SOCIOECONOMIC AND ENVIRONMENTAL IMPACTS OF FOREST CONCESSIONS IN BRAZIL: A COMPUTABLE GENERAL EQUILIBRIUM ANALYSIS

By

ONIL BANERJEE

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To my family.

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AAGR	Average Annual Growth Rate
ACPC	Annual Compound Percentage Change
APP	Permanent Preservation Area
Art.	Article
ATPF	Transportation Authorization Permits
BASA	Bank of Amazonia
BBC	British Broadcasting Corporation
BRACELPA	Associação Brasileira de Celulose e Papel
BRASAM	Brazilian Social Accounting Matrix
CEI	Integrated Economic Accounts
CES	Constant Elasticity of Substitution
CET	Constant Elasticity of Transformation
CGE	Computable General Equilibrium
CONAFLOR	Coordinating Commission of the National Forests Program
CONAMA	The National Environmental Council
CV	Compensating Variation
DETER	Real Time Deforestation Detection System
EV	Equivalent Variation
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistics
FCO	Central West Financing Fund
FCU	Foreign Currency Units
FNDF	National Fund for Forest Development
FNE	North Eastern Financing Fund

FNO	Northern Financing Fund
G-7	Group of Seven
GAMS	General Algebraic Modeling System
GDP	Gross Domestic Product
Ha	Hectare
IBAMA	Brazilian Institute for the Environment and Natural Renewable Resources
IBDF	Brazilian Institute for Forestry Development
IBGE	Instituto Brasileiro de Geografia e Estatística
ICMS	Tax on the Circulation of Merchandise and Services
IFPRI	International Food Policy Research Institute
INCRA	National Institute for Colonization and Agrarian Reform
INPE	National Institute for Space Research
I-O	Input-Output
IPEA	Research Institute for Applied Economics
IPI	Tax on Industrialized Products
ISA	Instituto Socioambiental
LCU	Local Currency Units
LES	Linear Expenditure System
MDA	Ministry of Agrarian Development
MMA	Ministério do Meio Ambiente
NGO	Non-Governmental Organization
No.	Number
OECD	Organisation for Economic Co-operation and Development
PAOF	Annual Forest Granting Plan
PFML	Public Forest Management Law

PIN	National Integration Program
PNF	National Forest Program
POLAMAZONIA	Program of Agricultural, Livestock and Mineral Poles
POLONOROESTE	The Northwestern Integrated Development Program
PRODES	Program for the Calculation of Deforestation in Amazonia
PRONAF-Florestal	National Program for Strengthening Family Agriculture
PT	Worker's Party
R$	Brazilian reais
RADAM	Radar of Amazonia
SAM	Social Accounting Matrix
SBS	Sociedade Brasileira de Silvicultura
SEMA	Secretariat for the Environment
SFB	Serviço Florestal Brasileiro
SISNAMA	The National Environmental System
SISPROF	Brazil's monitoring and control system for resources and forest products
SNUC	National System of Nature Conservation Units
SUDAM	Superintendency for the Development of Amazonia
SUDEPE	Secretary of Fisheries Department
SUDHEVEA	Superintendence for Rubber
T1	National Accounts Table 1
T2	National Accounts Table 2
US$	United States Dollar

Abstract of Dissertation Presented to the Graduate School
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By

Onil Banerjee

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Understanding the forces that drove policy in the past can inform our expectations of the effectiveness of policy implementation today. Historical analysis suggests that forest policies of countries with significant forested frontiers transition through stages reflecting the orientation of governments toward economic development on the frontiers, namely: settlement, protective custody and management. With respect to Amazonian forests, Brazil's path is no exception from this trend. This dissertation begins by following the trajectory of forest policy in Brazil to identify its path through the stages of policy development.

Brazil is on the cusp of a transition toward the management phase of policy development. As such, the question of whether this phase will represent a break from the historical tendency of largely ineffectual forest policy is addressed. For society to accept and support a forest policy, it should generate positive socio-economic and environmental benefits. Brazil's Public Forest Management Law (2006) and specifically the socioeconomic and environmental impacts of implementing forest concessions, are taken as a proximate indicators of whether the transition to management will in fact increase the relevance of forest policy. To evaluate these impacts, two quantitative experiments are conducted. In the first, a static computable general equilibrium

model is developed to evaluate the short-run policy effect on welfare, the forestry sector and levels of legal deforestation.

Given the economic importance of illegal logging and illegal deforestation in Brazil, the second experiment explicitly models these sectors. A recursive dynamic computable general equilibrium modeling framework is employed to consider the medium-term implications of the policy, to shed light on the resulting economic transition path, and to assess the short-term costs and longer-term gains resulting from policy implementation. Results of this analysis can provide important insights on forest sector and deforestation dynamics to policy makers, industry and civil society such that complimentary policies and programs may be developed to maximize benefits and minimize any negative impacts resulting from the implementation of forest concessions.

CHAPTER 1
INTRODUCTION

Overview

Sixty-three percent or 4 million km² of the Amazon biome is located in Brazil. Brazil's Legal Amazon is approximately 5 million km² or 59% of Brazil's total land area; 2.6 million km² of the Legal Amazon are forested[1]. This region is home to 22.5 million people (12% of Brazil's total population), 5.3 million of whom live in forested areas (Celentano & Veríssimo, 2007, p. 9). Brazil is the largest producer and consumer of tropical timber products and as such, the forest industry is an important component of the economy and in particular, the economy of the Legal Amazon. It is estimated that the forestry sector is responsible for 3.5% of Brazil's gross domestic product, generating 2 million formal jobs and accounting for 8.4% of Brazilian exports (Serviço Florestal Brasileiro [SFB], 2007a, p. 10). Furthermore, strategic sectors of the economy such as the steel and construction sectors have close linkages with the forest sector.

Approximately 500,000 families in the Amazon depend at least in part on forestry for their livelihoods (Lima, Merry, Nepstad, Amacher, Azevedo-Ramos, Resque & Lefebvre, 2006, p. 33). With 1.15 million km² of forests with a high potential for forestry activities, natural forest management presents a tremendous opportunity for promoting forest-based development and for maintaining environmental quality and economic value in the region (Veríssimo, Junior & Amaral, 2000, p. 6).

Until 2006, Brazil has lacked a mechanism to promote forest management on public lands. In March 2006, Brazil's Public Forest Management Law (PFML) was passed. One of the principal features of the law is the authorization of forest concessions which enables the state to sell the rights to harvest forest goods and services to private firms for a predetermined period of time. The implementation of such a framework for the promotion of natural forest management

and forest-based development is unprecedented in the history of Brazilian forest policy. This research is concerned with analyzing the trajectory of Brazilian forest policy and the potential socio-economic and environmental impacts of forest concessions in the Legal Amazon.

The remainder of this chapter outlines the purpose of this investigation and the research questions to be addressed. The second chapter provides an in-depth analysis of forest policy in Brazil with an emphasis on the transformations in Brazil's political and socio-economic structures that facilitated the approval of the PFML. The third chapter is quantitative in nature and develops a computable general equilibrium model to assess the short-run socio-economic and environmental impacts of forest concessions. The fourth chapter builds on the third by introducing recursive dynamics and an illegal logging and illegal deforestation sector into the model to evaluate the medium-run socio-economic impacts of forest concessions and the interactions between forest-based sectors. The final chapter unites the whole with a summary of the research findings and discusses complimentary policies to reduce any negative impacts of forest concessions and future research directions.

Research Questions

In following the trajectory of Brazilian forest policy, chapter two is designed to answer the following questions:

1. Historically, how has the state acted to develop the forestry sector?
2. What are the key legislative instruments that govern the forestry sector?
3. Given the poor implementation record of forest policy, does state action taken this decade represent a break from the past?
4. What factors were involved in facilitating the approval of the PFML?

Chapter three develops a static computable general equilibrium model to address the following questions in the short-run:

1. How are the forest and related sector output and prices affected by the implementation of forest concessions?

2. How are household economies affected by forest concessions?

3. How are the regional dynamics of deforestation affected by forest concessions?

The fourth chapter, incorporating recursive dynamics and illegal logging and illegal deforestation sectors, addresses the same questions as the previous chapter in the medium-run, as well as the following:

1. What are the interactions between legal and illegal logging and deforestation as forest concessions expand?

2. How is the trajectory of the economy affected by the implementation of forest concessions through time?

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[1] The Legal Amazon is composed of the states of Acre, Amazonas, Amapá, Pará, Rondônia, Roraima, Tocantins, Mato Grosso, and part of Maranhão (west of the longitude of 44º west) and Goiás (above the latitude of 13º south).

CHAPTER 2
TOWARD A POLICY OF SUSTAINABLE FOREST MANAGEMENT IN BRAZIL- AN HISTORICAL ANALYSIS

Introduction

Understanding the forces that drove policy in the past can inform our expectations of the effectiveness of policy implementation today. Historical analysis suggests that forest policies of countries with significant forested frontiers transition through stages reflecting the orientation of governments toward economic development on the frontiers, namely: settlement, protective custody and management (Marty, 1986). To present, with respect to Amazonian forests, Brazil's path is no exception from this trend[1]. This chapter follows Brazilian forest policy from its beginnings in the late 19th century to the colonization plans and "paper parks" of the military regime of the 1960s to the commitment to sustainable forest management of the current democracy to identify Brazil's path through the stages of forest policy development. The military regime's prioritization of industrialization and integrating the Amazon into the national economy contradicted sharply with the protectionist forest policies of the era thus marginalizing forest policy. This analysis provides evidence of profound changes in Brazil's governance structures through democratization and civil society's role in influencing public opinion and political processes as well as increasing awareness of the biophysical importance of forests and the emerging vision of the Amazon as a region whose primary vocation is sustainable forest management. Future implications of this transformation increase expectations of the relevance of forest policy for the region as the nation embarks into an era of sustainable forest management.

Settlement and Exploitation (1889 to 1964)

Early legislation on forests regulated the harvest of valuable species, such as Brazil wood (*Caesalpinia echinata*) and the harvest of forests adjacent to water. Land clearing occurred primarily in the Atlantic Forest Region to meet European demand for forest products, to produce

energy, and to establish farms and ranches. With declining timber stocks and the drastic transformation of this countryside, the need to regulate forest use was recognized in the 1920s when the government of Getulio Vargas passed the first Forestry Code in 1934 (Decree No. 23.793 January 23, 1934). With this law, private property rights were subordinated to the collective interest of society, an imposition that continues to resonate strongly today. A Legal Reserve requirement, which still exists although the requirements have changed, dictated that no more than 75% of the forested land in private rural properties could be cleared (art. 23). A fact rarely mentioned in current debates regarding forest concessions, a basic framework for concessions was written into the 1934 Code, although they were not implemented during this period[2]. The law was ambitious for the time, but resulted in few substantive changes in forest practices; government priorities were industrialization and integrating the Brazilian Amazon into the national economy through colonization and agricultural expansion.

Protectionist Approach to Natural Forests (1965 to 2000)

The transition to a paradigm of forest protection often occurs when unrestricted exploitation of the forests renders them unable to sustain forest industry capacity. Legislative command and control mechanisms are believed to be required to renew and protect natural forest resources. In the case of Brazil in the 1960s, however, while the Atlantic Forest was largely cleared or intensely fragmented, the forests of the Brazilian Amazon remained relatively intact (Fearnside, 1980; Torras, 2000 both cited in Siqueira & Nogueira, 2004, p. 5). Brazil's protectionist period was characterized by the promulgation of restrictive legislation, the creation of large protected areas and the provision of incentives for plantation forests. Initiatives for the development of the natural forest management sector were generally absent. Although a variety of legal instruments and institutions were put in place, they were largely ineffective in

controlling deforestation as the nation's resource extraction for economic growth model took precedence over the rational use of forest resources[3].

