THE ROLE OF THE FORESTRY SECTOR IN REGIONAL ECONOMIC DEVELOPMENT: A CASE STUDY OF MINAS GERAIS, BRAZIL

BY

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DISSERTATION

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ABSTRACT

For decades, governments have fostered the forestry sector for its economic returns and more recently for its environmental services. In a context of an increasing wood product market, especially in developing countries, the investigation of the socioeconomic impacts of this sector at local and regional levels is paramount. Brazil is one of the most important producers of wood products from forest plantations, which are of increasing economic importance for the national economy. This research uses the state of Minas Gerais, Brazil as a case study to analyze how the forestry sector affects the local and regional economies in the state. Minas Gerais is the state with the largest plantation area in Brazil since the 1980s and encompasses very unequally developed areas. This work begins to fill existing gaps in the literature regarding empirical research on plantations at local levels over a relatively long period of time. In addition, it analyzes the economic multipliers of this and other forestry sectors at sub-state level. Employing panel data methods and input-output analysis, the results show that plantation areas are associated with less poverty over time and higher per capita income. However, the regional analysis shows the economic multipliers of forest plantations are among the lowest in the state. The forest plantation sector generates relatively low income overall, but most of it stays in the same region and goes to the low-income classes, which helps explain the positive effect in reducing poverty. Most of the economic benefits of the forestry industry accrued to the more industrialized regions where the wood is processed and higher salaries are paid. The findings from this dissertation provide new insights on how forest plantations shape local development and who benefits from these plantations. The results therefore have important implications not only for scholarship but also for public policies seeking to support plantation expansion as a way to bring economic growth to remote and poorer areas.

DEDICATION

To my wonderful daughter

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1:

INTRODUCTION

With a growing and increasingly wealthy world population, the demand for natural commodities is increasing, including wood products from forests. To meet this demand and preserve natural forests at the same time, large-scale tree plantations have expanded in several regions, especially in the developing world and tropical areas, particularly Brazil, Chile, Vietnam, and China (FAO, 2010). The importance of plantations is expected to keep increasing as productivity and returns are higher than for natural forests (Kanninen, 2010). By 2050, it is anticipated that the area devoted to forest plantations will double in Latin America and Asia (Jurgensen, 2014; Cubbage et al, 2014; Indufor, 2012). Plantations are therefore increasingly relevant for national economies in these contexts, with wood products playing a growing role in exports. As plantations expand, they can also integrate the regional and local economies, influencing their socioeconomic development. However, the effects of plantations for regional economies and local populations are yet to be fully understood, as wood commodities form a relatively recent international market (FAO, 2010).

The expansion of tree plantations is not without controversy. Research has shown that they can bring both negative and positive environmental and social impacts. On the environmental side, planted forests, such as monocultures of eucalyptus and pine, use more water than unmanaged forests, store less carbon, and increase acidity in both soil and groundwater (Cannell, 1999). Plantations also hold less biodiversity than unmanaged and old growth forests (Ibid). However, some research suggests that plantations, when properly managed, can host a rich fauna and flora and be favorable for natural forest restoration (Cannell, 1999; Cossalter & Pye-Smith, 2003; Farinaci et al., 2013). Furthermore, compared to degraded lands, plantations can help mitigate climate disasters, such as floods and erosions, and on biodiversity conservation serve as part of conservation corridors linking habitat for wildlife (Farinaci et al., 2013).

The literature on socio-economic impacts of forest plantations also draws mixed conclusions. On one hand, there are several studies showing that plantations contribute to economic development, job creation, and poverty reduction for rural population (FAO, 2006, 2010; World Bank, 2007). On the other hand, many studies have shown negative effects at the local level (Malkamaki et al, 2018) and an increase in poverty (Andersson et al., 2016). The main negative effects on the local population, according to the literature, are degradation of public roads and infrastructure, lost job opportunities and access to non-timber forest products (NTFP) in previous common areas, reduction of water resources, cultural conflicts, and negative health effects due to pesticide use (Malkamaki et al, 2018). Positive outcomes include more job supply, regulation of environmental services in degraded areas, infrastructure development made by forest companies, and development of eco-tourism and leisure activities in environmentally-managed plantations (Ibid).

A key factor shaping socio-economic impacts is what existed before the plantation: whether the initial conditions were agricultural lands owned by small farmers, degraded lands, or primary forests (Cossalter & Pye-Smith, 2003). The impacts also depend on the destination of the wood production; for instance, furniture is more labor-intensive than pulp and paper production (Ibid), and whether the wood processing happens in the same region plantations are located. Thus, these studies argue that the outcomes will depend on how the plantations interact with other sectors in the economy (Obidzinski et al., 2014), and how plantations compete with other activities associated with native forests or agricultural land important for the local population (Hayter, 2003). Other relevant factors are land tenure and property rights, which are often the main reasons of conflicts. Some studies have found plantations displace rural population (Cotula et al, 2014; Kroger, 2014), and people who used to live in public lands fight plantation companies to whom the lands were given to by the government (Marchak, 1995). As such, the socioeconomic impacts also depend on how the land property is defined and divided between small and large producers (Schirmer, 2007). Given the current mix of evidence, it is important to examine the effects of plantations at different scales and contexts.

In Brazil, plantation expansion consisted mainly of monocultures of eucalyptus and pine and received a high level of fiscal incentives between 1965 through 1987. During this period, Brazil had the largest planted forest area in the world and the highest deforestation rate as well (Bull et al., 2006). However, the financial incentives were not successful in the long run and it is estimated that about 2 million ha out of the 6 million ha planted in those years were abandoned because they did not generate any commercial returns (Ibid). During this time, social conflicts focusing on plantations occurred in several parts of the country involving land tenure problems and the invasion of indigenous lands (Kröger, 2012; Myllylä, 2015). Then in 2000, plantation area started to increase again due to financing from several sources such as the government programs of the Brazilian Development Bank (BNDES) and international institutional investment through TIMOs (Timber Investment Management Organizations) (Mendes, 2005). Brazil is now the largest producer of roundwood from plantations and has had decreasing rates of forest loss since 1990 (FAO, 2015). In spite of the expansion of plantations, only a few studies in Brazil have investigated the socioeconomic impacts of planted forests, and most of them are qualitative. The gap in empirical research on socioeconomic impacts is not just in Brazil, but it is global (Andersson et al., 2016; Malkamaki et al, 2018).

Brazil is a tropical developing country that has successfully reduced poverty in the last few decades through economic stabilization and social programs (Hoffmann, 2012; Pochmann, 2012). Also, Brazil is one of the richest countries in the world with respect to biodiversity, has the largest natural forest, and has restored degraded lands as a way to promote both rural development and sustainability (Gurgel & Laurenzana, 2014). For instance, in 2011 the country made a commitment under the Bonn Challenge to restore 1 million ha by 2020. This and other commitments – such as the intended Nationally Determined Contribution (iNDC) to reduce emissions by 37% below what they were in 2005 by 2025 – led the Brazilian Government to launch the ABC Plan to finance an expansion of plantations by 40% by 2020 – from 7.2 million in 2011 to 10.2 million in 2020 (IBA, 2016). Although both initiatives have well-defined environmental goals, they lack specific socioeconomic ones. These important aspects are overlooked in the national policy and seem to be considered as collateral outcomes of investing in environmental targets.

In this context of an intensive increase in plantation area in Brazil in the next few decades, an analysis focusing on its socioeconomic impacts is paramount. Moreover, environmental impacts cannot be dissociated from the socioeconomic ones as they both interact and define the life conditions of the population. Therefore, we need to understand how the increase in plantations will impact the socioeconomic aspects of the region in which they will be implemented on, and how plantation expansion will contribute to the development of the regional economy. As such, this study intends to provide key knowledge to assist public policy makers in defining the more suitable agricultural subsidy programs for plantations that also foster regional economic development.

This research aims to shed light on the theory of forest expansion and economic development by investigating the role of the forestry sector in the regional economy. As a study case, I will focus on the state of Minas Gerais (MG), Brazil, as it is the state with the largest plantation area in the country since the 1980s. The main research questions this dissertation addresses are:

1) How have plantations affected local socioeconomic development in MG over time?
2) How has the forestry sector interacted with the other economic sectors to promote growth at regional level in MG?
3) What is the role of the different elements of the forestry sector in income generation and distribution?

Considering the socioeconomic impact of plantations, a recent systematic review on this issue revealed that most of the studies found more negative than positive impacts (Malkamaki et al., 2018). However, the authors point out that the effects differ depending on the time passed since the establishment of the plantations and that there is a lack of evidence of their long-term impact, as more generally in the case in forestry (Miller et al. 2017) . This study therefore contributes to this discussion by empirically analyzing the impacts of forest plantations over a twenty-year period to understand the trends that the expansion has on local economic growth. In MG the effects could be positive or negative, because they will depend on implementation of forest plantations and the specific context of the region.

In relation to the second question, research has shown that the economic benefits of forests will depend significantly on how they are integrated in the regional economic structure (Roberts et al, 1999). Plantations in MG are concentrated in areas with low economic development levels, whereas a great part of the wood production is processed in distant industrial centers. In addition, the employment multiplier of this plantation activity has been found to be very low (Berck et al, 2000). Therefore, I expect it to have low economic multipliers in regions with low industrial concentration, and that the higher benefits will be concentrated in the regions with the processing industries. Nevertheless, the goal is also to analyze the forestry industry as a whole to understand its dynamics in the state.

Regarding the third question, as a new and structured activity in poor areas, plantation may foster development and generate income, especially for low-income people. On the other hand, forests are highly profitable investments (Cubbage et al, 2014) and probably create more income for the high-income classes in metropolitan areas where the investors are. This study therefore also includes analysis of the effect of household consumption, and I expect to see that the overall expenditure will increase income in developed regions, as those areas concentrate the outputs in the state (Perobelli et al., 2013).

The structure of this dissertation is as follows. Chapter two investigates the impact of forest plantations on poverty rates at a local level in the state of Minas Gerais. Chapter three analyses the economic multipliers of the forestry sectors in the MG economy at a sub-state level, employing input-output (IO) analysis. Chapter four focuses on the contribution of the forestry sectors for income generation and distribution in the state, at the regional level and for different income classes. For chapter four I add the Miyazawa framework (Miyazawa, 1976) into the IO model. Chapter five presents conclusions with suggestions for further research.

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CHAPTER 2:

FOREST PLANTATIONS AND LOCAL ECONOMIC DEVELOPMENT: EVIDENCE FROM THE MUNICIPALITIES OF MINAS GERAIS, BRAZIL

Abstract

Globally, Brazil is one of the most important producers of wood products from forest plantations. The area devoted to forest plantations is rapidly increasing in the country, driven by climatic conditions suitable for high productivity, land availability, and strong market demand. Since most of it is exported, wood production brings important macroeconomic benefits. However, knowledge of the economic impacts of forest plantations at regional and local levels remains limited. This study investigates this issue by analyzing the socioeconomic impacts of tree plantations across the municipalities of Minas Gerais, the state with the largest plantation area in Brazil since 1980. Panel data regression methods are used to analyze data on plantation area, poverty, and other variables over a 20-year period. The results show that an increase in forest plantations is associated to a decrease in poverty over time.

Keywords: forest plantations, forest policy, poverty, economic development, Brazil, Minas Gerais.

2.1. Introduction

The area devoted to forest plantations is increasing worldwide due to growing consumer demand for wood products and higher productivity of plantations compared to natural forests (Kanninen, 2010; Pirard et al., 2016). Large-scale tree plantations are already responsible for more than one third of the world's wood production. The expansion of plantations is taking place mostly in the tropics, particularly in Brazil, Chile, Vietnam, and China (FAO, 2010), and the area devoted to it is expected to double in Latin America and Asia by 2050 (Jurgensen, 2014; Cubbage et al, 2014; Indufor, 2012).

Much of the plantation expansion is occurring in areas within countries where land remains inexpensive and poverty rates are relatively high (Cotula, 2012). While the literature has developed on the environmental impact of plantations (Cossalter & Pye-Smith, 2003; Pawson et al, 2013), knowledge of their impacts on local socioeconomic development remains limited. Available evidence shows mixed results. Some studies suggest that plantations will bring economic development and job creation in underdeveloped areas (World Bank, 2005, 2007), while others say that plantations have increased poverty (Berck et al, 2000; Andersson et al. 2016), displaced local people, unsettled smallholder livelihoods, and disrupted local markets (Kröger, 2014). Many available studies are qualitative or focused on small areas for a short period of time and there is a lack of quantitative evidence on plantation impacts over a long period of time (Anderson et al, 2016; Malkamaki et al, 2018). In fact, since plantation expansion is relatively recent, little is known about their future contributions to the economic, social, and environmental services (FAO, 2010).

In Brazil and elsewhere in South America, many plantations started in the 1970s. Incentivized by authoritarian regimes, South American countries used forest policies as instruments to achieve their goals of national development, and did not focus on local interests (Pretzsch, 2005). The expansion provoked several social conflicts over land, environmental degradation, and waste of public resources (Bull et al, 2006; Marchak, 1995; Myllylä, 2015). Currently, however, the global context has changed. Forests are now seen as multi-use areas and offer services that provide for multi-stakeholders interests (Lane & McDonald, 2002; Pretzsch, 2005; Byerlee et al., 2010). Therefore, the expansion of large-scale commercial plantations must be evaluated carefully, as they may or may not fulfill the expectation of rural development and poverty reduction they promise.

This study examines the role of tree plantations for local development over an extended period of time using statistical analysis of panel data. More specifically, I use empirical methods to assess whether plantation expansion has affected poverty rates, and if so, how. I focus on Minas Gerais (MG), the state with the largest plantation area in the country since 1980. MG is approximately the size of France, and although it is one of the richest states, it encompasses both wealthy areas that experience economic growth and highly underdeveloped regions. Large-scale tree plantations have been a relevant economic and environmental activity in MG for decades now, with expansion accelerating at different points in time (Bacha, 2008; Kroger, 2012; MG Government, 2013). Studying plantation expansion across the whole state provides new insights on how it affects subnational socioeconomic development.

2.2. Background

2.2.1 Literature review

Forest plantations[1] in Brazil consist mostly of monocultures of fast-growth trees such as eucalyptus, pine, acacia, and teak. The main products they yield are roundwood that provides pulp for paper production, lumber for construction, and firewood for energy production. The demand for such wood products is growing worldwide with plantation forests increasingly supplying this demand by both expanding their area and improving their productivity. Globally, forest plantation area increased from 167.5 million ha in 1990 to 277.9 million ha in 2015 (Payn et al., 2015). Productivity of eucalyptus plantations in Brazil is among the highest in the world and increased by 33% in 2015, from 30 m^3/ha/year in 1990 to 40 m^3/ha/year (IBA, 2016).

The environmental aspects of plantations have been relatively well explored in literature. Research shows that plantations have emerged as a key strategy to restore degraded lands, for climate control, erosion prevention, and delivery of other ecosystem services (Liu et al, 2013; Bonn Challenge, 2011). While plantations have been criticized for their impacts on biodiversity – notably when they have replaced natural vegetation (Bauhus et al, 2009) – some studies argue that monoculture of plantations can help protect biodiversity when used to restore degraded and deforested land (Cannell, 1999; Viani et al., 2010; Brockerhoff et al, 2013). Plantations can, however, have other negative environmental impacts such as eucalyptus plantations draining streams and compromising the water supply for agriculture and other uses (Crossalter & Pye-Smith, 2003). Careful management by maintaining natural vegetation and protecting waterways is required to mitigate such potentially negative impacts (Cannell, 1999; Cossalter & Pye-Smith,

[1]According to the FAO (2015) definition, Planted Forest is a "Forest predominantly composed of trees established through planting and/or deliberate seeding."

2003; Farinaci et al., 2013). Such management in multipurpose forests may also help improve socioeconomic impacts (Paquette and Messier, 2009).

Regarding socioeconomic aspects, most previous studies have focused on natural forests[2] and have shown how they can provide a range of resources for subsistence, protection, and as savings accounts for the poorest (Agrawal et al., 2013; Sunderlin et al., 2003). Natural forests can also serve as a mechanism out of poverty in a context of secure land tenure and defined property rights (Angelsen et al., 2014; Sunderlin et al., 2008). Even though forest plantations have been analyzed in the agricultural literature due to their obvious commercial purposes, comparatively little is known about their links to poverty and livelihoods. Sunderlin et al. (2003) suggest that forest plantations have both positive aspects and constraints to the poor. They concluded that good governance is an important requirement for plantations to serve the poorest. Sunderlin et al. (2008) support that forest plantations can alleviate poverty through local multiplier effects that forestry brings, such as constructing infrastructure. However, Malkamaki et al. (2018) have found various cases where plantation expansion lacks investment for infrastructure and restrain road access to local populations. The evidence is also mixed on large-scale industrial tree production. For example, Byerlee et al. (2010) argue that it does not support the poor, while Edwards (2017) has found that such investment has reduced poverty.

There are important aspects to consider regarding the socioeconomic impacts of forests generally and plantations specifically. On the economic standpoint, these considerations will depend on what existed before the plantations – whether it was farmland, degraded lands, or natural vegetation – and the destination of the product – as wood used for furniture, for example, has been shown to generate more jobs than fast-growth wood used for pulp and paper production

2 The FAO (2015) definition for Natural Forest is a: "Naturally regenerated forest of native species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed."

(Cossalter & Pye-Smith, 2003). On the social side, conflict is a key issue, usually stemming from disagreement over land tenure and property rights. For example, communities that used to live on land claimed by the government may resist plantation companies to whom these lands were given (Marchak, 1995). Research suggests that if local landowners are planting the trees instead of large companies, conflict is less likely (MMA, 2005; Schirmer, 2007; Thomson & Psaltopoulos, 2005). This dynamic is also supported by the theory of the commons – people who live close to natural resources accept that the local population should benefit from said resources rather than external groups only financially interested in the area (Ostrom, 1990).

Overall, the literature on socioeconomic impacts shows that plantations are likely to have different effects if the design focused on a pro-poor strategy or on large-scale tree production. For instance, China's "Grain for Green" program focused on the poor and small-holder farmers and has seen positive results for improving livelihoods (Uchida et al., 2007). Other programs in China and Vietnam were found to contribute to income mobility and poverty reduction in rural households (Liu et al, 2013; Sikor, 2012). In Indonesia some authors found that large-scale plantations of different types of wood tree have different impacts and perceptions by the local population. These impacts depend on the plantation management and opportunities offered, such as use of land, job opportunities, and infrastructure (Pirard & Mayer, 2009; Pirard et al, 2017). In Australia, Leys and Vanclay (2010) point out three main failures of the strategy to incentivize socioeconomic development through large-scale tree production: lack of regional infrastructure for the population to benefit from the expansion, poor environmental criteria, and the non-existence of community-based afforestation policy for sustainable development. In Chile, Andersson et al. (2016) found that the large-scale industrial forest plantations were associated with more poverty over time at a local level.

A recent systematic review of the socioeconomic effects of large-scale tree plantations (Malkamaki et al., 2018) concluded that forest plantations have more negative than positive impacts. These are related to land problems, such as displacement of the local population and land grabbing, and few job offers. Salaries in the forestry sector do not match salaries in agriculture or biofuels and the jobs are usually part-time and precarious, unless the plantations are connected to wood processing companies. Livelihood opportunities seemed to improve only when there were clear policies to integrate the population into the plantation benefits. Without such compensations, the loss of access to the land with natural vegetation had negative impacts. The authors concluded, though, that these generally occur in the first years after the plantations are established, especially compared to what existed before, whereas the benefits that arise over time depend on the opportunities created and who can access them. Therefore, a long-time approach seems to be the more suitable in assessing socioeconomic impacts from forest plantations, although the same authors point to the lack of strong evidence in such studies.

Despite the intense expansion of forest plantations, few studies in Brazil have investigated their socioeconomic implications. Most of these studies concentrate on the qualitative analysis of a limited number of municipalities (Carvalho, 2009; Kröger, 2012; Mendonca, 2009; Myllylä, 2015) and found negative socioeconomic impacts of plantations at a local level, such as displacement of people, unemployment, and cultural disruption. Mendonça (2009), however, found positive impacts of plantation expansion in municipalities in southern of Brazil where most of the production is from small to medium-sized landowners.

The present study addresses gaps in the literature regarding the socioeconomic impacts of forest plantations over long periods of time by employing a unique and complete data set at the municipal level on plantations in the state of Minas Gerais, Brazil. The goal is to assess whether forest plantation expansion has been associated with an increase or decrease in poverty rates over time at local level.

2.2.2 Study context

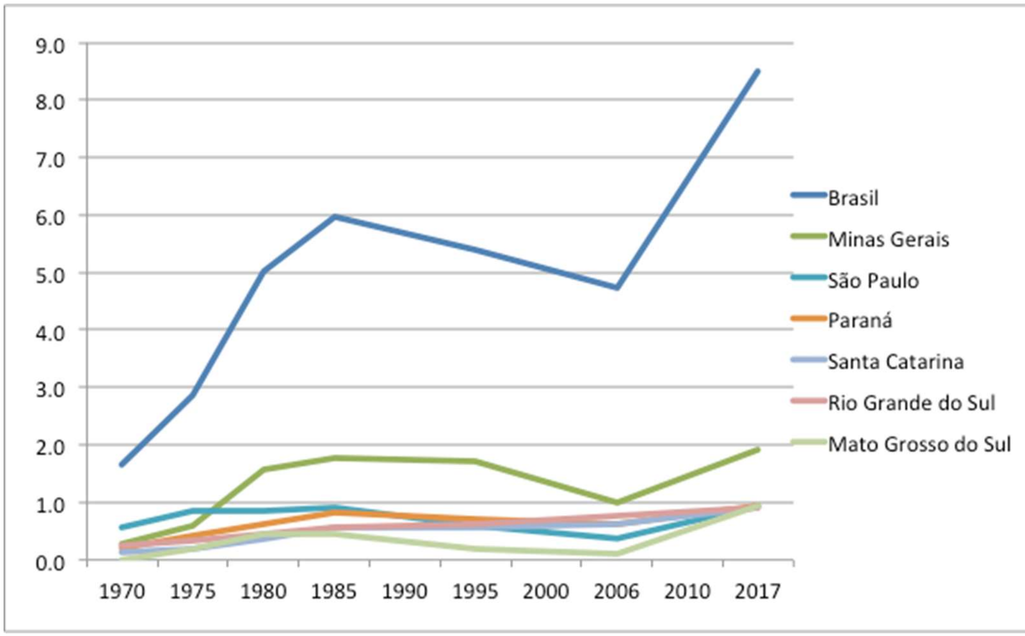
Brazil's wood products sector is currently increasing in importance for the national economy and has grown at high rates compared to the other economic sectors over the past few decades (IBA, 2016). In 2015, it was responsible for 1.2% of the GDP and 4.0% of exports (Ibid). Plantations are an essential part of this sector. Tree plantations in Brazil consist mostly of large-scale monocultures of eucalyptus (87%) and pine (10%), and the main products are pulp for export, paper, wood panels, and charcoal for the iron and steel industries (Ibid). Brazil has the highest eucalyptus productivity (40 m^3/ha/year) and the lowest growth time (6-8 years) in the world, resulting in the highest global returns of up to 30% (Cubbage et al., 2014). This economic performance has attracted large international investment from institutional funds, especially from the United States (Indufor, 2012).

Major government incentives from the 1960s to 1987 – approximately Brazil's military dictatorship – provided an extensive boost to forest plantations in Brazil. During this period, Brazil had the largest plantation area in the world as well as the highest deforestation rate (Bull et al, 2006). However, a great part of the plantation area was lost due to poor planning and management (Ibid). Social conflicts over plantations escalated in several parts of the country involving land tenure and invasion of indigenous lands (Kröger, 2012; Myllylä, 2015). During the 1990s, these conflicts gained widespread public attention and plantations had to adapt to new environmental regulations, such as federal law and international certification (May, 2008;

Moura, 2016). Finally, driven by reduced government subsides the total area devoted to forest plantations decreased during this period (Bull et al, 2006; Bacha, 2008).

Plantation area started to increase again in 2000 (Figure 2.1) due to financing from several sources such as, government programs of the Brazilian Development Bank (BNDES), international institutional investments, and investments in carbon storage projects (Mendes, 2005). In total, forest plantation area went from 5 million ha in 1990 to 7.8 million ha in 2015, a growth rate of 7.7% per year, the highest in the world during that period (FAO, 2010, 2015). The main change of this new phase was the improvement of productivity and efficiency, encouraging the creation of new technologies, such as the development of new tree hybrids to adapt to different climates, regions, and production purposes (de Paula et al., 2018). The main species planted in Brazil were hybrids of *Eucalyptus grandis* and *E. saligna* for paper production, *E. urophila* and *E. camaldulensis* for coal production, and *Pinus taeda* and *Pinus elliottii* for wood and paper production (Bacha & Barros, 2004).

In addition to commercially driven forest expansion in Brazil, the country has increased incentives to the sector since the 2000s to achieve several environmental goals. In 2011, the country committed to restore 1 million ha of degraded land by 2020 under the Bonn Challenge. In 2015, it submitted to the United Nations Climate Change Secretariat its intended Nationally Determined Contributions to reduce carbon emissions. These and other previous agreements led the government to launch the "ABC Plan" to fund green agriculture at low interest rates, stimulating the use of new technologies and methods for low carbon emission. The program included financing plantation expansion by 40% until 2020, i.e. from 7.2 million ha in 2011 to 10.2 million ha (IBA, 2016; FGV, 2017).



Source: IBGE Agricultural Censuses (IBGE, 2016)

Figure 2.1: Forest plantation area in Brazil and main states, 1970 – 2017 (all species; in millions of ha)

The lack of empirical studies on plantations in Brazil may be explained by the lack of data available on the forestry sector. Government data is incomplete and not widely released at the municipal level due to privacy rules (IBGE, 2016). Accurate information is owned by private consultancy agencies, a well-known worldwide problem regarding forestry data (Cossalter & Pye-Smith, 2003). Given limited empirical studies, major increases in plantation area, and national economic importance of forest plantations, analysis of their regional socioeconomic impact is paramount. To address this need, this study focuses on the state of MG (Figure 2.1), containing about 20% of the total plantation acreage in the country.

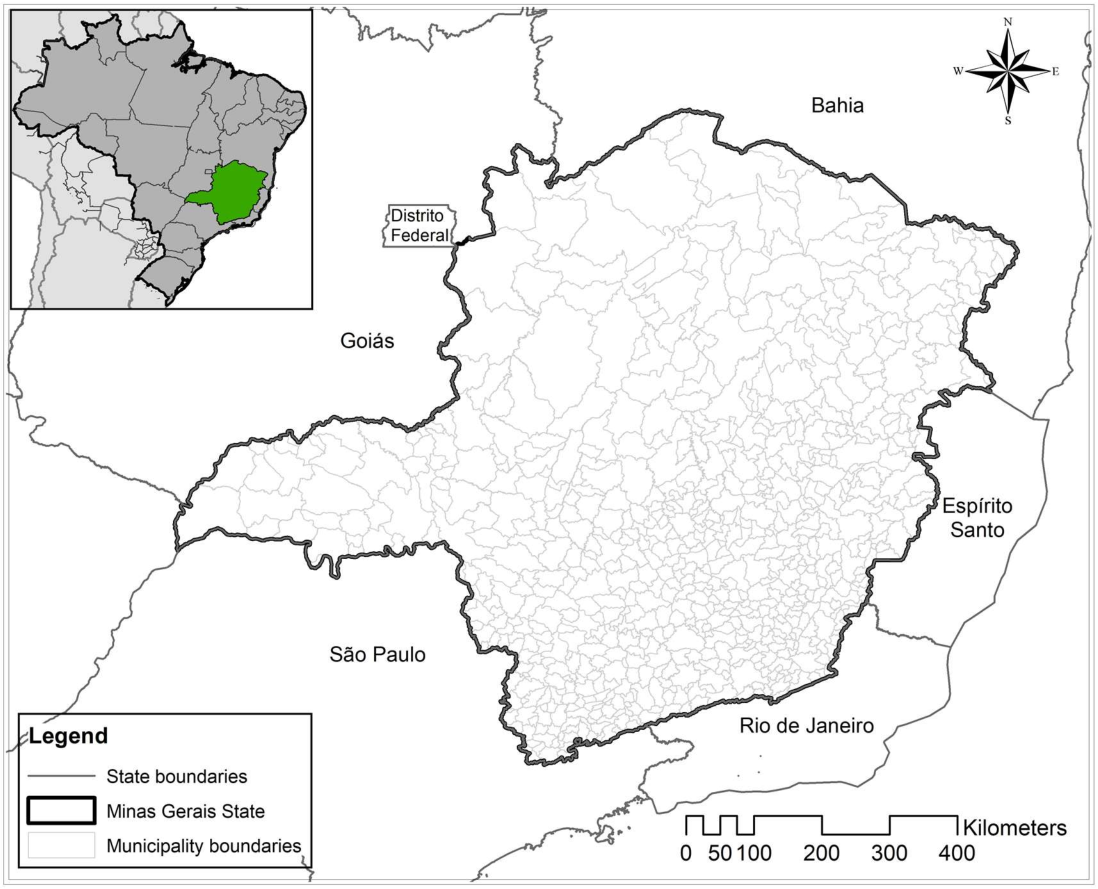
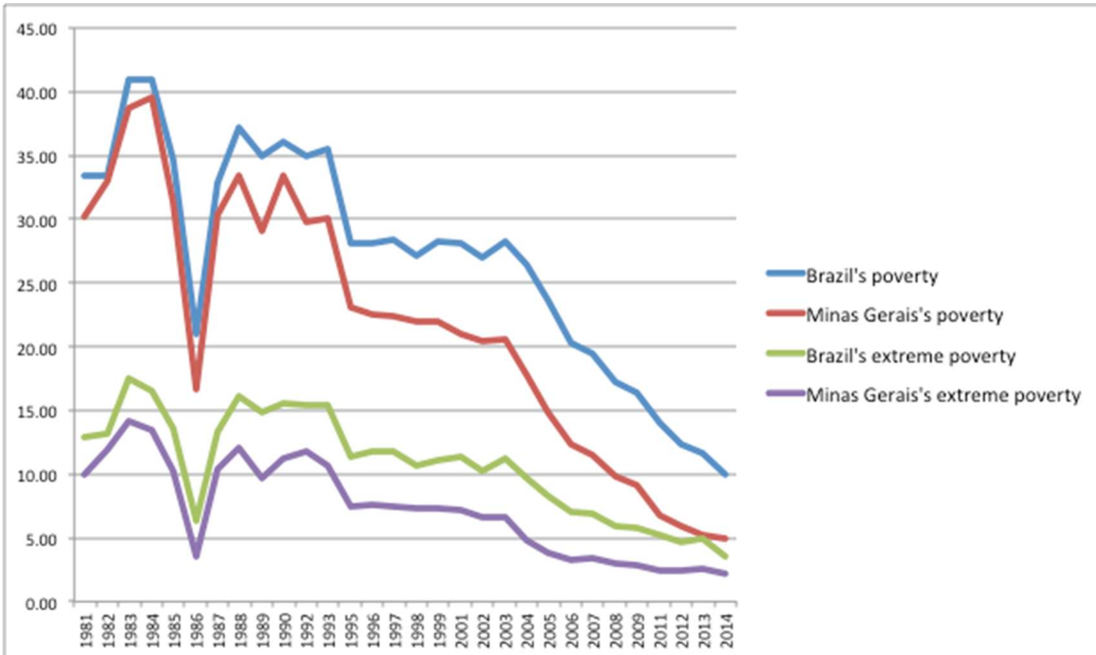


Figure 2.2: Map of the state of Minas Gerais and its 720 municipalities (i.e. minimum comparable areas – MCA – since 1970)

In MG, plantations increased greatly in the 1970s mostly to supply the demand of charcoal in iron and steel companies, and in chemical pulp production within neighboring states. Plantation areas started expanding in the south, next to the most industrialized state in Brazil, São Paulo, and advanced to the north as a new agricultural frontier with a larger rural population and higher poverty rates (Lemos, 2002; Leite & Almeida, 2012). MG has a history of conflicts around plantations mainly related to land tenure problems and public lands that were leased to private companies (MMA, 2005). In the past few decades, though, the expansion occurred through land purchasing and outsourcing schemes. This brought shared benefits for the small landowners and is associated with less conflict (Rode et al., 2014; MMA, 2005). Yet some authors argue that these contracts happened mostly with medium to large landowners, who did not live in the region, and therefore did not bring many socioeconomic benefits to the rural population (Diesel et al, 2006).

Even though MG is the third richest state in Brazil, it holds the tenth position in per capita income, as wealth and development are very unequal amongst the municipalities (IBGE, 2018). Poverty has been historically concentrated in the semi-arid northern part of the state. Nevertheless, poverty rates have decreased overall in Brazil since the 1990s due to a successful macroeconomic stabilization plan in 1994, social policies in the 2000s such as the cash transfer program *Bolsa Família*, and continued increases to the minimum wage. Consistent economic growth starting in 2004, a higher educational level of the population, and the creation of new jobs at the base of the economy were also factors that contributed to poverty reduction (Hoffmann, 2013; Oliveira & Hoffmann, 2013; Pochmann, 2012).

Figure 2.3 shows annual changes in poverty rate nationally and in MG since the early 1980s. Poverty rates are measured in percentage of people living below the poverty and extreme poverty lines, which are BRL 140 and BRL 70 monthly per capita income, respectively, both in prices of August 2010 for the whole period.



Source: Ipeadata.

Figure 2.3: Percentage of the Population Living in Poverty and Extreme Poverty in Brazil and in Minas Gerais, 1981-2014

2.2.3. Theoretical expectations

The mixed evidence from the literature suggests that the results of this study are difficult to anticipate. Plantations may negatively affect small farmers by creating or exacerbating environmental constraints – such as water shortages and pesticide pollution – and social ones – by isolating people from each other and not increasing the demand for labor. In most local economies, plantations are a remote activity, and production is usually taken to other regions to be processed (Crossalter & Pye-Smith, 2003; Malkamaki, 2018). Therefore, plantations may displace people from their lands and may not supply enough jobs to make up for lost livelihoods, as forest plantations do not require as much labor as food production or even biofuels (Malkamaki, 2018; Korhonem et al., 2014). However, out-migration resulting from plantations could in fact reduce the poverty rate in a given municipality by displacing the poorest from their lands or from public common areas replaced by plantations.

Forest plantations may also reduce poverty for other reasons. For example, they may have expanded to less developed regions, with large rural populations and higher poverty rates. For these regions, plantations may have brought development and reduced poverty by offering new jobs and fostering local economies. Considering the current high productivity in plantations on large-scale production, the harvest and planting of seedlings can occur at least annually and sometimes more than once a year, thereby necessitating greater labor. Such regions, therefore, might grow economically with the infrastructure brought by forest plantation activity and the incentive for development of other sectors.

