HS92_1),
```

```
                                    FUN = sum))

columns = c("year", "location_code")
DF_HS1 <- DF_HS1 %>% group_by_(.dots= columns) %>% mutate(Pj=export_value/sum(
    export_value))
DF_HS1 <- DF_HS1 %>% group_by_(.dots= columns) %>% mutate(URj=Pj*log2(1/Pj))

#Obtain related variety per region per year

UR_variety <- as.data.frame(aggregate(list(UR_r=DF_HS1$URj),
                                      by=list(location_code=DF_HS1$location_code,
                                              location_name=DF_HS1$location_name,
                                              year=DF_HS1$year),
                                      FUN = sum))
UR_variety$year <- as.factor(UR_variety$year)

variety_HS <- merge(Rel_var,UR_variety, by=c("location_code", "location_name","year
    "))

#write output file
write.table(variety_HS, file="variety_HS.csv", append=FALSE, quote = TRUE, sep=",",
     row.names=TRUE)
```

A.5 R code to calculate related/unrelated variety based on employment by the HS classification method

Only subtle differences compared to lisintg A.4, apart from the input data

Listing A.5: Code to calculate related/unrelated variety by the HS classification method

```
#!/mnt/ebinstall/software/R/3.5.1-foss-2018b/bin/Rscript
#
# Code to calculate related/unrelated variety based on the HS
# classification method
#
# Author:  Claudia Elizabeth Obando Rodriguez
#
# usage:
#
# ./variety.R
#
library(ggplot2)
library(anytime)
library(Hmisc)
library(reshape)
library(dplyr)

file = "industries_department-2008-2017.csv"
E <- read.csv(file, header = TRUE, sep = ",")

DF_E <- as.data.frame.matrix(E)

#short name for industry 2322:
DF_E$industry_name[DF_E$industry_code==2322] <- "Manufacture of refined petroleum
    products produced out of refinery"
DF_E$industry_name_es <- NULL

DF_E <- filter(DF_E, employment > 0)

DF_E["SIC_1"] <- floor(DF_E["industry_code"]/1000)
DF_E["SIC_2"] <- floor(DF_E["industry_code"]/100)

#Drop regions with insufficient and/or erratic data
```

```
drop <- c("Vichada", "Amazonas", "Caqueta","Choco", "Guainia",  "Putumayo", "Vaupes")
'%ni%' = Negate('%in%')
DF_E<- filter(DF_E, location_name %ni% drop)


#convert location into a factor
DF_E$location_code <-as.factor(DF_E$location_code)
DF_E$year <-as.factor(DF_E$year)

#create regional eemployment and pi
columns = c("year", "location_code")
DF_E <- DF_E %>% group_by_(.dots= columns) %>%
  mutate(reg_employ= sum(employment), pi=employment/sum(employment))

#create a new vector with the three main factors to calculate regional employment per year per variety set
columns = c("year", "location_code", "SIC_2")
DF_E <- DF_E %>% group_by_(.dots= columns) %>% mutate(Sr_employ=sum(employment))

#calculate Pr
DF_E <- DF_E %>% mutate(Pr=Sr_employ/reg_employ)

#calculate entropy per industry
DF_E <- DF_E %>% mutate(hi=(pi/Pr)*log2(Pr/pi))

#aggregate hi by variety set to obtain entropy per variety set
Hr <- as.data.frame(aggregate(list(hi=DF_E$hi),
                              by=list(location_code=DF_E$location_code,location_name=DF_E$location_name,
                                      year=DF_E$year,SIC_2=DF_E$SIC_2,Pr=DF_E$Pr),
                              FUN = sum))

#Obtain related variety per variety set
Hr <- Hr %>% mutate(RV_r=Pr*hi)

#Obtain related variety per region per year
Rel_var_employ <- as.data.frame(aggregate(list(RV_r=Hr$RV_r),
                                  by=list(location_code=Hr$location_code,
                                          location_name=Hr$location_name,
                                          year=Hr$year),
                                  FUN = sum))

#OBTAIN UNRELATED VARIETY

#calculate Pj

DF_SIC1 <- as.data.frame(aggregate(list(employment=DF_E$employment),
                                  by=list(location_code=DF_E$location_code,
                                          location_name=DF_E$location_name,
                                          year=DF_E$year, SIC_1=DF_E$SIC_1),
                                  FUN = sum))

columns = c("year", "location_code")
DF_SIC1 <- DF_SIC1 %>% group_by_(.dots= columns) %>% mutate(Pj=employment/sum(employment))
DF_SIC1 <- DF_SIC1 %>% group_by_(.dots= columns) %>% mutate(URj=Pj*log2(1/Pj))

#Obtain related variety per region per year

UR_variety_employ <- as.data.frame(aggregate(list(UR_r=DF_SIC1$URj),
                                      by=list(location_code=DF_SIC1$location_code,
                                              location_name=DF_SIC1$location_name,
                                              year=DF_SIC1$year),
                                      FUN = sum))



variety_HS_employ <- merge(Rel_var_employ, UR_variety_employ, by=c("location_code", "location_name","year"))

#print out the output file
write.table(variety_HS_employ,
            file= "variety_HS_employ.csv",
```

```
            append=FALSE,
            quote = TRUE,
            sep=",",
            row.names=TRUE)
```