With the poor implementation record of the previous Forestry Code, discussions about a new forestry code began in Congress in 1948 (Ahrens, 2003, p. 6; Ondro, Couto & Betters, 1995, p. 113). Seventeen years later and marking the transition to the paradigm of forest protection, the 1965 New Forestry Code (Law No. 4.771 September 15 1965) was passed by the military government of Humberto de Alencar Castelo Branco. This code increased the restrictions on private property rights and removed landowner entitlement to compensation for these restrictions. It introduced Permanent Preservation Areas (APP) for the protection of sensitive areas and increased the Legal Reserve requirements in some regions to 50%. The law also created a range of conservation area categories: national, state and municipal parks, biological reserves for the protection of flora, fauna and aesthetics as well as national, state and municipal forests for meeting economic, scientific or social objectives.

The military government's strategy of import substitution industrialization increasingly demanded raw materials to feed the nation's industry. Charcoal made from timber was particularly important for the metal and mineral industries (Kengen, 2001, p. 230; Mery, Kengen & Luján, 2001, p. 245). To ensure supply of these products, subsidized credit and tax exemptions for forest plantations were declared in the New Code and in a law passed in 1966 (Law No. 5.106, September 2, 1966). These incentives were the state's principal instrument for forest sector development and resulted in the planting of 6 million hectares between 1965 and 1987 when the subsidies were eventually terminated (Sociedade Brasileira de Silvicultura [SBS], 1998 as cited in: Mery et al., 2001, p. 245).

In 1967, the Brazilian Institute for Forestry Development (IBDF; Decree No. 289, February 28, 1967) was created. The IBDF was Brazil's first federal agency charged with the mandate of managing natural resource conservation (Drummond & Barros-Platiau, 2006, p. 91). Although the IBDF was created to engage in formulating forest policy, research, extension and creating conservation areas, given the importance of plantation incentives for the nation's industrialization, the agency's main role in practice was the administration of incentives and the commercialization of wood products (Chadwick, 2000, p. 153; Drummond & Barros-Platiau, 2006, p. 91; Kengen, 2001, p 26; Viana, 2004, p. 18).

Integrating the Brazilian Amazon into the National Economy

The military government's Operation Amazonia sought to develop, occupy and integrate the Brazilian Amazon with the national economy. Geopolitical concerns including securing Brazil's borders with other Amazonian countries and insuring ownership of mineral and other natural resources motivated the government's efforts to demonstrate control of the region. To help achieve this goal, the government pursued major road building and agricultural colonization projects and provided fiscal incentives for industry and agriculture. A regional development agency and bank, the Superintendency for the Development of Amazonia (SUDAM) and the Bank of Amazonia (BASA), respectively were created to manage and finance the strategy (Mahar, 1989, p. 11).

The National Integration Program (PIN) was launched in 1970 and financed the Transamazon and the Cuiabá-Santarém highways, which are now important commercial corridors as well as corridors of severe forest loss and land conflicts. Agricultural settlement in the region was encouraged by allocating land in a 20 km strip on either side of these highways to smallholder colonists. Settlers were lured from Brazil's drought stricken north east as well as the south by offers of housing subsidies, crop financing and loans for the purchase of farm plots. The

Northwestern Integrated Development Program (POLONOROESTE) began in 1981 and involved paving the BR-364 highway from Cuiabá to Porto Velho and the promotion of sustainable agriculture.

The model of colonization and development of the Brazilian Amazon contradicted sharply with protectionist provisions in the New Forestry Code. For example, a law passed in 1971 placed all land in the Brazilian Amazon within 100 km of a federal highway or 150 km of an international border under the jurisdiction of the National Institute for Colonization and Agrarian Reform (INCRA). According to INCRA policies, a settler would be granted transferable land titles in this area if they cleared it. Moreover, the settlers were offered title to an area three times the size of the area cleared, up to a maximum of 270 hectares. This policy dramatically accelerated land clearing and speculation in the region (Mahar, 1989, p. 37).

Following the Oil Crises in the 1970s and the resulting increased demand for foreign exchange, the state placed less emphasis on road building and settlement and instead concentrated on the promotion of large-scale export oriented projects in livestock, forestry and mining around 15 development centers in the Brazilian Amazon (Mahar, 1989, p. 40). This program was known as the Program of Agricultural, Livestock and Mineral Poles in the Brazilian Amazon (POLAMAZONIA) and lasted from 1974 to 1987. The project aimed to develop infrastructure and through fiscal incentives and subsidized credit, sought to improve the investment climate in the region while increasing foreign exchange earnings. The Greater Carajás Program established in 1980 was another such program designed to exploit the reserves of iron ore in the Serra dos Carajás region in the state of Pará (Mahar, 1989, p. 41).

The military government's strategy for Amazonian development was arguably effective in generating economic growth although not equitable from a distributional perspective. The politic

for the forest sector was aligned with the regime's emphasis on industrialization and as such concentrated on the promotion of forest plantations. With the lion's share of public resources devoted to industrialization, resources for promoting the sustainable use of forests were scarce. Institutions charged with forest protection were weak and underfunded and the protectionist stage of Brazilian forest policy lived out primarily on paper.

The Environmental Movement and Democratization

Political opportunity for the formation of an environmental movement began in late 1974 when then President Ernesto Geisel's government announced the opening (abertura) of the political system to the gradual implementation of democracy. The moderate government of President João Figueiredo declared amnesty for exiles, terminated censorship in the print media, permitted the formation of new political parties, and called for direct elections of state governors (Alonso, Costa & Maciel, 2005, p. 5; Chadwick, 2000, p. 125). This opening enabled the growing environmental movement to partner with established sectors of civil society and align itself with an increasingly organized international environmental movement.

Growth in the number of environmental non-governmental organizations (NGOs) appears to be correlated with important events in Brazilian democratization. NGO growth increased with the abertura in 1974, the amnesty law passed in 1978/1979, and direct elections of state governors in 1982. A record of 77 new environmental NGOs were established following the Constitution of 1988 (Chadwick, 2000, p. 163).

Democratization also brought with it new government institutions which were more responsive to civil society's demands and environmental concerns. With direct governor elections in 1982, the number of government environmental agencies increased as well as NGO counts. In 1995, there were three times more environmental agencies than at the beginning of the abertura (Chadwick, 2000, p. 159).

In 1981, the National Environmental Policy (Política Nacional do Meio Ambiente, Law No. 6938 August 31, 1981) was instituted and continues to be Brazil's most important environmental policy. Passed during the abertura, the enactment of this law provides evidence of civil society's increased presence and effectiveness in influencing policy (Drummond & Barros-Platiau, 2006, p. 92). Its principal motivation was to consolidate existing legislation pertaining to the work of the Secretariat for the Environment (SEMA; Paulo Nogueira-Neto interviewed in Urban, 1998, p. 316). The implementing agencies for this policy are organized as The National Environmental System (SISNAMA) which was created in 1981. SISNAMA is composed of the institutions responsible for environmental protection at the federal, state and municipal levels. SEMA was SISNAMA's principal agency, while other institutions such as the IBDF remained sectoral in nature (Kengen, 2001, p. 28). Regulations for the SISNAMA were instituted in 1990 and its implementing agency was The National Environmental Council (CONAMA; Figueiredo, 2007, p. 65). CONAMA is linked to the Presidency above the Ministry of the Environment (MMA) and is responsible for deliberating on regulations for environmental protection (Figueiredo, 2007, p. 65); it is composed of federal, state and municipal agencies, business leaders, and scientists and has a strong representation from environmental NGOs (Rylands & Brandon, 2005, p. 29). In 1989, due to SEMA and IBDF's often overlapping mandates, they and the Secretary of Fisheries Department (SUDEPE) and the Superintendence for Rubber (SUDHEVEA) were replaced by the Brazilian Institute for the Environment and Natural Renewable Resources (IBAMA; Rylands & Brandon, 2005, p. 30).

The emerging legal-bureaucratic structure provided political space and more responsive institutions for environmental claims as well as career opportunities within those institutions (Alonso et al., 2005, p. 6). Furthermore, the environmental movement's shift from a biocentric

focus which aimed to protect nature from human influence to a socio-environmental focus in the 1970s broadened the support for this movement[4].

At the end of the 1970s, social groups were mobilizing to inform the democratization process. The environmental movement's increasing social orientation enabled it to graft environmental concerns on to other socioeconomic and political agendas, effectively creating linkages between the environmental and democratization movements (Alonso et al., 2005, p. 12). For example, the National Front for Ecologic Action created in 1987 was dedicated to informing public opinion on environmental issues and successfully pressured for the inclusion of a chapter on the environment in the 1988 Constitution (Alonso et al., 2005, p. 17).

The formation of NGO networks was decidedly important in consolidating the Brazilian environmental movement. These networks were strategic for uniting and coordinating the actions of individual NGOs working on similar matters; they enabled the exchange of experience and information and the mobilization of individual citizens. These networks also proved to be effective at promoting their policy agendas (Chadwick, 2000, p. 171). They were the basis for large campaigns and served as a vehicle for obtaining government and international grants. Environmental associations on the other hand were heavily engaged in teaching and served as specialized consultants to government, providing scientific information to support policy development (Alonso et al. 2005).

Protected Areas

At the United Nations Conference on the Environment in Stockholm in 1972, Brazil committed to creating its first environmental ministry, the Secretariat for the Environment (SEMA; Decree 73.030 October 30 1973). SEMA was established within the Ministry of the Interior to develop policies for environmental protection and management (Drummond & Barros-Platiau, 2006, p. 91). Its main achievements include the establishment of 38 ecological

stations and 11 environmental protection areas between 1977 and 1986 (Aquino, 1979; Drummond, 1988; Nogueira Neto, 1980 and 2001 all cited in Drummond & Barros-Platiau, 2006, p. 92). With SEMA's addition of 3.2 million hectares of ecological stations, protected areas reached 13 million hectares (Urban, 1998, p. 107). The IBDF created a protected areas system parallel to that of SEMA's and between 1979 and 1986, it established 8.5 million hectares of National Parks and National Biological Preserves. These protected areas make up some of the largest and most important of Brazil's conservation areas today (Drummond & Barros-Platiau, 2006, p. 91).

The Ministry of Mines and Energy's Radar of Amazonia (RADAM) project was implemented between 1975 and 1983 to map the geology, geomorphology, hydrology, soils, and vegetation of the Brazilian Amazon. The project recommended the creation of 35.2 million hectares of protected areas and another 71.5 million hectares of sustainable use areas since these areas were considered unsuitable for mining or settlement (Rylands & Brandon, 2005, p. 30). Of the 25 priority conservation areas identified, only 5 national parks and 4 reserves were created (Figueiredo, 2007, p. 70; Mittermeier, Fonseca, Rylands & Brandon, 2005, p. 602).

The Our Nature Program (Decree No. 96.944, 1988) was a direct response to the Constitution of 1988 as well as international pressures for environmental responsibility, geopolitical concerns about the internationalization of the Amazon, and to strengthen Brazil's position in international relations (Ioris, 2005, p. 182; Lopez, 2000, p. 57). Its mandate was to reduce predatory activities, structure the environmental protection system, protect indigenous and extractivist communities, regenerate degraded ecosystems, participate in environmental education, and regulate the use of the Legal Amazon's natural resources by means of Ecological-Economic Zoning[5].