While both poverty outcomes are possible, the foregoing discussion suggests that forest plantations may have reduced poverty overall in MG, though the outcomes have likely varied across municipalities. Considering the increase in productivity in the new projects and the forest expansion to less developed areas with high levels of poverty, it is expected that this activity has brought economic development and reduced poverty on average in the state.

2.3. Data and Methods

2.3.1 Variables

The unit of analysis is the municipality, i.e. the minimum comparable area – MCA (Figure 2.2), which is either the municipality itself or a cluster of municipalities, representing a comparable area over the years. The methodology of MCA was developed by the Institute of Applied Economic Research (IPEA) to foster studies at municipal level over time, as many municipalities have been reshaped during the 80s and 90s due to creation of new ones. As such, the actual number of municipalities in MG is currently 853, but there are only 720 units of analysis (or MCAs), where 633 represent municipalities that have maintained their size since 1970 and 87 are clusters of municipalities.

I chose to use poverty as a measure of socioeconomic impact because it is considered to be a variable that encompasses many socioeconomic constraints (Edwards, 2017; Bourguignon, 2004). I used the poverty rate in order to evaluate the impacts of plantations on poverty. This rate is based on the poverty lines used by the Brazilian Atlas of Development of the United Nation Development Program - UNDP (UNDP, 2013) and is defined by the household per capita income equal to or less than 140 BRL per month, as of August 2010. For reference, the minimum monthly wage in Brazil in August 2010 was 510 BRL (or USD 291). Therefore, a family of four living with one minimum wage would be under the poverty line. The Atlas compiled data from the 1991, 2000, and 2010 Demographic Censuses from IBGE and made them comparable, so I used those three data points for the analysis.

The primary independent variable is the percent of the municipality area covered with plantations. As explained before, the Agricultural Censuses' data is incomplete at the municipal level because the IBGE has a privacy policy that forbids it from releasing information on plantation area when there are only three or less producers in the municipality (IBGE, 2016). In addition, the official agricultural data available are collected through questionnaires filled in by landowners or farmers in rural areas, which is not as accurate as data from remote imagery. Finally, the IBGE methodology to process information has changed over time among the Agricultural Censuses. Those are the reasons why I opted to use the Global Forest Watch Project/Transparent World[3] (GFW, 2014) data from remote imagery for plantation areas. I

[3] The data on plantations area was obtained from the Global Forest Watch Project, using the methodology developed by the Transparent World NGO, which is described on the Technical Note "Mapping Tree Plantations with Multispectral Imagery: Preliminary Results for Seven Tropical Countries" by Rachael Petersen et al., 2016, World Resource Institute, Washington D.C.

commissioned[4] data specifically for MG for the years 1991, 2000, and 2010. As such, apart from the automatic interpretation method, the data also received a visual treatment to increase its accuracy at small scale. It includes plantation area of eucalyptus, pine, and acacia, as well as the recently cleared areas in the buffer zone (5km) and small roads (<30m) inside plantations.

For control variables I included commonly used social characteristics that could affect poverty levels (Bustos et al, 2016; Andersson et al. 2016), such as rural population and population density. I added municipal expenditures as a measure of municipality wealth[5] because it can also influence poverty rates by attracting more poor people to regions with more economic opportunities. The *Bolsa Família* program (Family Grant Program) is a conditional cash transfer program established nationally since 2003 and focused specifically on the poor. I included in the 2010 data point the total amount transferred under that program to the municipality between 2003 and 2010. Finally, I controlled for natural vegetation, as the literature has shown that is an important asset for the poor (Angelsen et al, 2014; Agrawal et al, 2013). I used data on natural vegetation from the 1985, 1996, and 2006 IBGE Agricultural Censuses, as the percent of covered area in the municipality.

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[4] The data was purchased with funding from the University Library's Scholarly Commons at the University of Illinois at Urbana-Champaign.

[5] I chose to use current municipal expenditures instead of current municipal revenues because these include governmental transfers, which depend on the total municipal population.

Table 2.1. Summary Statistics of Variables Used in the Analysis at Municipality Level in 1991, 2000, and 2010*

	1991				
	Mean	Stan.Dev.	Min.	Median	Max.
Total area (km^2)	814.6	1349.6	47.1	379.3	13734.1
Percentage below poverty line	53.7	17.5	12.5	54.9	91.4
Percentage below extreme poverty line	25.5	15.2	2.2	23.2	82.4
Plantation area GFW/TW (percent area covered)	1.6	3.9	0	0	28.5
Rural population (percentage)	44.3	20.9	0.4	45.0	94.9
Population density (people/km^2)	50.1	248.0	1.5	22.4	5940.3
Natural Vegetation (percent area covered)	9.2	5.8	0.6	8.0	48.4
Municipal expenditures (R$)	46.0	112.0	0	19.3	1468.3
Bolsa Família Program (R$)	0	0	0	0	0

	2000				
	Mean	Stan.Dev.	Min.	Median	Max.
Total area (km^2)	814.6	1349.6	47.1	379.3	13734.1
Percentage below poverty line	33.4	17.1	6.3	29.9	75.6
Percentage below extreme poverty line	13.0	11.5	0	8.8	50.7
Plantation area GFW/TW (percent area covered)	1.5	3.7	0	0.1	33.1
Rural population (percentage)	35.6	19.5	0	34.2	86.9
Population density (people/km^2)	58.5	288.0	1.4	22.6	6652.4
Natural Vegetation (percent area covered)	9.1	5.5	0	7.7	48.6
Municipal expenditures (R$ million)	10.1	52.8	0.7	3.2	1301.0
Bolsa Família Program (R$)	0	0	0	0	0

	2010				
	Mean	Stan.Dev.	Min.	Median	Max.
Total area (km^2)	814.6	1349.6	47.1	379.3	13734.1
Percentage below poverty line	15.9	10.6	1.2	12.5	52.4
Percentage below extreme poverty line	5.3	5.5	0	3.1	29.0
Plantation area GFW/TW (percent area covered)	2.4	4.1	0	0.7	33.0
Rural population (percentage)	30.5	17.8	0	28.4	80.3
Population density	64.6	315.0	1.4	22.7	7110.5
Natural Vegetation (percent area covered)	8.8	5.4	0	7.6	44.1
Municipal expenditures (R$ million)	23.3	95.6	2.6	8.3	2275.3
Bolsa Família Program (R$ million)	0.73	1.66	0.02	0.33	34.52

* There are 720 observations for all variables.

2.3.2 Modeling Approach

Considering that municipalities have different individual characteristics that do not change over time and that might affect poverty, I used a fixed effect model with both time and individual effects. As the data points are ten years apart and they are significantly different, the time fixed effects account for time-trends of the variables. For instance, this approach should control for the overall decrease in poverty seen during the study period and trends in plantation area due to national policies.

The equation below describes my model:

$$Y_{it} = \alpha + \beta_1 X_{it} + c_i + \delta_t + \varepsilon_{it}$$

The dependent variable (Y) is poverty, modeled by the independent time-variant variables (X); α is the constant; δ_t is the time fixed effect where t indicates the time period; c_i is the unit fixed effect where i indicates the municipality; and ε_{it} is the error term. The variable of interest among the independent variables is the percentage of the municipality area covered by plantations.

The main limitation of this study is the lack of cofounding factors related to possible changes in land use that could have differently affected areas with forest plantation and the remaining areas. This could bias the analysis, as the impacts on poverty would have been affected either positively or negatively by other factors not accounted for in the models. However, I addressed this limitation by running robustness tests that account partially for the lack of cofounders. Another limitation could be the time difference between the establishment of plantations and its effect on poverty. Because plantations have different short and long-term impacts, I investigated the long-term effect over a specific time interval using the same time frame for all variables as a way to also account for the short-term effects.

2.4. Results

I present results for two fixed-effect models: one without the control variables and one with them. I employed both models to show that the effect of the variable of interest does not depend on the inclusion of the controls. In other words, I addressed the concern that the controls may be affected by the independent variable – plantations – and therefore bias our estimates. By showing that the results are similar with or without the controls, I demonstrated that the plantation effect on poverty is robust.

This way, the results on Table 2.2 suggest that forest plantation area is associated with a lower than average level of poverty during the period of analysis. The result for poverty on table 2.2 shows that a one unit increase (one additional percentage point) in the municipal plantation area was associated with 0.76 percentage point ($p < 0.001$) decrease in the poverty rate for that municipality. The results are fairly similar for both models. The control variables' coefficients are as expected.

Table 2.2. Effects of forest plantation area on poverty rate

Poverty				
Variables	Poverty rate (fixed effects)		Poverty rate (fixed effects)	
Plantation area GFW/TW (percent area covered)	-0.757	***	-0.776	***
	(0.194)		(0.166)	
Rural population (percentage)			0.333	***
			(0.047)	
Population density			0.010	*
			(0.004)	
Natural Vegetation (percent area covered)			0.175	**
			(0.051)	
Municipal expenditures (R$ mi)			0.025	(+)
			(0.015)	
Bolsa Familia' (R$ mi)			-0.764	(+)
			(0.408)	
Constant	54.867	***	38.033	***
	(0.383)		(2.120)	
R2 wihin	0.887		0.898	
R2 between	0.003		0.221	
R2 total	0.477		0.604	
Observations	2160		2160	
Number of municipalities	720		720	

Robust standard errors in parentheses (*** p <0.001; ** p <0.01; *p <0.05; (+) p <0.1). Models also include time fixed-effects with coefficient estimates not shown.

Considering that the poverty measure is the poverty line of household per capita income, I expected that plantations would also have positive effects on income. I further analyzed how plantations affect total per capita income and the per capita income quintiles. Data on these variables also came from the IBGE Demographic Censuses, compiled on the Atlas of Development (UNDP, 2013). As such, I ran fixed-effects models for total per capita income and quintiles (all log transformed) as dependent variables, with plantation forest as my main variable of interest. For controls I included the municipal expenditures, as a measure of the municipality wealth, and the *Bolsa Família* total cash transfer.

The results displayed in Table 2.3 show positive and significant association between forest plantation and total per capita income: one percentage point increase in plantation area is associated with 0.9 % ($p < 0.01$) increase in total per capita income. For every quintile, coefficients for plantation area are positive. As such, one percentage point increase in plantation area is associated with 1.4%, 1.2%, 1.2%, 1.1%, and 0.7% increase in income for the 1^{st}, 2^{nd}, 3^{rd}, 4^{th}, 5^{th} quintiles, respectively.

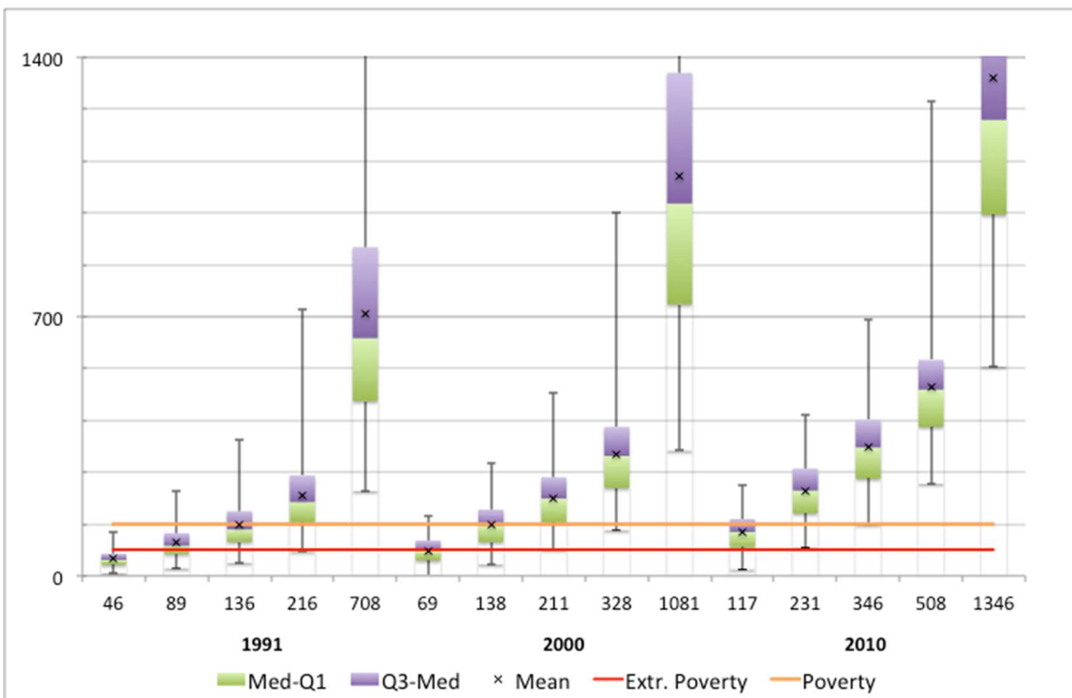
Although I ran the models for extreme poverty and found significant correlation to less extreme poverty rates, the results are not robust. I present the results in section 4.2.

Table 2.3: Effect of plantation forest on per capita income and quintiles

Per capita income (log)						
Variables	Total per capita income	1st Quintile Poorest	2nd Quintile	3rd Quintile	4th Quintile	5th Quintile Richest
Plantation area GFW/TW	0.009 **	0.014	0.012 **	0.012 ***	0.011 ***	0.007 (+)
(percent area covered)	(0.003)	(0.010)	(0.004)	(0.003)	(0.003)	(0.004)
Municipal Expenses	-0.266 *	-0.050	-0.367 *	-0.435 *	-0.474 (+)	-0.212 (+)
(R$ billion)	(0.135)	(0.074)	(0.176)	(0.217)	(0.250)	(0.110)
Bolsa Família (R$ billion)	6.228	-3.957	7.747 (+)	7.855	10.017	9.049 (+)
	(4.192)	(4.011)	(4.690)	(5.720)	(7.101)	(4.981)
Constant	5.390 ***	3.718 ***	4.383 ***	4.819 ***	5.284 ***	6.468 ***
	(0.007)	(0.017)	(0.008)	(0.007)	(0.007)	(0.009)
R2 wihin	0.882	0.722	0.916	0.928	0.922	0.760
R2 between	0.020	0.006	0.014	0.018	0.025	0.018
R2 total	0.401	0.292	0.480	0.512	0.506	0.299
Observations	2160	2160	2160	2160	2160	2160
Number of municipalities	720	720	720	720	720	720

Robust standard errors in parentheses (*** p <0.001; ** p <0.01; *p <0.05; (+); p <0.1). Models also include time fixed-effects with coefficient estimates not shown.

Given these results, it is important to understand the association between poverty and the per capita income quintiles over time. Figure 2.4 shows the municipality quintiles for each data point of this analysis – 1991, 2000, and 2010 – as well as the poverty and extreme poverty lines. One can see the evolution of income for all quintiles and the decrease in poverty in MG over this period – the fourth quintile moved entirely out of the poverty zone and the third quintile moved almost completely out. Still, 25% of the population was under the poverty line in 2010. Since the results show that forest plantations expansion is associated to higher income, especially for the middle-income quintiles, it suggests that forest plantations positively contributed to lifting people out of poverty.



Source: Atlas of Development UNDP (2013). Municipalities as minimum comparable areas - MCA7000 (IPEA/IBGE). Means showed on the X axis. Poverty and extreme poverty lines (BRL 140 and 70, respectively)

Figure 2.4. Per capita income quintiles and poverty lines in the municipalities of Minas Gerais – 1991, 2000, and 2010.

2.4.1. Robustness tests

I tested the robustness of my models by employing two tests: controlling for the effect of the next period's plantation area and controlling for the municipal linear trends. The first test includes another control variable for the next period of forest plantation area. This new model indicates whether the next plantation wave would explain any variance on the dependent variable in the present period. I expected not, and that this new variable would not be significant, otherwise it would indicate that plantation area is not affecting poverty independently. Instead, these plantation effects on poverty may be related to other common factors between dependent and independent variables.

For the second robustness test, since the data set has only three time periods, it is adequate to assume the municipalities follow individual linear trends over the years. These linear trends refer to all municipalities' characteristics apart from plantation area and the control variables in the model. The linear trends could be considered the control pathway that a municipality would follow had the plantation area and the other variables not changed. I assumed, therefore, that two similar municipalities would have parallel linear trends. So if the plantation area changed for only one of them, the difference on poverty would be the real effect of plantation on poverty for this municipality and not a result of a particular trend the municipality would be following anyway. After controlling for individual linear trends, I wanted to see whether the coefficient for plantation area was still significant, as I would expect so.

The first test results for poverty are displayed on Table 2.4 and are robust, as the coefficient for the next period of plantation area on poverty is not significant on either of the two models. The second robustness test results for poverty (Table 2.5) are also robust and show that the coefficients for plantation area in both models are still significant even after controlling for the linear municipal trends. Since both models displayed significant results, I assume my model is consistent in testing the effects of plantations on poverty during the period of analysis.

Table 2.4. First robustness test results of the effect on poverty

Poverty				
Variables	Fixed Effects		Fixed Effects	
Plantation area GFW/TW (percent area covered)				
Original	-1.237	**	-1.285	***
	(0.398)		(0.385)	
Next Period	-0.334		-0.290	
	(0.219)		(0.221)	
Rural population (percentage)			0.196	**
			(0.065)	
Population density			0.006	
			(0.004)	
Natural Vegetation (percent area covered)			0.123	
			(0.077)	
Municipal expenditures (R$ mi)			0.015	(+)
			(0.009)	
Bolsa Família (R$ mi)			0	
			(omitted)	
Constant	56.137	***	45.015	***
	(0.828)		(3.124)	
R2 wihin	0.825		0.831	
R2 between	0.003		0.079	
R2 total	0.172		0.303	
Observations	1440		1440	
Number of municipalities	720		720	

Robust standard errors in parentheses (*** p <0.001; ** p <0.01; *p <0.05; (+) p <0.1). Models include time fixed-effects with coefficient estimates not shown.

Table 2.5. Second robustness test on poverty, controlling for linear trends

Poverty		
Variables	Fixed Effects	Fixed Effects
Plantation area GFW/TW (percent area covered)	-0.706 *	-0.671 *
	(0.340)	(0.326)
Rural population (percentage)		-0.020
		(0.088)
Population density		-0.052
		(0.038)
Natural Vegetation (percent area covered)		0.236 **
		(0.089)
Municipal expenditures (R$ mi)		-0.045 (+)
		(0.025)
Bolsa Família (R$ mi)		-1.442 **
		(0.454)
Constant	54.786 ***	56.013 ***
	(0.552)	(4.577)
R2 wihin	0.957	0.958
R2 between	0.329	0.008
R2 total	0.314	0.284
Observations	2160	2160
Number of municipalities	720	720

Robust standard errors in parentheses (*** p <0.001; ** p <0.01; *p <0.05; (+) p <0.1). Models also include time fixed-effects with coefficient estimates not shown.

2.4.2 Analysis of plantation area on extreme poverty

I also investigated the effect of plantation area on extreme poverty rate – the percentage of people living under the extreme poverty line, R$70/month household per capita income, in prices of August 2010. The model is the same used for the poverty level. Table 2.6 shows the results for the models with and without the controls. The plantation coefficients are again fairly similar for both models, and the control coefficients are as expected. I can see that the coefficients for population density, natural vegetation, and the *Bolsa Família* Program are higher than for poverty and more significant. Meanwhile, the municipal expenditures coefficient is lower and not significant, which can be explained by the fact that the poorest do not benefit directly from the economic opportunities of wealthy regions.

Table 2.6: Effects of forest plantation area on extreme poverty rate

Extreme Poverty		
Variables	Extreme Poverty (fixed effects)	Extreme Poverty (fixed effects)
Plantation area GFW/TW (percent area covered)	-0.456 *	-0.494 **
	(0.183)	(0.156)
Rural population (percentage)		0.320 ***
		(0.046)
Population density		0.019 ***
		(0.003)
Natural Vegetation (percent area covered)		0.220 ***
		(0.057)
Municipal expenditures (R$ mi)		0.022
		(0.16)
Bolsa Família (R$ mi)		-1.308 *
		(0.627)
Constant	26.183 ***	9.120 ***
	(0.365)	(2.089)
R2 wihin	0.708	0.738
R2 between	0.002	0.177
R2 total	0.325	0.418
Observations	2160	2160
Number of municipalities	720	720

Robust standard errors in parentheses (*** p <0.001; ** p <0.01; *p <0.05; (+) p <0.1). Models also include time fixed-effects with coefficient estimates not shown.

However, the robustness tests for the extreme poverty models did not turn out consistent. Table 2.7 shows the results for the first robustness test, which controls for the next period of plantation area. The coefficient for this variable should not be significant, but it is in both models. The second robustness test (Table 2.8) also did not present robust results for the models, as the coefficients for plantation area after controlling for linear trends should be significant, but they are not.

Our findings indicate plantations have a direct impact on poverty and on per capita income. The significant results we found on the coefficients for forest plantations associated with less extreme poverty over time in the original model may indicate the impacts on this variable are residual and indirect. The poorest may be negatively affected by the replacement of natural areas by plantations, but might also benefit from the economic development brought to the region. These assumptions, however, would need further analysis to be confirmed.

Table 2.7: First robustness test results of the effect of plantation on extreme poverty

Extreme Poverty

Variables	Extreme Poverty (fixed effects)	Extreme Poverty (fixed effects)
Plantation area GFW/TW (percent area covered)		
Original	-0.931 *	-0.983 *
	(0.439)	(0.428)
Next Period	-0.566 **	-0.508 *
	(0.217)	(0.218)
Rural population (percentage)		0.207 ***
		(0.057)
Population density		0.014 ***
		(0.004)
Natural Vegetation (percent area covered)		0.116
		(0.074)
Municipal expenditures (RS million)		0.007
		(0.008)
Bolsa Família (R$ million)		0
		(omitted)
Constant	27.802 ***	16.868 ***
	(0.798)	(2.813)
R2 wihin	0.682	0.694
R2 between	0.002	0.070
R2 total	0.082	0.199
Observations	1440	1440
Number of municipalities	720	720

Robust standard errors in parentheses (*** p <0.001; ** p <0.01; *p <0.05; (+) p<0.1). Models also include time fixed-effects with coefficient estimates not shown.

Table 2.8: Second robustness test results of the effect of plantation on extreme poverty

Extreme Poverty

Variables	Extreme Poverty (fixed effects)	Extreme Poverty (fixed effects)
Plantation area GFW/TW (percent area covered)	-0.193	-0.158
	(0.350)	(0.340)
Rural population (percentage)		-0.053
		(0.076)
Population density		-0.047 (+)
		(0.027)
Natural Vegetation (percent area covered)		0.077
		(0.073)
Municipal expenditures (RS mi)		-0.050 *
		(0.025)
Bolsa Família (R$ mi)		-1.430 ***
		(0.395)
Constant	25.77 ***	29.681 ***
	(0.552)	(3.859)
R2 wihin	0.935	0.937
R2 between	0.677	0.099
R2 total	0.074	0.057
Observations	2160	2160
Number of municipalities	720	720

Robust standard errors in parentheses (*** p <0.001; ** p <0.01; *p <0.05; (+) p<0.1). Models also include time fixed-effects with coefficient estimates not shown.

2.5. Discussion

Much of the literature on forests plantations concludes they do not bring socioeconomic development to rural areas. In a review of socioeconomic impacts of forest plantations, Malkamaki et al. (2018) concluded that plantations have more negative than positive impacts, and claim that their "findings largely corroborate the dynamics observed in other large-scale land-based investments" (p. 99). However, the authors found that there is no conclusive empirical evidence on the long-term impacts of forest plantations. Nevertheless, given certain conditions, such as high poverty rate and high productivity, the impacts could be positive. In this context, these results shed light on that gap in the literature and show that in the long-run forest plantations have brought socioeconomic improvement to MG municipalities. I found that forest plantations are associated with less poverty over time and with higher per capita income.

One question that arises from my results is whether plantation area is reducing poverty rates by displacing people out of the municipality. Using migration data from Bustos et al. (2016)[6], I did not find an overall association between migration and plantation area (Table 2.5). Moreover, when I grouped the municipalities according to the percentage plantation covered area, I found that for the municipalities with forest cover above 2.5% and the ones above 10% plantation area was associated with positive average migration rates. The coefficients mean that one percentage point increase in plantation area is associated with 0.4 ($p<0.05$) and 0.6 percentage point ($p<0.01$) more people in that municipality, respectively. These results suggest that out-migration may not explain why plantations have affected poverty. However, to understand the potential role of migration in explaining poverty outcomes, more detailed

[6] On "Technical Appendix to Agricultural Productivity and Structural Transformation" Bustos et al. (2016) found migration rates for the same Demographic Censuses we use in this research – 1991, 2000, and 2010 – and for 721 MCA in MG. Therefore, I had to average their calculations for two MCA to get data for the 720 MCA. They calculated the net migration rate between two Census years using the cohort average method (Shryock, Siegel and Larmon 1980).

information is needed on migration at a finer spatial scale and by income classes. For example, are poor people moving out of certain municipalities while high-skilled labor (e.g. middle class) are moving in? Finer grained research, beyond the scope of this study, could also examine rural-urban migration patterns poverty rates within municipalities.

Table 2.9: Effect of Forest Plantation on migration

Migration				
Variables	Overall	>0 to <2.5 % area covered	Above 2.5% area covered	Above 10% area covered
Plantation area GFW/TW	0.136	-0.089	0.419 *	0.646 **
(percent area covered)	(0.167)	(0.602)	(0.174)	(0.235)
Municipal Expenses	5.121	1.847	26.769 *	178.039 *
(R$ billion)	(4.261)	(2.545)	10.367	(66.68)
Constant	-0.215	-0.600	-3.046 *	-10.139 **
	(0.328)	(0.376)	(1.50)	(3.681)
R2 wihin	0.117	0.054	0.188	0.391
R2 between	0.002	0.055	0.001	0.167
R2 total	0.064	0.04	0.048	0.253
Observations	2160	1205	395	116
Number of municipalities	720	560	182	51

Robust standard errors in parentheses (*** p <0.001; ** p <0.01; *p <0.05; (+) p<0.1). Models also include time fixed-effects with coefficient estimates not shown.

Generally, these findings are consistent with some recent empirical findings on socioeconomic impacts of large-scale tree plantations. For example, Edwards (2017) investigated the palm oil tree expansion in Indonesia over 15 years and found that poverty has declined faster in the districts that had increase in palm oil production. He also found higher household income and consumption associated with palm oil tree expansion. Although, one important aspect that differentiates palm oil tree cultivation from forest plantation for wood products is that palm oil is necessarily closely associated with the processing industry, as the oil has to be processed within 24 hours after the harvest (Edwards, 2017, p. 6). For wood products there is no such restriction, and the mills for cellulose production, for instance, can be up to 150 km away from the plantations (Rode et al., 2014). Other differences are that palm oil tree cultivation is labor intensive with short rotation time, while wood trees require much less work, on a high-mechanized harvest, and a long rotation time.

One of my hypotheses for a positive impact of plantations was that their expansion in developing areas would foster economic development by supplying jobs and bringing infrastructure. The north part of MG is well known for being a poor region with low infrastructure. It has been shown that an improvement on transportation links between the north and south of the state would bring development to the whole state, especially to the north (de Almeida et al., 2009). Forest-livelihoods research demonstrates that infrastructure is a way plantations can bring socioeconomic development (Sunderlin et al., 2008). The plantation expansion in MG is also associated to the pulp production, and there are only three locations where pulp is produced in MG, all in the middle-south region of the state. Therefore, the improvement or construction of new roads to integrate developing and more developed areas in the state may have been a possible outcome of forest expansion with positive impact on poverty over time. There is also a pulp industry that buys wood from MG in the east neighbor state of Espírito Santo, and the north-east municipalities in MG that supply them wood have lower poverty rate in the region (UNDP, 2013).

Our results also resonate with some previous research on the long-term socioeconomic impacts of large-scale agricultural investment. For instance, Dell and Olken (2017) found that villages growing sugar cane starting during the Dutch colonial era in the 19^{th} century were relatively better off in socio-economic terms today than villages where sugar industry investment was absent. They conclude that the principal reason for this outcome was the infrastructure constructed to process and transport the sugar to export. This finding contrasts with the “Dutch disease" theory where the exploitation of a single resource would delay economic development compared to areas that have more diversified economies.

However, this outcome is not always the case, especially if there are limited economic opportunities in a region given lack of resources and other constraints. Research on rubber extraction in Congo at the end of the 19th century had negative socioeconomic impacts in the long run, mainly due to the high violence associated with it (Lowes & Montero, 2018). Further research is needed to draw broader conclusions about the long-term effects of large-scale investment in agricultural and forest commodities in rural areas, including how they may vary by commodity type and context.

The expansion of forest plantations to the semi-arid regions of the north of MG was possible due to a high productivity increase on this sector at the beginning of the 2000s. The plantation companies went through restructuring to stay competitive and invested in advanced technology to improve productivity by developing clones suited for different regions, climates, and wood purposes (Mendes, 2005; de Paula et al, 2018). High productivity in plantations also led to high mechanization of the activities, making them more labor-saving. The soybean industry in Brazil also went through a similar increase in productivity in the 2000s, which was analyzed by Bustos et al. (2016) under the structural change theory. The authors compared the municipality economic development before and after the increase in productivity over a 10-year interval. They observed that high productivity increased the marginal returns of labor and thus reduced the job offers in soybean farms. Releasing people from the agricultural sector increased labor supply in other sectors and ultimately fostered their development. The authors found that the municipalities that had an increase in soybean production also had more economic development based on manufacture and services. This could also be happening in the forest plantation sector because the development of non-agricultural sectors is also important to support plantation production.

Apart from pulp production, plantations in MG are strongly associated with charcoal production. According to the MG Forestry Association, 82.5% of the charcoal used in the state is internally produced, where that 86.3% come from forest plantation while 13.7% come from natural forests (MG Government, 2013). The production sites are usually next to plantations, demand many low-skill workers, and pay low salaries compared to other wood industries. These economic activities associated with plantation products also bring socioeconomic development to the region. The appropriate instrument to investigate their effect on regional economy would be input-output analysis of their economic multipliers. Therefore, apart from the multipliers of the plantations activity itself, the other associated sectors also impact the local livelihoods.

The key pathways through which forest plantations may have positively affected poverty are new infrastructure and economic multipliers brought to poor regions, the supply of formal and high skilled jobs, and the release of labor to other sectors. Previous studies have already identified the importance of the agricultural productivity for economic development (Gollin, 2010; Dercon & Gollin, 2014), especially to support the non-agricultural sectors, which have even more importance in both fostering economic development (Gollin et al., 2002) and lifting rural people out of poverty (Foster & Rosenzweig, 2004; Christiaensen et al, 2011; Ney & Hoffmann, 2008). Therefore, even though some authors argue that large-scale tree plantations do not fit into a new paradigm for agriculture focused on increasing environmental services, reducing poverty, and reducing inequality (Byerlee et al, 2010; Kröger, 2012), this research's findings suggest that they have indeed contributed to socioeconomic development in the MG case.

2.6. Conclusion

The literature is unsettled on effects of forest plantations, especially large-scale plantations. This study helped understand their socioeconomic impacts at local level over time by studying the municipalities in the state of Minas Gerais (MG), Brazil. I found that plantation area in MG is associated with lower poverty rates over a 20 year time period with robust results. I also found that plantation expansion is associated with higher per capita income.

These findings stand in contrast with the literature evidence on socioeconomic forest plantation impacts at the local level. While this literature posits how large-scale tree plantations for wood production displaces people from the region, I did not find an overall association between migration and plantation area. In fact, for municipalities with a large percentage of covered area, I found a positive and significant correlation between forest plantation and in-migration. My results are consistent with other recent findings concerning empirical analysis of the socioeconomic impacts of other large-scale plantations at a local-level over a long period of time. Considering that not all findings on the impacts of large-scale plantations are similar, other aspects may be important to determine the outcomes, such as culture, laws, climate, and public policies, and should be further investigated.

For the state of MG, one main aspect that could have alleviated poverty is the plantation expansion to new agricultural frontiers with high poverty rate, bringing infrastructure and fostering development. Another aspect would be the increase in productivity in the plantation sector along with the mechanisms explained by structural theory. As follow-up research, it would be helpful to investigate the regional economic multipliers of plantations and analyze rural and urban impacts within municipalities to understand who is benefitting and how they are benefitting from plantations.

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CHAPTER 3:

THE RELEVANCE OF THE FORESTRY SECTOR FOR THE ECONOMY OF MINAS GERAIS

Abstract

This chapter examines the economic integration of the forestry sector in the state of Minas Gerais, Brazil. The forestry sector as a whole is composed of five economic sectors: forest plantations, wood products, furniture, paper products, and chemical pulp. The planted forest sector is comprised mainly of eucalyptus and pine plantations and is rapidly increasing due to high international demand for wood products, especially cellulose for paper production. To evaluate the regional economic importance of these sectors, this study divides Minas Gerais into 13 regions and develops a multiregional input-output framework to capture sectorial and regional interdependencies. In addition, I apply the hypothetical extraction for all sectors and the fields of influence method to understand the importance of forestry transactions in comparison to other prominent economic activities. Also, to visualize the forestry products' flow within the state, I constructed the structural path analysis for each region and for the state as a whole, starting with the forest plantation sector. Results show the contribution of all forestry sectors on employment, output, value added, and income generation for each region, the state as a whole, and the rest of Brazil. I found that plantations have low economic multipliers, with the exception of value added. Other forestry sectors have higher multipliers in Minas Gerais, with the exception of pulp production that largely benefits the rest of Brazil.

Keywords: input-output, analysis, economic, multipliers, Minas Gerais, Brazil, forestry, forest plantations

3.1 Introduction

Plantation forests are significantly growing all over the world due to increasing demand for wood products (Kanninen, 2010). This expansion occurs mostly in tropical areas with high productivity rates and inexpensive land. Among tropical countries, Brazil leads the way with the highest plantation expansion rate and the best return rates in the world (Cubbage et al., 2014; Payn et al. 2015). Wood production from plantations goes mainly to chemical pulp production for exports, charcoal, and other industries as intermediary inputs. In all, between 1990 and 2015, planted forests[1] increased from 167.5 million ha to 277.9 million ha (Payn et al, 2015).

Despite the growth and importance of the plantation forestry sector in Brazil, few studies have investigated the sector's economic contribution at the regional scale. Most of the existing studies are at national and state levels (Valverde et al., 2003; Valverde et al., 2005) due in large part to data constraints. Because plantation areas will continue expanding in the coming decades, it is crucial to understand the economic contributions of forestry at sub-state levels. To address this gap, I examined dynamics in Minas Gerais (MG), the Brazilian state that has the largest plantation area since the 1980s. I focused on the importance of the forest industry for the state's economy by analyzing the forestry value chains in the state and their integration with the other main sectors at sub-state levels. To do so, I used a detailed set of data covering the 66 microregions of the state.