Although 11% of continental Brazil was allocated to protected areas, the majority of the country's 60 national parks were considered paper parks (Figueiredo, 2007, p. ii). Paper parks are areas declared by the government to be protected in law but not in practice; they are characterized by a lack of management capacity, financing, infrastructure, and integration of local communities in their management, as well as contradictory legislation. In some instances, the creation of protected areas was a cost effective way of demonstrating a commitment to the environment before domestic and international interests without fulfilling the commitment in any substantive way. As an indication of this weak implementation, funding for the protected areas system in Brazil was low; between 1993 and 2000, federal spending for protected areas accounted for 0.3% to 0.5% of the MMA's budget, most of which was allocated to administrative and financial expenditures (Young & Roncisvalle, 2002 as cited in Young, 2005, p. 757). Nonetheless, Brazil's protected areas, although underfunded, have had a quantifiable effect on deterring deforestation and encroachment (Nepstad, Schwartzman, Bamberger, Santilli, Ray, Schlesinger, Lefebvre, Alencar, Prinz, Fiske & Rolla, 2006, p. 72).

Constitutions, International Agreements and the 1990s

Early treatment of forest resources in Brazil's Constitutions focused on the jurisdiction between state and federal governments. The 1891 Constitution granted states autonomy over forest resources while property rights were unlimited. The 1934 Constitution (art. 5, XIX, j) transferred responsibility for forestry law back to the Federal Government, although states could develop supplemental or complimentary legislation. In the 1967 Constitution and the 1969 Amendment, the responsibility of forest management was granted exclusively to the Federal Government (Viana, 2004, p. 9).

The current Constitution of 1988 which followed democratization provides explicit treatment of forests and includes a chapter on environmental quality and protection. This chapter

places environmental limits on the developmentalist model formerly pursued by the military government (Drummond & Barros-Platiau, 2006, p. 95) and charges federal and state governments with developing and implementing legislation pertaining to the environment. While municipal authority to legislate on forests is not explicitly stated, municipalities may legislate on issues of local interest thereby supplementing federal legislation (art. 30, I and II; Viana, 2004, p. 10). Chapter VI of the Constitution, "On the Environment" proclaims that an ecologically balanced environment is a civil right of present and future generations and confers the protection of this right to the state and the public. A number of biomes, including the Brazilian Amazon, were declared national patrimony and as such may only be used in such a way that the environment and natural resources are preserved and ecological functions are maintained.

The 1990s were particularly active years for forest policy in Brazil, both through domestic and international engagement. The MMA was created in 1992 and is to date Brazil's top-level institution in its hierarchy of environmental institutions (Figueiredo, 2007, p. 65). There was also a dramatic increase in international interest in the Amazon region as its importance for biodiversity and carbon sequestration became more evident, as did threats to its existence. The United Nations Environment and Development Conference held in Rio de Janeiro in 1992 resulted in Agenda 21 which dealt explicitly with forest resources. In 1998, the Environmental Crimes Law (Law No. 9.605, Lei de Crimes Ambientais) was passed to systematize the sanctions outlined in numerous legislative instruments and to address the recommendations of Agenda 21 (Viana, 2004, p. 22). In Chapter V of this law, "On Crimes against the Environment", the penalties for violations of the New Forestry Code are described. An innovation introduced in the law is that companies would become subject to prosecution; prior to this law, only citizens were liable for environmental crimes (Drummond & Barros-Platiau, 2006, p. 100).

Political Economy Impacts on the Forestry Sector

Figure 2-1 reveals potential correlations between forest sector indicators and political and economic events between 1961 and 2007. First, roundwood production shows a steady increase over the period. Following the Oil Crisis in 1973, production grows at an unprecedented rate for the remainder of the decade. Growth in forest plantations follows an exponential trend, little affected by the elimination of plantation subsidies in 1987. Exports appear to follow deforestation levels closely which may be related to the fact that most timber harvested in the Amazon until the mid 1970s was exported due to the lack of infrastructure connecting the region to the south which would later become the largest source of timber demand (Lima et al., 2006, p. 29). Peaks and troughs in exports appear to be correlated with the institution of the Plano Real, changes in Legal Reserve requirements, and the development of Regulations for the New Forestry Code[6]. Estimates on deforestation also follow these general trends.

Until 2005, deforestation levels have generally increased steadily. Laurance, Albernaz and da Costa (2002, p. 11) show that although deforestation rates (absolute and per capita) declined slightly in the first few years of the 1990s compared with the period between 1978 to 1989, they returned to historically high levels between 1995 and 2005. Variation in the rate of deforestation between years appears to be closely correlated with economic variables. For example, the relatively lower levels of deforestation between 1991 and 1994 are likely associated with the freezing of bank accounts which occurred in 1990, thus constraining investment and economic activity (Laurence et al., 2002, p. 12). The drastic increase in 1995 is hypothesized to be a response to the increase in investment funds available resulting from stabilization measures contained in the Plano Real (Fearnside, 1999 as cited in Laurence et al., 2002). To help contain the deforestation that followed the Plano Real and to improve Brazil's credibility in environmental policy with the international community, a provisional measure (Provisional

Measure 1.511, August 22, 1996) was passed, increasing the Legal Reserve requirements to 80% in the Amazon biome (Hirakuri, 2003, p. 16; Toni, 2006, p. 28). The increasing trend in deforestation beginning in 2000 was a response to greater economic growth (Bugge, 2001 as cited in Laurence et al., 2002, p. 12). Reductions in deforestation following 2004 may be related to the government's action plan to combat deforestation and the strengthening of the Brazilian real relative to the US dollar.

Sustainable Forest Management (2000 to present)

As the influence of the environmental movement grew and civil society became more active in the political affairs of the country, forest policy began to transition to the management phase of forest policy development with the turn of the millennium. Four critical developments can be identified which signal this transition, namely: the institution of the National Forest Program (PNF) and the National System of Nature Conservation Units (SNUC), the provision of fiscal incentives for natural forest management, and the Public Forest Management Law (PFML). These developments are discussed in turn.

In 1997, the Federal Government and the Food and Agriculture Organization (FAO) of the United Nations developed the Positive Agenda for the Forestry Sector to manage forests for socioeconomic development while maintaining environmental quality and ecosystem integrity. The Positive Agenda is one of Brazil's first policy references to forest-based sustainable development, differing significantly from the biocentric, protectionist paradigm of previous years. The PNF and the Secretariat for Biodiversity and Forests were instituted as a result of this agenda.

The PNF is central to the political transition to balancing use and conservation, setting concrete and ambitious targets for the sustainable management of forest resources. It aims to increase Brazil's share of international timber markets from 4% to 10% by 2010, increase the

area of sustainably managed forests on private land by 20 million hectares, create 50 million hectares of sustainable production forests on public land, and increase exports from natural forests from 5% to 30% by 2010 (Macqueen, Grieg-Gran, Lima, MacGregor, Merry, Prochnick, Scotland, Smeraldi & Young, 2003, p. vi; Viana, 2004, p. 24). Implementation of the PNF rests with the Coordinating Commission of the National Forests Program (CONAFLOR). CONAFLOR is composed of various government agencies and civil society; its mandate is to develop policy in the areas of land tenure reform, credit and financing, environmental legislation, research, and training. Such a program for promoting sustainable forest management is unprecedented and marks the government's explicit recognition of the Brazilian Amazon as a region best suited for forest-based development (MMA, 2001, p. 12). Affirming the significance of this program, the forestry sector was included as one of three priority program areas in the Government's Multi-Year Plan for 2000 to 2003, the federal strategy for capital expenditures during a President's tenure.

The SNUC (Law 9.985, 2000) was created in 2000 and details criteria and guidelines for the creation and management of conservation areas. The SNUC's mandate is to protect biodiversity while promoting sustainable development (Viana, 2004, p. 23). The law provides for two main categories of conservation areas, namely sustainable use areas and strictly protected areas. While strictly protected areas have resource conservation as their main objective, sustainable use areas, which include national forests, seek to balance conservation with the sustainable harvest of natural resources. Demonstrating this new approach to natural forest resources, legislators use the term management instead of protection and consider communities an integral component of the landscape (Drummond & Barros-Platiau, 2006, p. 98; Silva, 2005, p. 609). Between 2002 and 2004, over three million hectares of protected areas were created and

currently approximately 11% of Brazil's area has been designated by federal or state governments as protected areas (Figueiredo, 2007, p. 61).

Since 1965, numerous provisional measures have been issued to modify the New Forestry Code, most of which deal with aspects of the Legal Reserve and Permanent Preservation Areas. In force today, a Provisional Measure issued in 2001 (Medida Provisória No. 2.166-67, August 24, 2001) established Legal Reserve requirements of 80% and 35% for the high tropical forest and cerrado biomes, respectively and 20% for other regions (Viana, 2004, p. 17)[7] . Restructuring of IBAMA in 2001 (Decree 3833) resulted in the creation of the Forestry Directorate to coordinate, supervise, regulate and orient federal action with regards to reforestation and access to and management of forest resources, and to provide recommendations on the creation and management of National Forests and Reserves.

Financial incentives for promoting natural forest management are new and coincide with the implementation of the PNF (Verissmo, 2006, p. 6). Incentives are financed through Constitutional Funds for Regional Financing established by the 1988 Constitution; these funds include the Northern Financing Fund (FNO), the Central West Financing Fund (FCO), and the North Eastern Financing Fund (FNE). Banks, according to government directives, offer lines of credit with below market interest rates appropriate for the long maturation periods of forestry investments (Verissimo, 2006, p. 20). The PNF's creation of the forestry arm of the National Program for Strengthening Family Agriculture (PRONAF-Florestal) also provides resources to family farmers engaged in forest management and agroforestry. All of these programs have disbursed a small fraction of the resources available, however, which is largely due to the current scarcity of forestland for legal forestry operations. In the case of PRONAF-Florestal, lending is expected to increase in the future as farmers are informed of the program and better technical

support for the development and implementation of projects becomes available (Verissimo, 2006, p. 7).

Contemporary Forest Policy and the Public Forest Management Law

The creation of the PNF, SNUC, PFML and incentives for natural forest management mark the transition from a protectionist to a sustainable management approach to forest resources. With impetus from the PNF and the opportunity created by prevailing social and political economy considerations, a law promoting the management of public forests became a source of intense debate. Although rudimentary provisions for such a law were first made in the Forestry Code of 1934, the PFML details a comprehensive program for instituting forest management by private agents on public land. The implications of this law for promoting forest-based development in Brazil are unprecedented and thus the conditions that facilitated its approval merit an in depth analysis. In this section, the development of the law and its provisions are briefly described. The factors which interacted in such a way as to create a political window receptive to this policy are considered in detail.

The Public Forest Management Law

Until 2006, Brazil lacked a framework to regulate forest management on public land (SFB, 2007a, p. 10). Since the 1934 Forestry Code, the first serious proposal to promote the sustainable management of public forests for timber and other forest goods and services was submitted by the government of Fernando Henrique Cardoso in 2002. This proposal was motivated by the need to control the illegal use of public forests, maintain its capacity to produce goods and services, and foster socio-economic development (SFB, 2007a, p. 10). With President Luiz Inácio Lula da Silva's government entering office in 2003, however, the proposal was withdrawn and the consultation process was re-opened (Guevara, 2003, p. 3). A working group involving all levels of government, researchers, and leaders in business, social mobilization, environmentalism

and politics met on various occasions over a period of 14 months to further develop the proposal. After numerous consultations and revisions, Brazil's first Public Forest Management Law (Law 11.284) was approved by Congress and sanctioned by President Lula in March of 2006.

The law regulates the management of public forests for sustainable use and conservation and creates the SFB and the National Fund for Forest Development. Key principles of the law are the promotion of forest-based development, research, conservation, and the creation of the necessary conditions to stimulate long-term investment in forest management and conservation (art. 2). The law mandates the establishment of national, state and municipal forests and forest concessions. In the case of forests occupied or used by local communities, extractive reserves and sustainable development reserves will be created.

Forest concessions, the law's principal mechanism for promoting forest sector development, are defined as the government's entrustment, through a competitive bidding process, to a legal private entity the right to practice sustainable forest management for the production of goods and services. Sustainable forest management is defined in the law as management for the production of economic, social and environmental benefits, while respecting ecosystem structure and function which considers the management of various tree species, multiple non-wood products, and other forest goods and services (art. 3, VI).

Forest concessions auctioned in a given year are to be described in the Annual Forest Granting Plan (PAOF; art. 10). To facilitate the participation of smaller enterprises in the concessions process, the PAOF will contain a variety of concession sizes to accommodate regional characteristics such as the structure of production, local infrastructure and markets (art. 33). To prevent concentration of concessions in the possession of only a few firms, firms and consortiums can only hold up to 2 concessions, while the percentage of concession area in the

PAOF that one firm may possess will be restricted (art. 34). Concession contracts are of a maximum duration of 40 years while only 20 years in the case of concessions for the provision of forest services such as carbon sequestration (art. 35).

The price of a particular concession is intended to be a function of the harvestable forest goods and services, the consideration of environmental, social and technical criteria, and some of the administrative costs incurred by the SFB in the concessions process. The minimum price is set to encourage competition and the competitiveness of the forest sector, be competitive with forest management on private land, and promote socio-economic development (art. 36).

The SFB's main functions are to formulate the PAOF, create and maintain the National Forestry Information System, manage the National Public Forest Registry, and develop, manage and monitor concession contracts including the bidding process (art. 54). Third-party monitoring of a concession must be conducted at least every three years, the cost of which is borne by the concessionaire (art. 42). The law establishes the Management Commission for Public Forests, composed of members of the business community, civil society, scientists, and the public service. Its mandate is to propose and evaluate regulations for public forest management and serve as the consultative arm of the SFB (art. 51). In March of 2007, a decree (Decree No. 6.063) was issued to regulate the PFML. In particular, it regulates the National Public Forest Registry, the allocation of forests to local communities, the PAOF, environmental licensing, the competitive bidding process, concession contracts, monitoring, and public audiences.

A number of political, economic and social variables interacted to create a political window receptive to the PFML. Some of these variables evolved over time such as the growing influence of the environmental movement and professional capacity in sustainable resources management. The first six years of 2000 were also marked by events which created political

opportunities for the development and eventual institution of the law. Record levels of deforestation in 2002 raised concerns about this seemingly untenable problem. Between 2003 and 2006, numerous covert enforcement operations uncovered the pervasiveness of illegal logging and exposed the entrenched interests of firms as well as public officials. The murder of an activist from the United States in 2005, fuelled by land disputes, drew domestic and international attention to the increasing violence in rural regions of the Brazilian Amazon. Crisis in the forestry sector in 2004 was brought about by government attention to questions of land tenure irregularities and the illegal use of public lands. Finally, the election of President Lula's Workers Party (PT) in 2002 and the appointment of key progressive-minded leaders contributed to a shifting tide of political will to address these issues. These variables are discussed in detail below.

Increasing Deforestation and Illegal logging

Data released by the National Institute for Space Research (INPE) revealed that from August 2001 to 2002, there was a 40% increase in deforestation compared to the previous period (Fearnside & Barbosa, 2004, p. 7). Occurring during a period of economic contraction, this was the second highest level of deforestation in history, second only to the deforestation that occurred in 1995. In light of acute domestic and international pressure, the government was forced into action. In 2003, a Presidential Decree was issued (July 3, 2003) creating the Permanent Inter-Ministerial Working Group for the Reduction of Deforestation Indices in the Legal Amazon whose mandate was to develop measures and coordinate actions to reduce deforestation in the Legal Amazon (Presidência da Republica, 2004, p. 7). The main lines of action presented in their comprehensive Action Plan for the Prevention and Control of Deforestation in the Legal Amazon were land tenure reforms, improved environmental monitoring and enforcement, and support for sustainable forest-based development activities. Shortly after the plan was instituted, 19.5 million

hectares of Federal Conservation Units were established and activities with potentially negative environmental impacts were prohibited along the BR-163 and BR-319 highways in the states of Pará and Amazonas, respectively.

Reductions in deforestation between 2004 and 2006 indicate that this plan may be contributing to improving monitoring and enforcement (Instituto Socioambiental [ISA], 2006b). Since 2004, for example, 19 field enforcement stations staffed with federal and military agents were located strategically within the so-called arc of deforestation[8]. Stations monitor satellite data on land cover change and target gangs involved in illegal logging and the illegal occupation of public land. Deforestation statistics released by INPE reveal that deforestation has been significantly reduced in areas proximate to these field stations (ISA, 2006b).

The timeliness of deforestation statistics has also improved drastically in recent years. Previously, reporting of deforestation indices was delayed by a number of years, often for political reasons (Fearnside & Barbosa, 2004, p. 9). For example, the increase in deforestation in 1992 was not reported until 1995, while the historical peak of deforestation in 1995 was not reported until one month following the December 1997 Kyoto Conference on Global Warming. In 2002, the government announced that future estimates would be released as soon as they were available. Land use and land cover change monitoring technology has also improved; the Real Time Deforestation Detection System (DETER) has allowed state agencies to monitor the Brazilian Amazon by satellite with a monthly coverage period. The state's enhanced ability to obtain land cover change information in a timely manner and the increased transparency of the system is believed to be contributing to reducing levels of deforestation.

Since the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon, the state and police have taken unprecedented action to tackle the problem of illegal

logging on public land. Between October 2003 and 2006, 221 operations were conducted to detect and punish illegal logging; 814 thousand cubic meters of wood were seized, 800 million reais in fines were issued, and 186 people were incarcerated, 63 of which were public servants, as a result of these operations[9]. Of these operations, Operation Black September (state of Rondônia, 2003), Operation Farwest (state of Pará, 2004) and Operations Curupira I and II (states of Mato Grosso and Rondônia, 2005) were the largest. The perpetrators of the crimes were identified as a highly organized network of loggers, business people, and public officials. Operations Belém I and II also recovered substantial information regarding the trade in fraudulent Forest Product Transportation Authorization Permits (ATPFs) which set the stage for the implementation of Operation Green Gold (Consulate General of Brazil in San Francisco, 2005). As a result of this operation, in October 2005 the Federal Police temporarily suspended the transport of all logs from the Brazilian Amazon (Lima et al., 2006, p. 29).

Forestry Sector Crisis

The crisis in the forestry sector began in December of 2004 when the Ministry of Agrarian Development (MDA) and INCRA issued a Governmental Decree (Portaria Conjunta No. 10) requiring rural property owners to register their properties within 60 to 120 days depending on property size. In response to this order, IBAMA's Director of Forests issued a Memorandum (Memorandum No. 619, December 10, 2004) recommending that all management plans in the Legal Amazon be suspended until INCRA released a formal statement on the results of the registration process (ISA, 2005c). As a result, on December 31, 2004, IBAMA in Pará suspended 26 management plans in the region of Santarém.

Since August of 2003, by the direction of IBAMA, forest management plans were no longer approved without proper documentation of legal land title. Prior to 2003, management plans were approved based on precarious documentation from INCRA and state property

registries. Furthermore, as long as a firm provided proof that it had initiated the land legalization process, it was able to submit a forest management plan for approval. Often by the time INCRA reached a decision regarding the legality of the claim, the property was harvested and the logger had moved on (Lima et al., 2006, p. 30). In 2000, there were 3000 management plans in the Brazilian Amazon. Following property registration and the inspection of existing forest management plans, close to 2000 management plans were canceled or suspended. With the forest industry's access to private forestland brought to a near-standstill, access to public forestland became critically important and consequently fueled debate on the proposal for the PFML.

In mid-2004, worker unions and forest sector associations petitioned the government to begin approving new forest management plans. Despite the fact that the government had decided not to authorize new forest management plans on public land until the land tenure situation was resolved, it conceded to evaluating 49 areas of public forest for their potential management for timber. INCRA geo-referenced 33 of these areas and discussions took place on whether or not they would be made available for harvest. While management plans were being developed, the Government Decree requiring the registration of all rural properties was issued (Portaria Conjunta No. 10, December, 2004). On December 28, 2004, the MDA in Pará announced that the 33 areas would not be available until January of 2005. ISA (2005c) reports that the industry was under considerable strain and lacked sufficient volume of legally harvested timber to meet the demand of processing facilities. The situation reached crisis proportions with the suspension of 26 forest management plans in the region of Santarém on December 31, 2004.

Loggers responded to the crisis by initiating a blockade on January 25, 2005 on the BR-163 highway (Cuiabá-Santarém) at Novo Progresso, paralyzing southwestern Pará for 11 days. On February 3, 2005 government officials, members of parliament and state representatives from

Pará, along with leaders of timber and rural producer's organizations, came to an agreement to end the blockade. The federal government conceded to re-evaluate the suspended forest management plans, authorize new plans in settlement areas and send the proposal for a PFML to Congress (ISA, 2005c).

Escalating Violence

In the last 20 years, over 500 people have been killed due to land conflicts in the state of Pará alone, from farmers and colonists, to leaders of agrarian reform and other social movements (ISA, 2006a). In the municipalities of Altamira and São Félix do Xingu in Pará, local residents reported that armed bandits evicted sixty families from their land (90% of the population living along the margins of the Xingu and Iriri Rivers). In some cases, the bandits, accompanied by the state military police, looted homes and set them on fire. The state argues that the recent increase in violence was a reaction to the land tenure regularization process (ISA, 2005b).

In February of 2005, the government responded to the killings of several rural workers and leaders of social movements, in particular, the murder of Dorothy Stang, a US missionary in Anapu, and the murder of Daniel Soares da Costa, a Rural Workers Union leader (British Broadcasting Corporation [BBC], 2005b); the state sent 110 soldiers to Anapu and another 2,000 troops were deployed in Pará to maintain order (BBC, 2005a). The government also launched a program to interdict land clearing on 8.2 million hectares in the area of the BR-163 highway until a land management plan was developed for the area.

One year following Dorothy Stang's murder, the Federal government, on February 13, 2006, created 7 new conservation areas and increased the size of the National Park of Amazonia. These areas sum to 6.4 million hectares of protected area along the BR-163 (ISA, 2006b) increasing the total conservation area in the Amazon to 45.8 million hectares. Fifteen million hectares of this area were created by the government of President Lula and make up the

country's first Sustainable Forestry District within which 5 million hectares were allocated for forest management. The creation of this district is the first state action founded in the new regulatory framework established by the PFML which was approved by Congress the week prior (ISA, 2006b).

International Concern for the Amazon

International interest in the Amazon has increased gradually in recent decades due to greater transparency, a globalized media, the timeliness of deforestation figures and, a growing recognition of the importance of the Amazon forest for conserving biodiversity and carbon sequestration. In 1988, for example, deforestation was 8 million hectares. This figure, the intense media coverage of the fires burning in the Amazon, and news of the assassination of rubber tapper Chico Mendes in 1988 drew attention to the region, increasing concerns about global climate change and the rural workers' struggle to earn a livelihood from managing the forest (Kolk 1996, p. 78). The World Commission on Environment and Development's 1987 report, "Our Common Future" acknowledged the Amazon's importance as a genetic storehouse thus piquing international interest in the region's potential reserves of medicines and chemicals. The size of the Brazilian Amazon also made it an easy target of international attention (Kolk, 1996, p. 137).