The forestry sector in MG is composed of 5 specific sectors: forest plantations, wood products, furniture, paper products, and chemical pulp. To better evaluate sectorial impacts, I divided the state into 13 regions of analysis according to their forest production. I measured the

[1] The FAO FRA report (2015) defines planted forests as: forests predominantly composed of trees established through planting and/or deliberate seeding, where the planted/seeded trees are expected to constitute more than 50 percent of the growing stock at maturity.

impact of these sectors on the economy by employing the input-output methodology (Miller & Blair, 2009) to determine employment generation by number of jobs created; employment compensation measured in wages paid; the output as the total value of production; and the value added equal to total production minus the costs of the purchased inputs. The economic impacts are direct (in the sector itself), indirect (the value chain impacts), and induced (through the expenditures by households of direct and indirect income). I also simulated the extraction of each sector in the state to see how it would change the total output and value added in each region. Furthermore, I made charts to visualize the flow of the forestry chain products among the regions within MG. At the microlevel, I elaborated maps comparing all intermediate transactions between the sectors to verify which are most influential to foster the state's economy.

This chapter provides background information on the history of plantations in MG, their economic importance, and the state's socioeconomic context. I then present a theoretical model where data and methods are explained. Results are followed by a discussion of my main findings. My conclusion offers future perspectives and public policy suggestions.

3.2 Background information

The state of MG comprises 227 thousand square miles and is the fourth largest among the 27 Brazilian states, comparable in size to France with 247 thousand square miles, occupying 7% of the country (Figure 3.1). MG is part of broader southeastern Brazil, occupying 64% of this region alongside the states of São Paulo, Rio de Janeiro, and Espírito Santo. In 2015, MG encompassed 1.43 thousand ha of plantation forests – 20% of the country's total – mainly on a large-scale industrial model (IBA, 2016). Historically, plantations were first incentivized by the government to provide charcoal for the iron and steel industry in the 1970s (Lemos, 2002) and later expanded throughout the state to supply wood for chemical pulp within the state and in the neighboring states. Current plantations provide supplies to many additional industries and have an important role in the MG economy.

In 2014, total industry production in MG was equivalent to US$ 195 billion, accounting for an 8.9% share in the national GDP and was the third largest economy among the Brazilian states, only behind São Paulo's 32.2% and Rio de Janeiro's 11.6% (IBGE, 2016). MG has a diversified industry encompassing iron and steel, agriculture, biotechnologies, chemicals, and others (Lemos, 2002). The state has about 80% of the national iron ore reserves and produces 73% of this mineral's total production in Brazil, which in turn is the third largest producer in the world (MG Government, 2013). The iron ore mining and the iron and steel industries are responsible for 17% and 9% of the state's gross product (CNI, 2015).

To supply raw material to the iron and steel industry, MG became the largest producer of charcoal in the country with 85% of national production (IBGE, 2016) used almost entirely within the state (MG Government, 2013). According to the MG Forestry Association (AMS), more than 85% of the raw material for the state's charcoal consumption comes from plantations and only around 15% comes from natural forests (AMS, 2009). Plantations in MG consist mainly of eucalyptus (97%) and pine (2.7%) (IBA, 2016) and their primary products in production value are charcoal (65%), roundwood (30%), and resin (<1%) (PEVS/IBGE, 2011). In 2010, MG provided 19% of the total national forestry production, second among all 27 Brazilian states (Ibid).

Eucalyptus wood production spreads to most parts of the state and in more than 500 municipalities (59% of the 853 total) (Rezende et al, 2013). In the early 2000s, the destination of the wood diversified from traditional industries such as charcoal and cellulose production to furniture, construction, wood products, and biomass for energy generation in the food industry (Ibid). Furniture in particular has had a consistent growth, boosting the wood products sector (de Almeida et al., 2014). Cellulose and paper have also increased their contribution to the national GDP (Ibid).

Minas Gerais is the second most populous state in the country with 21 million people representing 10% of Brazil's population, only behind São Paulo's 45 million people, 22% of the national population (IBGE, 2010). The urbanization rate is 85% for the state as a whole, though it varies across municipalities. In spite of its economic development, MG is one of the most economically unequal states in Brazil, with both rich and dynamic areas and poorly developed ones. MG can be divided into two major regions: the poor north and the wealthy south. The north hosts about 20% of the population in almost half of the state's territory, responsible for only 6% of the state's economic production (IBGE, 2010). The northern area comprises the mesoregions of North of MG, Jequitinhonha and Mucuri Valley (Figure 3.1), is in a semi-arid region, and borders the relatively underdeveloped state of Bahia. The south borders São Paulo, the most industrialized state in the country, and the west borders the Federal District, the state with the highest per capita income in Brazil.

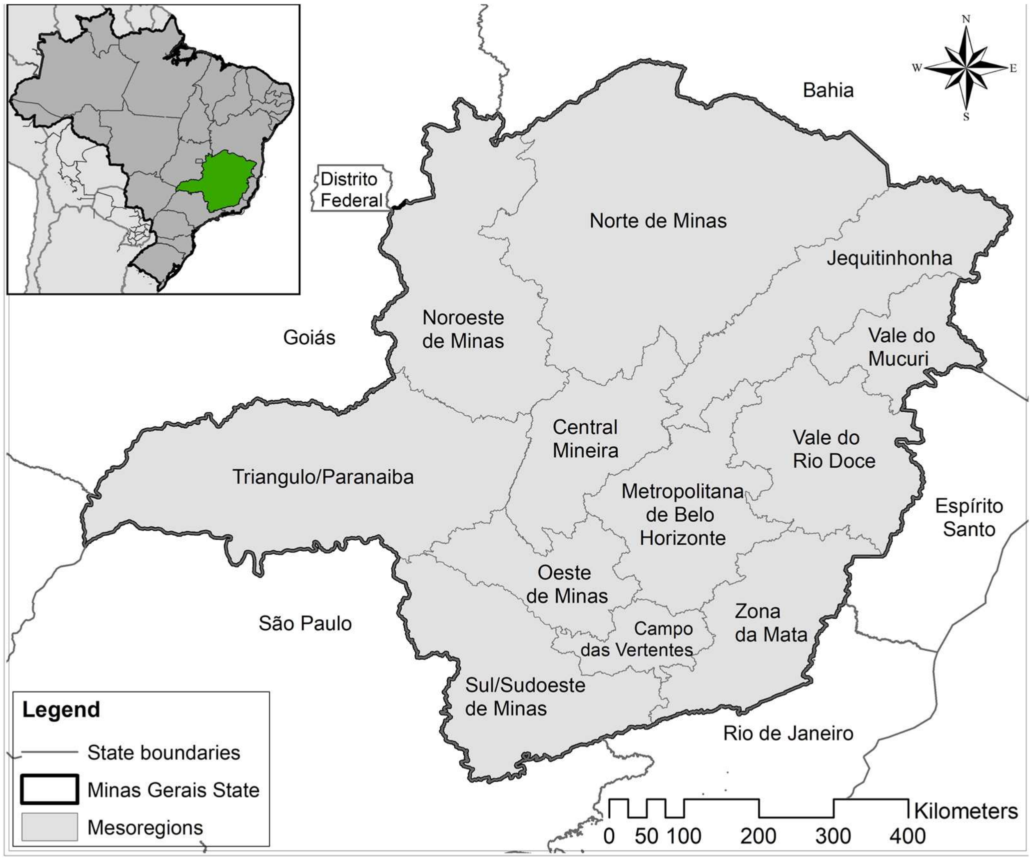


Figure 3.1: Map of Minas Gerais

3.2.1 Region of analysis

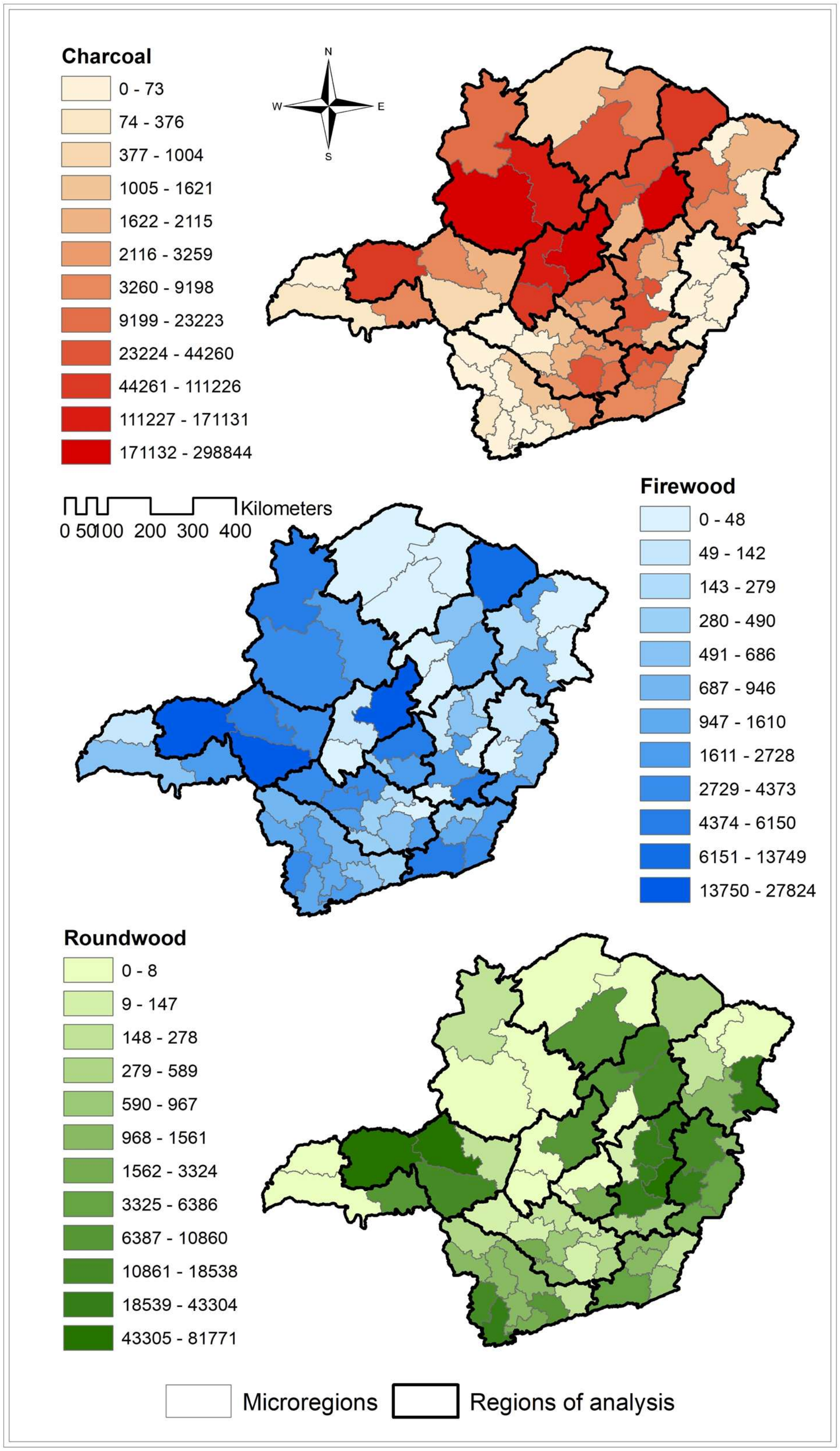
To analyze the regional economic impact of the forestry sector in MG, I divided the state into regions based on plantation forests, the first sector of the forestry chain. I then organized the data by microregion detailing the production of the primary plantation products: charcoal, roundwood, and firewood. Based on the total production value of these products, I clustered the 66 microregions into 13 regions for analysis (Figures 3.2). In Figure 3.3, I illustrate the official division of the state, the mesoregions, with our regions of analysis. The mesoregions and microregions are the official IBGE geographical divisions. Among the regions of analysis, only Regions 10 and 12 coincide with mesoregions: Central MG and South MG. Also, Regions 1 and

2 together represent the mesoregion MG Triangle and Paranaiba. The other regions of analysis do not coincide with the mesoregions.

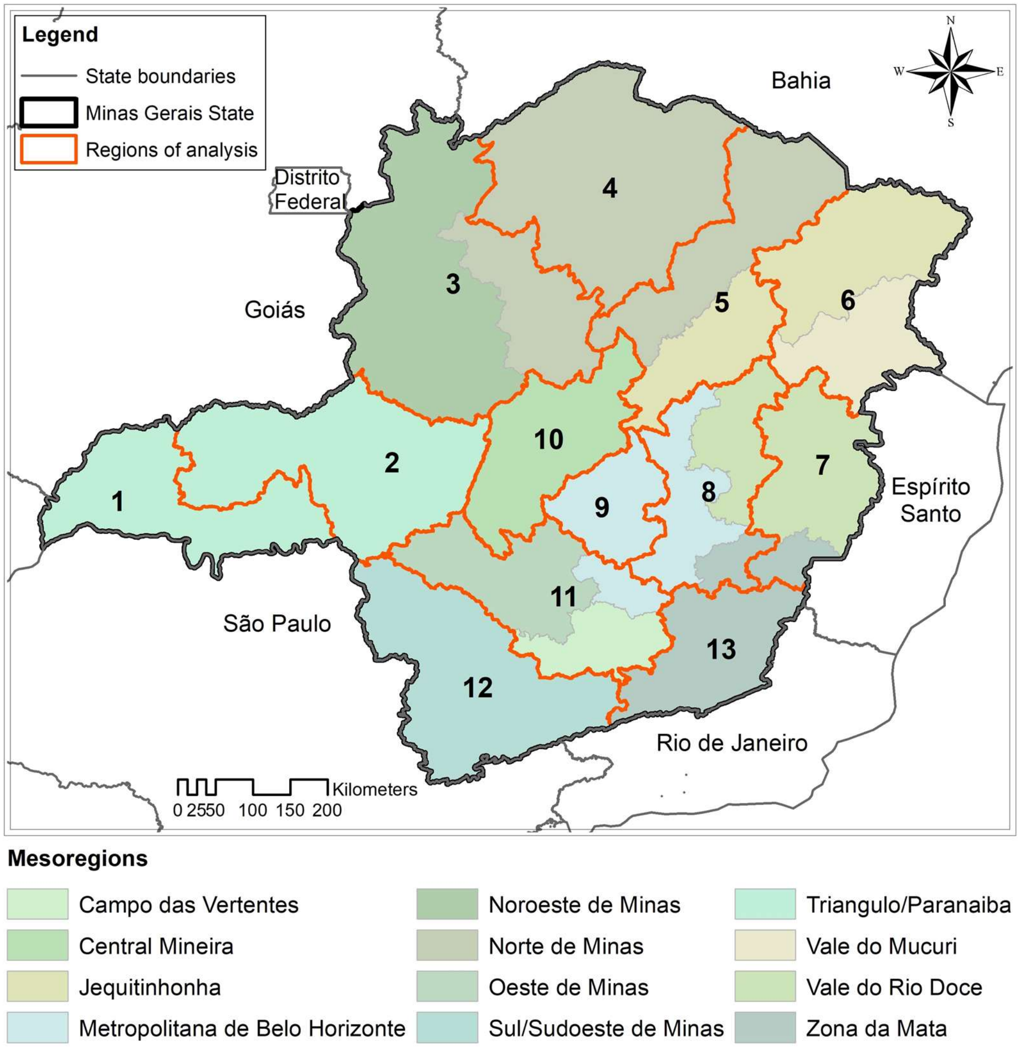
3.2.2. Socio-Economic Characteristics of the Regions

Table 3.1 provides descriptive statistics on key socioeconomic variables of the regions of analysis. The most productive region is Region 9, encompassing the central part of the capital metropolitan area, with the highest industrial concentration in the state. The south, or Region 12, is a highly developed industrial area and tightly integrated to the southern and prosperous state of São Paulo. Regions 1 and 2 taken together are the third most productive area, especially for agro-industry. Region 8 has substantial iron production and the larger chemical pulp industry in the state. Region 7 is mostly an agricultural region and provides forest plantation inputs to both Region 8 and the neighbor state of Espírito Santo. Regions 3 to 6 are the poorest ones, especially when considering their total area to GDP ratio. Region 10, the central region, is an intermediate region in terms of development and production, concentrating its activities on services.

MG has a positive interstate and international commercial balance overall, with international trade balance responsible for half of its total positive balance (Botelho et al, 2012). The largest commercial flows are between MG and the rest of southeastern Brazilian states of São Paulo, Rio de Janeiro, and Espírito Santo. About 64% of its imports come from this region and 52% of the MG exports go to it. The international commercial flow is the second largest with 16% of all inflows and 24% of the state's exports. MG has a positive trade balance with all other Brazilian states with the exception of São Paulo and Amazonas. Its main international exports are iron ore, steel products, and coffee, while its main domestic exports are vehicles, steel products, and food/agriculture (Ibid).



Figures 3.2. Production value in BRL thousand of charcoal, firewood, and roundwood by microregions and the regions of analysis in 2011 (source: PEVS/IBGE)



Figures 3.3. Mesoregions of Minas Gerais and Regions of analysis 2011

Though MG's population is concentrated in the south and holds the state's highest Municipal Human Development Indexes (*Índice de Desenvolvimento Humano Municipal* – IDHM), the average IDHM in MG is still lower than Brazil's national Human Development Index of 0.76.

Table 3.1.Descriptive statistics on socioeconomic indicators for the regions of analysis, 2010/2011

	Total Area ($1,000\ km^2$)	Total Pop (1,000)	GDP Billion US$	% Area in MG	% Population in MG	% GDP in MG	Per capita GDP (1,000 US$)	IDMH (average)
Region 1	34.9	676	9.8	6.0	3.4	4.7	14.48	0.71
Region 2	55.6	1,490	21.2	9.5	7.6	10.2	14.20	0.71
Region 3	85.4	535	5.4	14.6	2.7	2.6	10.18	0.67
Region 4	70.6	1,130	5.3	12.0	5.7	2.6	4.72	0.63
Region 5	54.2	605	2.4	9.2	3.1	1.2	4.03	0.62
Region 6	50.9	806	3.2	8.7	4.1	1.5	3.92	0.60
Region 7	31.9	1,160	6.8	5.4	5.9	3.3	5.89	0.64
Region 8	37.6	1,571	22.1	6.4	8.0	10.7	14.09	0.65
Region 9	16.2	5,334	74.0	2.8	27.0	35.6	13.87	0.71
Region 10	31.7	415	3.3	5.4	2.1	1.6	7.83	0.69
Region 11	42.0	1,833	16.8	7.2	9.3	8.1	9.15	0.69
Region 12	49.6	2,453	25.1	8.5	12.4	12.1	10.22	0.70
Region 13	26.0	1,722	12.3	4.4	8.7	5.9	7.12	0.67
Region 14	2,701	177,271	2,145	-	-	-	12.10	0.76*

* IDH for the whole country
Source: IBGE

3.2.3. Theoretical expectations

Previous research demonstrates applications of the IO methodology for the forestry industry. Thompson & Psaltopoulos (2005) identified key elements of the forestry sector for Scotland's rural economy under different scenarios based on plantation expansion. They found that the effects on employment are greater when the region contains other industries down the production chain, such as sawmilling, plywood, wood panel, and others. In another study examining Scotland, Roberts et al. (1999) show that the multiplier effects of forestry sector differ by region depending on the type of woodland and the structure of the regional economy. They also claim that the downstream multiplier effects are more likely to be retained at the local level than the upstream effects. Furthermore, they found that a large part of plantation expansion gains leak to urban areas rather than benefitting rural ones. In Brazil, Valverde et al. (2003) studied the forestry of the country's economy and Valverde et al. (2005) analyzed the forestry sectors for the state of Espírito Santo. They concluded that forestry is a relevant sector for both the country and the state as it has above average economic multipliers.

Within my knowledge, there has not been a study applying IO at the sub-state level in any state in Brazil to analyze forestry sectors. Given the characteristics of MG and previous studies, I expected to find different economic multiplier effects for the forestry sectors, especially considering the economic structure of the regions. Wood products and furniture are more job intensive activities and closely connected to other industries downstream. The paper industry requires more labor than cellulose production and the output mostly goes to Brazil's internal market while cellulose is mainly exported. Forest plantations can be considered the most isolated sector among the forestry sectors. It does not demand much labor due to the increasing mechanization, long intervals between planting and harvesting, and the fact that wood can be processed far from plantations. Therefore, its economic returns depend on the economic structure in the region to benefit from that sector. Apart from plantations, the nature of the other forestry activities requires these activities to be integrated with other industries.

3.3. Theoretical model

3.3.1. The input-output model

The structure of the IO model for only one region with n industry sectors is briefly described in Table 3.2.

Table 3.2: Input-output framework for one region with n sectors

Selling sector	Purchasing sector				Final demand	Total output
	1	2	...	n		
1	z_{11}	z_{12}	...	z_{1n}	f_1	x_1
2	z_{21}	z_{22}	...	z_{2n}	f_2	x_2
...	...	...	...	...	...	...
n	z_{n1}	z_{n2}	...	z_{nn}	f_n	x_n
Imports	m_1	m_2	...	m_n	...	M
Value Added	v_1	v_2	...	v_n	...	V
Total input	x_1	x_2	...	x_n	$C \quad I \quad G \quad E$	X
Labor (phys. terms)	l_1	l_2	...	l_n	...	L

Note:

z_{ij} represents the amount of goods sold by sector i to sector j, which used them as inputs.

m_i is the import amount of sector i, and M is the total imports in the economy.

v_j is the value added to the production of that sector, which includes the salaries paid, profits, interests payment, rental payments, and taxes. V is the total value added.

f_i is the final exogenous demand by sector, and can be divided into consumption (C), investments (I), government (G), and exports (E) for all sectors.

x_i is the total output of the i sector, and x_j is the total inputs bought by the j sector. X is the total output in the economy.

l_j is the number of jobs in the j sector, and L is the total number of jobs.

The equilibrium in the system exists when the sum of the line is equal to the sum of the column for each sector (excluding labor):

Row: $\Sigma_j z_{ij} + f_i = x_i$, for all $i = 1, \ldots, n$

Column: $\Sigma_i z_{ij} + m_j + v_j = x_j$, for all $j = 1, \ldots, n$

The matrix of all technical coefficients is known as direct requirements matrix and is usually named the **A** matrix. This matrix comprises the technical coefficient of production and indicates the value of input i used in making a dollar's worth of output j:

$$a_{ij} = z_{ij}/x_j$$

Therefore, the total output (X) can be written as:

$$x_{ij} = a_{ij}x_j$$

$$\Sigma_j a_{ij}\, x_j + f_i = X$$

From this, we derive the following equation:

$$\mathbf{AX} + \mathbf{F} = \mathbf{X}$$

$$(\mathbf{I}\text{-}\mathbf{A})^{-1}\mathbf{F} = \mathbf{X}$$

The Leontief Inverse Matrix $(\mathbf{I}\text{-}\mathbf{A})^{-1}$ is also called matrix **B** or the matrix of output multipliers. Changes in final demand will be multiplied by the **B** matrix to give the new total output in the economy.

Since I analyzed several regions at the same time, the model is the multiregional IO model (MRIO). The MRIO makes it possible to observe the interactions among all regions and the sectors within them. To illustrate this model, I present how the multi-matrices would be structured for a two region (L and M) and two sector model (1 and 2): (Miller, 1997)

$$\mathbf{X} = \begin{bmatrix} \mathbf{X}_1 \\ \mathbf{X}_2 \end{bmatrix} \qquad \mathbf{Z} = \begin{bmatrix} \mathbf{Z}_{11}\mathbf{Z}_{12} \\ \mathbf{Z}_{21}\mathbf{Z}_{22} \end{bmatrix} \qquad \mathbf{F} = \begin{bmatrix} \mathbf{F}_1 \\ \mathbf{F}_2 \end{bmatrix}$$

$$\mathbf{A}^{LL} = \begin{bmatrix} a_{11}{}^{LL} & a_{12}{}^{LL} \\ a_{21}{}^{LL} & a_{22}{}^{LL} \end{bmatrix} \qquad \mathbf{A}^{LM} = \begin{bmatrix} a_{11}{}^{LM} & a_{12}{}^{LM} \\ a_{21}{}^{LM} & a_{22}{}^{LM} \end{bmatrix}$$

$$\mathbf{A}^{MM} = \begin{bmatrix} a_{11}{}^{MM} & a_{12}{}^{MM} \\ a_{21}{}^{MM} & a_{22}{}^{MM} \end{bmatrix} \qquad \mathbf{A}^{ML} = \begin{bmatrix} a_{11}{}^{ML} & a_{12}{}^{ML} \\ a_{21}{}^{ML} & a_{22}{}^{ML} \end{bmatrix}$$

Changes in final demand for Sectors 1 and 2 from any region will spread between both regions to give the final product or output:

$$\Delta\mathbf{X} = \begin{bmatrix} \Delta\mathbf{X}^L \\ \Delta\mathbf{X}^M \end{bmatrix} \begin{bmatrix} \mathbf{B}^{LL}\mathbf{B}^{LM} \\ \mathbf{B}^{ML}\mathbf{B}^{MM} \end{bmatrix} \begin{bmatrix} \Delta\mathbf{F}^L \\ \Delta\mathbf{F}^M \end{bmatrix}$$

3.3.2 Data

To construct a multi-regional IO model for the 13 regions of analysis, the main source of data is the IO framework from the Intermunicipal Input-Output Model for the Brazilian Economy (SIIP-BR Model) developed by Prof. Guilhoto and his team at the University of São Paulo (Guilhoto et al. 2017; Guilhoto & Sesso Filho, 2010). I used this framework to construct the IO, comprising 14 regions: the 13 regions of analysis inside MG and the last region of analysis representing the rest of Brazil as the 14th region. The data-base of the SIIP-BR Model is from 2011.

The original SIIP-BR matrix has 149 sectors and 194 products. I aggregated them into 17 sectors with their respective products to illustrate my focus on MG's forestry sectors. The sectors are displayed in Table 3 along with their acronyms used later in the presentation of the result. I selected the most relevant sectors for the state's economy and the five forestry sectors: forest plantation, wood products, furniture, chemical pulp, and paper products.

Table 3.3: Sectors and products for each region in the MRIO matrix.

Sectors division/aggregation:	**Products division/aggregation:**
1) Agriculture - AGR	1) Agriculture
2) Industry - all others - IND	2) Industry - others
3) Commerce – COM	3) Commerce
4) Services - SER	4) Services
5) Government - GOV	5) Public administration
6) Forestry production from planted and natural forests - FOR	6) Products from forestry production – wood and others
7) Wood products manufacture - WOP	7) Woods products
8) Furniture production -FRT	8) All furniture products
9) Chemical pulp, as cellulose - CEL	9) Pulps for paper production
10) Paper and manufacture of paper products - PAP	10) Paper, cardboard, packaging and paper products
11) Siderurgy - SID	11) Iron, steel, and other products
12) Automotive industry - VEH	12) Cars, buses, tractors, etc.
13) Iron and metal ore mining - MIN	13) Iron, copper, aluminum, etc.

Table 3.3 (Cont.)

Sectors division/aggregation:	**Products division/aggregation:**
14) Construction - CON 15) Food industry - FOO 16) Transportation -TRA 17) Utilities Industry: Public services - UTI	14) Construction activities 15) Food and beverages 16) Transportation 17) Energy generation, water and gas distribution, sewage, and recycling

Forest production represents the production from both natural and planted forests and includes both wood and non-wood products, as they cannot be separated in the data source. Thus, products can include rubber, fruits, and other NTFP (non-timber forest products) collected in natural areas. However, the percentage of these products in the total forestry sector in MG is less than 1% and wood products from natural areas represent less than 5% of the 2011 total production value (IBGE/PEVS, 2011). We can therefore consider that most of the production from forests is derived from eucalyptus and pine plantations.

Table 3.4 displays summary statistics for outputs per sector and per MG region according to the IO matrix created with the SIIP-BR Model data. The total MG output in 2011 was about R$350 billion (US$190 billion). The most important sectors in the state were services (29.1%), government (14.7%), and commerce (11.8%). The forestry sectors contributed 1.7% of the total output of the state. Forest plantations are the most relevant among them with about 0.8% in total output. Furniture contributed 0.5%, wood products contributed 0.2%, while cellulose and paper products contributed around 0.1% each.

The most important regions for the forest plantations sector were Regions 5, 3, and 10, with respectively 29%, 16%, and 14% of the total state production. These regions were not relevant for any other forestry sector. However, according to Figures 3.2, they were all important producers of charcoal for the iron and steel industry and firewood for the other sectors. Region 5 was also important in roundwood production (see Figure 3.2 above).

Furniture production was concentrated in Region 13 (46%), Region 9 (21%), and Region 11 (12%). Wood products were made mainly in Region 2 (23%), Region 9 (18%), and Region 12 (15%). Only three regions produced chemical pulp for paper production or cellulose. Most of the state's production occured in Region 8 with 94% of the total, Region 11 with 5%, and Region 9 with 1%. Finally, paper production was concentrated mostly in Region 13 (27%), Region 9 (23%), and Region 12 (20%).

The information presented thus far focuses on the direct contribution of each sector. In the following section, I used some further analytical tools, based on the multiregional input-output system, to evaluate the total contribution of the forestry sectors for the state's economy.

Table 3.4: Total MG GDP by regions and sectors of analysis, using the SIIP-BR Model data for 2011

	AGR	IND	COM	SER	GOV	FOR	WOP	FRT	CEL	PAP	SID	VEH	MIN	CON	FOO	TRA	UTI	TOTAL
Reg 1	12.0	4.0	3.6	2.8	3.4	0.9	4.8	2.3	0.0	4.5	0.0	0.1	0.0	2.8	13.5	2.4	3.0	3.5
Reg 2	20.6	7.4	11.1	9.0	7.1	9.5	22.9	3.3	0.0	4.0	3.1	1.2	0.2	7.3	19.7	7.3	3.9	8.4
Reg 3	10.6	1.3	2.0	1.2	2.3	15.5	2.0	0.4	0.0	0.1	5.4	0.1	1.1	1.2	1.4	1.1	0.8	2.2
Reg 4	4.1	2.0	3.8	2.5	4.0	4.5	2.4	1.2	0.0	0.8	1.2	0.2	0.1	2.1	1.7	1.5	0.1	2.5
Reg 5	1.8	0.7	1.1	0.7	2.3	29.0	4.1	0.5	0.0	0.0	4.1	0.0	0.1	0.6	0.7	0.8	0.1	1.3
Reg 6	3.5	0.7	1.7	1.1	2.8	2.4	0.7	0.1	0.0	0.1	0.0	0.0	0.0	1.2	1.5	0.7	0.1	1.4
Reg 7	7.0	1.4	4.3	3.1	4.4	2.1	3.5	1.6	0.0	2.9	0.1	0.2	0.2	2.8	3.4	1.8	3.0	3.1
Reg 8	3.2	4.1	6.0	4.9	8.2	9.5	4.5	3.1	94.3	1.7	25.8	0.9	52.4	11.0	5.5	4.9	2.1	9.6
Reg 9	2.3	44.2	37.9	51.4	38.6	1.4	17.8	21.1	1.0	23.0	29.2	76.3	27.0	54.0	19.9	48.2	69.8	42.2
Reg 10	2.7	1.4	1.6	1.0	1.7	14.2	3.7	1.5	0.0	1.1	1.9	0.1	0.0	0.7	3.0	1.1	0.2	1.4
Reg 11	8.1	9.9	8.2	6.5	7.9	4.7	8.5	11.7	0.0	14.1	22.5	3.4	17.7	5.7	8.6	7.1	2.2	8.2
Reg 12	19.8	17.8	11.7	8.0	10.5	3.5	14.7	7.6	4.7	20.2	2.6	13.9	0.8	5.3	13.9	8.1	6.0	9.6
Reg 13	4.3	5.1	7.1	7.6	6.8	2.8	10.5	45.6	0.0	27.3	4.2	3.5	0.2	5.4	7.0	15.1	8.7	6.7
	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	
MG total	6.0	6.8	11.8	29.1	14.7	0.8	0.2	0.5	0.1	0.1	2.4	2.8	7.1	6.9	2.5	4.4	3.8	100
BRL 350 billion						**1.7 % Forestry Sector**												

3.3.3. Input-output analysis

3.3.3.1. Multipliers and linkage analysis

The output multiplier represents the amount of output needed in the economy t satisfy a one-unit increase in final demand. The output multipliers for the total economy are obtained by the column summation of the Leontief Matrix for each sector:

$$\text{Out\_Mult}_j = \Sigma^n{}_{i=1} b_{ij}$$

This is the total output (or backward) multiplier for sector j, and b_{ij} is the Leontief matrix element. The forward multiplier is calculated by the row sum of the Goshian matrix and represents the total supply of one sector as a proportion of this sector's total output (Miller & Blair, 2009).

Backward and forward linkage analysis is used to evaluate the sector's interaction with the others sectors in the economy. The backward linkage (BL) shows how much one sector depends on the others to get inputs, whereas the forward linkage (FL) shows how important a sector is to supply inputs to the others. The equations for both linkages are shown below in a normalized form for a single region's economy.

b_{ij} is the Leontief inverse matrix element and $g_{ij}$is the Goshian inverse matrix element.

$$BL_j = \frac{n\, \Sigma_i b_{ij}}{\Sigma_i \Sigma_j b_{ij}} \quad \text{and} \quad FL_i = \frac{n\, \Sigma_j g_{ij}}{\Sigma_i \Sigma_j g_{ij}}$$

Since it is multi-region analysis, I calculated linkage indexes by sector on each region by summing this sector's linkages over all regions.

$$BL_j^L = BL_j^{LL} + BL_j^{ML} \qquad \text{and} \qquad FL_i^L = FL_j^{LL} + FL_j^{ML}$$

Through the backward and forward indexes we find key sectors, the most relevant sectors for a region and the whole economy. They have above average values for BL and/or FL and have values above one in our normalized form.

The method is similar for income or value added multipliers, although one has to multiply the Leontief matrix by the respective coefficient vector first. The value added coefficient is the value added per unit of each sector's output and the income coefficient is the income paid per unit of each sector's output. Multiplying the Leontief matrix by each coefficients vector will transform it into either an income or value added multiplier matrix.

$VA\_Mult_j = \Sigma^n_{i=1} c_{n+1,i} b_{ij}$; where $c_{n+1,i}$ is the value added coefficient for that sector

$Inc\_Mult_j = \Sigma^n_{i=1} e_{n+1,i} b_{ij}$; where $e_{n+1,i}$ is the income coefficient for that sector

The employment multiplier also follows the same methodology. The employment coefficients represent the number of jobs necessary to supply one unit of a sector's final output. The employment coefficient vector is multiplied by the Leontief matrix to give the employment multiplier matrix for that economy.

$Emp\_Mult_j = \Sigma^n_{i=1} l_{n+1,i} b_{ij}$; where $l_{n+1,i}$ is the employment coefficient for that sector

Finally, it is also possible to calculate the multipliers for only one or multiple regions with column summation only for the matrix elements for one or multiple regions.