The Group of Seven's (G-7) concern for the environment was formalized in a 1989 summit where tropical forests were recognized for their important function in sequestering carbon. Out of the G-7's actions, the Pilot Programme for the Brazilian Amazon was particularly significant, contributing to capacity development in policy, research, and management. The growth and mobilization of NGOs also assisted in bringing attention to the Amazon. NGOs in the US campaigned heavily against the multilateral development banks, beginning in 1983, for their involvement in setting development agendas in developing countries. The World Bank funded

POLONOROESTE and Carajás projects were principal targets for their poor environmental records (Kolk, 1996, p. 290).

The Workers Party

Finally, the election of the PT, led by Luis Inácio Lula da Silva, has contributed to creating a political environment which was more receptive to proposals for forest-based development. Lula is considered Brazil's first left-leaning President in the last 4 decades (Morton, 2005, p. 14). Becoming active in trade unions in 1978, he was a founding member of the PT in 1980, and on his fourth attempt at the presidency, he was elected in October 27, 2002. The PT has committed itself to fighting poverty and encouraging the participation of grassroots organizations (BBC, 2002).

Four years following the assassination of Chico Mendes, Jorge Viana, member of the PT and a close associate of Mendes, was elected governor of the Amazonian state of Acre. His goal was to be a "government for the forest" and its people (Rohter, 2002). Viana in fact is a forest engineer and considers that Acre's primary vocation is sustainable forest management. Marina Silva joined the PT in 1985 and was elected to the Senate in 1994. Also a close friend of Mendes, Silva was appointed to the post of Minister of the Environment by Lula's government in January 2003 (Environment News Service, 2002).

Discussion and Conclusions

The period of settlement and exploitation from 1889 to 1964 was characterized by land clearing, primarily in the Atlantic Forest Region, to meet European demand for forest products, to produce energy, and to establish farms and ranches. With declining timber stocks and the visible degradation of the countryside, legislators became concerned by the destruction and passed the first Forestry Code in 1934.

In 1965, Brazil entered the protectionist period of forest policy development. The 1965 New Forestry Code placed unprecedented restrictions on private property rights. Numerous laws and institutions were created for regulating forests and environmental quality. Vast protected areas were established, though generally low levels of management capacity and financing left them vulnerable to destructive forces. The military government's push for industrialization and integration of the Amazon into the national economy was an overwhelming counterforce to protectionist policies, however, rendering them largely insignificant. Although legislators demonstrated preoccupation with the environment and legislated on its behalf, a developmentalist agenda was the priority to which most resources were allocated.

With the abertura in 1974, political space was created for the beginnings of an environmental movement. As this movement strategically aligned itself with already established domestic movements and the international environmental movement, environmental issues gained increasing attention. A break with the military government's developmental model was written into the 1988 Constitution where growth was to be limited by environmental sustainability constraints.

It is argued that with Brazil's democratization, the growing influence of the environmental movement, and civil society's effective engagement in political affairs, forest policy began to transition to a sustainable management model with the turn of the millennium. Various policies and programs mark this transition such as the SNUC, PNF, fiscal incentives for natural forest management, and in particular, the PFML. Taking the PFML as the proximate indicator of this transition in approach to natural forest resources, the variables that led to the political opening for the approval of this law are of considerable interest.

Until 2003, deforestation increased steadily since reliable estimates have been available, reaching historic highs in 1995 and in 2002. With greater transparency and a globalized media, both domestic and international interests expressed concern for the fate of the region. In response to these statistics and the illegal use of public lands and illegal logging, the government established an inter-ministerial group to address the issue.

These factors, combined with escalating violence in the Amazon and a forest sector crisis, prompted the government to send the PFML proposal to Congress as a constitutional emergency. This proposal, likely aided by the election of the left-leaning PT, passed relatively swiftly through Congress and was signed into Law on March 2, 2006. The law's provision for the establishment of forest concessions represents the transition to a sustainable forest management model on public lands and can prove to be a powerful mechanism for directing the development of the natural forest management sector.

The next few years will reveal whether the new policies and institutions established since 2000 represent a break with the low levels of implementation of the protectionist policies and programs of the past. The experience with forest concessions, their ability to control the illegal use of public lands, achieve sustainable yields, and manage the forest for multiple uses will provide indication of whether forest policy has in practice moved towards sustainable forest management.

With recent efforts to delimit public lands and conservation units, the state in partnership with civil society is making measurable progress in regulating public land use and occupation. Government neglect of the illegal exploitation of public lands is no longer an option from a political standpoint with the globalized civil society and media ensuring that the illegal clearing of the countryside does not go unnoticed. Collusion between bureaucrats, politicians and

business has been exposed and the risks involved in the illegal exploitation of forest resources are becoming too great.

Distinct from the protectionist phase of forest management, the state has committed the institutional support of government agencies and funding to gain control of forest resources in the Brazilian Amazon. The potential forests hold for creating socio-economic stability and generating revenue, and the role forest concessions and conservation areas may play in broadening support for political parties has rendered sustainable forest management an attractive alternative. As such, the state has recognized the Brazilian Amazon's primary vocation as forest-based development. While protectionist policies were outweighed by the colonization and resource extractive agenda of the military regime, forest policy is becoming more aligned with extra-sectoral and economic development policies. The elimination of subsidies for cattle ranching, the allocation of forests for community use, and the management of public forests for the production of goods and services are indicative of this increasing policy coherence.

A successful transition to sustainable management will require the state to address the question of forest management on private land. Land rent between private land and concessions with similar characteristics should be equal if forest management is to continue on private land at a socially optimal level (Merry & Amacher, 2005, p. 29). Integrating smallholder timber producers into the legal timber market will involve inter-institutional collaboration and greater flexibility. The main obstacle to their integration relates to the procedural burden of preparing forest management plans and obtaining deforestation permits. Although required by law, most smallholders do not obtain deforestation permits while forest management plans require the contracting of a professional for their preparation, which is often beyond the means of small producers. Creating a system that is more responsive to the particular characteristics of

smallholders is required if sustainable forest management is to be a paradigm that applies to forests in general regardless of tenure type. Mechanisms to facilitate smallholder production can go a long way to reduce illegality and contribute to the socioeconomic development of the some 500,000 families settled in the Brazilian Amazon (Lima et al., 2006, p. 34).

Brazil's transition to a politic of sustainable forest management is occurring at a time when the very concept of sustainable management is evolving rapidly. The environmental movement's focus on climate change and the environmental services that forests generate has increased the significance of forests in achieving broader environmental sustainability goals. New instruments for the promotion of sustainable forest management, such as payments for environmental services, carbon credits for carbon sequestration, tradable deforestation permits, and potential incentives for avoided deforestation are some of the options under consideration. This rapidly changing environment presents challenges and potential synergies for the implementation of Brazilian forest policy. Though the complexity of instruments has increased, the broadening definition of sustainable forest management is adding value to standing forests not only for the socioeconomic benefits they generate, but for the environmental services they provide.

Brazil has undergone profound political and economic changes over the last two decades with democratization, a free and globalized media, an engaged civil society, and a more stable economy. The political opportunity for the PFML's approval set in the context of consistent economic growth and public engagement in the democratic process leads us to expect a significant shift both in policy and in practice in how natural forest resources are managed and for whom.

[1] Given Brazil's size and regional diversity, the particular period in time at which a transition to a subsequent phase of forest policy development occurs and the impact of forest policy may differ by region. This analysis focuses on the overall trends in forest policy development with a bias towards the Brazilian Amazon.

[2] Forest concessions enable the state to sell the rights to harvest forest goods and services to private firms for a predetermined period of time.

[3] This model has economic expansion as its primary objective with little consideration for the sustainable uses of resources. In Brazil, this model was characterized by pervasive state intervention in the economy, state-corporatist mechanisms and clientelism. To manage the ambitious developmentalist program, the state apparatus grew significantly, including state-run enterprises.

[4] The biocentric approach viewed environmentalism as the business of science and scientists whereas the socio-environmental approach viewed environmental issues from the perspective of the social sciences (Alonso et al., 2005, p. 10).

[5] Ecological-Economic Zoning is a form of land use planning that identifies areas where particular land uses should be encouraged and areas with special needs that may require conservation considering the physical, biotic and socioeconomic environments (FAO, 1996).

[6] The Plano Real was an economic stabilization plan developed by the government of President Fernando Henrique Cardoso.

[7] The cerrado is a tropical grassland savannah and is considered the world's most biologically rich grassland biome.

[8] The arc of deforestation is formed by the BR-163 highway in western Pará, passing through the extreme northeast of Mato Grosso until the southern reaches of Amazonas in close proximity to the Transamazon highway.

[9] The average exchange rate for the year 2003 was 3.1 reais to the US dollar.

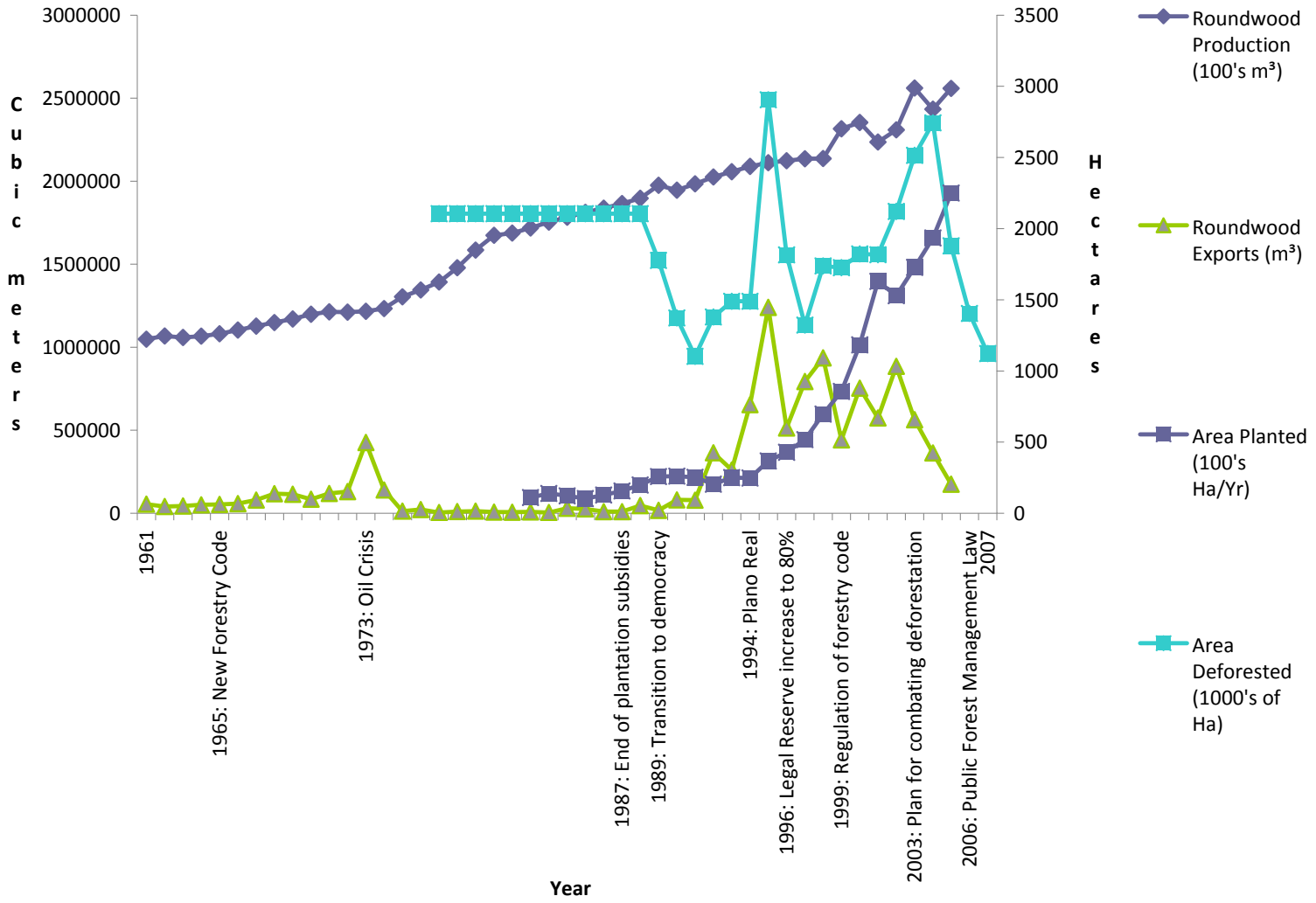

Figure 2-1. Roundwood production and trade, area planted for pulp and paper, and area deforestedSources: Roundwood production, imports and exports (FAOSTAT, 2007); area planted (Associação Brasileira de Celulose e Papel [BRACELPA], 2005); area deforested (INPE, 2007)

CHAPTER 3
STATIC COMPUTABLE GENERAL EQUILIBRIUM ANALYSIS OF FOREST CONCESSIONS IN BRAZIL

Introduction

The management of natural forests in Brazil is concentrated in the states of the Legal Amazon with almost all legal timber extraction occurring on private land. While the government has promoted the development of forest plantations through economic incentives, state involvement with natural forests has focused on regulation. Over 1 million km² in the Legal Amazon have been identified as suitable for the production of forest goods and services and other resource-based activities (Verissimo et al., 2000, p. 6). Only recently, however, has the state taken action to harness the potential this vast public resource holds for promoting sustainable development. In March 2006, the Public Forest Management Law (PFML) was passed by the government of President Luiz Inácio Lula da Silva. A key feature of this law is a framework for creating forest concessions on public lands. With the goal of establishing up to 13 million hectares of forest concessions by the end of the decade, an initiative for the development of the forest sector is unprecedented in Brazilian history, marking the state's recognition of the Amazon's vocation as one of forest-based development.

Forestry is an important economic driver in the Brazilian Amazon. Investment in forest management is low, however, since managing for high value timber species requires long-term investments in sometimes unstable political environments (Rice, Gullison & Reid, 1997 in Pinedo-Vasquez, Zarin, Coffey, Padoch & Rabelo, 2001, p. 220). Compounding this disincentive is the often unsecure tenure situation in the Amazon, illegal logging, and deforestation. As a result, industrial forestry in the Amazon has followed a boom and bust cycle where, rather than investing in management, firms mine high value species until depletion and then migrate further into the forest in search of new timber sources. Forest concessions present an opportunity to

counteract some of the negative incentives for forest management. By providing industry and communities with secure tenure, investment in management may increase. Increasing transparency in the regulatory environment further reduces risks and costs. Concessions, as in the case of protected areas, may also act as a barrier to deforestation and encroachment (Nepstad, Schwartzman, Bamberger, Santilli, Ray, Schlesinger, Lefebvre, Alencar, Prinz, Fiske, & Rolla, 2006, p. 72).

Taking forest concessions as a proximate indicator of Brazil's transition towards the management phase of forest policy development, the economic, welfare, and environmental response to concessions provide an indication of the degree to which, if fully implemented, forest policy will be accepted and supported by society. In this chapter, a static computable general equilibrium (CGE) model is developed to evaluate the short-run socio-economic and environmental implications of implementing forest concessions in the Brazilian Amazon.

Following this introduction, the second section of this chapter provides a brief overview of the Brazilian forest sector while the third section describes key components of the PFML. The fourth section is an overview of CGE models and their applications in forestry. Next, the procedures followed in constructing the dataset are described and the CGE model is developed. Following model development, the scenario design and modeling results are presented. The final section offers a discussion and conclusions.

The Brazilian Forestry Sector

Brazil is the largest producer and consumer of tropical timber products and as such, the forest industry is an important component of the economy and in particular, the economy of the Legal Amazon. The forestry sector is responsible for 3.5% of Brazil's gross domestic product (GDP; Serviço Florestal Brasileiro [SFB], 2007a, p. 10). The natural forest management sector in the Legal Amazon accounts for 15% of GDP (Veríssimo, 2006, p. 23). The Brazilian forestry

sector generates 2 million formal jobs and accounts for 8.4% of exports (Serviço Florestal Brasileiro [SFB], 2007a, p. 10); forest product exports are third in importance to the Legal Amazon (Celentano & Veríssimo, 2007, p. 22). In 2006, the value of forest sector output was over 10.9 billion reais[1]. Forest plantations were responsible for 66% of this output while natural forest management and non-timber forest products extraction accounted for 34% (Instituto Brasileiro de Geografia e Estatística [IBGE], 2007a). Roundwood, charcoal and firewood made up the majority of this production (71%) with pulp and paper, and non-timber forest products accounting for 23% and 6%, respectively (Figure 3-1). Forest plantations produced over 69% of the value of roundwood, charcoal, fuelwood, and pulp and paper. While most of the timber volume harvested from natural forests is destined to wood products, over half of forest plantation production is processed into pulp and paper.

The Brazilian forest industry is regionally distinct; the majority of natural forest management occurs in the states of the Legal Amazon while most forest plantation management occurs in the south and south east[2]. Total roundwood, charcoal and fuelwood production from natural forests totaled 3.18 billion reais in 2006, 43% of which was produced in the north, 27% in the north east, 17% in the center west, 8% in the south and 5% in the south east (Figure 3-2). The value of roundwood, charcoal and fuelwood from forest plantations was 4.5 billion reais with 57% of production concentrated in the south, 33% in the south east, 4% in the north and 3% in both the north east and center west (Figure 3-3).

In 2006, approximately 14 .6 million cubic meters of timber (excluding charcoal and fuelwood), valued at over 1.4 billion reais, were harvested from natural forests in the Legal Amazon. Forest plantations in the Legal Amazon produced 4 million cubic meters of timber

(excluding charcoal, fuelwood and wood for pulp and paper), amounting to 187 million reais in value.

Between 1998 and 2004, roundwood production in the Legal Amazon dropped by 15%. The number of logging centers, however, increased from 72 to 82 as the industry advanced to new logging frontiers. These new logging centers form an arc from the BR-163 highway in western Pará to the northeast of Mato Grosso until the southern reaches of the state of Amazonas. The number of logging and processing companies increased from 2,600 to 3,100, mainly due to an increase in micro-mills in Pará. Forest sector employment grew slightly (less than 3%) over this period, reaching 124,000 and 255,000 direct and indirect jobs, respectively, representing 3% of the economically active population (Lentini et al., 2005a).

Forest product exports increased between 1998 and 2004 from 14% to 36%. The value of forest product exports increased by 250% in part due to a favorable exchange rate and an increase in North American, European, and Asian demand for Brazilian forest products. The United States is Brazil's largest export market, consuming 31% of Brazilian forestry exports, while China consumes 12% and France 11% (Lentini et al., 2005a, p. 99). The internal market consumes 64% of production with the south and south eastern states consuming 42% of total production in 2004 (Lentini et al., 2005a, p. 67; 93).

In 2003, there were 2.1 million hectares of forest with approved management plans, over 91% of which were located in the north (Table 3-1). Also in 2003, there were 210,032 hectares of forest authorized for deforestation, over 59% of which were also in the north. In 2004, 71% of timber was extracted by firms on forestland owned by third-parties while 29% was extracted by firms owning or renting forestland (Lentini et al., 2005a, p. 72). In 2006, 627,000 hectares of

forest plantations were established, a 13% increase in relation to the previous year. Most new planting occurred in the south east (44%) and the south (28%; Table 3-2).

Illegal logging and illegal deforestation are pervasive problems in the Brazilian forest sector. As of 2004, 14% of the Amazon was deforested (Lentini et al., 2005a, p. 29). From 2004 to 2007, deforestation dropped significantly from 27,379 km² to 11,224 km² (Figure 3-4). Some estimates suggest that 80-90% of timber in Brazil is produced illegally; more conservative figures estimate that illegal logging accounted for approximately 43% of production in 2004 (Lentini, 2006).

As of 2007, the Legal Amazon has 194 million hectares of public forests, 56% of which are indigenous territories, 28% are conservation areas, 15% are other public lands, and 1% are sustainable development projects (SFB, 2007b). Thirty-three percent of the Legal Amazon is considered terra devoluta, which is land without legal title or land with a title in dispute (Lentini et al., 2005a, p. 32).

The Public Forest Management Law

Brazil's 1934 Forestry Code contained legislation for the concession of forest management on public land, though concessions were never implemented. Motivated by the need to control the illegal use of public lands and to promote socio-economic development, a proposal for a public forest management law was submitted by the government of Fernando Henrique Cardoso in 2002 (SFB, 2007a, p. 10). With President Luiz Inácio Lula da Silva's government entering office in 2003, the proposal was withdrawn and the consultation process was re-opened (Guevara, 2003, p. 3). A multi-stakeholder working group was formed to debate and further develop the proposal. After this lengthy consultation period, numerous public audiences, and congressional discussion, the PFML (Law 11,284) was approved by Congress and sanctioned by President Lula on March 2nd of 2006.

The PFML regulates the management of public forests for sustainable use and conservation and creates the Brazilian Forest Service (SFB) and the National Fund for Forest Development (FNDF). Key principles of the law are the promotion of forest-based development, research, conservation, and the creation of the necessary conditions to stimulate long-term investment in forest management and conservation (art. 2). The law mandates the establishment of national, state and municipal forests, and forest concessions, and creates a framework for designating forests for community management.

Forest concessions, the law's principal mechanism for developing the natural forest management sector, are defined as the government's entrustment to a legal entity the right to practice sustainable forest management for the production of goods and services. This right is conferred through a competitive bidding process. The winning bidder must comply with all criteria in the published request for bids and demonstrate the capacity to meet all contractual requirements at its own risk for a pre-determined period of time (art. 3, VII). Sustainable forest management here is defined as management for the production of economic, social and environmental benefits, while respecting ecosystem structure and function which considers the management of various tree species, multiple non-wood products and other forest goods and services (art. 3, VI).

Forest concessions auctioned in a given year are to be described in the Annual Forest Granting Plan (PAOF; art. 10). To encourage the participation of smaller firms, the PAOF will contain a variety of concession sizes to accommodate regional characteristics such as the structure of production, local infrastructure, and markets (art. 33). To prevent concessions from being concentrated in the possession of only a few firms, firms and consortiums may only hold two concessions at a time, while the percentage of total concession area that one firm may

possess will be restricted (art. 34). Concession contracts for the harvest of forest goods are valid for up to 40 years and up to 20 years in the case of forest services such as carbon sequestration (art. 35).

The price of a particular concession is intended to be a function of the harvestable forest goods and services, the consideration of environmental, social and technical criteria, and some of the administrative costs incurred by the SFB. The minimum price is set to encourage firm participation, promote forest sector competitiveness, be competitive with forest management on private land, and promote socio-economic development (art. 36).

The SFB's main functions are to formulate the PAOF, create and maintain the National Forestry Information System, manage the National Public Forest Registry, and develop and manage concession contracts and the bidding process (art. 54). Third-party monitoring of a concession must be conducted at least every 3 years, the cost of which is borne by the concessionaire (art. 42). The law establishes the Management Commission for Public Forests, composed of members of the business community, civil society, scientists, and the public service. Its mandate is to propose and evaluate regulations for public forest management and serve as the consultative arm of the SFB (art. 51). In March of 2007, a decree (Decree No. 6.063) was issued to establish regulations for the PFML, in particular, the National Public Forest Registry, the allocation of forests to local communities, the PAOF, environmental licensing, the competitive bidding process, concession contracts, monitoring, and public audiences.