3.3.3.2. Hypothetical extraction model

Hypothetical extraction is a method used to find out the total linkage of one sector in an economy or its relative importance amongst the other sectors (Miller & Blair, 2009). The method extracts one sector or a group of sectors from the **A** matrix and calculates the decrease in total output and in total value added for this new economy. I did that for every sector to see which had the larger economic impact. In addition, I was able to compare how the total, backward, and forward linkages were reduced. For this hypothetical extraction situation, I assumed that the inputs from the excluded sector would be imported from other regions.

Considering the IO structure previously described, to extract the industry in a region, it is necessary to replace the columns and rows of that sector in the **A** matrix and in the respective final demand with zeros. Therefore, we will have a new **A** matrix, called $\underline{\mathbf{A}}$ and a new final demand called $\underline{\mathbf{f}}$. To satisfy this new final demand, the same as the original apart from the extracted sectors, the equation will be:

$$\underline{\mathbf{X}} = (\mathbf{I}-\underline{\mathbf{A}})^{-1}\underline{\mathbf{f}} = \underline{\mathbf{Lf}}$$

The new value added will be calculated as follows:

$$\underline{\mathbf{V}} = \mathbf{c}'\underline{\mathbf{X}} = \mathbf{c}'\,\underline{\mathbf{Lf}}$$

Where **c** is the vector of the value added coefficients, or the values added per unit of each sector output:

$$c_j = v_j/x_j$$

The differences in outputs and values added are:

Diff_X = $\mathbf{i}'(\mathbf{x} - \underline{\mathbf{x}})$; where **i** is the column summation vector consisting of ones.

Diff_V = $\mathbf{c}'(\mathbf{x} - \underline{\mathbf{x}})$

Since the sectors of interest are the forestry sectors comprising the whole chain of wood products, I extracted all sectors at once for each region and calculated the decrease in output and value added that would occur for: 1) that region itself, 2) the rest of the state, and 3) the rest of Brazil (or region 14). I present the results normalized as percentage change for both output and value added:

$$\Delta X_j = 100\ \mathbf{i}'(\mathbf{x} - \underline{x_j})/\mathbf{i}'\mathbf{x} \qquad \text{and} \qquad \Delta V_j = 100\ \mathbf{c}'(\mathbf{x} - \underline{x_j})/\mathbf{c}'\mathbf{x}$$

3.3.3.3. Structural path analysis

According to Sonis *et al.* (1994), structural path analysis is a technique to capture the economic influence at the microlevel by analyzing the structural change and how the transmission of such influence occurs. The technique consists of constructing influence graphs where the vertices are the sectors and the magnitude linking them, or the arc ($j \rightarrow i$) is equal to a_{ij} (the matrix **A** element). The transactions have ripple effects associated with multiplier effect, also identified by a sequence of arcs. One path from vertex *j* to vertex *i*, *p(j,i)* may be represented by:

$$(j,k_1), (k_1,k_2), \ldots, (k_r,i), k_r \neq k_s$$

The total influence $J^T p(j,i)$ of *j* to *i* along with one elementary path is given by:

$$J^T p(j,i) = a_{k1j}\, a_{k2}\, k_1 \ldots a_{ikr} \frac{\underline{M[p(i,j)]}}{\Delta}$$

Where a_{kj} is an element of **A** (the matrix of direct inputs), Δ = det(**I** – **A**), and ***M****[p(i,j)]* is the minor of the matrix (**I** – **A**) obtained by removing rows and columns $j, k_1, k_2, \ldots, k_r$ and i, **M**(p)/Δ is the path multiplier. The global influence of the vertex *j* to vertex *i* is given by the Leontief matrix element b_{ij}, thus considered the matrix of global influences.

There are various paths that occur among the sectors. In order to be able to identify the most important ones, one needs to filter the transactions by volume. As such, not all influence paths are identified in the graph and the small ones are aggregated in the final demand; the final destination of all intermediary product paths. Although the total influence is not captured in this methodology, it is in the fields of influence.

3.3.3.4. Fields of influence

This methodology was developed by Sonis and Hewings (1989, 1992) and captures the changes that would occur in the entire Leontief matrix when one makes an incremental change on one element of the **A** matrix (technical coefficient matrix) (Blair & Miller, 2009).

$$\mathbf{L}^*_{(ij)} = \mathbf{L} + \Delta\mathbf{L}_{(ij)} = \mathbf{L} + [(\Delta a_{ij})/(1 - l_{ji}\Delta a_{ij})]\mathbf{F}[i,j] = \mathbf{L} + \mathbf{F}[i,j]\mathrm{k}^1_{(ij)}$$

Where $\mathrm{k}^1_{(ij)}$ is a constant for each Δa_{ij}:

$$\mathrm{k}^1_{(ij)} = \Delta a_{ij}/(1 - l_{ji}\Delta a_{ij})$$

And $\mathbf{F}[i,j]$ represents the fields of influence through the Leontief matrix:

$$\mathbf{F}[i,j] = [l_{ri}l_{js}], \text{ for } r, s = 1, \ldots, \mathrm{n}$$

The fields of influence help identify the most important coefficients or sectors in the economy, i.e. the ones that have the strongest influences on the other sectors overall. Since the Leontief matrix is the basis of the sectors' economic connection, the resulting change in the matrix as a result of an incremental change on element of the **A** matrix is a good measure of that influence. To compare the results of each Δa_{ij}, I calculated the summation of all $\mathbf{F}[i,j]$ elements, or its norm:

$$||\mathbf{F}|| = \Sigma_{\mathrm{ij}} |f_{ij}|$$

The highest summation, or index, indicates stronger influence of those sectors over the economy. I present the results in figures with a spectrum of colors showing the intensity of the influence.

3.4. Results

3.4.1. Output multipliers and linkage analysis

Backward and forward linkages in I-O analysis are used to measure the connection of one sector to the rest of the economy, as a buyer and a supplier of goods respectively. Therefore, the sector with the highest linkages is the more connected or the more relevant (Miller & Blair, 2009).

I present all multipliers in three tables: a) the total effect in the whole economy averaged by sector for the MG regions (I excluded region 14's effect); b) the total effect in MG also averaged by sector and for the MG regions; and c) the total effect per sector and region in the same area.

The backward multipliers are displayed in Table 3.5. The table shows that an increase of one unit in final demand for forest products of any MG region will generate an average increase in output of 1,238 units for the whole country. Table 3.5.b lists the output increase only for the state of MG, and Table 3.5.c lists it for the same region with the increase in final demand. The results show that plantation forests have the lowest multipliers at all levels among all sectors of the economy. This was expected, since forests are the first level-supplying sector for the production chain. For furniture, Region 13 has the lowest multiplier for the same region with 45% of the state's production. The same is true with the cellulose sector in Region 8. Perhaps this is due to the fact that most of their inputs come from other regions and the regional linkages of these activities are small. Therefore the difference between the multiplier at national and state levels suggests that most of the effects do not occur within the state. An increase in final demand for the forestry sectors in MG will create more production outside MG than inside it.

Tables 3.6 present the forward multipliers. The forward multiplier measures the importance of a given sector as a supplier of intermediary goods to other sectors. Although plantation forests have the lowest values, this time the larger producer regions have high forward multipliers regionally, reflecting their importance as suppliers. In this case, it is a minor difference between national and state multipliers and suggests that most of forestry inter-industry production stays in MG.

A useful way to present these results compared to other sectors is calculating the key sectors in the economy. Key sectors are found based on the normalized backward and forward linkages of all sectors within a region. Tables 3.7 present the key sectors at national, state, and regional levels. The forestry sectors are bolded.

At the national and state levels, cellulose production in Region 8 is a key sector for the economy. Its backward and forward linkages are above average, meaning this region/sector is dependent on other regions/sectors to get inputs and to sell its production. Though at the regional level cellulose in Region 8 is not considered to be a key sector.

The forest sector is an independent and non-key sector at all levels because it has below average backward and forward linkages. At the state level, cellulose, wood products, paper, and furniture in Region 13 are economically integrated. At the regional level, only wood products, paper, and cellulose (in Regions 9 and 12) are not considered independent sectors and therefore have important roles in fostering the region's economy.

Table 3.5.a. Backward multipliers – average total effect per sector and by MG region

Average for the MG regions	AGR	IND	TRD	SER	GOV	FOR	WOP	FRT	CEL	PAP	SID	VEH	MiN	CON	FOO	TRA	UTI
	1.800	2.130	1.539	1.491	1.344	1.238	1.876	1.808	2.092	2.112	2.195	2.219	1.598	1.910	2.378	1.894	1.669

Table 3.5.b. Backward multiplier – average total effect for the MG state per sector and by MG region

Average for the MG regions	AGR	IND	TRD	SER	GOV	FOR	WOP	FRT	CEL	PAP	SID	VEH	MiN	CON	FOO	TRA	UTI
	1.330	1.487	1.297	1.278	1.199	1.122	1.491	1.346	1.534	1.588	1.584	1.590	1.226	1.507	1.770	1.422	1.430

Table 3.5.c. Backward multiplier – total effect per sector and region in that same region

	AGR	IND	TRD	SER	GOV	FOR	WOP	FRT	CEL	PAP	SID	VEH	MiN	CON	FOO	TRA	UTI
Reg1	1.133	1.339	1.205	1.236	1.150	1.097	1.274	1.245	1.000	1.340	1.501	1.469	1.191	1.364	1.410	1.336	1.356
Reg2	1.137	1.364	1.191	1.233	1.162	1.094	1.227	1.280	1.000	1.400	1.351	1.485	1.191	1.369	1.499	1.333	1.340
Reg3	1.076	1.369	1.149	1.217	1.091	1.059	1.344	1.270	1.000	1.383	1.197	1.452	1.177	1.395	1.582	1.308	1.321
Reg4	1.137	1.295	1.111	1.166	1.078	1.070	1.316	1.233	1.000	1.309	1.264	1.405	1.158	1.322	1.547	1.263	1.271
Reg5	1.116	1.304	1.127	1.163	1.045	1.055	1.236	1.220	1.000	1.326	1.119	1.360	1.155	1.358	1.539	1.255	1.264
Reg6	1.082	1.244	1.092	1.137	1.045	1.062	1.313	1.190	1.000	1.292	1.413	1.375	1.142	1.233	1.469	1.231	1.249
Reg7	1.105	1.315	1.136	1.188	1.101	1.087	1.290	1.213	1.000	1.293	1.469	1.386	1.169	1.255	1.499	1.278	1.287
Reg8	1.272	1.406	1.210	1.239	1.111	1.078	1.397	1.288	1.070	1.485	1.291	1.499	1.063	1.268	1.539	1.336	1.351
Reg9	1.284	1.397	1.260	1.229	1.175	1.104	1.346	1.296	1.458	1.434	1.520	1.387	1.199	1.392	1.433	1.358	1.349
Reg10	1.149	1.337	1.149	1.198	1.094	1.058	1.271	1.234	1.000	1.360	1.196	1.431	1.173	1.381	1.468	1.300	1.309
Reg11	1.243	1.362	1.207	1.231	1.141	1.098	1.334	1.223	1.000	1.274	1.305	1.470	1.092	1.425	1.601	1.337	1.338
Reg12	1.189	1.295	1.197	1.226	1.134	1.092	1.288	1.257	1.368	1.296	1.389	1.366	1.189	1.397	1.548	1.352	1.333
Reg13	1.259	1.381	1.233	1.226	1.161	1.098	1.296	1.078	1.000	1.183	1.334	1.465	1.185	1.389	1.511	1.219	1.321
Reg14	1.605	1.937	1.504	1.490	1.383	1.410	1.826	1.755	1.984	1.985	1.940	2.043	1.430	1.795	2.208	1.777	1.740

Table 3.6.a. Forward Multiplier – average total effect per sector and by MG region

	AGR	IND	TRD	SER	GOV	FOR	WOP	FRT	CEL	PAP	SID	VEH	MiN	CON	FOO	TRA	UTI
Average for the MG regions	1.450	2.059	1.456	1.756	1.249	1.051	1.157	1.128	1.402	1.106	1.688	1.472	1.184	1.687	1.894	1.286	1.263

Table 3.6.b. Forward Multiplier – average total effect for the MG state per sector and by MG region

	AGR	IND	TRD	SER	GOV	FOR	WOP	FRT	CEL	PAP	SID	VEH	MiN	CON	FOO	TRA	UTI
Average for the MG regions	1.446	2.047	1.453	1.750	1.248	1.051	1.157	1.127	1.400	1.106	1.679	1.467	1.181	1.681	1.887	1.284	1.262

Table 3.6.c. Forward multiplier – total effect per sector and region in the same region

	AGR	IND	TRD	SER	GOV	FOR	WOP	FRT	CEL	PAP	SID	VEH	MiN	CON	FOO	TRA	UTI
Reg1	1.340	1.770	1.324	1.478	1.177	1.034	1.118	1.061	1.000	1.076	1.144	1.149	1.018	1.383	1.830	1.199	1.226
Reg2	1.320	1.711	1.341	1.571	1.160	1.043	1.145	1.036	1.000	1.064	1.387	1.193	1.021	1.389	1.730	1.226	1.203
Reg3	1.325	1.645	1.331	1.505	1.180	1.052	1.114	1.033	1.000	1.055	1.518	1.123	1.132	1.376	1.353	1.200	1.198
Reg4	1.276	1.632	1.305	1.474	1.164	1.044	1.113	1.059	1.000	1.049	1.407	1.143	1.030	1.447	1.381	1.166	1.094
Reg5	1.204	1.510	1.254	1.424	1.157	1.073	1.117	1.029	1.000	1.045	1.489	1.096	1.040	1.263	1.344	1.189	1.117
Reg6	1.277	1.582	1.275	1.410	1.147	1.043	1.099	1.024	1.000	1.048	1.244	1.153	1.022	1.451	1.433	1.162	1.105
Reg7	1.283	1.488	1.333	1.532	1.179	1.039	1.131	1.060	1.000	1.071	1.109	1.191	1.030	1.452	1.476	1.186	1.226
Reg8	1.217	1.689	1.371	1.617	1.203	1.047	1.097	1.069	1.108	1.065	1.494	1.184	1.339	1.567	1.705	1.243	1.202
Reg9	1.100	1.912	1.314	1.701	1.169	1.038	1.131	1.117	1.046	1.142	1.437	1.501	1.101	1.643	1.555	1.250	1.301
Reg10	1.248	1.665	1.297	1.446	1.167	1.054	1.121	1.064	1.000	1.065	1.446	1.044	1.022	1.234	1.690	1.201	1.135
Reg11	1.288	1.786	1.334	1.513	1.183	1.041	1.127	1.116	1.000	1.080	1.547	1.230	1.162	1.370	1.680	1.219	1.188
Reg12	1.318	1.911	1.330	1.469	1.176	1.033	1.134	1.072	1.059	1.146	1.338	1.429	1.032	1.310	1.603	1.201	1.212
Reg13	1.203	1.552	1.264	1.524	1.155	1.038	1.136	1.137	1.000	1.082	1.384	1.274	1.020	1.415	1.566	1.243	1.254
Reg14	1.495	4.150	1.844	2.692	1.563	1.102	1.341	1.227	1.174	1.503	1.476	1.782	1.059	2.122	2.476	1.494	1.428

Table 3.7.a. Key sectors for the MG regions at the national level

		Total forward linkage	
		Low (< avg)	**High (> avg)**
Total backward linkage	**Low (< avg)**	I - Generally independent	II - Dependent on interindustry demand
		FOR (all regions)	**FRT (13)**
		FRT (all but 13)	AGR & TRD (1,2,3,4,5,6,7,10,12)
		GOV (all regions)	SER (all regions)
		AGR & TRD (8,9,11,13)	MIN (8)
		MIN (all but 8)	
		UTI (all regions)	
	High (> avg)	III - Dependent on interindustry supply	IV - Generally dependent
		WOP (all regions)	**CEL (8)**
		CEL (9,12,14)	SID (2,3,4,5,8,10,11,13)
		PAP (all regions)	VEH (9,12,14)
		SID (1,6,7,9,12)	CON (1,2,3,4,5,6,7,8,9,13)
		VEH (1,2,3,4,5,6,7,8,10,11,13)	FOO (all regions)
		CON (10,11,12)	TRA (13)
		TRA (all but 13)	IND (all regions)

Table 3.7.b. Key sectors for the MG regions at the state level

		Total forward linkage	
		Low (< avg)	**High (> avg)**
Total backward linkage	**Low (< avg)**	I - Generally independent	II - Dependent on interindustry demand
		FOR (all regions)	**FRT (13)**
		FRT (all but 13)	AGR & TRD (1,2,3,4,5,6,7,10,12)
		AGR & TRD (8,9,11,13)	SER (all regions)
		GOV (all regions)	MIN (8)
		MIN (all but 8)	
		TRA (8,9,12)	
	High (> avg)	III - Dependent on interindustry supply	IV - Generally dependent
		WOP (all regions)	**CEL (8)**
		CEL (9,12)	SID (2,3,4,5,8,10,11,13)
		PAP (all regions)	VEH (9,12)
		VEH (1,2,3,4,5,6,7,8,10,11,13)	FOO (all regions)
		CON (10,11,12)	TRA (13)
		TRA (1,2,3,4,5,6,7,10,11)	IND (all regions)
		UTI (all regions)	

Table 3.7.c. Key sectors for the MG regions at the regional level

		Total forward linkage	
		Low (< avg)	**High (> avg)**
Total backward linkage	**Low (< avg)**	I - Generally independent **WOP (1,2,13)** **FOR (all regions)** **FRT (all regions)** **PAP (11,13)** **CEL (8)** AGR (5,8,9,11,13) MIN (all but 8) GOV (all regions) TRD (9,13) TRA (13)	II - Dependent on interindustry demand AGR (1,2,3,4,6,7,10,12) SER (all regions) SID (3,5,10) TRD (1,2,3,4,5,6,7,8,10,11,12) MIN (8) CON (8)
	High (> avg)	III - Dependent on interindustry supply **WOP (3,4,5,6,7,8,9,10,11,13)** **CEL (9,12)** **PAP (1,2,3,4,5,6,7,8,9,10,12)** VEH (1,2,3,4,5,6,7,8,10,11) CON (10) TRA (all but 13) UTI (all regions) SID (1,7)	IV - Generally dependent SID (2,4,6,8,9,11,12,13) VEH (9,12,13) CON (1,2,3,4,5,6,7,9,11,12,13) FOO (all regions) IND (all regions)

3.4.2. Value added, income, and employment multipliers

For the value added, income, and employment multipliers, I present the average per sector among all MG regions at national, state, and regional levels. I analyzed the averages to better demonstrate the sectors' impacts at the three geographical levels of interest since the multiplier values for the sectors are similar among all MG regions.

The value added multiplier in Table 3.8 represents how the total value added in the economy (national, state, or regional) increases on average when the final demand for that sector increases by one unit in one MG region. Likewise, Table 3.9 shows income multipliers, which are how much the income in the economy increases when the final demand for a sector increases by one unit.

For the value added multiplier, the forest sector has the highest value at all geographical levels. Though it is important to understand what value added accounts for: salaries paid, profits, interests payment, rental payments, and taxes. Value added, thus, includes salaries that are used to calculate the income multipliers. The forest sector has the highest value added multiplier and the lowest income multiplier. This means that most of the effect of the value added multiplier does not come from salaries, rather from payment to capital, rent, and taxes.

Wood products have the highest income multipliers and present high-value added multipliers. Hence, income represents a substantial share of the value added for this sector. The paper sector has the lowest value added among forestry sectors but has a high to medium income multiplier. This may suggest that other components of the value added for the paper sector are not as high as for the other forestry sectors. Furniture has middle-sized multipliers for both income and value added, while cellulose has low values for both. Because cellulose industries are known for paying high salaries, the low-income multiplier may be due to low employment in this sector and a concentration of production on exports, ultimately reducing both multiplier effects in the national economy.

Table 3.8 Average value added multipliers at the national, state, and regional levels per sector for MG regions

Value added multipliers per sector (avg MG regions)		Value added multipliers per sector within the state		Value added multipliers per sector within a region	
FOR	0.95	FOR	0.90	FOR	0.88
GOV	0.95	GOV	0.88	GOV	0.83
SER	0.91	SER	0.81	SER	0.77
TRD	0.91	TRD	0.79	TRD	0.73
MIN	0.88	UTI	0.76	UTI	0.70
UTI	0.87	MIN	0.73	MIN	0.70
AGR	0.86	AGR	0.67	AGR	0.60
WOP	0.85	WOP	0.67	CON	0.60
TRA	0.84	CON	0.66	TRA	0.60
FRT	0.84	TRA	0.65	FRT	0.59
CON	0.83	FRT	0.64	WOP	0.56
FOO	0.82	CEL	0.57	CEL	0.51
CEL	0.81	PAP	0.56	PAP	0.45
PAP	0.79	FOO	0.55	FOO	0.43
SID	0.74	VEH	0.48	VEH	0.41
VEH	0.73	SID	0.48	IND	0.40
IND	0.73	IND	0.47	SID	0.35

Table 3.9. Average income multipliers at the national, state, and regional levels per sector for MG regions

Income multipliers per sector (avg MG regions)		Income multipliers per sector within the state		Income multipliers per sector within a region	
GOV	0.596	GOV	0.572	GOV	0.557
WOP	0.340	TRD	0.293	TRD	0.272
TRD	0.333	WOP	0.282	SER	0.258
TRA	0.314	SER	0.270	WOP	0.254
SER	0.305	TRA	0.245	TRA	0.226
PAP	0.301	CON	0.233	CON	0.210
FRT	0.300	FRT	0.227	FRT	0.210
CON	0.293	PAP	0.221	PAP	0.186
VEH	0.290	IND	0.198	IND	0.177
IND	0.290	VEH	0.198	VEH	0.175
FOO	0.284	FOO	0.198	FOO	0.159
CEL	0.242	CEL	0.161	AGR	0.131
SID	0.234	AGR	0.154	CEL	0.130
AGR	0.219	SID	0.150	FOR	0.124
UTI	0.174	UTI	0.138	UTI	0.123
MIN	0.154	FOR	0.130	SID	0.120
FOR	0.146	MIN	0.099	MIN	0.088

The employment multiplier on Table 3.10 represents the number of jobs in the national, state, or regional economies that would be required to supply one unit's worth of final demand of that sector in any MG region. The type I (Table 3.11) employment multiplier represents the total change in the number of jobs throughout the economy per job created in that sector.

Wood products, furniture, and forest plantations have the highest employment multipliers of forestry sectors. The type I employment multipliers for wood products and furniture are relatively lower, meaning these sectors are themselves job intensive but do not create as many jobs in the economy.

Forest plantations have a considerably higher employment multiplier at the regional level, meaning that jobs created by this activity occur at the regional level. Nevertheless, plantations are the lowest type I employment multiplier among all sectors together with agriculture, although agriculture has the highest employment multiplier. The difference between agriculture and forest plantations for employment is that plantations have longer harvesting cycles and can be more mechanized, requiring fewer jobs per unit of output. Both sectors have low type I employment multipliers because both supply basic primary inputs to the economy.

Cellulose has a low employment multiplier but the highest type I employment multiplier because it employs few people and most of the production is exported. It is however at the top of the forestry chain and requires major supply from other sectors.

Table 3.10. Average employment multipliers at the national, state, and regional levels per sector for the MG regions

Employment multipliers per sector (avg MG regions)	
AGR	61.90
WOP	41.03
TRD	38.16
FOO	36.46
FRT	32.95
SER	30.66
CON	30.16
FOR	28.06
TRA	25.21
IND	22.10
GOV	21.12
PAP	19.30
CEL	18.38
VEH	15.76
SID	12.81
UTI	9.87
MIN	8.49

Employment multipliers per sector within the state	
AGR	56.04
TRD	35.08
WOP	34.35
SER	27.91
FRT	26.77
FOO	26.59
FOR	26.39
CON	25.58
TRA	20.36
GOV	19.25
IND	15.10
PAP	13.38
CEL	11.67
VEH	9.60
UTI	7.29
SID	7.14
MIN	4.71

Employment multipliers per sector within a region	
AGR	53.78
TRD	33.26
WOP	31.07
SER	26.69
FOR	25.68
FRT	25.16
CON	23.60
FOO	20.46
TRA	18.79
GOV	17.84
IND	13.24
PAP	10.36
VEH	7.80
CEL	7.25
UTI	6.12
SID	4.96
MIN	3.68

Table 3.11. Average type I employment multipliers at the national, state, and regional levels per sector for the MG regions.

Type I Emp. multipliers per sector (avg MG regions)	
CEL	9.51
MiN	7.80
FOO	6.75
SID	6.59
VEH	6.01
PAP	3.58
UTI	3.44
IND	2.71
TRA	1.81
WOP	1.66
CON	1.65
FRT	1.56
SER	1.36
GOV	1.35
TRD	1.27
AGR	1.23
FOR	1.18

Type I Emp. multipliers per sector within the state	
CEL	6.04
FOO	4.92
MiN	4.32
SID	3.67
VEH	3.66
UTI	2.54
PAP	2.48
IND	1.86
TRA	1.46
CON	1.40
WOP	1.39
FRT	1.27
SER	1.24
GOV	1.23
TRD	1.17
AGR	1.12
FOR	1.11

Type I Emp. multipliers per sector within a region	
FOO	3.79
CEL	3.75
MiN	3.38
VEH	2.97
SID	2.55
UTI	2.13
PAP	1.92
IND	1.63
TRA	1.35
CON	1.29
WOP	1.26
FRT	1.19
SER	1.18
GOV	1.14
TRD	1.11
FOR	1.08
AGR	1.07

3.4.3. Hypothetical Extraction analysis

For the hypothetical extraction I aggregated forestry sectors 6 to 10 to see the impact of the entire forestry industry. I then extracted each of the 13 resulting economic sectors separately and for all MG regions at the same time to see how much the total output (Table 3.12) and the total value added (Table 3.13) would be reduced for each region.

Table 3.12 shows the percentage reduction in final output of a region after the extraction of that sector from the whole state. The extraction of the forestry sector would mainly reduce the outputs of Regions 3, 5, 10, the most important forest plantation producers, and Region 13, the main furniture and paper producer.

With respect to the percentage changes in value added (table 3.13), the extraction of the forestry sector would affect mostly regions 8, 9, and 12. Region 8 is the main cellulose producer in the state and regions 9 and 12 are important producers of wood products, paper, and furniture. They are all highly industrialized and developed regions, and aggregate more value added than other regions. The forestry sector extraction reduces the value added in more than 20% for MG regions, which is more than the other industries with about 18%. This is an interesting finding regarding the forestry sector and points to its importance for the state. However, the value added does not always translate in more economic growth, especially if it primarily represents payment to capital that may leave the state or the country. The output change after extraction may be a better measure of this sector's importance for regions and the state.

Table 3.12. Hypothetical Extraction results: percentage decrease in output per region after the extraction of each sector in the whole state's economy

	AGR	IND	TRD	SER	GOV	Forestry	SID	VEH	MIN	CON	FOO	TRA	UTI
Reg1	-20.91	-23.36	-10.70	-19.29	-10.53	-1.27	-0.98	-1.20	-0.66	-8.33	-32.00	-3.96	-3.55
Reg2	-16.28	-17.35	-14.51	-26.53	-10.03	-1.71	-3.49	-2.27	-0.87	-9.08	-21.73	-5.25	-2.14
Reg3	-30.07	-22.68	-9.76	-14.09	-11.51	-4.09	-16.89	-1.75	-3.89	-6.37	-10.95	-3.20	-1.69
Reg4	-12.49	-15.94	-17.69	-26.65	-18.97	-1.87	-4.21	-1.73	-0.87	-9.52	-9.47	-3.96	-0.39
Reg5	-10.47	-11.73	-9.65	-14.75	-19.11	-13.20	-21.59	-1.58	-1.00	-5.76	-6.58	-3.90	-0.41
Reg6	-18.35	-17.11	-14.44	-22.35	-23.57	-1.32	-0.60	-0.76	-0.51	-8.69	-14.11	-3.27	-0.39
Reg7	-16.60	-12.14	-16.38	-27.15	-17.40	-1.43	-1.06	-1.59	-1.08	-9.36	-12.62	-3.90	-4.44
Reg8	-2.96	-5.66	-7.18	-13.05	-9.57	-3.23	-20.44	-2.46	-33.46	-11.05	-5.91	-3.23	-1.11
Reg9	-1.49	-9.09	-10.97	-29.30	-11.04	-0.81	-6.99	-12.32	-5.13	-12.59	-4.96	-7.02	-6.55
Reg10	-13.67	-18.32	-12.69	-19.27	-13.59	-6.81	-9.75	-1.54	-0.69	-5.75	-20.27	-4.68	-0.72
Reg11	-7.32	-13.10	-10.63	-18.68	-10.34	-1.88	-19.41	-4.67	-13.05	-7.63	-10.34	-5.01	-1.31
Reg12	-13.96	-19.51	-12.81	-19.91	-11.65	-1.75	-2.87	-10.12	-1.19	-6.30	-13.78	-5.10	-2.67
Reg13	-5.81	-10.16	-13.03	-28.84	-12.26	-5.44	-6.13	-5.46	-1.38	-8.96	-11.17	-12.31	-5.51
Reg14	-0.27	-0.60	-0.22	-0.42	-0.14	-0.06	-0.34	-0.31	-0.22	-0.28	-0.36	-0.21	-0.07

Table 3.13. Hypothetical Extraction results: percentage decrease in value added per region after the extraction of each sector in the whole state's economy

	AGR	IND	TRD	SER	GOV	Forestry	SID	VEH	MIN	CON	FOO	TRA	UTI
Reg1	-9.10	-17.87	-8.61	-9.88	-3.63	-20.65	-9.86	-9.84	-6.89	-6.73	-11.81	-11.62	-5.51
Reg2	-8.69	-17.78	-8.72	-10.20	-3.64	-20.59	-10.19	-9.74	-7.10	-6.79	-9.55	-11.57	-5.52
Reg3	-8.80	-18.15	-8.61	-9.81	-3.73	-20.73	-10.62	-9.79	-7.21	-6.76	-9.01	-11.59	-5.57
Reg4	-8.54	-18.19	-8.73	-10.12	-3.84	-20.70	-10.32	-9.80	-7.16	-6.79	-9.09	-11.57	-5.62
Reg5	-8.51	-18.07	-8.59	-10.05	-3.90	-20.81	-10.74	-9.82	-7.21	-6.77	-9.14	-11.60	-5.57
Reg6	-8.58	-18.63	-8.70	-10.29	-3.91	-20.71	-10.11	-9.83	-7.07	-6.79	-9.18	-11.55	-5.54
Reg7	-8.54	-18.43	-8.73	-10.15	-3.72	-20.71	-10.16	-9.84	-7.06	-6.81	-9.15	-11.54	-5.55
Reg8	-7.96	-16.70	-8.20	-9.44	-3.54	-26.14	-9.93	-9.08	-7.19	-6.41	-8.68	-11.06	-5.41
Reg9	-7.56	-16.94	-8.60	-11.90	-3.81	-25.03	-9.27	-9.08	-6.57	-6.50	-8.14	-11.00	-5.57
Reg10	-8.70	-18.72	-8.56	-9.96	-3.69	-20.75	-10.35	-9.80	-7.16	-6.75	-9.87	-11.63	-5.64
Reg11	-8.45	-18.12	-8.59	-10.06	-3.71	-20.63	-10.44	-9.78	-7.29	-6.79	-9.02	-11.58	-5.53
Reg12	-8.08	-17.80	-8.29	-9.73	-3.52	-25.93	-9.52	-9.32	-6.59	-6.33	-8.58	-11.10	-5.41
Reg13	-8.44	-17.87	-8.60	-10.16	-3.63	-20.80	-10.27	-9.81	-7.13	-6.79	-9.08	-11.81	-5.55
Reg14	-0.10	-0.40	-0.06	-0.12	0.00	-0.09	-0.33	-0.06	-0.16	-0.01	-0.05	-0.09	-0.07

3.4.4. Structural path analysis - SPA

I employed the structural path analysis (SPA) methodology for the forestry sector to observe the forestry production chain within the state as a whole and among the regions. The SPA starts with plantations forests (sector 6) as it is the first supplier on the wood chain. In order to better visualize the production flow for the MG regions, I aggregated the 17 sectors into 10, displayed them on table 20, and allowed up to three production levels before achieving final demand. Also, the SPA model for the 13 MG regions aggregates in final demand the region's production that goes to the rest of Brazil (Region 14). This way, the charts for the regions only display the production flows within the state. The analysis adds information on how the forestry sectors are connected to the region's economy by visualizing the production flows translated from the IO matrix.

Table 3.14. Aggregating 17 Sectors in 10 Sectors for the Structural Path Analysis (SPA)

1- Agriculture	Agriculture – AGR
2- Industries others	Others - OTH
3- Trade	Others - OTH
4- Services	Others - OTH
5- Government	Others - OTH
6- Forest Production	Forest Production - FOR
7- Wood Industry	Wood Production - WOD
8- Furniture	Furniture - FRT
9- Cellulose Industry	Cellulose Industry - CEL
10- Paper Industry	Paper Industry - PAP
11- Iron and Steel Industry	Iron and Steel Industry - SID
12- Automobiles	Others - OTH
13- Mining	Others - OTH
14- Construction	Construction - CON
15- Food and Beverage	Food and Beverage - FOO
16- Transportation	Others - OTH
17- Utility Industry	Others - OTH

Figure 3.4 presents the flow between MG and the rest of Brazil. One can see that almost half of the MG forest plantation production (brown bar on the left) goes directly to final demand (FD – the blue bar on the right). This production could go to family consumption, exports,

government, or investment. From the part that goes to the other industries, the chart shows that a large share goes to other Brazilian industries, especially for cellulose production, wood products, and others for the first level (L1). For the second level of production (L2), the main receiving sectors are food and construction in the rest of Brazil. Level 1, or L1, means the level of production right before reaching final demand. The logic number is backwards: L2 means that this flow still has one more production level before reaching final demand, and on L3 it has two more levels. For instance, the last flow goes first to CEL_BR_L3, which means cellulose production in the rest of Brazil, then to PAP_BR_L2, or paper production in the rest of Brazil, next to SER_BR_L1 – services sector in the rest of Brazil, and finally to final demand as a product from that last sector.

Figure 3.5 complements the previous figure by presenting flows limited to MG. Cellulose, agriculture, and the forest sector itself are the main receivers of plantation production. Charcoal production is likely the destination of the forest plantation production included in the forestry sector itself. Food’s important participation may reflect the use of firewood for energy generation and the use of non-wood forest products in the food industry. Despite the low value and limited flow of charcoal production, siderurgy absorbs most of it.

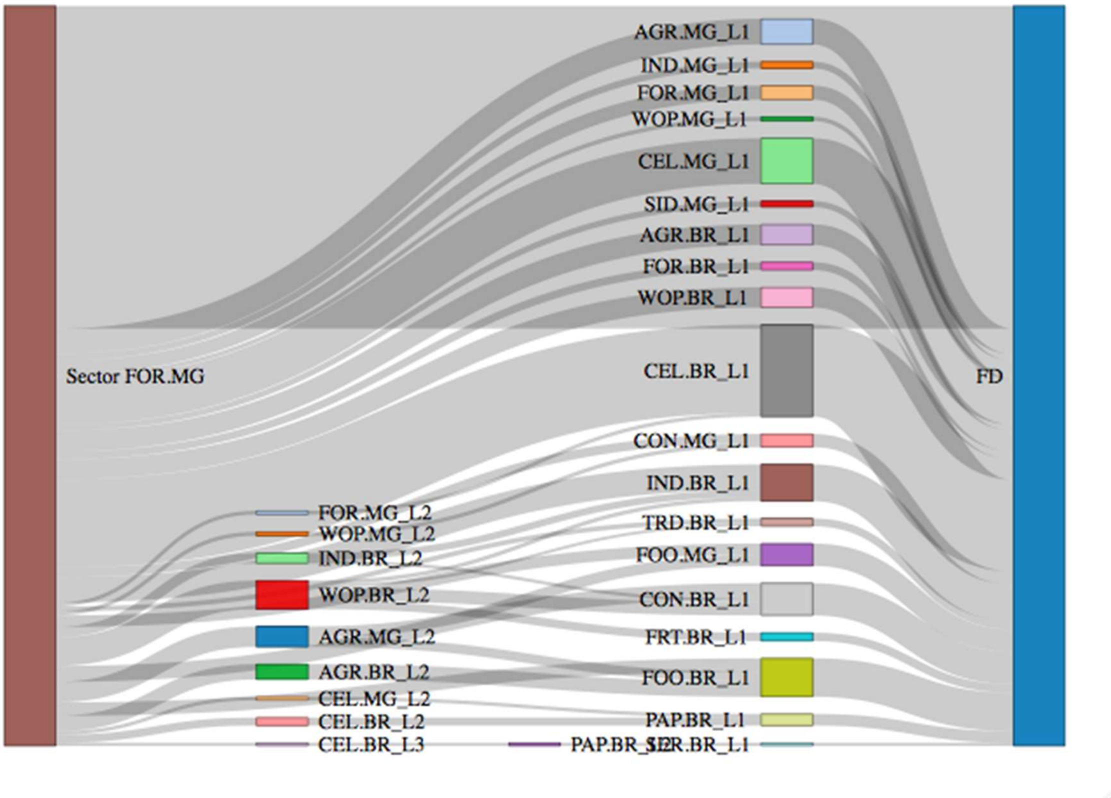


Figure 3.4. SPA for the state of Minas Gerais and the rest of Brazil

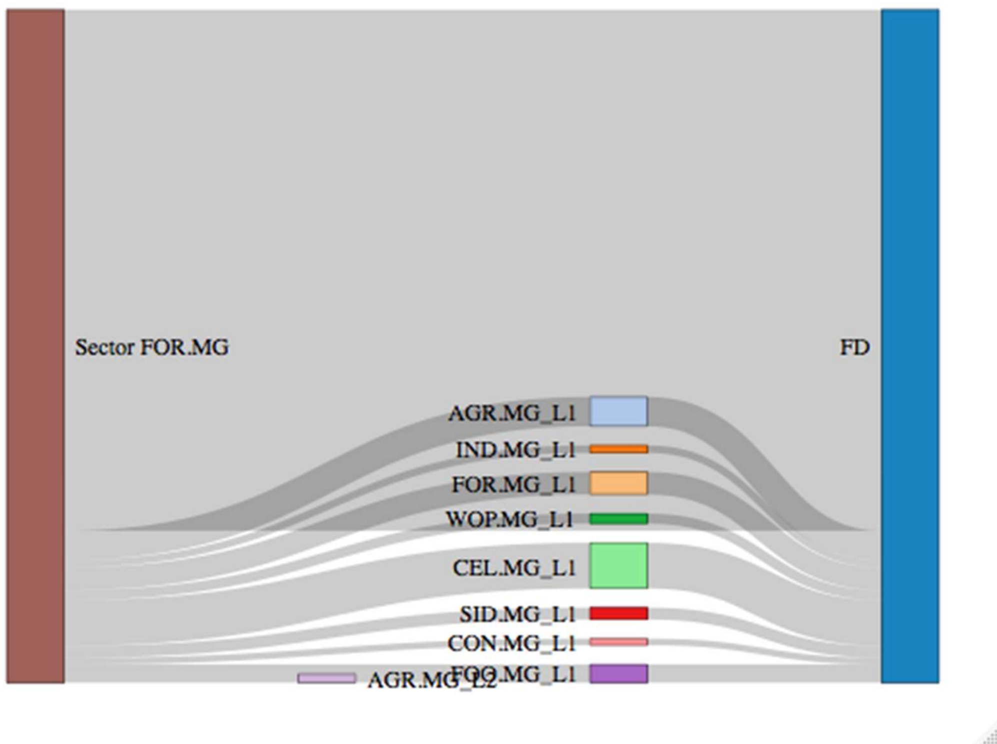


Figure 3.5. SPA within the state of Minas Gerais

3.4.4.1 SPA of the MG regions

For the MG regions of analysis, I focused on the main forestry producers by sector and their participation in the state's total production as a measure of their economic development. I summarized the main findings and conclusions on how the forestry industry is integrated to the state's economy.

For the main forest plantation producers, Regions 5, 3, and 10 (Figures 3.6 to 3.8), as for the other regions in the state, the larger production share goes directly to final demand. Only about 25-30% goes to the MG's inter-industry and a substantial part goes to cellulose production in Region 8.

These three regions are among the poorest in the state and do not keep much of their forest production with exception of siderurgy in Region 3 and food in Region 10. They supply the larger share to Regions 8 and 9 of the capital metropolitan area, Region 12, and to agriculture in Regions 1, 2, and 7. Region 12 is relevant to various wood industries. Regions 1 and 2 are strong in agriculture, food, and wood products. Though Region 7 is a poor region, it also has a developed agriculture.

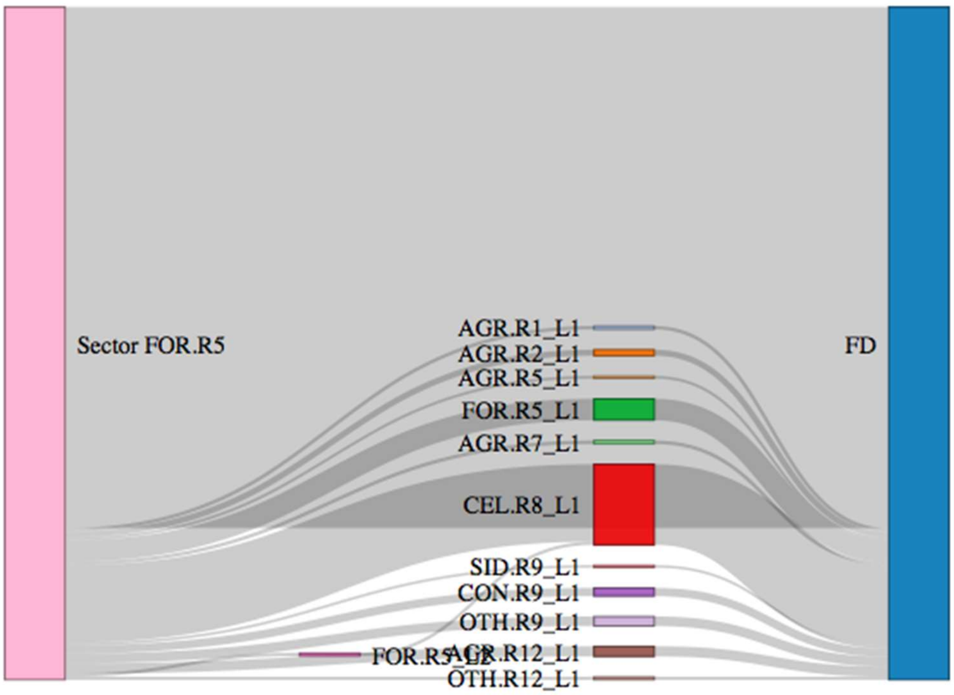


Figure 3.6. SPA for Region 5

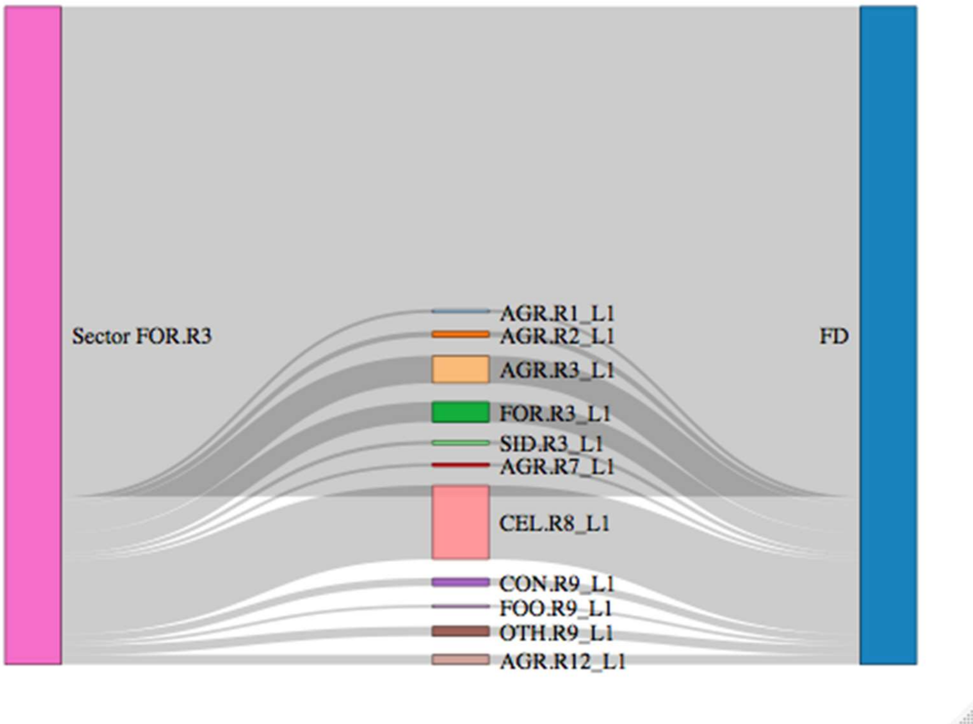


Figure 3.7. SPA for Region 3

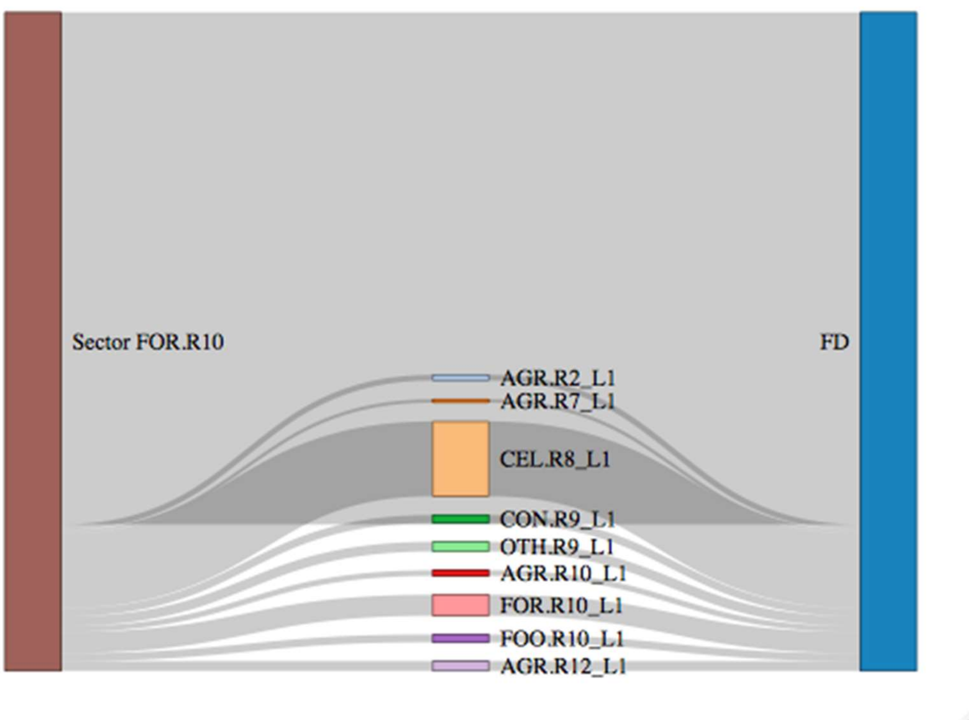


Figure 3.8. SPA for Region 10

Regions 2, 9, and 12 (Figures 3.9 to 3.11) are the main producers of wood products, paper, and furniture in the wood industry and are the richer regions of the state. Region 2 also has an important share of forest plantation production (9.5%). As such, apart from cellulose in Region 8, a large part of its forest production stays in the same region or goes to the other two regions. These regions are connected economically through forestry production.

Regions 13 and 11 (Figures 3.12 and 3.13) are respectively the first and the third biggest furniture producers. They are also important paper producers. Region 11 has the third largest siderurgy production in the state. Region 11 is in the capital metropolitan area and has higher GDP than region 13. Both may be considered middle-level developed regions. They retain most of their forest production and send the remainder to Region 9, 12, and 2.

Region 8 (Figure 3.14) concentrates more than 94% of the cellulose production and most of the production on mining, siderurgy, and construction in MG. It is a highly industrialized area and part of the capital metropolitan mesoregion. As such, the forest production stays mostly in the region and a small share goes to Regions 9 and agriculture to Region 12.

Regions 4, 6, and 7 (Figures 3.15 to 3.17) are poor regions in the state, especially Regions 4 and 6. Region 7 is not in a semi-arid region. It is economically integrated to Region 8 and to the developed neighboring state of Espírito Santo. Though they have lower shares of the state's forest production, Region 4 has double the forest production than the others. Region 4 keeps a fair amount of its production. In spite of its distance to the industrial centers, Region 4 sends its remaining production to Regions 9, 12, and 2. Similarly, a small part of Region 6's production goes to Regions 9 and 12, while Region 7 keeps its entire production.

Region 1 (Figure 3.18) produces less than 1% of the state's forest products and has the lowest participation in the sector. Most of its production goes to the rest of Brazil and final demand directly. Part of its production goes to cellulose in Region 8 and the rest stays in Region 1 to the agriculture and food sectors, the most significant sectors for the region's economy.

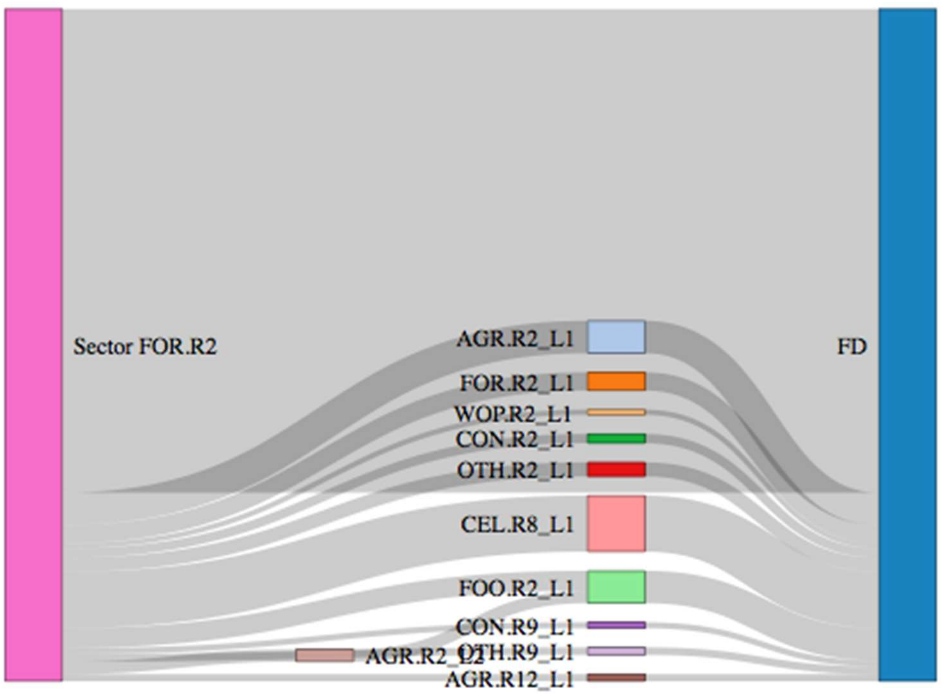


Figure 3.9. SPA for Region 2

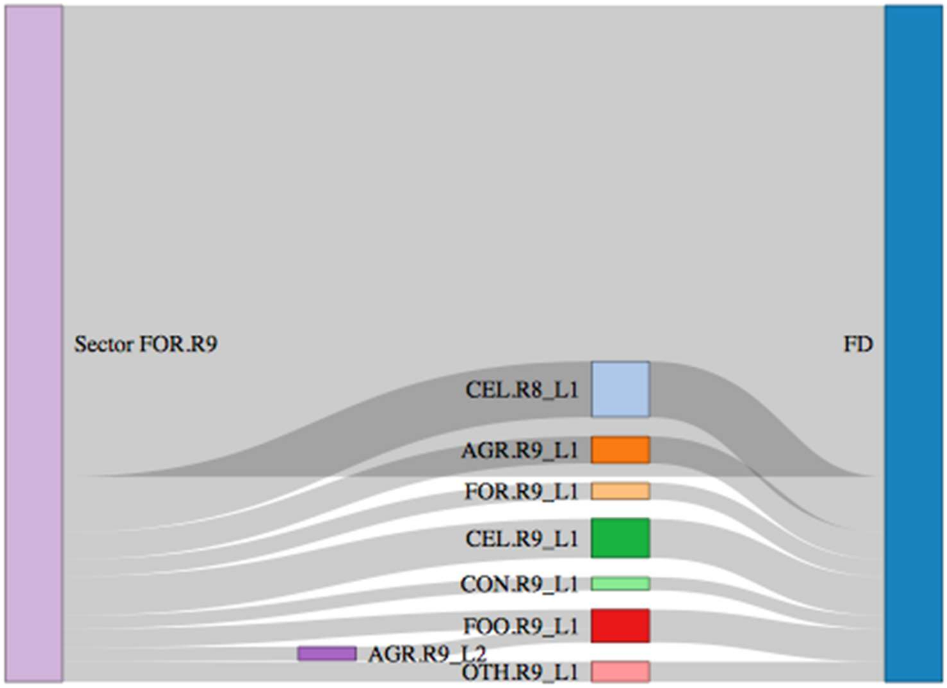


Figure 3.10. SPA for Region 9

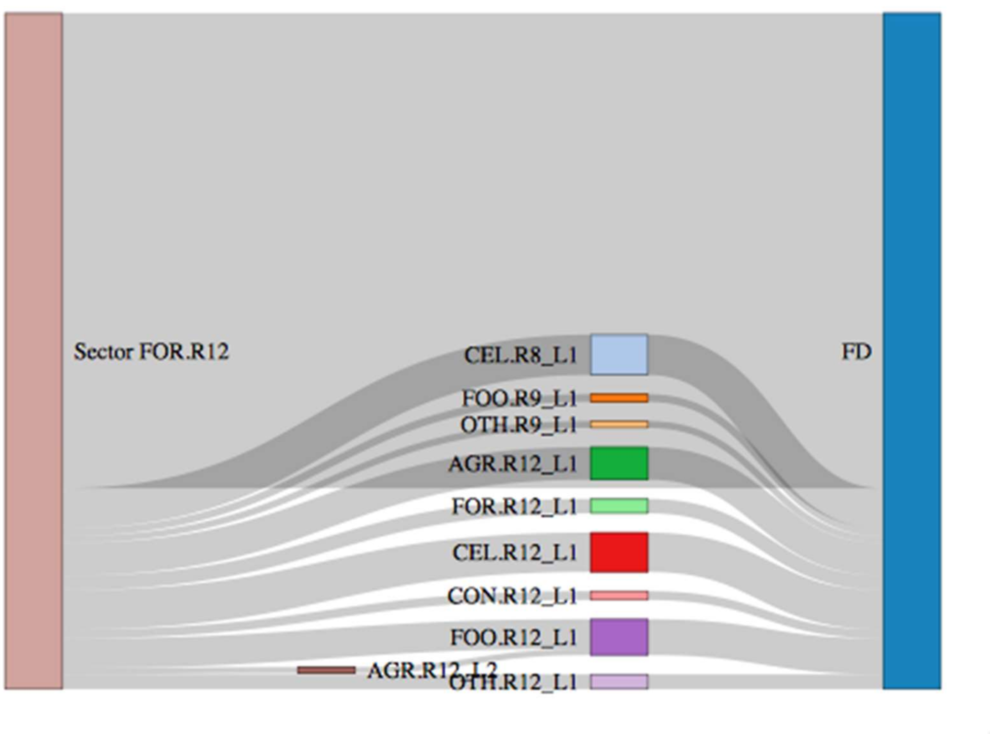


Figure 3.11. SPA for Region 12

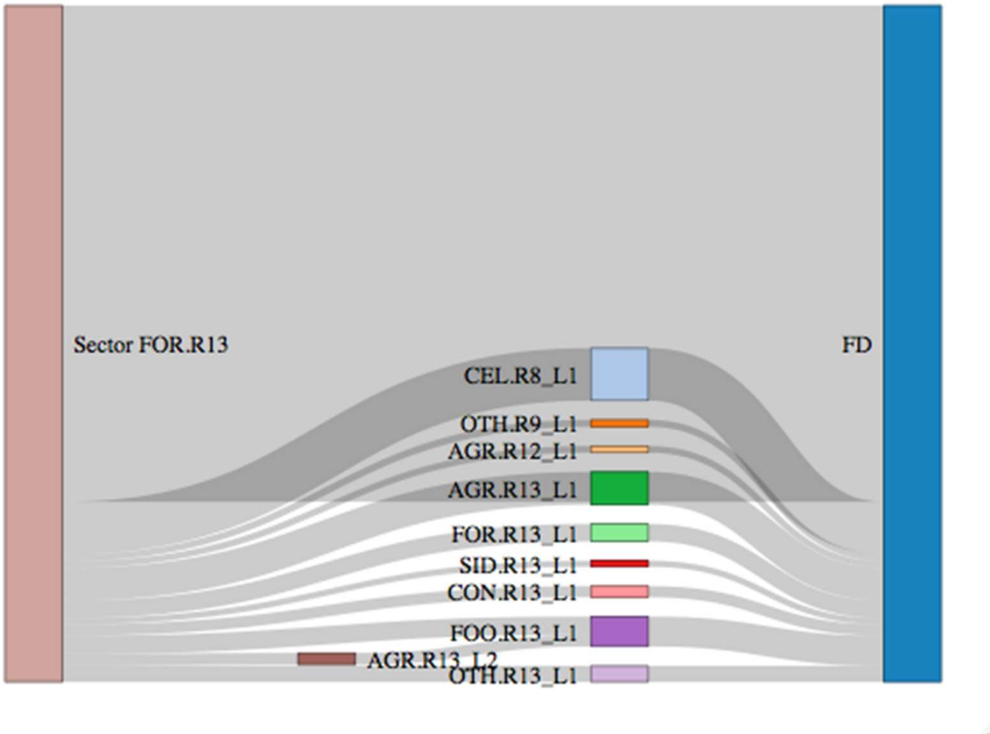


Figure 3.12. SPA for Region 13

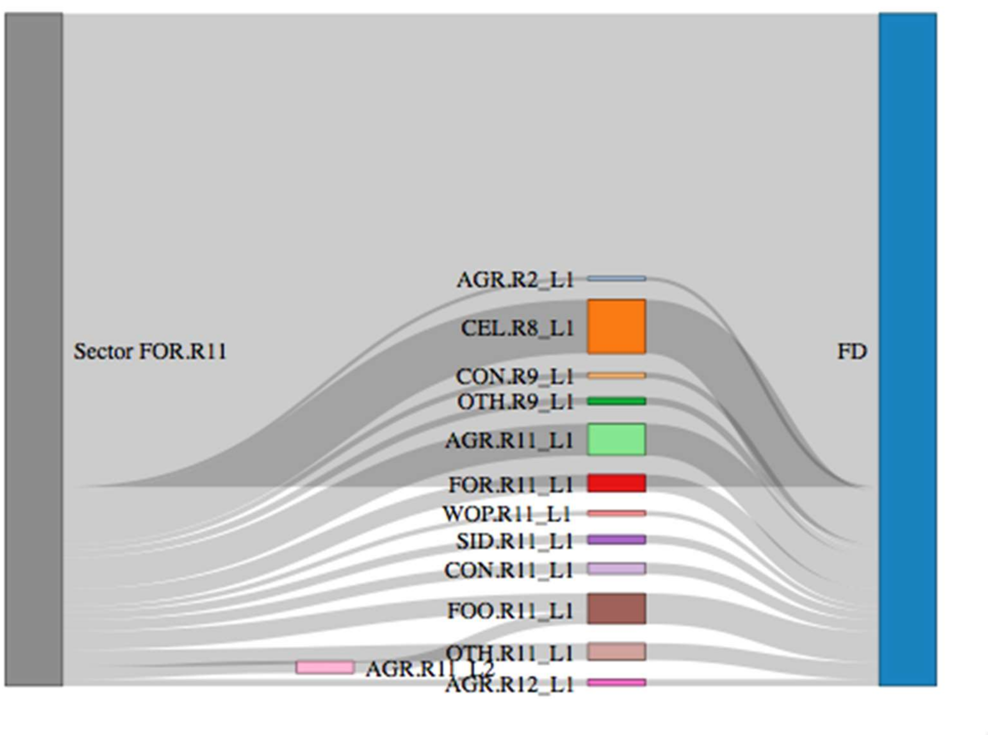


Figure 3.13. SPA for Region 11

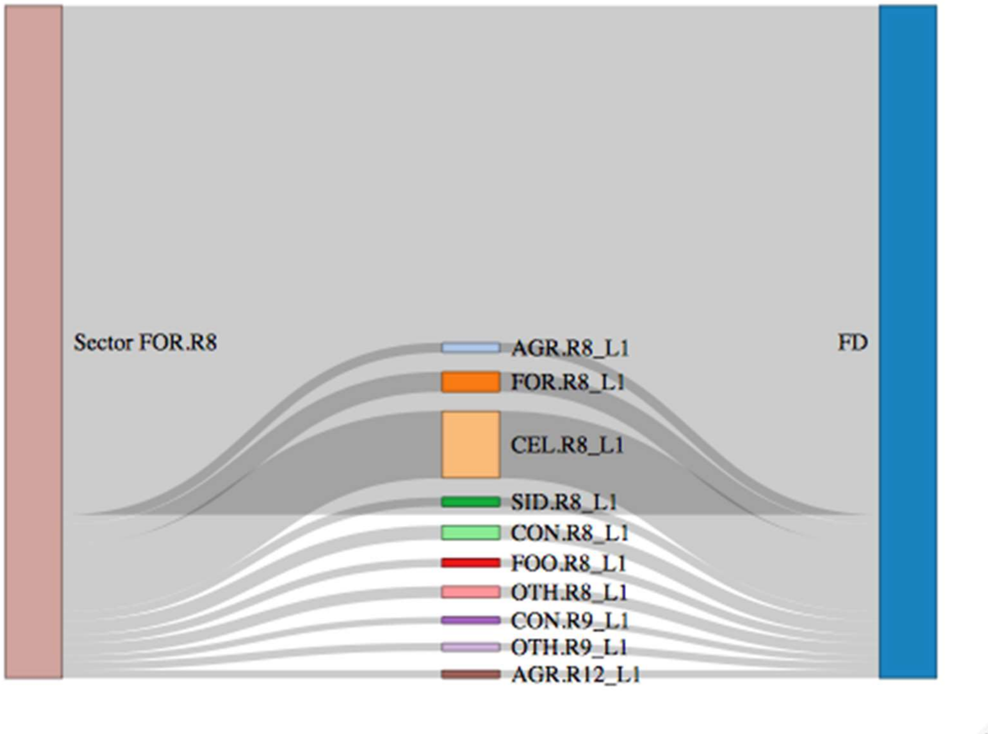


Figure 3.14. SPA for Region 8

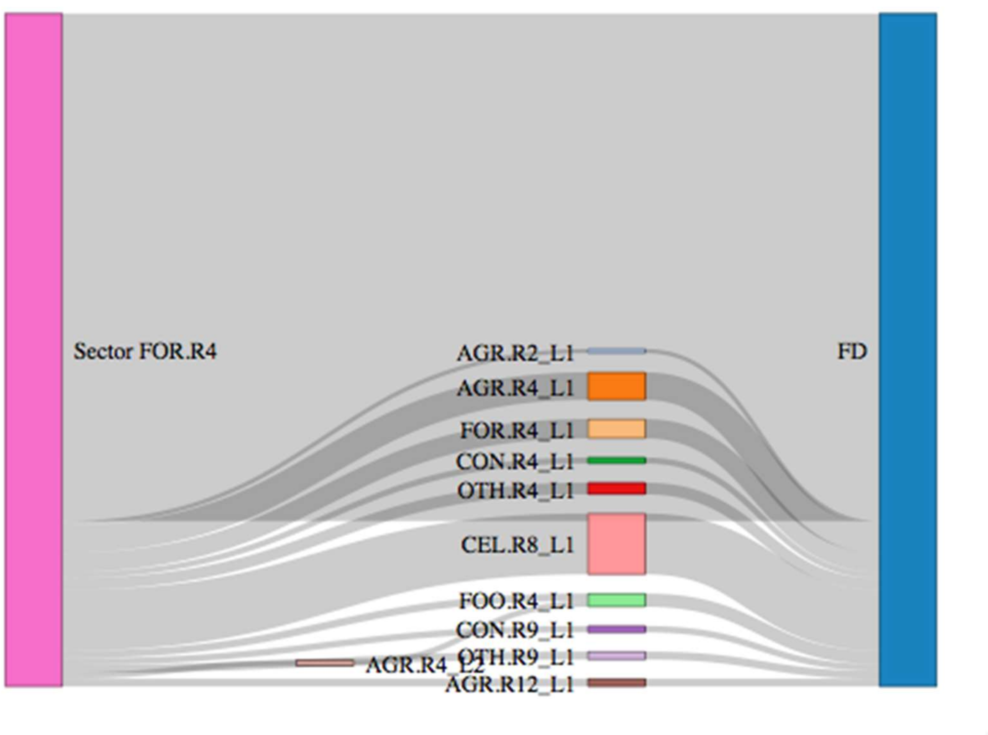


Figure 3.15. SPA for Region 4

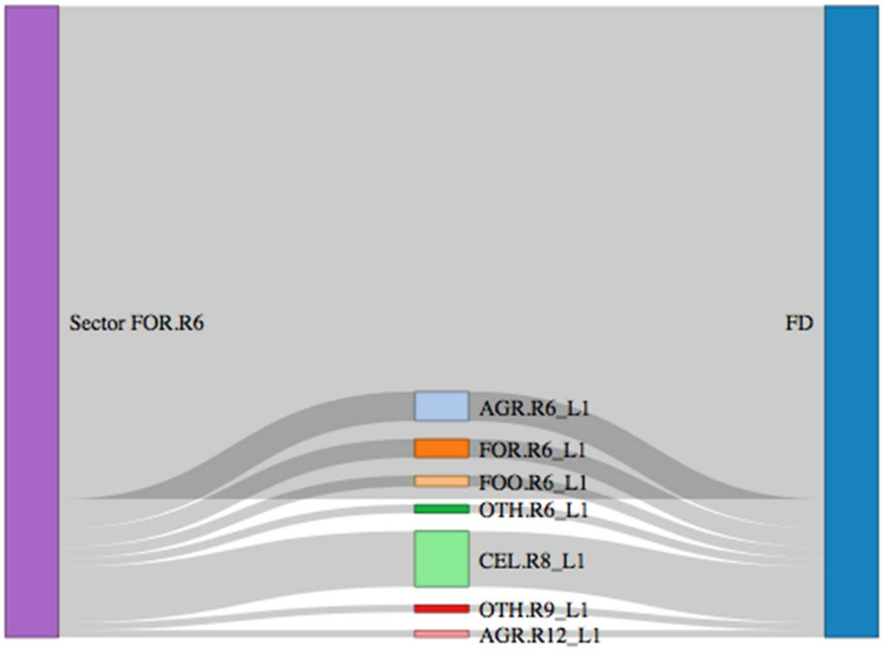


Figure 3.16. SPA for Region 6

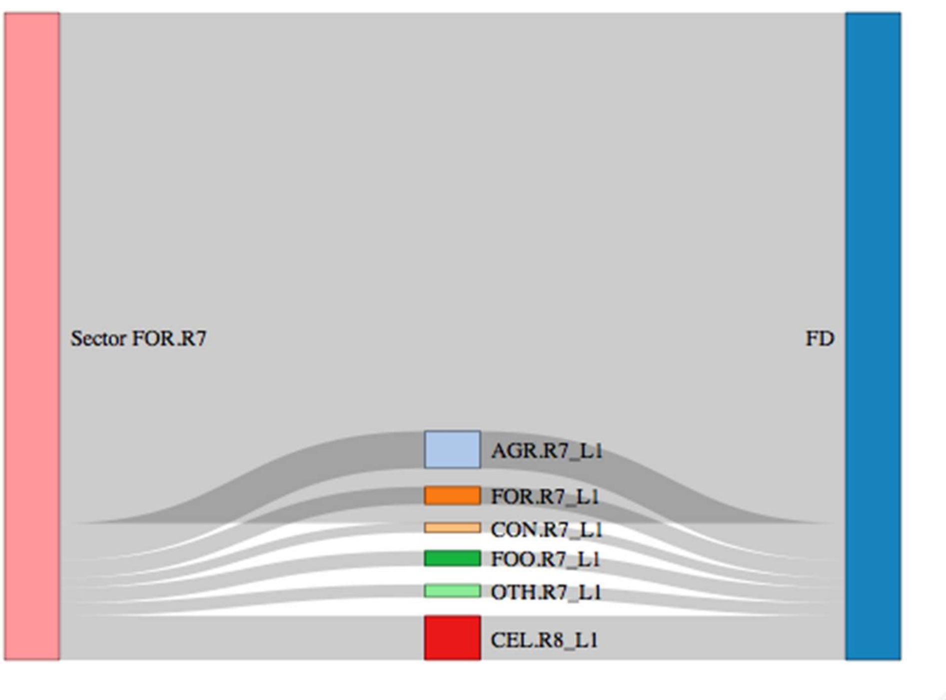


Figure 3.17. SPA for Region 7

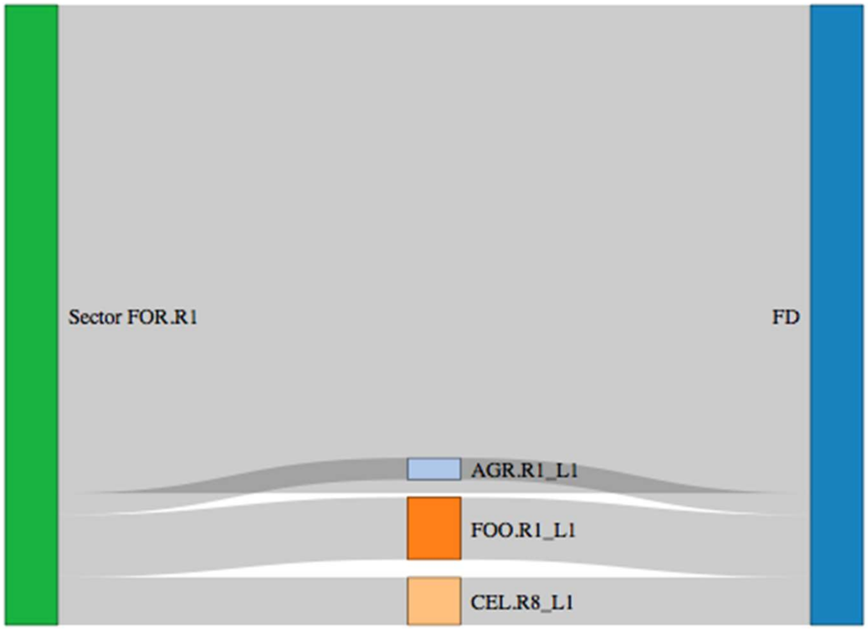


Figure 3.18. SPA for Region 1

3.4.4.2. Summary of the SPA analysis

Most of the MG forest plantation production goes to other parts of Brazil, mainly to cellulose production, wood products, food, agriculture, and construction. In the state, the production goes largely to cellulose production in Region 8, followed by agriculture in all regions, and to siderurgy in Regions 8, 9, 3, 11, and 13. The analysis showed that the main forest producers, Regions 3, 5, and 10 do not retain most of their production, due to low industrialization. In Region 3, good part production goes to siderurgy within its own region. In Region 10 it goes to food in its own region, but in Region 5 there is no relevant industry to use forest products. Regions 2, 9, and 12 are the most developed ones with prominent participation in the forestry sectors, receiving forest production from several regions across the state. The middle-level developed regions (11 and 13) use their production for furniture and siderurgy, while the low-developed regions (4, 6, and 7) do not have large forest production and use it mainly in agriculture, food, and construction. This analysis showed that the forest production of MG is an important supplier for other sectors outside the wood chain such as agriculture, food, siderurgy, construction, among others. However, few industries are located in the main forest producer regions.