Overview of Computable General Equilibrium Models

CGE models have their roots in the input-output framework developed by the economist Wassily Leontief in the 1930s (Dixon, Parmenter, Powell & Wilcoxen, 1992, p. 19). Input-output (I-O) models are used for economic planning and are effective in elucidating the inter-sectoral linkages which result from the production and consumption of intermediate inputs (Bandara,

1991, p. 6). This type of model is frequently applied to identify important economic sectors and estimate the effect of changes in demand on output and employment. In addition, I-O models can shed light on the impact of private sector decisions and public sector policies on the economy (Rose, 1995, p. 297). I-O models continue to be the most common approach to estimating the impact of public policies on the forestry sector (Alavalapati, Adamowicz & White, 1998a, p. 711).

Despite their popularity, I-O models have a number of limitations which have prompted the development of CGE models. I-O models assume fixed prices, unlimited factor supply, and that factors of production and intermediate inputs are used in fixed shares; final demand is treated exogenously (Alavalapati et al., 1998a, p. 711). As a result of these assumptions, final demand determines output levels, input substitution is not possible, and producer and consumer behavior is not responsive to changes in relative prices (Banadara, 1991, p. 7). Bridging the gap between I-O and CGE models is the work of Leif Johansen and his Multi-Sectoral Growth model. Further developing this framework was Irma Adelman and Sherman Robinson with their model of South Korea (Bandara, 1991, p. 10).

A CGE model is a mathematical representation of the economy, from a household to a country, to the entire world economy. Creating a basic CGE model involves developing a theoretical structure of the economy which is formalized by equations representing demand for commodities, intermediate and factor inputs, equations relating prices to costs, and market clearing equations for factors and commodities (Dixon et al., 1992, p. 87). Supply and demand equations describe the behavior of utility maximizing consumers and profit maximizing producers. The system of equations is solved simultaneously for the economic equilibrium (Bandara, 1991, p. 9).

This class of models represents a significant improvement over I-O models by incorporating an endogenous demand and price system, substitutability in production and demand, optimization of agent behavior, factor scarcity, and a more detailed treatment of institutions and the macroeconomic environment. Customization of the model in terms of the structure of production and consumption, the macroeconomic environment, and institutional interactions enables the analyst to more realistically model the economy of concern (Alavalapati et al., 1998a, p. 712). With producers competing for scarce resources and consumer expenditures, CGE models are effective in capturing the distributional aspects of policy changes (Buetre, Rodriguez & Pant, 2003, p. 2).

The principal data source for a CGE model is a social accounting matrix (SAM). A SAM is a square matrix representing an economy; it empirically describes the structure of production and transactions between sectors, institutions, and factors of production. A SAM has two main functions: the organization of data and to provide the statistical basis for the development of an economic model (King in Pyatt & Round, 1985, p. 17). SAM's are typically constructed based on national accounts data and government surveys such as household expenditure surveys and census data.

CGE models have been criticized on a number of grounds. First, CGE models often require a large amount of consistent data in the form of a SAM (Devarajan & Go, 1998, p. 678). This data, where available, is collected with some degree of error and the use of a variety of data sources may introduce inconsistencies into the dataset. Constructing a SAM is also a very labor intensive process.

Second, CGE models are typically calibrated using data from a benchmark year. At this benchmark year, the economy is assumed to be in equilibrium, that is, factors of production are

fully utilized and optimally allocated given the policy parameters and societal preferences of the day. The quality of the model and the reliability of results are in large part dependent on the quality of the data in the benchmark year; random or extraordinary economic events in the benchmark year may put model results into question (McKitrick, 1998, p. 544). Furthermore, since the calculated parameters are based on a single year, they are typically not accompanied by measures of confidence.

Third, additional data is required in terms of elasticities. Elasticities represent preferences and production technologies and can have a significant effect on model results (Alavalapati et al., 1998a, p. 712; McKitrick, 1998, p. 544). Elasticity estimates in the literature, where they exist, may be at times contradictory, however (Shoven & Whalley, 1984, p. 1020). These estimates are often not available for some countries and as such, estimates from other countries are often applied or a best-guess is made (Bandara, 1991, p. 18). One approach that has been used to overcome uncertainty in elasticities is to produce central tendency tables of these parameters for each sector (Shoven & Whalley, 1992, p. 119). Sensitivity analysis may also be performed to determine how robust the model is to variations in elasticities (Stenberg & Siriwardana, 2005, p. 409).

Fourth, the choice of macroeconomic balances can have a significant impact on model behavior (Dewatripont & Michel, 1987, p. 66).There are three macroeconomic balances in a CGE model: the current government balance, the current account of the balance of payments, and the savings and investment balance. Decisions regarding these balances are known as closure rules and are required to maintain a balanced economic environment. To avoid erroneous conclusions due to model sensitivity to closure rules, it is good modeling practice to conduct experiments under a variety of closure settings.

Fifth, CGE models typically assume perfect competition between producers. Perfect competition implies that one firm alone cannot influence market prices and producers earn zero pure profits. This assumption is often fair for primary sectors of the economy; it is an empirical reality however, that monopolies, monopsonies and oligopolies exist. This assumption ignores whatever pricing power a firm may have. More complex CGE models have addressed this issue by incorporating imperfect competition in some sectors.

Computable General Equilibrium Applications in Forestry

CGE models are frequently used to study international trade, taxes, economic policy packages such as structural adjustment programs, and climate change issues (Stenberg & Siriwardana, 2005, p. 412). More recently, they have been applied to the study of forest sector policies. Dee (1991) developed a model to evaluate the impact of increasing the minimum harvest age of trees and variations in stumpage and discount rates in Indonesia. Wiebelt (1994) studied how macroeconomic policies affect forest resource use in Brazil. Alavalapati, Percy and Luckert (1997) developed a regional model to analyze distributional effects of an increase in the stumpage price in Canada. Thompson, Van Kooten and Vertinsky (1997) studied forest management options when non-timber values are considered in the model. Alavalapati, White, Jagger and Wellstead (1998b, p. 349) evaluated the impact of land use restrictions on a resource dependent economy in Canada. Dufournaud, Jerrett, Quinn and Maclaren (2000, p. 15) evaluated the economic impact of an export ban and an increase in royalties and export taxes. Gan (2004) evaluated the potential impacts of trade liberalization on China's forestry sector. Gan (2005) evaluated the impact of forest certification on welfare, output, prices, and trade patterns. Stenberg and Siriwardana (2007) examined the economic effects of selective logging, stumpage taxes, set-aside areas, and secure forest land tenure on the Philippine economy using a standard CGE model and a forestry sub-model.

A few modelers have addressed the interactions between land use and deforestation. Persson and Munasinghe (1995) developed a model of the Costa Rican economy to assess the impact of economy-wide policies on deforestation and compare agent behavior in the face of insecure property rights. The authors addressed the question of deforestation by introducing logging and deforestation activities under secure and insecure tenure regimes and by incorporating a market for deforested land. Loggers clear land to harvest trees for sale to the market. The amount of land cleared is a function of the demand for forestland and the world market price of logs (Persson & Munasinghe, 1995, p. 267). Where property rights are secure, loggers incorporate the social value of forests in their utility function. Logging technology exhibits decreasing returns to scale to model the diminishing availability of forests due to illegal logging. A deforestation sector clears land to sell to the agricultural sector. In the case of insecure property rights, the cost of clearing land is a function of labor inputs; where property rights are secure, the deforestation sector incorporates the social value of forests in its utility function (Persson & Munasinghe, 1995, p. 266).

Cattaneo (2001 and 2002) built on the work of Persson and Munasinghe (1995) and examined the relationship between economic growth, poverty and natural resource degradation in Brazil. Cattaneo considered the effects of currency devaluation, reduced transportation costs, changes in land tenure regimes, adoption of regionally specified agricultural technology, and fiscal incentives on land use change. Cattaneo's research emphasized the role of land types as factors of production, specifically, forestland, arable land, grassland, and degraded land.

To model deforestation, Cattaneo (2002, p. 36) included a deforestation sector which is responsible for land clearing, the amount of which is a function of the returns to arable land and profit maximization subject to technological constraints. The price of arable land is a function of

the returns to agricultural land, taking into account the degradation and transformation of arable land into grassland and its subsequent transformation into degraded land which must be left to fallow. In order to simulate the presence of land tenure insecurity in the Amazon, returns to deforestation do not include potential returns from forested land.

Construction of a Social Accounting Matrix for Brazil

An Aggregated Social Accounting Matrix for Brazil

The SAM developed for Brazil follows the framework presented in Lofgren, Harris, Robinson, Thomas and El-Said (2002). In this framework, activities are distinguished from commodities, with activity and commodity account receipts valued at producer and consumer prices, respectively. The advantage of this structure is that one particular activity can produce multiple commodities while one particular commodity may be produced by more than one activity. Marketing margins are also explicitly considered, which are the costs involved in shipping a product from the producer to the consumer whether the good is an import, export, or domestically produced and consumed good (Lofgren et al., 2002, p. 7).

The main data sources used in the construction of the Brazilian SAM are Brazil's national accounts for 2003 (IBGE, 2004a). The year 2003 was chosen as the reference year since this is the most recent year for which definitive national accounts were available, along with national household survey and expenditure data (IBGE, 2004b and IBGE, 2007b). The regional disaggregation of agriculture and forestry was supported by regional accounts for 2003 (IBGE, 2005) and IBGE data on production and extraction of forest products and silviculture (IBGE, 2004c). Additional sources include the 2000 demographic census (IBGE, 2003), preliminary results from the 2006 agriculture and cattle ranching survey (IBGE, 2007c), The Research Institute for Applied Economics' (IPEA) 2003 SAM for Brazil (Tourinho, Costa da Silva & Alves, 2006) and Cattaneo's (2002) 1995 SAM for Brazil.

The 2003 national accounts feature supply and use tables with 55 sectors and 110 goods and services. Since for the purposes of the present analysis, such sectoral and goods and services detail was not required, an aggregate SAM was created by aggregating sectors and commodities to 15 and 14, respectively (Tables 3-3 and 3-4). This aggregation was performed to the supply-use tables for goods and service supply, activity production, and imports of goods and services (Table 1 of the national accounts). This aggregation was then performed to the supply-use tables for intermediate consumption, final demand, and components of value added (Table 2 of the national accounts). Data on institutional transfers, taxes, savings, and investment were obtained from the national account's Integrated Economic Accounts (CEI) table and the IPEA SAM. These data were input into the SAM as described in Tables 3-5a and 3-5b.

Disaggregating Land Types and Regional Forestry and Agricultural Activities

In the national accounts, expenditures on land are aggregated with capital. From Cattaneo (2002), approximately 20% of total agricultural and forestry expenditure is on land. To calculate expenditure on land in the aggregate SAM, the product of total agricultural and forestry expenditures and 20% was taken. This amount was then deducted from agricultural expenditure on capital and attributed to expenditure on land.

In the national accounts, natural forest management and forest plantation management are aggregated with agriculture. The following procedure was employed to disaggregate an aggregate forestry sector from agriculture. First, indirect taxes on the forestry activity were calculated by applying the same proportion of agriculture's expenditure on indirect taxes to the forestry sector's total expenditure. Indirect taxes paid by the forestry sector were subtracted from the agricultural sector's indirect tax payments. Next, forestry's expenditure on intermediate consumption and factor inputs was calculated. Total forestry expenditure less forestry expenditure on transportation in Cattaneo (2002) was calculated[3]. The intermediate and factor

consumption as a proportion of total forestry expenditure in Cattaneo was then calculated. These proportions were applied to total forestry expenditure in the aggregate SAM to obtain expenditures on intermediate consumption and factors; these expenditures were then subtracted from the agricultural sector's expenditures.