3.4.5. Fields of influence

The following IO tool applied is the field of influence in order to add detailed information on the inter-industry trade at a more detailed level. To have a good visualization applying the fields of influence methodology, I aggregated the 17 initial sectors in 10, as showed in Table 3.15. The results are displayed on Figures 3.19 to 3.24, on their log-transformed form. The figures are not directly comparable, therefore, I can only analyze the fields of influence within the regions/sectors on each particular chart.

Table 3.15. Aggregating 17 Sectors in 10 Sectors for the Fields of Influence analysis

1- Agriculture	Agriculture – AGR
2- Industries others	Industry – IND
3- Commerce	Commerce – COM
4- Services	Services – SER
5- Government	Government – GOV
6- Forest Production	Forest Production – FOR
7- Wood Industry	Wood Production – WOP
8- Furniture	Furniture – FRT
9- Cellulose Industry	Cellulose Industry – CEL
10- Paper Industry	Paper Industry – PAP
11- Iron and Steel Industry	Industry – IND

Table 3.15 (Cont.)

12- Automobiles	Industry – IND
13- Mining	Industry – IND
14- Construction	Industry – IND
15- Food and Beverage	Industry – IND
16- Transportation	Industry – IND
17- Utility Industry	Industry – IND

Figure 3.19 shows the fields of influence amongst Regions 1 to 7. The darkest cell colors illustrate the most influential trades between two sectors for the whole region. For instance, the sales from industry and services in Region 1 to the other regions and sectors are represented by the two dark rows in the upper block of lines. This means that these sales have major influence or multiplier power in the area covered by the chart. As supplying sectors, industry and services are more relevant in Regions 1 and 2 than in the other regions. The forest sector horizontal lines for Regions 5 and 3 are darker than on the other regions and show that the supply of their products to the other regions/sectors is important for the entire area's economy.

The vertical dark lines indicate the important buying sectors. For all regions, industry and paper products have the largest influence followed by wood products and furniture. The cellulose sector has light color in all regions because none produce cellulose, and therefore this sector does not buy from any other sector/region. It is important to note that the best way to read the charts is through the consistency of the lines.

On Figure 3.20, we have the intermediate sales from the sectors in Regions 7 to 13 to the sectors in Regions 1 to 7. Industry and services of the capital metropolitan area Region 9 have strong multiplier power over the entire area. The same sectors in Regions 8, 11, 12, and 13 follow as important influence sectors. In Region 8, the cellulose sector has an expectedly dark horizontal line, meaning that the supply of cellulose to the other regions is economically relevant for the area. Among the most influential buying sectors are paper, furniture, and wood product.

Figure 3.21 displays the sales from Regions 1 through 7 to Regions 7 through 13. Just as in the first chart, here the sales from industry and services in Regions 1 and 2 are the most influential in the area, followed by these sectors in the other regions. The cellulose sectors in Regions 8, 9, and 12 have dark columns. Their purchases from the other sectors are important for the region's overall economy. The forest sector is an important supplier in Regions 3 and 5. Regions 1 and 2 are significant suppliers of wood products. Here the intermediate purchases of paper, furniture, and wood products also have high multiplication power throughout the regions.

Figure 3.22 shows the intermediate transactions among Regions 7 through 13. Industry and services in Regions 9 stand out as the most important sectors for the region's economy. As supplier sectors, cellulose is prominent in Region 8. In Region 5, the forest sector shows up slightly dark but not as much as Region 8 cellulose.

Figures 3.23 and 3.24 display the transactions from the rest of Brazil under Region 14 to Regions 1 to 7 and to Regions 8 to 14, respectively. Industry and services have the highest influence followed by commerce and agriculture. Paper, wood product, and forest supplying sectors are the most important for the regions for the forestry sectors.

The fields of influence analysis showed that wood products, furniture, and paper are the buying sectors and have great multiplier power over all regions in MG. Wood products are also particularly important as a selling sector for all regions, and so is the forest plantations sector, but with lower influence. This shows that even though forest plantation has been found to be an independent sector in the key-sector analysis, its supply to inter-industry trade remains relevant.

As for the cellulose trade, it is concentrated in region 8 as the main supplier, though; the cellulose production from Regions 8, 9, and 12 is influential to all regions.

The fields of influence analysis revealed large multiplier effects that the forestry sector has, especially for wood products and furniture as both buyers and suppliers, and forest plantation as supplier for various regions. As seen above, cellulose in Region 8 is relevant as supplier for the state in general and is an important buyer in a few regions, while its trade is relevant for other regions.

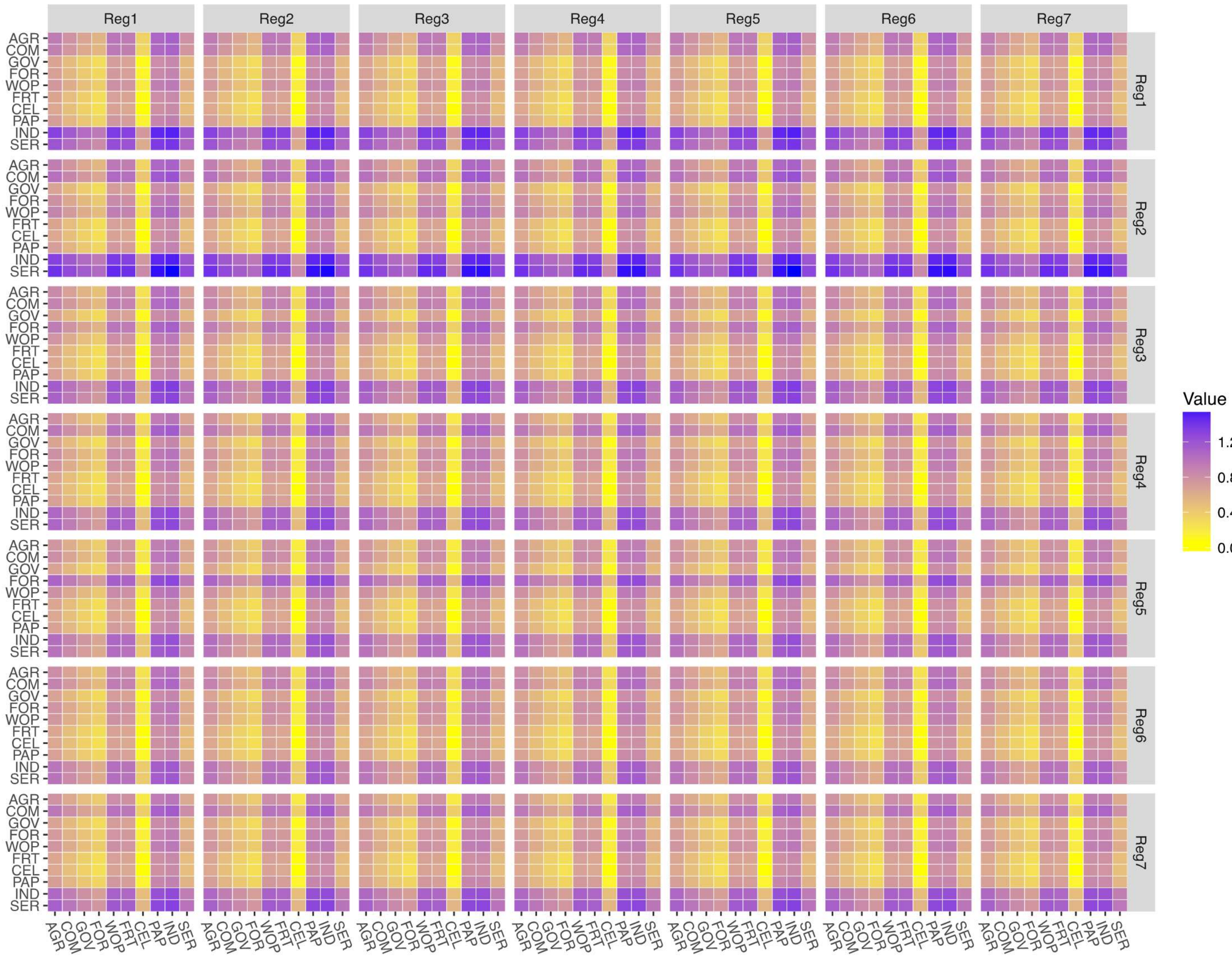


Figure 3.19. Fields of influence for Regions 1 to 7

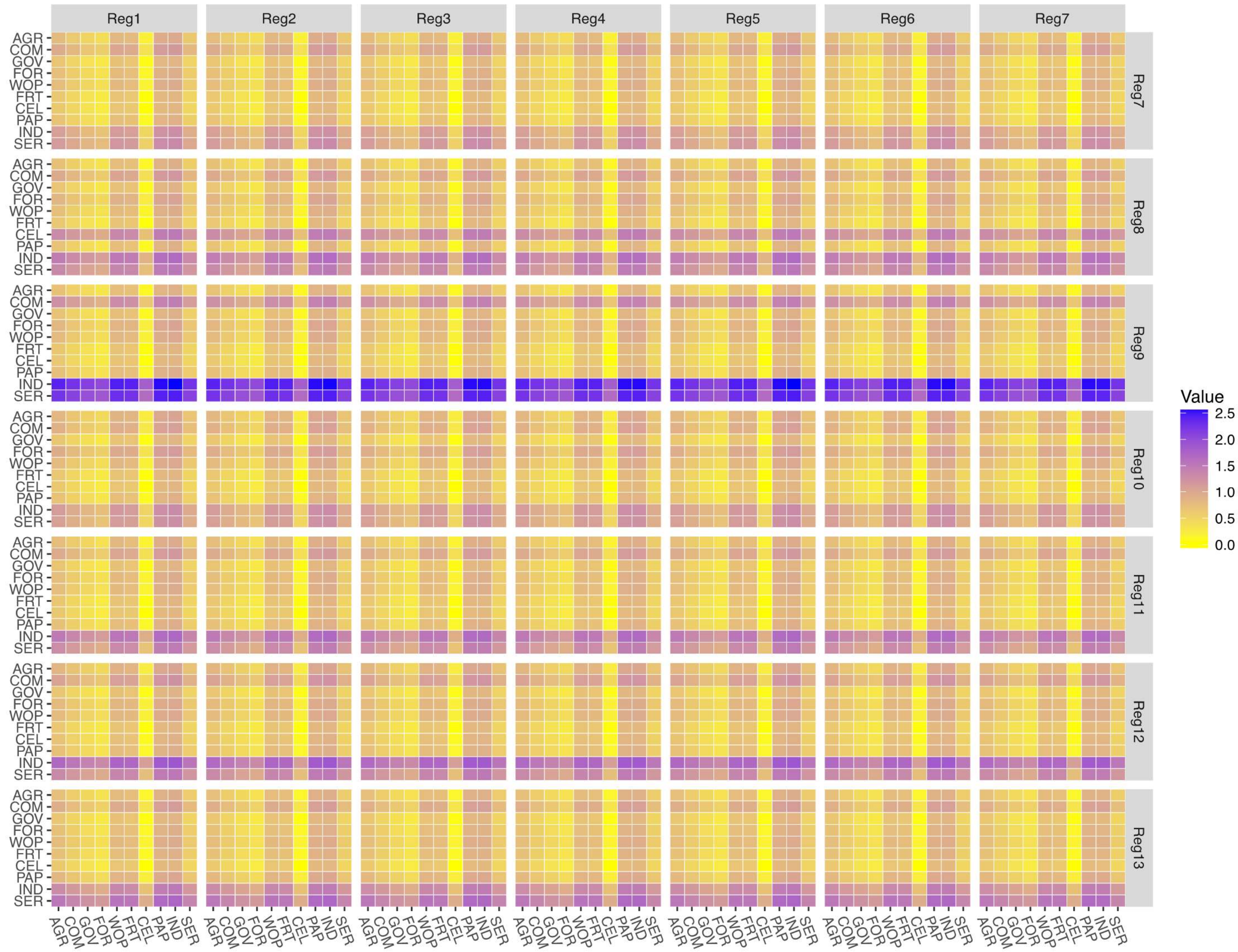


Figure 3.20. Fields of influence for Regions 1 to 7 and Regions 7 to 13

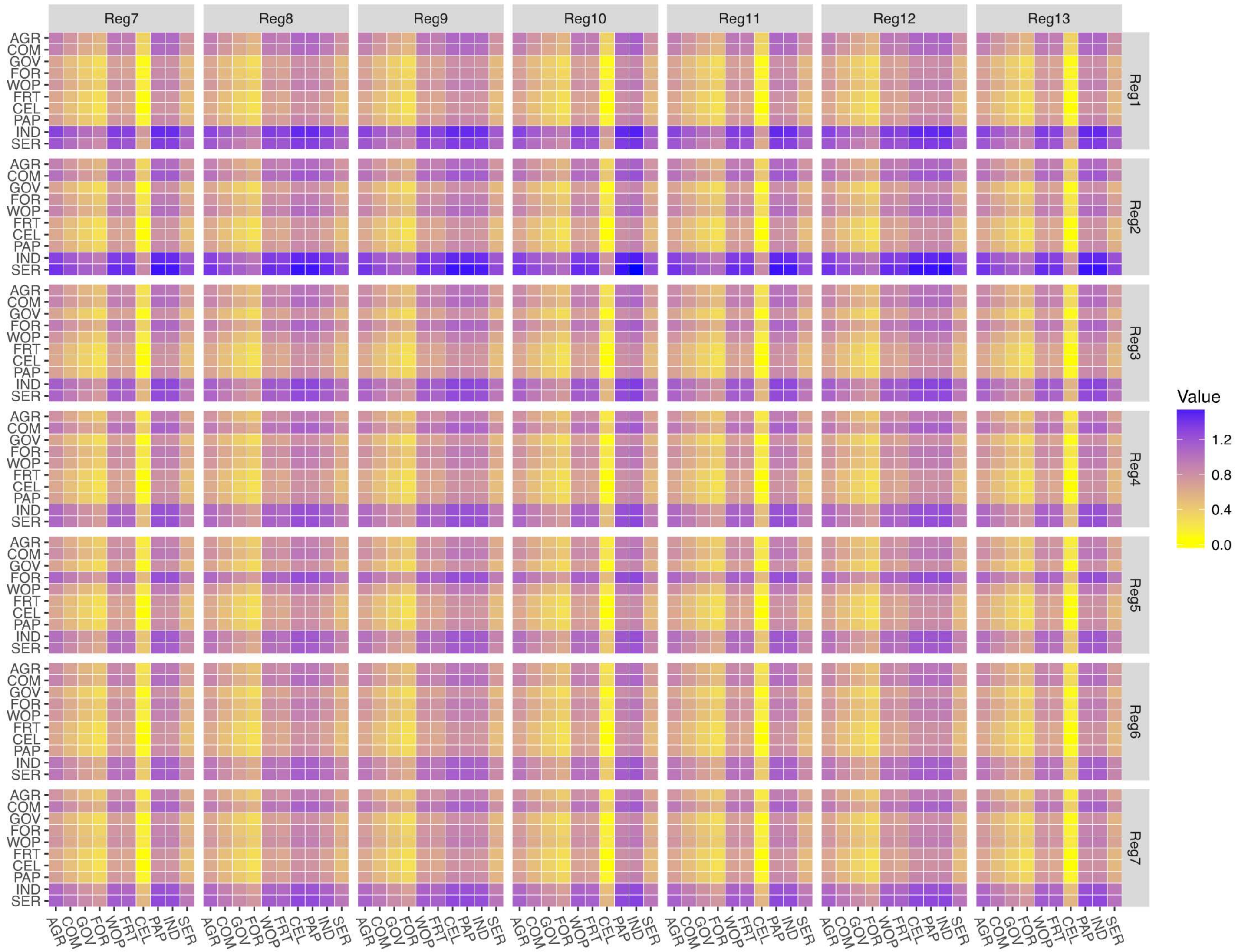


Figure 3.21. Fields of influence for Regions 7 to 13 and Regions 1 to 7

Figure 3.22. Fields of influence for Regions 7 to 13

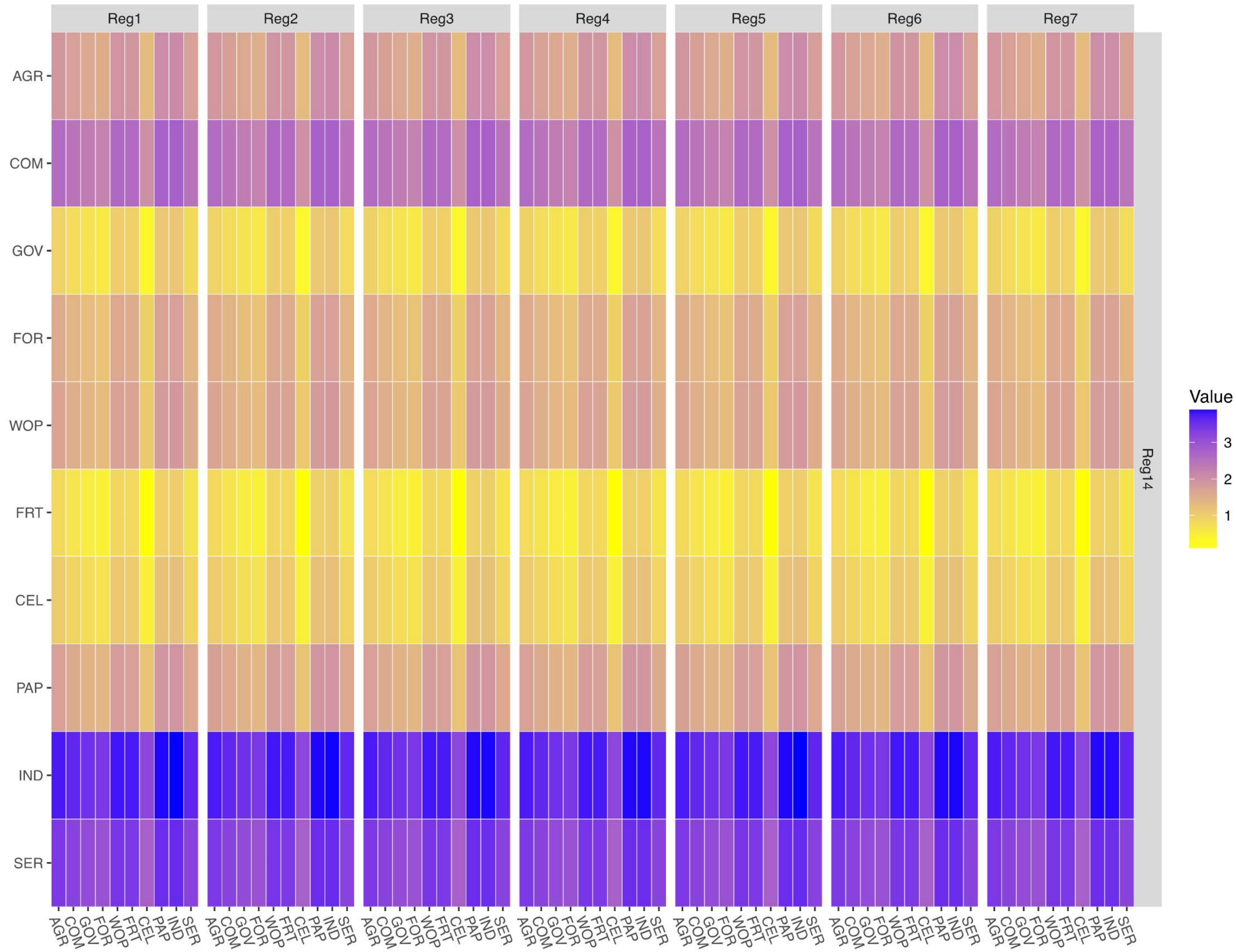


Figure 3.23 Fields of influence for Regions 1 to 7 and Region 14

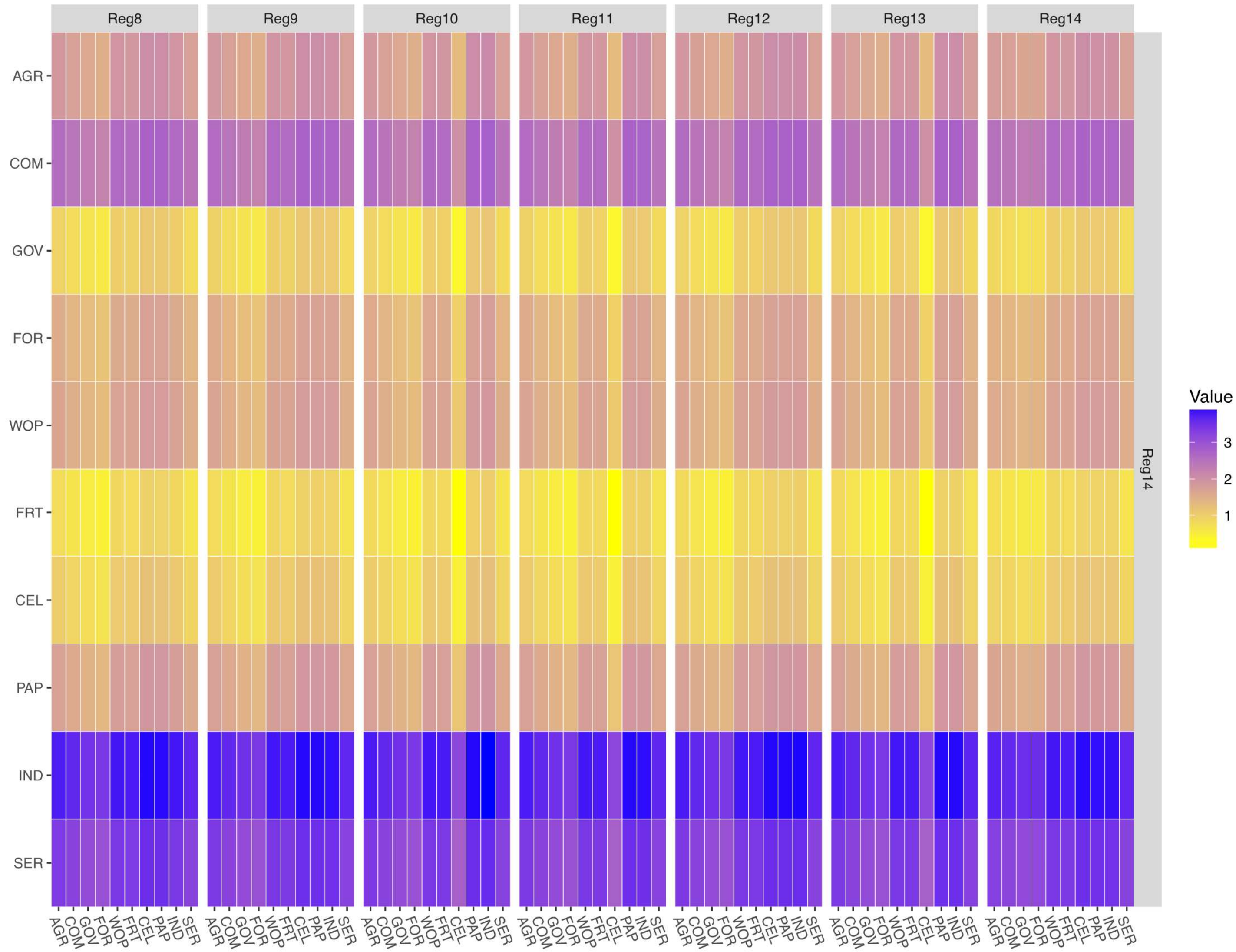


Figure 3.24. Fields of influence between Regions 8 to 14 and Region 14

3.5. Discussion

In this chapter I investigated the economic effects of the forestry sectors – forest plantations, wood products, furniture, paper, and cellulose – for the Minas Gerais economy at the regional level. One goal was to investigate how the important producer regions for forest plantations are integrated into the economic benefits generated by the forestry industry or other industries that use its products as inputs. To do that, I divided the state into 13 regions according to their main production of roundwood, charcoal, and firewood. I then applied the multi-regional IO analysis and analytical tools, based on an IO matrix specifically created for this study to extract information on the 17 main economic sectors in the state, focusing on the forestry industry.

My main hypothesis was that plantations are an isolated sector in the region they are located and do not have significant regional economic multipliers. The basis for this hypothesis is that wood can be processed far away from plantations and great part of the wood production is for exported cellulose production. Moreover, plantations have a long harvesting cycle and are becoming more mechanized, requiring fewer jobs. For the other forest sectors, I expected that, apart from cellulose, the other processing industries would have average to high economic multipliers as they are usually labor-demanding activities and supply inputs for many other industries.

On the linkage analysis, the results showed that forest plantations have the lowest backward and forward multipliers among all sectors, confirming my hypothesis. However, among all regions, the primary forest producer Regions, 3, 5, and 10 have the highest forward multipliers, suggesting that this sector is more important for these Regions' economy than for others. Also, Region 3's backward multiplier for other forestry sectors like paper, wood products, and furniture are amongst the highest. This means that the demand for these sectors produce economic growth inside the region even though these sectors are not large in total production. Hence only Region 3 among the larger forest producers is integrated with other forestry sectors and receives relevant benefits from the forestry industry development.

In the key-sector analysis, forest plantations are considered an independent sector because their backward and forward multipliers are below average among the sectors at all geographical levels. Nevertheless, the fields of influence analysis showed that plantations are an important supplying sector for the state's economy. This suggests that forests may be isolated economically and do not bring much economic multiplier by themselves. It is, however, a relevant sector for the overall economy when analyzed in a broader context. It indicates, though, that the benefits may not be evenly spread and are appropriated by other industries.

For the value added, income, and employment analysis, I found that forest plantations have the largest value added multiplier and the lowest income multiplier. Since income is part of the value added, it means that the value added multiplier refers to its other components as profits, interest payments, rental payments, and taxes. While plantations slightly impact income generation, they have the highest returns to capital. Cubbage et al. (2014) confirmed this by finding that Brazil has the highest returns in plantation investment in the world. However, returns to capital may benefit owners who are not located in the region or even in the state, hence the local economic impacts may be small or negligible. The employment multiplier is average for all sectors, but the type I employment multiplier is the lowest. This means that plantations also do not have a considerable impact on employment generation throughout the economy.

On the hypothetical extraction I found a discrepancy between output and value added generation by the forestry sector as a whole. The results showed that the impact in output would be higher in the main forest producers regions and in Region 13, which concentrates the furniture production in the state. Interestingly, the reduction in value added would be the highest among all sectors and about 21% for every region. These results again show the difference between regional and state effects of plantations on value added and product.

With the structural path analysis (SPA) it was possible to verify the connections of the forestry chain among the other sectors and regions. First, the results showed that the MG forest plantations production goes mostly to the rest of Brazil or directly to final demand, including exports. About 30% stays in the state and out of that the major share goes to cellulose production in Region 8. An interesting finding was that plantations are important suppliers for other industries outside the wood chain. Apart from siderurgy, a well-known buyer of charcoal, receivers of forest products are also seen in agriculture, food, construction, and other industries. In addition, SPA revealed that the large forest producer regions keep only a small part of their production, sending instead it to more developed and industrialized regions.

As for the other forestry sectors, I found that cellulose has low to average economic multipliers except for type I employment multiplier. This reflects the fact that cellulose is both at the top of the forestry industry value chain and has high labor productivity. Cellulose production requires significant amounts of wood and generates relevant employment in forests. However, few employers in the cellulose factory can process multiple inputs while producing the cellulose. As such, cellulose is more integrated with the national economy than state and regional economies. This can also be an isolated sector especially if its production goes mainly to exports. Wood products and furniture are the sectors with the highest multiplier effects in forestry and play a significant role in the state's economy. Although paper has lower multipliers than the furniture sector, it is also relevant for the state's overall economy.

These findings confirmed my expectations that forest plantations have lower than average economic multipliers and do not foster local economic development, unless they are connected to other industries in the same region. The processing industries have higher multipliers, especially if their production is for the national market. This way, forest production for cellulose exports is likely to bring very few benefits in terms of income, employment, and output generation. In MG, the forest production goes to various industries, which in their turn distributes the benefits within the regions they are located.

3.6. Conclusion

My research contributes to the literature on regional economy and forestry by presenting an input-output analysis of the forestry sector at the sub-state level. To my knowledge, this is the first time that such analysis has been conducted for a Brazilian state. Therefore, the details presented in these results can help answer questions on the regional impacts of the forestry sector in the state of Minas Gerais, Brazil, and shed light on this sector's impacts in other regions. The findings corroborate with previous research that forest plantations need to be closely associated to the regional economic structure to bring consistent benefits, otherwise it can be an isolated activity. Nevertheless, I found that at state level forest plantations is an important supporting activity for many industries.

As follow up research, the impacts that forest plantations have in rural areas should be further investigated. The rural context has changed drastically in the past few decades with the increase of commodity production through highly mechanized methods. It would be interesting to find out how populations and the economy in rural areas are adapting to it. Additionally, the discrepancy between value added and income multiplier in forest plantations also merits inquire.

It can uncover the large difference in returns to labor and returns to capital for this activity, a relevant topic to a recent debate regarding income inequality (Piketty, 2014). An investigation on how forest plantations contribute to income generation and distribution at the regional level would complement a discussion on income inequality.

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CHAPTER 4:

ANALYZING THE FORESTRY PRODUCTION STRUCTURE AND INCOME DISTRIBUTION IN MINAS GERAIS, BRAZIL USING THE MIYAZAWA FRAMEWORK

Abstract

This study investigates the main economic sectors of the state of Minas Gerais (MG) at a regional level, and how they generate wealth for different income classes. I focused on forestry sector income linked to both production and consumption. The goal was to investigate how gains in these sectors are distributed to the population of MG. I employed a multi-regional input-output model with a Miyazawa extended framework covering 13 regions, 16 sectors, and 10 income classes. Results show that forestry sectors are important for income generation in the state, especially for lower income classes. More industrialized regions receive income from either an increase in production or in consumption and concentrate their income in the top income class. Although forest plantations generate low overall income, most of it remains in the same region the plantation is located. Conversely, the cellulose and paper sector pays higher salaries, but most wealth leaks to other MG regions and the rest of Brazil. These findings offer important information for policies that promote the forestry industry for fostering economic growth in remote and less developed areas.

Keywords: input-output, Miyazawa, production, regional development, income, distribution, multipliers

4.1. Introduction

Global demand for wood products is increasing and promotes the expansion of areas planted with trees, especially in developing countries (Jurgensen, 2014; Cubbage et al, 2014; Indufor, 2012). In Brazil, the country with the largest such expansion since 1995 (FAO, 2015), forest growth occurs mainly on degraded lands, regions where land prices are inexpensive, and areas with low economic development levels. Apart from the market driven forest expansion, the Brazilian government also funds several reforestation projects as part of environmental commitments of restoration and climate change. According to the FAO (2010), the world market for wood products is relatively new and little is known about its environmental and socioeconomic impacts. Given this context and Brazil's leading position in plantation expansion, I investigated the economic effects of the forestry sector as a whole and how the benefits created are allocated among populations in different areas.

Minas Gerais (MG) is the state with the largest plantation area in the country since the 1980s, and has an important forestry industry for both the state's economy and that of its neighboring states (Lemos, 2002). The main plantation products are charcoal and roundwood for pulp production, followed by industrial production of wood products and furniture (Buainain & Batalha, 2007; de Oliveira et al. 2010). Forest plantations are the primary sector for the forestry value chain. However they are not always located in the same regions as the other forestry industries. It is critical to understand how these regions benefit from the forestry industry development, especially in terms of income generation. My main goal was to investigate how an increase in output in the forestry sectors creates and distributes income within the state's different income classes and how family consumption influences income creation and distribution within the state.

My analysis employs a multiregional input-output (IO) model with the Miyazawa extended framework for 13 regions of MG and the 14th as the rest of the country, also encompassing 16 sectors. The Miyazawa (1976) framework was designed to include family consumption in the regular IO model. This way, consumption works as another economic sector, and its demand has the power to promote more output production and income generation. The model also allows for income distribution dynamics among regions and classes of income.

The IO matrix represents a complete portrait of the productive structure of a region based on available data. As described in Chapter 3, the multiregional model gives the specific productive interactions among included sectors for all regions. Usually, the IO analysis is applied to larger geographical areas such as a state or country due to the lack of micro information on production and trade. In this study, though, I created subregional IO matrices using on the SIIP-BR Model developed by NEREUS/USP for 2011 (Guilhoto et al, 2017; Guilhoto & Sesso Filho, 2010). Such analysis is unprecedented for MG.

The Miyazawa framework is applied to investigate the interdependence of income and output generation for multiple scenarios. For instance, Hewings et al. (2001) investigated the economic interaction among the metropolitan areas of Chicago. They found that people's commuting trips between these regions and the resulting income flows from labor have more impact on income formation in the regions than the trade flows between them. Furthermore, they found the importance of the consumption in some regions for income creation in others. Similarly Perobelli et al. (2013) applied the methodology for the metropolitan area of São Paulo and concluded that the income flows are associated with the production flows. This means that the more industrialized regions generate more income for themselves and for the neighboring areas. However, the industrialized regions also receive more income induced by consumption in other regions.

On plantations, Obidzinski et al. (2014) examined the socioeconomic impacts of different expansion scenarios for state development of palm oil in Indonesia in 2010. They found that the expansion in plantation area would bring “minimal income improvement for the low-income households” (p. 1189), as the wages paid to unskilled workers are low and therefore would not contribute much to increase their overall earnings. For the forestry sector in Brazil, we do not know of any study that has applied this methodology. Moreover IO studies in Brazil for the forestry sector are mainly at state or national levels (Valverde et al. 2003, 2005) rather than an in-depth regional scale. My research provides new insight on input-output analysis and for policies promoting forestry industry in Brazil and other countries by focusing on regional dynamics.

Apart from this introduction, the next section introduces the theoretical model used; section 3 describes the region of analysis and discusses the theoretical expectations; and section 4 presents the source of data. Section 5 presents and discusses results, and the final section concludes by discussing the policy relevance of this study and suggestions for further research.

4.2. Theoretical model

For the income and output analysis among MG regions, I employed a multiregional input-output methodology with the Miyazawa extended framework (Miyazawa, 1976). I added the Miyazawa matrices of consumption and value added as income to the multiregional IO matrices obtained using the SIIP-BR Model developed by Nereus-USP (Guilhoto et al, 2017; Guilhoto & Sesso Filho, 2010). Since my interest is in income distribution and income generated by production, I estimated 1) the interrelational income multiplier matrix and 2) the multi-sector income multiplier matrix.

4.2.1. The Miyazawa Framework

The first step of the extended Miyazawa IO model (M-IO) notes family income in several income groups and separates the family consumption by these groups. The new income and consumption matrices are added to the standard IO model. The matrix notation for the M-IO is:

$$\begin{bmatrix} X \\ Y \end{bmatrix} = \begin{bmatrix} A & C \\ V & O \end{bmatrix} \begin{bmatrix} X \\ Y \end{bmatrix} + \begin{bmatrix} f \\ g \end{bmatrix} \quad (1)$$

Where X is a vector of output, Y is the income vector of total income for each group, A is the direct input coefficient matrix, V is the matrix of the value-added as income ratios for the income groups, C is the matrix of consumption coefficients, *f* is a vector of final demand, and *g* is a vector of exogenous income for the income groups. Supposing $g = 0$, I created the following system:

$$\begin{bmatrix} X \\ Y \end{bmatrix} = \begin{bmatrix} B[I+CKVB] & BCK \\ KVB & K \end{bmatrix} \begin{bmatrix} f \\ g \end{bmatrix} \quad (2)$$

$$M = \begin{bmatrix} A & C \\ V & O \end{bmatrix} \quad (3)$$

$$\underline{B} = \begin{bmatrix} B[I+CKVB] & BCK \\ KVB & K \end{bmatrix} \qquad (4)$$

$B = (I-A)^{-1}$ is the Leontief inverse matrix and $\mathbf{K} = (I-VBC)^{-1}$ is the Miyazawa interrelational income multiplier matrix, which gives the total effects on each income group that results from the expenditure of one extra unit of income by other groups. The matrix B(I+CKVB) is the Miyazawa output multiplier matrix and gives total output, including the effect of family consumption in the economy. The **KVB** matrix shows the effect of an additional unit of final demand on income generation for each group and is called the multi-sector income multiplier. The BCK matrix indicates the effect of one additional unit of consumption by each group on the final production by sector. $\underline{B} = (I-M)^{-1}$ is the Leontief matrix of the augmented system.

To add the spatial dimension to the model, the matrices have the following dimensions:

A is a np x np matrix;

C is a np x pq matrix; and

V is a pq x np matrix.

Where n represents the sectors (i, j = 1,…, n), p represents the regions (k, l = 1,…, p), and q represents the household income groups (g, h = 1,…, q).

Matrix elements are, respectively:

a_{ij}^{kl} = represents the input required from sector j in region l to sector i in region k to produce one unit worth of production;

c_{ih}^{kl} = is the household demand from group h in region l for the sector's i output in region k ;

v_{gj}^{kl} = means income payment from sector j in region l to households in group g in region k.

In a multiregional IO model, the calculation of these coefficients, the matrices' elements, requires information on family income and consumption by each income group, for each sector, and by region, which is very demanding in its data requirements (Miller & Blair, 2009). I explained how the data was identified in the data section.

4.3. Regions of analysis

The state of Minas Gerais in Brazil (Figure 4.1) has had the largest plantation area in the country since the 1980s and currently has about 20% of the country's total amount, or 1.8 million ha (IBA, 2016). Forestry has developed since the 1970s to support the base industries such as iron and steel, construction, and, more recently, cellulose and paper production. These industries are concentrated in the southern regions next to São Paulo, the richest state in Brazil. The production of charcoal occurred mainly in the central and northern parts of the state and initially used mostly natural vegetation. Charcoal production from plantations developed later in the 1990s on already degraded lands. Furthermore, forest products are used in a broader range of industries, including agriculture and food production and the wood industry in general. Although the industries are still concentrated in the southern regions, the bulk of the plantation expansion occurs in the less economically developed central and northern areas. Plantations can therefore be isolated from the wood processing centers; however, they can also be an important economic activity for poorer areas.

The forestry industry can be divided in five main sectors: forest plantations, wood products, furniture, paper, and cellulose production. The sectors differ in levels of technology, job requirement, salaries, and output destination. Their economic multipliers, therefore, can vary significantly, especially when considering the economic structure surrounding them. For instance, cellulose production pays the highest salaries among the forest industries mostly for people in large urban centers. The cellulose destination is also mainly for exports and for other states in Brazil. The paper sector overall pays high wages as well, but requires more workers than cellulose production. Wood products and furniture use mostly local inputs, are job intensive, and supply inputs and final products to local industries and consumers. Plantations pay lower salaries and are becoming increasingly mechanized over the years, requiring less but more skilled workers in rural areas. Nevertheless, the low salaries paid by the forest sector are more likely to stay within a region than higher salaries as they are expected to be fully used for subsistence. Yet the increase in plantation technology has also increased productivity and reduced the harvesting time. This could have increased labor demand and improved the economic impact of this activity.

I examined how forestry sectors contribute to the state's regional income generation and distribution. How does increasing in output demand for each forestry sector create income within regions and for different income classes? I expected that these effects would depend heavily on the economic structure of each region regarding the processing of wood and its integration to the main industrial centers. These areas are likely to receive a great share of income due to their large production of goods. I also presumed income generation would leak to highly populated areas due to the higher salaries paid there and commuting journeys to work. The Miyazawa framework allows the investigation of income generation originated by the increase in salaries followed by consumption. I expected that an increase in consumption would have different impacts on socioeconomic classes.

To analyze the economic impact of the forest industry regionally, I divided the state based on forest production clusters of the main products: charcoal, roundwood, and firewood. As such, I aggregated the 66 microregions in MG into 13 regions depicted in Figure 4.2 below. This division does not coincide with the mesoregions, the official microregion aggregations used by the Brazilian Institute of Geography and Statistics (IBGE). To illustrate the differences between them, I present both divisions in Figure 4.3.

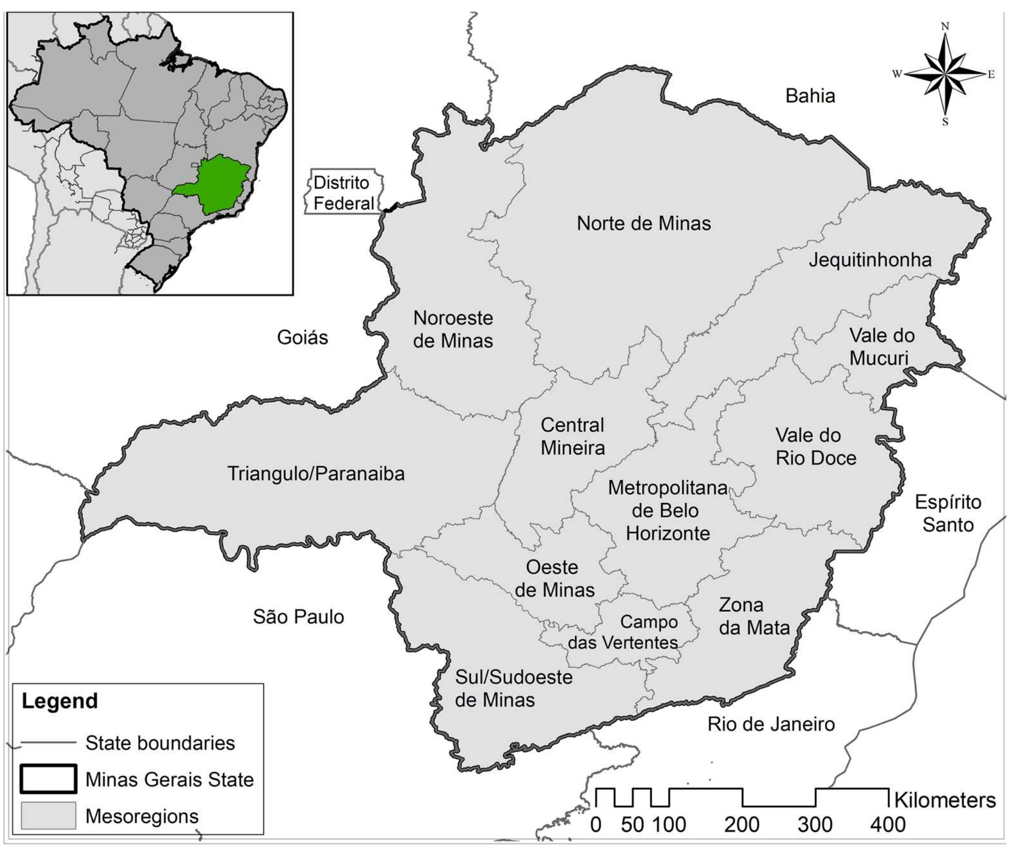
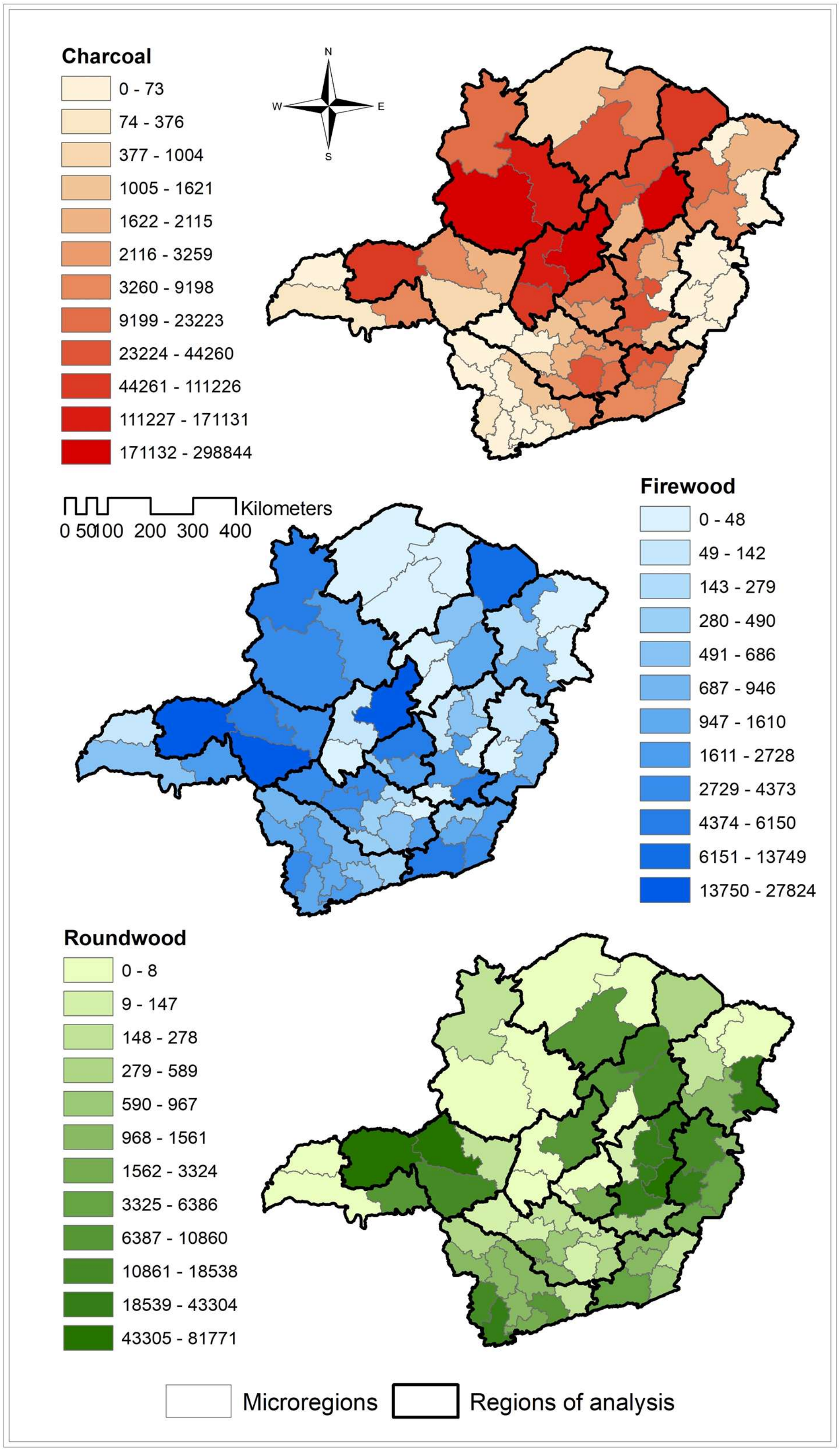


Figure 4.1: Map of Minas Gerais in Brazil



Figures 4.2. Production value in BRL thousand of charcoal, firewood, and roundwood by microregions and the regions of analysis in 2011. (source: PEVS/IBGE)

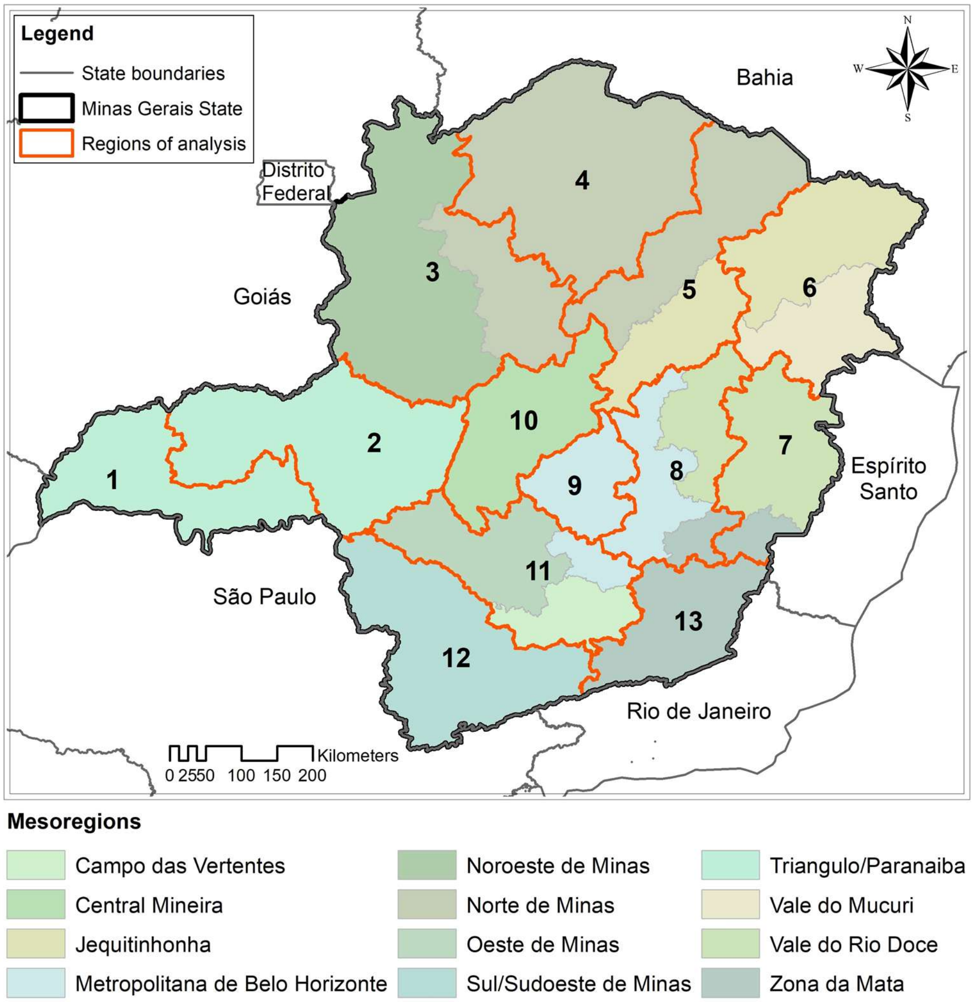


Figure 4.3. Mesoregions of Minas Gerais and Regions of analysis

4.3.1. Socioeconomic characteristics of the Regions

Minas Gerais is the third richest state in the country. However, it is very unequally developed. It encompasses poor areas, especially in the semi-arid northern part of the state (Regions 4 to 6) and other highly developed regions in the south. The population is concentrated in the southern regions and around the capital metropolitan area, as seen in Table 4.1. Regions 8, 9, and 11 contain parts of the capital metropolitan area, have high population density, and the highest industry concentration in the state. Regions 12 and 13 are also developed regions with high population density. Region 12 is very integrated with the southern rich state of São Paulo.

Regions 1 and 2 together are defined as the third most productive area in the state, especially with respect to agroindustry, and have the highest average Human Municipal Development Index (IDHM). In Region 8 there are multiple iron/steel firms and the largest chemical pulp company in MG. Adjacently, Region 7 provides agricultural and forest plantation products to both Region 8 and the neighboring state of Espírito Santo. Regions 4 to 6 of the northern regions are the poorest ones, especially when considering their total area to production ratio. Region 10 is the central region. It is average in terms of development and production and is an important charcoal producer.

Table 4.1. Socioeconomic data of the regions of analysis for 2010/2011.

	Total Area (1,000 km^2)	Total Pop (1,000)	% Area in MG	% Population in MG	Pop Density (average)	IDMH (average)	% MG Product
Region 1	34.9	675.9	6.0	3.4	19.34	0.71	3.80
Region 2	55.6	1,489.7	9.5	7.6	26.80	0.71	8.46
Region 3	85.4	534.6	14.6	2.7	6.26	0.67	2.18
Region 4	70.6	1,130.3	12.0	5.7	16.01	0.63	2.21
Region 5	54.2	604.6	9.2	3.1	11.16	0.62	1.21
Region 6	50.9	805.7	8.7	4.1	15.84	0.60	1.20
Region 7	31.9	1,160.0	5.4	5.9	36.40	0.64	2.76
Region 8	37.6	1,571.1	6.4	8.0	41.77	0.65	9.48
Region 9	16.2	5,334.1	2.8	27.0	330.02	0.71	41.90
Region 10	31.7	415.2	5.4	2.1	13.08	0.69	1.37
Region 11	42.0	1,832.6	7.2	9.3	43.65	0.69	8.72
Region 12	49.6	2,453.1	8.5	12.4	49.48	0.70	10.22
Region 13	26.0	1,721.9	4.4	8.7	66.27	0.67	6.49
Region 14	8,516	190,733	-	-	22.40	0.76*	-

* IDH for the whole country
Source: IBGE and SIIP-BR Model by Nereus/USP

4.4. Source of Data

4.4.1. Value Added and Consumption Data

To construct the value added and consumption matrices for the Miyazawa framework, I needed information on family consumption and on income by region of analysis and income classes. I extracted that information from the 2008 IBGE Household Expenditure Survey (2008 POF), a national survey that investigates expenses, income, and family property to calculate economic indexes such as inflation. The families are sampled and results are released for different geographical levels. The total number of families in the survey for MG was 5.028 whereas the national total was 55.970. The survey has data on the paying sectors of family income and consumption of more than 14,000 items. Based on the data available one can aggregate families by income levels and obtain both their consumption and income (or value added) by economic sector.

There are two main limitations that particularly hinder this study. The first concerns the geographical level, since the 2008 POF does not have results at microregion or even at mesoregion levels. It only contains data at the state level and for the capital metropolitan areas. As such, I could only calculate three sets for income and consumption coefficients: for the MG capital metropolitan area, for the rest of the MG state apart from the capital metropolitan area, and for the rest of the country beyond MG. I used the first set of coefficients for Regions 8, 9, and 11 because they have parts of the capital metropolitan area, the second set of coefficients for the other MG regions, and the third set for Region 14. The second limitation is in regards to how the economic sectors are defined. The 2008 POF combines the pulp and paper sectors into one, therefore I aggregated them in the production matrix as well. I understand this consolidation limits forestry industry studies in general as pulp and paper sectors have different economic dynamics.

For the income classes, brackets, or groups, I used the typology adopted by Ferreira Filho & Horridge (2006). Families were divided in 10 income classes by monthly income in Brazilian Reais (BRL) with the correspondent 2008 minimum wages:

Income in BRL		Minimum wages
1. Class 1:	0 to 830	(0 to 2)
2. Class 2:	830 to 1245	(2 to 3)
3. Class 3:	1245 to 2075	(3 to 5)
4. Class 4:	2075 to 2490	(5 to 6)
5. Class 5:	2490 to 3320	(6 to 8)
6. Class 6:	3320 to 4150	(8 to 10)
7. Class 7:	4150 to 6225	(10 to 15)
8. Class 8:	6225 to 8300	(15 to 20)
9. Class 9:	8300 to 12450	(20 to 30)
10. Class 10:	above 12450	(above 30)

4.4.2. The sectors in the M-IO Model

I used the multiregional matrix defined in Chapter 3 for the same regions of analysis. However, as explained above, I aggregated the pulp and paper sectors due to the lack of separate data on consumption and income. Table 4.2 displays the 16 sectors with their respective products along with their acronyms used later on the result tables.

Table 4.2. Sectors and products for each region in the MRIO matrix.

Sectors division/aggregation:	Products division/aggregation:
1) Agriculture - AGR	1) Agriculture
2) Industry - all others - IND	2) Industry - others
3) Commerce - COM	3) Commerce
4) Services - SER	4) Services
5) Government - GOV	5) Public administration
6) Forestry production from planted and natural forests - FOR	6) Products from forestry production – wood and others
7) Wood products manufacture -WOP	7) Woods products

Table 4.2 (Cont.)

Sectors division/aggregation:	**Products division/aggregation:**
8) Furniture production -FRT	8) All furniture products
9) Chemical pulp, as cellulose and Paper 10) and manufacture of paper products – CEL + PAP	9) Pulps for paper production + 10) Paper, cardboard, packaging and paper products
11) Siderurgy - SID	11) Iron, steel, and other products
12) Automotive industry - VEH	12) Cars, buses, tractors, etc.
13) Iron and metal ore mining - MIN	13) Iron, copper, aluminum, etc.
14) Construction - CON	14) Construction activities
15) Food industry - FOO	15) Food and beverages
16) Transportation -TRA	16) Transportation
17) Utilities Industry: Public services– UTI	17) Energy generation, water and gas distribution, sewage, and recycling

Tables 4.3 and 4.4 show salary distributions to families by sector and income brackets for Minas Gerais and Brazil. These results are from to the 2008 POF and are aggregated according to the sectors and income classes of this research. Since the data is derived from a sample of families, there are significant differences between the two tables, especially for the forestry sectors. For instance, classes 9 and 10 are not represented in most forestry sectors of MG. Overall, pulp and paper are the sectors that pay the highest salaries while forest plantation pays the lowest in both tables.

Table 4.3. Distribution of the total salary payments to the income classes made by the sectors (in percentages) in Brazil, 2008

	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Total
Agriculture	12.3	11.4	18.8	6.1	9.1	5.9	11.2	5.2	7.0	13.0	100
Industry	2.4	5.3	12.8	7.9	12.4	9.0	13.6	10.5	14.1	12.0	100
Commerce	3.4	6.3	15.3	7.3	11.5	10.2	14.9	9.2	8.8	13.2	100
Services	2.6	4.7	10.2	4.7	8.4	7.3	12.7	10.3	12.9	26.1	100
Government	1.0	2.4	7.0	3.7	8.0	8.0	16.8	11.1	13.5	28.6	100
Forest Plantations	**15.9**	**17.1**	**19.8**	**6.1**	**9.0**	**5.8**	**5.2**	**1.1**	**9.8**	**10.3**	100
Wood Products	**8.0**	**12.3**	**23.9**	**9.2**	**9.1**	**10.3**	**15.7**	**2.9**	**6.8**	**1.8**	100
Furniture	**4.8**	**8.9**	**23.9**	**8.6**	**10.0**	**7.1**	**11.6**	**12.0**	**3.9**	**9.2**	100
Pulp and Paper	**1.5**	**7.8**	**14.0**	**6.1**	**11.1**	**10.9**	**23.0**	**10.4**	**4.3**	**11.0**	100
Siderurgy	1.5	4.2	13.1	6.6	12.9	7.6	19.8	13.8	10.3	10.2	100
Vehicles	0.5	1.4	7.1	5.2	10.1	11.4	22.6	10.1	10.8	20.8	100
Iron and Steel	2.0	2.5	11.9	4.0	18.4	12.3	17.3	3.6	12.9	15.0	100
Construction	7.6	12.4	20.7	8.3	11.7	7.8	9.2	5.8	6.6	10.1	100
Food Industry	4.9	8.5	22.5	9.1	16.4	8.4	15.3	5.0	5.1	4.8	100
Transportation	3.0	5.4	18.0	7.8	14.1	10.6	15.3	9.0	9.7	7.2	100
Utilities Industry	3.2	6.5	10.4	7.9	8.3	9.8	9.6	10.8	9.4	24.2	100

Source: Own elaboration with data from the 2008 POF/IBGE.

Table 4.4. Distribution of the total salary payments to the income classes made by the sectors (in percentages) in the state of Minas Gerais, 2008

	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Total
Agriculture	13.0	14.2	21.8	5.7	11.6	7.7	5.0	5.4	6.0	9.5	100
Industry	3.7	6.5	17.5	10.7	12.2	10.9	14.1	13.2	2.2	8.9	100
Commerce	2.3	5.1	15.0	8.1	14.9	10.1	13.2	9.2	7.5	14.5	100
Services	2.4	4.4	11.8	4.4	8.6	7.7	12.9	7.3	9.9	30.6	100
Government	1.0	2.1	8.5	4.9	8.7	7.3	13.8	8.4	12.2	33.2	100
Forest Plantations	**28.6**	**17.5**	**19.9**	**9.6**	**6.9**	**13.1**	**1.0**	**0.0**	**3.4**	**0.0**	100
Wood Products	**12.8**	**3.5**	**17.2**	**13.5**	**7.9**	**18.5**	**17.5**	**0.0**	**0.0**	**9.0**	100
Furniture	**6.5**	**23.5**	**16.3**	**9.1**	**17.8**	**20.2**	**0.5**	**6.2**	**0.0**	**0.0**	100
Pulp and Paper	**4.9**	**0.0**	**13.3**	**20.9**	**30.6**	**0.0**	**22.0**	**8.3**	**0.0**	**0.0**	100
Siderurgy	0.7	3.2	9.0	3.6	11.8	19.4	23.8	9.4	11.6	7.5	100
Vehicles	0.0	6.3	22.4	5.6	22.2	5.2	13.7	11.5	13.1	0.0	100
Iron and Steel	0.9	0.0	11.7	2.8	30.9	10.4	3.1	0.0	0.0	40.2	100
Construction	7.0	12.5	22.7	8.4	12.1	7.7	7.1	4.0	11.5	7.1	100
Food Industry	2.9	9.2	22.4	13.8	14.7	9.3	7.2	6.0	7.2	7.4	100
Transportation	2.6	6.3	18.8	9.2	14.0	14.6	14.8	12.3	1.4	5.9	100
Utilities Industry	2.2	12.5	12.1	2.0	7.8	3.2	11.9	33.5	0.0	14.9	100

Source: Own elaboration with data from the 2008 POF/IBGE.

Table 4.5 displays the outputs per sector and per MG region according to the multiregional IO matrix. The total MG GDP in 2011 was about R$350 billion (US$190 billion). The most important sectors in the state were services with 29.1% of GDP, followed by government with 14.7%, and commerce with 11.8%. The forestry sectors participated with only

1.7% of GDP. Forest plantation is the most relevant sector with 0.8% of the total, followed by furniture with 0.5%, and both wood product and cellulose with 0.2% each.

The most important regions for forest plantations are Regions 5, 3, and 10 with respectively 29%, 16%, and 14% of the total state forest production. These regions are not relevant to any other forestry sector. However, according to Figures 4.2, they are all important producers of charcoal mainly for the iron and steel industry and firewood for other sectors. Region 5 is also important for roundwood production used for producing cellulose mostly in Region 8 (see Figure 3.5).

Furniture production is concentrated in Regions 13 (46%), 9 (21%), and 11 (12%). Wood products are mostly made in Regions 2 (23%), 9 (18%), and 12 (15%). More than half of cellulose and paper production occurs in Region 8, since almost all the cellulose in the state is produced in that region. Therefore, this sector combined with paper is significant in Regions 8, 9, 12, and 13.

4.5. Results

4.5.1. Interrelational income multiplier matrix

The interrelational income multiplier matrix shows the results of an increase in income when salaries grow for all classes in all regions by one unit, generating 140 (14 regions x 10 income classes) more income units in this economy in terms of wages. Table 4.6 displays the results aggregated by region while Table 4.7 shows them by class. In both tables, the new total income (140 units plus the income created) in this economy is 222.023 units.

The last line in Table 4.6 has the column sums and the total income created by each region. For example, for Region 1, after increasing income of each class by one unit and this income circulates the economy, the total income created over all regions would be 15.887 units. From this, 11.918 are created in Region 1 itself, 2.915 in Region 14 or the rest of the country, and 0.557 in Region 9, the central part of the capital metropolitan area. The total among regions is very similar due to the use of two consumption/income coefficients sets for all MG regions. The regions that retain most income are the more developed ones; Regions 1, 2, 9, 11, 12, and 13. The poorer northern Regions, 3, 4, 5, and 6 retain less income. The row sums in the last column on the far right show the induced effects received by each region. Region 14 concentrates about one quarter of the total income generated due to its size. Regions 9, 2, and 13 receive the most induced income in the state as they are the most industrialized.

The results from Table 4.7 are similar but aggregated by classes for all regions taken together. They show income generated by an increase in salaries for each class in all regions. For instance, one unit increase in the wage of class 1 in all regions would increase the income in the economy by 21.936 units. Classes 7 to 10 generate more income overall, and classes 10, 3, 7, and 5 receive the highest induced income in that order. Overall, maybe due to the same sets of income and consumption for most of the regions, there's hardly a difference in income generated by their consumption.

4.5.2. Multi-sector income multiplier matrix

The multi-sector income multiplier matrix gives the direct, indirect and induced incomes for each income group generated by an increase in final demand of the sectors. This way, Table 4.8 displays the results of an increase in final demand by one unit for all sectors in all regions aggregated by region. When increasing final demand by 226 units (14 regions x 16 sectors), the total income increases by 127.63 units. From the total column sums in the last line, demand increases in Regions 2, 9, and 12 in MG generates more income overall. The row sums at the last column show the induced income received by classes and concentrates on classes 10, 3, 7, and 5 as seen in the interrelational income multiplier matrix. For Regions 8, 9, and 11, the capital metropolitan regions, the greatest share goes to class 10. The same for the rest of the country.

Tables 4.9.a and 4.9.b display the average increase in income resulting from an increase in final demand of a sector by one unit generated in: the same region, the rest of the state, and the rest of Brazil. Table 4.9.a displays the results averaged by sector for all MG regions. As an example, one extra unit in final demand in agricultural products in any MG region increases income for that region by 0.18 units, for the rest of the state by 0.06, and for the rest of Brazil by 0.18 units. The sectors that generate more overall income are trade, government, wood products, and transportation. However, services are more important than transportation in the state of MG.

Table 4.9.b shows the results of Table 4.9.a in percentages. More than 60% of the income created by trade, services, government, and forest plantations is generated in the same region. The sectors that induce more income leak beyond MG are industry, siderurgy, vehicles, and mining. Wood products and furniture demands create more than 50% of the new income in the same region while cellulose and paper demand has a high participation in the rest of the state's new income.

Table 4.10 shows the results aggregated by sector. The increase in income per class resulted from an increase in final demand by one unit for all sectors in all regions. The last line has similar results to Tables 4.9.a and 4.9.b regarding the sectors that create more income in total: trade, government, wood products, and transportation. Interestingly, the only sector in which demand does not generate a meaningful share of income for class 10 is forest plantations. For this sector, about 40% of income generated by an increase in final demand goes to the bottom three classes and 63% goes to classes 1 to 5. Wood products generate more income to the lowest class (0.78) and furniture creates more income for class 2 (1.11). Of the forestry sectors, only cellulose and paper do not have a relevant role for the lower income classes.

Table 4.5. Total MG GDP by regions and sectors of analysis, using the SIIP-BR Model data for 2011

	AGR	IND	COM	SER	GOV	FOR	WOP	FRT	CEL + PAP	SID	VEH	MIN	CON	FOO	TRA	UTI	TOTAL
Reg 1	12.0	4.0	3.6	2.8	3.4	0.9	4.8	2.3	2.4	0.0	0.1	0.0	2.8	13.5	2.4	3.0	3.5
Reg 2	20.6	7.4	11.1	9.0	7.1	9.5	22.9	3.3	2.1	3.1	1.2	0.2	7.3	19.7	7.3	3.9	8.4
Reg 3	10.6	1.3	2.0	1.2	2.3	15.5	2.0	0.4	0.1	5.4	0.1	1.1	1.2	1.4	1.1	0.8	2.2
Reg 4	4.1	2.0	3.8	2.5	4.0	4.5	2.4	1.2	0.4	1.2	0.2	0.1	2.1	1.7	1.5	0.1	2.5
Reg 5	1.8	0.7	1.1	0.7	2.3	29.0	4.1	0.5	0.0	4.1	0.0	0.1	0.6	0.7	0.8	0.1	1.3
Reg 6	3.5	0.7	1.7	1.1	2.8	2.4	0.7	0.1	0.0	0.0	0.0	0.0	1.2	1.5	0.7	0.1	1.4
Reg 7	7.0	1.4	4.3	3.1	4.4	2.1	3.5	1.6	1.5	0.1	0.2	0.2	2.8	3.4	1.8	3.0	3.1
Reg 8	3.2	4.1	6.0	4.9	8.2	9.5	4.5	3.1	45.8	25.8	0.9	52.4	11.0	5.5	4.9	2.1	9.6
Reg 9	2.3	44.2	37.9	51.4	38.6	1.4	17.8	21.1	12.5	29.2	76.3	27.0	54.0	19.9	48.2	69.8	42.2
Reg 10	2.7	1.4	1.6	1.0	1.7	14.2	3.7	1.5	0.6	1.9	0.1	0.0	0.7	3.0	1.1	0.2	1.4
Reg 11	8.1	9.9	8.2	6.5	7.9	4.7	8.5	11.7	7.4	22.5	3.4	17.7	5.7	8.6	7.1	2.2	8.2
Reg 12	19.8	17.8	11.7	8.0	10.5	3.5	14.7	7.6	12.8	2.6	13.9	0.8	5.3	13.9	8.1	6.0	9.6
Reg 13	4.3	5.1	7.1	7.6	6.8	2.8	10.5	45.6	14.3	4.2	3.5	0.2	5.4	7.0	15.1	8.7	6.7
	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
MG total	6.0	6.8	11.8	29.1	14.7	0.8	0.2	0.5	0.2	2.4	2.8	7.1	6.9	2.5	4.4	3.8	100.0
BRL 350 billion						**1.7 % Forestry Sector**											

Table 4.6. Interrelational Income Multiplier Matrix by regions

Region of Income Receipt	Region of Income Origin Reg 1	Reg 2	Reg 3	Reg 4	Reg 5	Reg 6	Reg 7	Reg 8	Reg 9	Reg 10	Reg 11	Reg 12	Reg 13	Reg 14	Total
Reg 1	11.918	0.024	0.048	0.032	0.056	0.038	0.031	0.065	0.045	0.032	0.031	0.029	0.027	0.009	**12.386**
Reg 2	0.107	12.367	0.149	0.127	0.200	0.168	0.104	0.175	0.114	0.108	0.093	0.089	0.071	0.021	**13.895**
Reg 3	0.014	0.010	**11.437**	0.010	0.019	0.012	0.014	0.028	0.022	0.012	0.016	0.016	0.014	0.005	**11.631**
Reg 4	0.018	0.010	0.025	11.764	0.037	0.021	0.013	0.034	0.023	0.016	0.017	0.016	0.013	0.004	**12.013**
Reg 5	0.007	0.004	0.008	0.004	**11.188**	0.005	0.005	0.011	0.008	0.005	0.006	0.006	0.005	0.002	**11.265**
Reg 6	0.007	0.004	0.010	0.005	0.009	**11.393**	0.006	0.014	0.010	0.006	0.007	0.007	0.005	0.002	**11.485**
Reg 7	0.023	0.013	0.033	0.016	0.046	0.026	11.891	0.045	0.030	0.022	0.021	0.020	0.015	0.005	**12.207**
Reg 8	0.053	0.030	0.074	0.048	0.105	0.075	0.045	**11.271**	0.054	0.052	0.046	0.046	0.035	0.012	**11.946**
Reg 9	0.557	0.312	0.824	0.758	0.981	1.016	0.670	0.792	12.289	0.719	0.516	0.517	0.332	0.084	**20.366**
Reg 10	0.012	0.007	0.015	0.010	0.017	0.012	0.009	0.021	0.015	11.768	0.010	0.009	0.008	0.003	**11.917**
Reg 11	0.069	0.044	0.098	0.050	0.094	0.060	0.053	0.122	0.068	0.061	11.962	0.055	0.041	0.017	**12.791**
Reg 12	0.098	0.076	0.141	0.097	0.146	0.108	0.091	0.174	0.100	0.096	0.081	12.083	0.072	0.024	**13.388**
Reg 13	0.088	0.055	0.129	0.084	0.122	0.091	0.073	0.142	0.080	0.088	0.080	0.073	12.324	0.015	**13.445**
Reg 14	2.915	2.902	2.909	2.907	2.916	2.911	2.904	2.925	2.913	2.914	2.925	2.922	2.905	15.417	**53.285**
Total	**15.887**	**15.857**	**15.901**	**15.914**	**15.938**	**15.938**	**15.910**	**15.820**	**15.771**	**15.902**	**15.811**	**15.889**	**15.866**	**15.620**	222.023

Table 4.7. Interrelational Income Multiplier Matrix by income classes

Receipt	Origin Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Total
Class 1	14.253	0.250	0.248	0.249	0.247	0.246	0.242	0.240	0.244	0.241	**16.460**
Class 2	0.466	14.462	0.459	0.465	0.461	0.460	0.454	0.453	0.458	0.453	**18.590**
Class 3	1.127	1.117	15.124	1.150	1.133	1.147	1.138	1.151	1.146	1.142	**25.375**
Class 4	0.517	0.513	0.518	14.534	0.523	0.531	0.523	0.530	0.530	0.525	**19.244**
Class 5	0.856	0.854	0.867	0.895	14.878	0.895	0.890	0.909	0.898	0.897	**22.838**
Class 6	0.694	0.693	0.702	0.719	0.711	14.722	0.717	0.726	0.728	0.727	**21.139**
Class 7	1.046	1.052	1.071	1.094	1.090	1.105	15.112	1.135	1.124	1.133	**24.962**
Class 8	0.721	0.727	0.739	0.752	0.750	0.759	0.762	14.776	0.771	0.776	**21.535**
Class 9	0.786	0.796	0.809	0.817	0.824	0.831	0.843	0.855	14.850	0.864	**22.274**
Class 10	1.470	1.502	1.516	1.523	1.554	1.558	1.599	1.610	1.620	15.651	**29.605**
Total	**21.936**	**21.968**	**22.053**	**22.199**	**22.171**	**22.255**	**22.281**	**22.385**	**22.366**	**22.408**	222.023

Table 4.8. Multi-sector income multiplier matrix by income classes

	Reg 1	Reg 2	Reg 3	Reg 4	Reg 5	Reg 6	Reg 7	Reg 8	Reg 9	Reg 10	Reg 11	Reg 12	Reg 13	Reg 14	Total
Class 1	0.30	0.35	0.29	0.28	0.28	0.26	0.28	0.08	0.16	0.29	0.09	0.33	0.32	1.61	4.92
Class 2	0.43	0.50	0.40	0.40	0.38	0.37	0.40	0.24	0.54	0.40	0.26	0.49	0.49	2.83	8.14
Class 3	0.99	1.17	0.90	0.92	0.85	0.85	0.93	0.78	1.56	0.91	0.81	1.15	1.11	6.53	19.45
Class 4	0.49	0.58	0.45	0.45	0.42	0.42	0.46	0.25	0.46	0.45	0.27	0.58	0.57	3.16	9.00
Class 5	0.78	0.91	0.72	0.73	0.66	0.68	0.75	0.64	1.13	0.71	0.67	0.92	0.89	5.24	15.42
Class 6	0.49	0.60	0.46	0.47	0.43	0.42	0.47	0.59	1.11	0.46	0.64	0.59	0.57	4.27	11.57
Class 7	0.69	0.83	0.64	0.65	0.60	0.60	0.66	0.57	1.51	0.64	0.63	0.80	0.79	7.09	16.69
Class 8	0.45	0.54	0.40	0.40	0.36	0.37	0.43	0.42	1.00	0.40	0.47	0.54	0.55	4.82	11.16
Class 9	0.37	0.46	0.34	0.35	0.31	0.32	0.36	0.38	0.88	0.34	0.41	0.42	0.42	5.88	11.22
Class 10	0.44	0.57	0.39	0.41	0.35	0.37	0.42	1.53	3.79	0.39	1.64	0.48	0.50	8.78	20.06
Total	5.44	6.51	4.97	5.06	4.64	4.65	5.16	5.47	12.15	4.98	5.87	6.30	6.21	50.21	127.63

Tables 4.9.a and 4.9.b: Multi-sector income multiplier matrices by regions

Average for all MG Regions (1 to 13)

	AGR	IND	TRD	SER	GOV	FOR	WOP	FRT	CEL+PA	SID	VEH	MIN	CON	FOO	TRA	UTI
Same region	0.18	0.27	0.41	0.37	0.86	0.17	0.37	0.31	0.27	0.19	0.27	0.14	0.31	0.24	0.34	0.19
Rest of MG	0.06	0.06	0.07	0.06	0.11	0.03	0.08	0.06	0.09	0.07	0.07	0.03	0.07	0.09	0.06	0.04
Rest of BR	0.18	0.25	0.18	0.17	0.26	0.08	0.22	0.23	0.24	0.22	0.26	0.15	0.20	0.24	0.23	0.12
Total	0.42	0.58	0.66	0.60	1.23	0.28	0.67	0.60	0.60	0.48	0.59	0.32	0.58	0.57	0.63	0.36

Percentage average for all MG Regions (1 to 13)

	AGR	IND	TRD	SER	GOV	FOR	WOP	FRT	CEL+PA	SID	VEH	MIN	CON	FOO	TRA	UTI
Same region	43.80	45.99	61.22	62.79	69.85	62.55	55.47	52.35	45.33	39.23	45.53	43.87	53.46	42.45	53.65	53.45
Rest of MG	13.41	10.60	10.97	9.45	8.74	9.55	12.26	9.89	15.01	14.25	11.13	10.16	11.56	15.18	10.30	12.23
Rest of BR	42.80	43.41	27.81	27.76	21.41	27.90	32.26	37.77	39.67	46.52	43.34	45.97	34.98	42.37	36.06	34.32
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table 4.10. Multi-sector income multiplier matrix. Total increase in class income resulted from an increase in demand by one unit in all sectors in all regions.

All regions together

	AGR	IND	TRD	SER	GOV	FOR	WOP	FRT	CEL+PAP	SID	VEH	MIN	CON	FOO	TRA	UTI
Class 1	0.32	0.27	0.26	0.25	0.34	0.49	0.78	0.43	0.28	0.16	0.17	0.10	0.39	0.29	0.25	0.14
Class 2	0.48	0.48	0.51	0.45	0.67	0.38	0.55	1.11	0.35	0.33	0.50	0.18	0.68	0.56	0.51	0.40
Class 3	0.92	1.22	1.40	1.14	1.96	0.67	1.73	1.47	1.48	0.84	1.27	0.61	1.42	1.32	1.36	0.66
Class 4	0.36	0.65	0.70	0.49	0.98	0.27	0.72	0.70	0.79	0.39	0.54	0.23	0.62	0.63	0.68	0.25
Class 5	0.66	0.93	1.18	0.85	1.72	0.64	0.81	0.98	1.33	0.77	1.21	0.93	0.92	0.93	1.08	0.48
Class 6	0.49	0.77	0.88	0.71	1.37	0.37	0.95	0.86	0.54	0.74	0.72	0.47	0.70	0.71	0.93	0.35
Class 7	0.63	1.11	1.26	1.07	2.42	0.28	1.62	0.77	1.25	1.06	1.04	0.47	0.89	0.93	1.22	0.64
Class 8	0.47	0.85	0.84	0.71	1.53	0.19	0.50	0.59	0.72	0.63	0.79	0.31	0.58	0.66	0.94	0.86
Class 9	0.56	0.66	0.79	0.88	2.04	0.26	0.54	0.52	0.57	0.69	0.87	0.35	0.78	0.70	0.64	0.35
Class 10	0.96	1.17	1.42	1.78	4.05	0.37	1.10	0.91	1.04	1.08	1.09	0.74	1.09	1.18	1.16	0.91
Total	**5.84**	**8.10**	**9.25**	**8.32**	**17.09**	**3.91**	**9.31**	**8.34**	**8.36**	**6.69**	**8.21**	**4.40**	**8.08**	**7.93**	**8.78**	**5.04**

Table 4.11. Multi-sector income multiplier matrix. Income created by the increase in the forestry sector demand in all regions.

	Reg1				Reg2				Reg 3				Reg 4			
	FOR	WOP	FRT	CEL+PAP	FOR	WOP	FRT	CEL+PAP	FOR	WOP	FRT	CEL+PAP	FOR	WOP	FRT	CEL+PAP
Reg 1	64.44	54.76	53.44	46.51	0.23	0.46	0.25	0.33	0.47	0.43	0.34	0.39	0.34	0.39	0.37	0.48
Reg 2	0.77	1.86	1.05	1.26	66.75	55.44	56.78	51.88	1.34	1.25	0.97	1.09	1.08	1.53	1.09	1.17
Reg 3	0.23	0.48	0.17	0.23	0.16	0.44	0.11	0.16	58.37	54.83	51.99	47.09	0.17	0.16	0.10	0.17
Reg 4	0.14	0.28	0.15	0.24	0.10	0.29	0.10	0.13	0.25	0.21	0.16	0.19	61.10	55.50	51.98	45.82
Reg 5	0.33	0.87	0.17	0.20	0.22	0.61	0.07	0.16	0.13	0.14	0.07	0.17	0.19	0.29	0.10	0.16
Reg 6	0.06	0.12	0.05	0.09	0.04	0.12	0.04	0.05	0.10	0.08	0.06	0.07	0.05	0.05	0.04	0.06
Reg 7	0.17	0.28	0.17	0.30	0.12	0.32	0.12	0.16	0.32	0.28	0.21	0.24	0.17	0.18	0.13	0.18
Reg 8	0.41	0.72	0.61	2.26	0.28	0.73	0.33	1.96	0.70	0.62	0.54	2.13	0.48	0.48	0.44	2.09
Reg 9	3.57	4.98	3.96	6.02	2.59	5.44	2.54	3.33	6.76	6.42	5.08	5.92	5.95	6.19	5.28	6.68
Reg 10	0.21	0.54	0.16	0.20	0.14	0.40	0.08	0.13	0.18	0.17	0.11	0.16	0.16	0.23	0.11	0.15
Reg 11	0.49	0.78	0.70	0.89	0.39	0.94	0.44	0.55	0.94	0.85	0.67	0.74	0.56	0.58	0.49	0.62
Reg 12	0.67	1.03	0.75	1.32	0.64	1.39	0.73	1.10	1.34	1.26	0.97	1.27	0.96	1.11	1.00	1.45
Reg 13	0.60	1.04	0.86	1.24	0.49	1.16	0.63	0.83	1.25	1.26	1.10	1.37	0.94	1.13	1.17	1.87
Reg 14	27.90	32.28	37.77	39.24	27.86	32.25	37.77	39.23	27.85	32.22	37.73	39.15	27.83	32.18	37.69	39.10
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

	Reg 5				Reg 6				Reg 7				Reg 8			
	FOR	WOP	FRT	CEL+PAP	FOR	WOP	FRT	CEL+PAP	FOR	WOP	FRT	CEL+PAP	FOR	WOP	FRT	CEL+PAP
Reg 1	0.53	0.64	0.48	0.55	0.39	0.44	0.44	0.56	0.27	0.37	0.32	0.47	0.49	0.43	0.39	0.81
Reg 2	1.65	1.90	1.40	1.60	1.36	1.90	1.45	1.49	0.77	1.36	0.93	1.18	1.29	1.41	1.13	2.47
Reg 3	0.23	0.26	0.15	0.21	0.19	0.17	0.14	0.18	0.23	0.35	0.17	0.22	0.26	0.24	0.19	1.27
Reg 4	0.32	0.39	0.31	0.34	0.21	0.20	0.19	0.24	0.11	0.19	0.13	0.19	0.26	0.23	0.21	0.65
Reg 5	56.66	49.44	48.89	43.68	0.22	0.34	0.13	0.17	0.34	0.58	0.12	0.18	0.20	0.28	0.12	1.99
Reg 6	0.10	0.12	0.06	0.07	58.48	53.51	48.92	43.43	0.05	0.08	0.05	0.07	0.11	0.09	0.08	0.28
Reg 7	0.40	0.48	0.35	0.39	0.25	0.25	0.22	0.27	63.48	55.50	52.33	45.73	0.33	0.30	0.27	0.63
Reg 8	0.87	1.02	0.92	2.48	0.67	0.65	0.76	2.31	0.36	0.57	0.59	2.19	59.46	55.98	52.04	30.13
Reg 9	7.64	8.85	6.45	7.63	7.49	7.23	6.87	8.29	4.58	5.73	4.99	6.90	5.99	5.27	4.73	9.86
Reg 10	0.20	0.23	0.13	0.19	0.19	0.26	0.14	0.17	0.20	0.36	0.12	0.18	0.20	0.24	0.15	1.16
Reg 11	0.94	1.17	0.70	0.77	0.66	0.57	0.66	0.69	0.44	0.69	0.67	0.84	0.93	0.82	0.77	1.73
Reg 12	1.40	1.77	1.22	1.53	1.07	1.15	1.15	1.59	0.73	1.09	0.93	1.51	1.34	1.19	1.07	2.30
Reg 13	1.23	1.54	1.25	1.48	1.02	1.18	1.30	1.60	0.65	0.97	1.01	1.26	1.14	1.07	1.01	2.03
Reg 14	27.83	32.20	37.69	39.08	27.80	32.13	37.62	39.01	27.78	32.15	37.65	39.09	28.00	32.45	37.84	44.69
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

(Cont.)

Table 4.11 (Cont.)

	Reg 9				Reg 10				Reg 11				Reg 12			
	FOR	WOP	FRT	CEL+PAP	FOR	WOP	FRT	CEL+PAP	FOR	WOP	FRT	CEL+PAP	FOR	WOP	FRT	CEL+PAP
Reg 1	0.31	0.36	0.33	0.40	0.40	0.47	0.32	0.37	0.22	0.28	0.34	0.53	0.22	0.33	0.23	0.46
Reg 2	0.79	1.34	0.98	1.04	1.13	1.33	0.88	0.98	0.65	1.34	1.18	1.48	0.66	1.21	0.74	1.37
Reg 3	0.23	0.52	0.18	0.24	0.19	0.20	0.12	0.17	0.20	0.34	0.18	0.28	0.28	0.49	0.17	0.34
Reg 4	0.17	0.30	0.20	0.23	0.21	0.25	0.16	0.16	0.12	0.19	0.20	0.30	0.14	0.26	0.14	0.29
Reg 5	0.29	0.81	0.12	0.20	0.12	0.14	0.07	0.16	0.27	0.60	0.14	0.22	0.42	0.74	0.11	0.37
Reg 6	0.07	0.12	0.07	0.08	0.08	0.09	0.05	0.06	0.05	0.08	0.08	0.12	0.06	0.11	0.06	0.12
Reg 7	0.21	0.29	0.24	0.28	0.27	0.32	0.19	0.20	0.15	0.21	0.25	0.37	0.14	0.26	0.15	0.34
Reg 8	0.41	0.69	0.50	2.04	0.59	0.69	0.57	2.09	0.33	0.51	0.56	2.36	0.37	0.68	0.53	1.85
Reg 9	67.50	60.39	57.28	52.80	6.28	7.22	5.32	6.09	3.58	4.32	4.85	7.23	3.54	5.00	3.92	6.85
Reg 10	0.20	0.49	0.14	0.19	59.94	53.44	52.02	47.46	0.17	0.37	0.16	0.23	0.24	0.44	0.11	0.28
Reg 11	0.48	0.66	0.57	0.68	0.76	0.91	0.58	0.61	65.02	57.81	52.26	44.32	0.42	0.71	0.59	0.99
Reg 12	0.70	0.89	0.80	1.10	1.13	1.39	0.94	1.18	0.57	0.77	0.99	1.64	65.03	56.48	54.57	45.12
Reg 13	0.65	0.85	0.79	1.00	1.04	1.29	1.03	1.25	0.64	0.88	1.00	1.41	0.55	0.97	0.83	1.39
Reg 14	28.00	32.30	37.81	39.72	27.86	32.25	37.76	39.20	28.02	32.30	37.81	39.51	27.94	32.33	37.86	40.22
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

	Reg 13				Reg 14			
	FOR	WOP	FRT	CEL+PAP	FOR	WOP	FRT	CEL+PAP
Reg 1	0.23	0.37	0.58	0.71	0.11	0.10	0.10	0.12
Reg 2	0.55	1.06	1.73	1.79	0.27	0.26	0.25	0.29
Reg 3	0.21	0.45	0.30	0.33	0.11	0.12	0.07	0.11
Reg 4	0.11	0.26	0.33	0.39	0.06	0.06	0.05	0.07
Reg 5	0.31	0.67	0.21	0.24	0.13	0.16	0.05	0.14
Reg 6	0.05	0.10	0.11	0.14	0.03	0.03	0.02	0.03
Reg 7	0.12	0.24	0.38	0.45	0.06	0.06	0.06	0.07
Reg 8	0.29	0.62	0.99	2.56	0.18	0.17	0.21	0.36
Reg 9	2.43	3.91	6.40	8.21	1.01	0.91	1.04	1.19
Reg 10	0.18	0.41	0.25	0.28	0.09	0.10	0.05	0.09
Reg 11	0.33	0.68	1.30	1.40	0.22	0.20	0.25	0.25
Reg 12	0.58	1.05	1.77	2.22	0.30	0.26	0.28	0.35
Reg 13	66.74	57.90	47.83	42.04	0.19	0.18	0.19	0.23
Reg 14	27.87	32.27	37.80	39.25	97.24	97.39	97.38	96.70
Total	100	100	100	100	100	100	100	100

Table 4.12. Income distribution result from the final demand of the forestry sectors

	Total	Reg 1	Reg 2	Reg 3	Reg 4	Reg 5	Reg 6	Reg 7	Reg 8	Reg 9	Reg 10	Reg 11	Reg 12	Reg 13	Reg 14
Final demand (R$ mi)	5674.4	81.6	170.4	76.5	67.1	154.0	20.3	71.7	999.3	566.1	109.0	332.9	313.6	1001.1	1,711
Percentage (%)	100	1.4	3.0	1.3	1.2	2.7	0.4	1.3	17.6	10.0	1.9	5.9	5.5	17.6	30.2
New income (R$ mi)	3016.9	37.4	83.9	24.6	24.6	39.9	6.9	28.3	177.1	320.6	33.8	123.5	126.8	305.6	1683.7
Percentage(%)	100	1.2	2.8	0.8	0.8	1.3	0.2	0.9	5.9	10.6	1.1	4.1	4.2	10.1	55.8
Class 1	4.7	8.5	10.2	18.9	11.6	22.3	15.8	9.6	0.7	2.1	16.0	2.3	7.8	8.4	3.4
Class 2	9.3	15.1	13.1	14.8	15.7	16.0	13.6	15.8	2.6	8.3	16.9	9.7	14.5	23.0	6.4
Class 3	18.1	23.1	22.1	20.4	22.2	20.8	20.8	22.5	50.3	10.1	22.2	9.5	21.8	25.3	14.6
Class 4	7.1	10.7	9.8	9.5	10.6	9.6	9.7	10.7	1.7	4.4	10.4	4.9	12.0	12.2	6.5
Class 5	12.0	11.5	10.6	8.7	11.0	7.4	9.6	11.5	20.9	14.6	9.3	20.2	13.7	11.5	10.2
Class 6	9.9	8.0	9.0	11.4	9.3	11.8	10.6	8.5	6.2	18.2	10.1	22.2	7.8	7.4	8.5
Class 7	11.2	10.2	10.9	6.1	8.2	5.0	7.8	8.8	3.5	8.5	6.3	5.8	10.1	4.4	14.6
Class 8	7.9	4.9	4.8	2.9	3.8	1.6	3.7	4.7	3.5	9.7	2.6	10.1	5.4	2.8	9.6
Class 9	7.2	3.5	4.3	4.2	3.8	3.7	4.5	3.6	2.0	4.2	3.4	3.0	3.2	2.1	10.3
Class 10	12.7	4.4	5.2	3.1	3.9	1.8	4.0	4.2	8.5	19.9	2.7	12.3	3.7	2.8	15.7
Total new income	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table 4.13. Total rural credit by region from the SFN in MG between 2013 and 2016 (BRL million and percentage)

Total	Reg 1	Reg 2	Reg 3	Reg 4	Reg 5	Reg 6	Reg 7	Reg 8	Reg 9	Reg 10	Reg 11	Reg 12	Reg 13	Reg 14
1245.2	20.6	302.2	211.7	36.9	294.0	53.7	10.6	45.5	97.9	76.4	42.3	39.3	14.1	-
100	1.7	24.3	17.0	3.0	23.6	4.3	0.9	3.7	7.9	6.1	3.4	3.2	1.1	0

Table 4.11 details the income generated through increase in final demand for forestry sectors in each region. Since most cellulose production occurs in Region 8, the increase in final demand in this sector in all regions leads to a substantial increase in income for Region 8. Regions 2, 9, and 12 receive a large part of overall created income as they are the most industrialized and developed regions in the state. Region 2 receives income from the demand of wood products and forest plantations in several other regions. Although Regions 3, 5, and 10 have the highest production from forest plantations, they do not receive income from the increase in demand of this sector in the other regions. Region 13 has the highest concentration of furniture companies in the state and therefore receives a significant share of income created by this sector's demand in Regions 3, 4, 7, 10, and 12.

This analysis shows that highly industrialized regions receive more induced income created from both increase in demand and increase in wages in other regions. Although the regions that generate more overall income are the less developed ones (Regions 4 to 7 as seen in Table 4.4), these regions retain relatively low percentages of that income. In the capital metropolitan area, class 10 receives the largest share of income from increase in demand or in salaries. In other regions, classes 3, 5, and 7 get larger shares. Among the forestry sectors, increased demand for wood products and furniture creates more income than the others and more than 50% remains in the same region. Cellulose and paper is in third place for income generation and a significant part leaks to the other regions and the rest of the country. Although demand for forest plantation products creates the lowest income among all sectors, more than 62% of it stays in the same region. Forest plantation demand generates income mostly to lower classes. Wood products and furniture demand creates income for the middle and low classes while cellulose and paper concentrates income within higher classes.

4.5.3. Income distribution resulted from the final demand of the forestry sectors

To further investigate the impact of demand for the forestry sectors in the state of MG, I multiplied the multi-sector income matrix by the final demand vector of the initial matrix. The final demand vector contains the MG demand for the four forestry sectors by region and zero for demand for the other sectors. I used equation 2 to do the calculation: income (Y) will be equal to the multi-sector income multiplier matrix (KVB) multiplied by the final demand vector (*f*), with the exogenous income (*g*) equal to zero.

The first two rows of Table 4.12 show the total demand for the forestry sectors by region and its percentages. The next two rows present the total new income generated by these demands. The results show that the regions with the highest demand also receive the highest share of income, with the exception of Region 9 where income share is larger than the demand share. The less industrialized regions, Regions 4 to 7, have low participation on the income generated relative to the increase in their demands. Income concentrates in the lower classes in these regions. Overall, income gains from the increase in demand for the forestry sectors go mainly to classes 3, 10, and 5, in that order. More than 30% of new income goes to the rest of Brazil. In MG, the capital metropolitan area concentrates income in class 10. For the rest of the state, the lowest three classes receive most of the new income.

4.6. Discussion

This chapter investigated the interaction between output generation and income formation in the state of MG, focusing on the forestry sectors. The results show homogeneity for the regions due to the lack of specific income and consumption data for each and the incomplete sample source for all classes of income. Despite these limitations, the findings corroborate my hypothesis that the regions that retain the largest shares of overall income are the ones with largest production in the state. These regions also create more income originating from an increase in both salaries and in demand. Regarding the income classes, the wealthiest class retain the largest share of the new income generated either by an increase in income for all classes or in final demand for the sectors altogether. This finding is most relevant for the capital metropolitan area. Class 3 is second in income received, followed by the middle-income classes 5 and 7. For other regions in MG, classes 3, 5, and 7 receive the largest shares of income, demonstrating the differences between income/consumption structures for the capital area compared to the rest of the state. However, even when considering the homogeneity of the results for the other regions outside the capital area, the analysis shows the relevance of other developed regions in the state regarding income formation.

For the forestry sectors, I found that increases in final demand for wood products and furniture are most important for income generation, especially for the region where they are produced. Wood products and cellulose plus paper pay higher salaries, whereas forest plantations both generate the lowest income and pay lower salaries, though a large part of the forest income stays in the same region. Analyzing the regions by their forestry production, Regions 3, 5, and 10 have the highest production in forest plantations, but the lowest increases in income resulted from the increase in demand for the forestry sectors. Moreover, most of the income is concentrated in the lower classes. This suggests that the benefits generated by the forestry industry for the regions with larger plantation areas do not go beyond the plantation effects themselves. Therefore, although plantations bring most income to the lower classes and can alleviate poverty, it remains isolated from the value generated by the whole forestry chain.

This is relevant for policies that incentivize plantation expansion to promote development in remote areas. Table 4.13 displays the total rural credit from 2013 to 2016 that came from the Brazilian Financial System (SFN)[8], which comprises all financial institutions in the country. The rural credit from the SFN represents only about 30% of the total agriculture funding in Brazil. In the forestry sector, for instance, foreign investments in plantation by TIMOs (Timber Investment Management Organizations) represent about 10% of the total area with forests in the country according to the Brazilian Tree Institute (IBA, 2016). Even though the amount from the SFN is not the total invested on new forests, it still represents real investment made in MG and includes governmental funding. In table 4.13, Regions 2, 5, 3, 9, and 10, in that order, have received the largest shares of investment. From previous findings, the resulting increase in supply of forest products, and most likely in final demand, will not create much income overall. In addition, Regions 3, 5, and 10 will retain less income than Regions 2 and 9 as these are highly industrialized. It will therefore be necessary to promote other forestry sectors in the low developed regions with large plantation area to improve efficiency in forest policies.

Other studies have found similar results. In Scotland, Thomson & Psaltopoulos (2005) concluded that for different plantation expansion scenarios in rural Scotland, higher salary gains would occur if the wood was processed locally. Phimmavong (2012) investigated plantation expansion in the People's Democratic Republic of Lao and its impacts in income generation and distribution. He assessed how forestry development interacts with both micro (poverty and inequality rates) and macro economies (growth). He also combined a computable general equilibrium and a micro simulation model to examine the links between national forest policies and both poverty and inequality. He found that an increase in plantation areas would slightly

[8] The data was extracted from the Sicor (System of the Rural Credit Operations and Proagro) database of the Central Bank of Brazil. It consists of the summation of all contracts on forest plantations investments from 2013 to 2016 for each region of analysis.

increase welfare for both urban and rural households and promote a small reduction in poverty. However, it would also lead to a small increase in inequality. The difference between my analysis is that Lao's context consists mainly of rubber trees, requiring considerably more labor than trees produced for wood. I made no conclusions on inequality in my analysis. However, results suggest that poverty would also decrease in MG given the highest share of income formation for the lower classes resulted from the increase in demand for forest products.

4.7. Conclusion

This chapter applied IO analysis with the Miyazawa extended framework to investigate the income generation and distribution related to the forestry sectors in the state of Minas Gerais, Brazil. This was a novel approach to the forestry sector in Brazil, especially at the sub-state level. Results showed that the impact of income generation through forest plantation expansion is small and mainly occurs in the lower income classes. Moreover, low developed regions retain less created income due to increase in demand for forest products. These findings corroborate with previous findings where developed and industrialized regions retain more of the direct and induced income. However, my research found that most of the income created in the regions where expansion occurs go to lower classes, thus benefitting them.

According to available data, the income in the capital metropolitan area concentrates in higher income classes than in the rest of the state. For the other regions, the middle income classes receive the larger shares. To further investigate income distribution among regions, more specific data is required on family income and consumption. It is important to have data for mesoregion and microregion and separated by rural and urban areas. Since forestry activity is increasing in importance in Brazil, data in official surveys should be more specific regarding the sectors.

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CHAPTER 5:

CONCLUSION

This research intended to investigate the economic consequences of the forest plantation expansion in a developing country. One goal was to empirically analyze the impact of plantation expansion at a local level over time in the state of Minas Gerais, Brazil. In addition, I expanded the study for other elements of the forestry sector in the production chain and how they would interact in the economy to promote growth at the sub-state level.

The literature on forest plantations has found more negative than positive effects of plantation expansion at the local level, with few exceptions. In this dissertation, I found that plantation expansion in MG was positively associated with lower poverty rates over time for the municipalities and higher per-capita income overall. These results were unexpected since they contrast with most of the literature. However, they are consistent with findings in other large-scale plantations in the world, which have been associated with less poverty and more socioeconomic development over a long period of time (e.g. forestry in many parts of Europe). Furthermore, also in contrast with the literature, I did not find an overall association between migration and plantation expansion. In fact, for municipalities with large plantation areas, I found a positive association with in-migration. The results show that plantations brought socioeconomic development to MG. This finding could have been due to several factors, such as infrastructure development, job offerings, and the fostering of other economic sectors.

In the regional analysis at sub-state level and various sectors in MG, focusing on the forestry value chain, I found that forest plantations had the lowest multipliers for income and employment generation. However, most of the income created by this activity stayed in the region where the plantations are located and went to the poorer classes. When plantations expand to poor regions, their importance was more significant, as they create formal jobs for unskilled workers. This finding helps explains the poverty reduction found in chapter two. Nevertheless, these primary positive effects are just that, primary, since the economic multipliers were very low, apart from the value added multiplier. A high value added multiplier does not mean economic growth or returns to the region because a high value added with low income multiplier indicates large profits that may be accruing to owners and investors in other regions or outside the state or even the country.

The results show that plantations are, in fact, an isolated activity that depends on the regional economic structure to provide consistent development. As such, the more industrialized regions concentrate the economic benefits generated by plantations. The main producer regions do not benefit from an increase in demand of forest products, since they do not have many industries. Therefore, the wealth created by an increase in production leaks to other regions.

I analyzed the interaction of the main forestry sectors in the economy and the effects on income distribution using the Miyazawa framework. I found that the capital metropolitan area concentrates income created by both increase in consumption and production in the higher income classes. For the rest of the state, the middle income classes received the highest share in income created, since the salaries were lower outside the capital area and other industrialized regions.

These findings are relevant for policies that promote forest plantation as a way to foster economic development in poor and remote areas. Even though the forest plantation multipliers are low and affect mainly lower classes, plantations still bring more development than what existed before. Thus, they can bring growth and help reduce poverty. However, for sustained improvement over time, it will be necessary to associate plantations to other industries, wood processing or otherwise. At the state level, such as MG, plantations were found to be an important base industry for many others in various regions. Therefore, given the climate advantage Brazil has in forest plantations, developing programs to incentivize more industries linked to forests is especially promising strategy for more widely shared economic development.

Further research is needed to better understand the factors contributing to the outcomes found in this study, including cultural, political, and environmental ones. Additional data on plantation forestry area, holdings, and revenues, which remains scarce and not entirely public, is needed to realize more empirical analysis. It would also be relevant to investigate the effects large plantation estates have in both rural and urban areas, considering change in rural production across the world.