To disaggregate the natural forest management, forest plantation management and deforestation sectors from the aggregate forestry sector, the proportional output of forest products from natural forest management, forest plantations and deforestation was calculated based on IBGE's production and extraction of forest products and silviculture survey (IBGE, 2004c) and deforestation authorization permits from Brazil's monitoring and control system for resources and forest products database (MMA, 2008a). The proportions of total aggregate forest sector output for natural forest management, forest plantation management, and deforestation were used to determine intermediate consumption, factor inputs, and indirect taxes.

Agriculture was regionally disaggregated according to Brazil's major administrative units. To determine regional agricultural expenditure on labor, the product of the number of people employed in agriculture by region (IBGE, 2007c) and the average wage in agriculture by region (IBGE 2003) was calculated. The proportion of agriculture's total expenditure on labor by region was calculated and applied to agriculture's total expenditure on labor. To calculate agriculture's regional expenditure on capital, the proportion of tractors by region (IBGE, 2007c) was calculated and applied to agriculture's total expenditure on capital. To calculate agriculture's regional expenditure on land, the product of agricultural land area by region (IBGE, 2007c) and the average land price by region (Reydon & Plata, 2000) was calculated. This sector's proportional expenditure on land by region was calculated and applied to the agricultural sector's total expenditure on land.

The agricultural sectors' expenditure on intermediate consumption by region was calculated as the proportion of intermediate consumption by region based on regional accounts data (IBGE, 2005); these proportions were applied to agriculture's total intermediate consumption. In the case of indirect taxes, the proportion of agricultural output value by region was calculated from the regional accounts (IBGE, 2005). These proportions were applied to agriculture's total indirect tax payment to obtain indirect taxes by region. Agricultural receipts by region were calculated as receipts from each product as a proportion of agriculture's total receipts. These proportions were applied to the agricultural activity's total receipts by region to determine regional agricultural receipts from each product.

Next, the natural forest management, forest plantations, and deforestation sectors were regionally disaggregated. The product of the area of forest under sustainable forest management plans by region (MMA, 2008a) and the average land price by region (Reydon & Plata, 2000) was calculated. The proportion of this product by region was calculated and applied to the natural forest management sector's expenditure on forestland to obtain expenditure on forestland by region. The product of the area of forest plantations by region (Associação Brasileira de Celulose e Papel [BRACELPA], 2003) and the average land price by region (Reydon & Plata, 2000) was calculated. The proportion of this product by region was calculated and applied to the forest plantation sector's expenditure on agricultural land to obtain the forest plantation sector's expenditure on agricultural land by region. The product of the area deforested by region (MMA, 2008a) and the average land price by region (Reydon & Plata, 2000) was calculated. The proportion of this product by region was calculated and applied to the deforestation sector's expenditure on forestland to obtain the deforestation sector's expenditure on forestland by region.

Each forest sector's expenditure on indirect taxes was calculated proportional to the value of output from each of these sectors. The forest sectors' intermediate consumption was also calculated in this manner. Regional natural forest management, forest plantation, and deforestation sectors' expenditure on labor was calculated following the same procedure as for the agricultural sector; expenditures on capital were calculated according to proportional capital expenditures based on Cattaneo's (2002) SAM.

The product produced by the deforestation enterprise requires special attention. The deforestation product was calculated as a function of the product of the price differential between forested and agricultural land (Reydon & Plata, 2000), and the area deforested (MMA, 2008a). This amount summed with the deforestation sector's forest product output represents the deforestation sector's total receipts.

Disaggregating Labor and Households

Following Tourinho et al. (2003), labor was disaggregated into 6 types based on skill level and formal or informal participation in the labor market. Labor that formally participates in the market makes indirect tax payments (i.e. social security contributions), while informal labor does not. Low-skilled workers possess 0-8 years of schooling, mid-skilled workers possess from 9 to 11 years, and high-skilled workers have more than 11 years of schooling.

Households were disaggregated into 3 income categories: low-income, mid-income and high-income. Income disaggregation is a function of the number of minimum wages (240 reais per month is equal to 1 minimum wage) a household earns per month. The low-income household earns from 1 to 3 minimum wages per month, the mid-income household earns from 4 to 10 minimum wages per month, and the high-income household earns 11 or more minimum wages per month (Tourinho et al., 2006, p. 36).

The proportion of labor income paid to a particular household income class and to indirect taxes was based on proportions calculated from the IPEA SAM (Tourinho et al., 2006). A sector's payment to a particular labor class was based on the proportion of that labor class employed in that activity in the IPEA SAM (Tourinho et al., 2006, p. 34).

Distribution of land rent to households and the enterprise was based on the IPEA SAM (Tourinho et al., 2006, p. 38) and inferred from national household survey data (IBGE, 2004b). Tourinho et al. (2006) determined that the large number of informal low-skilled workers in the agricultural sector earning up to 1 minimum wage per month and the large number of informal low-skilled workers in the agricultural sector earning over 20 minimum wages is accounted for by the fact that some of these workers claim land rent as a portion of their income. On this basis, it was assumed that families earning up to 6 minimum wages do not receive land rent while those earning 8 or more minimum wages do. The amount of land rent included in returns to labor is the difference between declared labor income and the average labor income of families earning up to 6 minimum wages. This provides the imputed value of land rent for each household income class participating in agriculture and forestry, and the proportional receipt of land income for each household class (Tourinho et al., 2006, p. 38).

Household consumption by income class was based on national household expenditure survey data (IBGE, 2007b); a household class's share of the total consumption of each product was calculated based on the IPEA SAM. With regards to savings, it was assumed that households earning 6 or less minimum wages per month have negligible savings (Tourinho et al., 2006, p. 40).

Taxes

In the Brazilian SAM, indirect taxes on activities are the sum of effective social security contributions and other production taxes net of subsidies. Commodity taxes are the sum of a tax

on the circulation of merchandise and services (ICMS), a tax on industrialized products (IPI), and other taxes net of subsidies. Tariffs are import taxes on commodities. Direct taxes on households and enterprises are taxes on current income and property.

Balancing the Social Accounting Matrix

In constructing a SAM from a variety of data sources, as in the case of the Brazilian SAM, some imbalances between symmetrical row and column sums are unavoidable. To eliminate these imbalances, the cross-entropy balancing approach described in Robinson, Cattaneo and El-Said (2001) was employed. The procedure was executed in the General Algebraic Modeling System (GAMS), a software system designed for solving mathematical programming and optimization problems (GAMS, 2008). The program code is available in Robinson and El-Said (2000). Table 3-6 is a complete listing of all SAM accounts and Table 3-7 presents an aggregated version of the SAM developed for Brazil, reference year 2003[4].

Standard Computable General Equilibrium Model in GAMS

The model developed herein is based on the International Food Policy Research Institute's (IFPRI) Standard CGE Model. This model is implemented in GAMS and is solved as a mixed complimentary problem using the PATH solver. This model was developed by IFPRI to facilitate the use of CGE models in developing countries (Lofgren et al., 2002, p. vi). Although this model is very well documented in Lofgren et al (2002), the basic model structure is presented here following Lofgren et al. Appendix A provides a listing of the core model equations.

While the SAM is a numerical representation of the equilibrium payments and receipts between agents in the economy, the CGE model is developed to describe the behavior of these agents and their economic environment (Thurlow, 2004, p. 3). The model is a system of equations describing the utility maximizing behavior of consumers, profit maximizing behavior of producers, and the equilibrium conditions and constraints imposed by the economic

environment. Agent behavior is represented by linear and non-linear first order optimality conditions while the economic environment is described as a series of equilibrium constraints for factors, commodities, savings and investment, the government, and rest of the world accounts (Lofgren et al., 2002, p. 8). The model may be broken into a series of blocks, namely: production, factor markets, institutions, commodity markets, and macroeconomic balances. These are discussed in turn.

Production

The model allows for an activity to produce more than one commodity, while any particular commodity may be produced by more than one activity. Producers maximize profits subject to nested technological constraints described in Figure 3-5. At the bottom of the technology nest, domestic and imported commodities are aggregated into a composite intermediate input according to fixed shares. Value-added is created by a constant elasticity of substitution (CES) aggregation of primary factor inputs. Constant elasticity of substitution functions enable non-unitary though constant price elasticities (i.e. identical elasticities between all pairs of commodities), non-zero but constant substitution elasticities, and a unitary income elasticity (Annabi, Cockburn & Decaluwé, 2006, p. 9). Primary factors are used until the marginal revenue product for each factor is equal to its wage (Lofgren et al., 2002, p. 8). The wage paid to a particular factor can vary for each sector depending on the factor market closure. Intermediate and value added inputs are aggregated according to fixed shares. Since any one sector can produce more than one commodity, at the activity level, the commodities that a particular sector produces are determined by fixed yield coefficients.

Factor Markets

Factor market closures describe the mechanism by which the supply of a factor equilibrates with demand. The model allows for three main factor market closures, the choice of which

depends on the application and the temporal scale under consideration. The first closure fixes the quantity of a factor at the benchmark level allowing the economy-wide wage to adjust; the factor is fully employed and mobile between sectors. The second closure is a Keynesian closure where the economy-wide factor wage is fixed and the factor may go unemployed. The third closure is a segmented market closure where each industry hires the base-year quantities of a factor. In this closure, factor demand and the economy-wide wage are fixed and the industry-specific wage and supply are flexible (Lofgren et al., 2002, p. 9). This closure is often used for short-term analysis[5].

Institutions

The 8 institutions in the model are three household income classes, a deforestation institution, a general enterprise, an interest account, a government, and the rest of the world. Households purchase marketed commodities according to a linear expenditure system (LES) where households use their income to first consume a minimum level of subsistence goods and services. The income remaining after subsistence consumption (i.e. supernumerary income) is used to purchase commodities according to a linear relationship between income and consumption. The difference between the CES function and the LES function is that income elasticity in the LES function is non-unitary (Annabi et al., 2006, p. 13). All households pay direct taxes (income and property taxes); mid and high-income households also save. All households receive income from labor and capital, while mid and high-income households also receive income from returns to agricultural and forestland. In addition, households receive transfers from social security benefits, interest as property income, the enterprise (i.e. indirect income from factors), the government, and the rest of the world. Direct taxes and transfers to domestic institutions are computed as fixed shares of household income while savings are specified as flexible (Lofgren et al., 2002, p. 10). The deforestation institution receives all its

income from the returns to agricultural land and spends its income entirely on the deforestation product. It does not pay taxes, nor does it save.

The enterprise transfers factor income to households, pays direct taxes, pays interest as property income, and saves. The enterprise receives income from capital and agricultural and forestland. The difference between the behavior of households and the enterprise is that the enterprise does not consume. As in the case of households, direct tax payments and transfers are fixed shares of enterprise income, while savings are flexible. The interest account receives income from the government, the enterprise, and the rest of the world, and transfers its entire income to households.

The government receives income from the indirect, direct and commodity tax accounts as well as the tariff account. The government consumes, in particular, public goods and services produced by the public administration sector (e.g. public health, education and public security) and to a much lesser degree, private services. The government makes transfer payments to households which are indexed by the consumer price index, pays interest on property, and saves. Government savings may be negative and is treated as a flexible residual (Lofgren et al., 2002, p. 10). The rest of the world purchases exports, makes transfers to households, and receives (when the column entry is negative) income from interest. The rest of the world's savings is the current account deficit (when the column entry is negative), which is the difference between a country's expenditure and its receipts (Lofgren et al., 2002, p. 11). The rest of the world receives income from imports.

Commodity Markets

Outputs of a particular commodity from different sectors are treated as imperfect substitutes due to potential differences in the timing and quality of output, and the distance to markets. As a result, commodity prices are sector-specific. The demand for a sector's output is

determined by minimizing the cost of supplying the aggregate commodity subject to the CES function (Lofgren et al., 2002, p. 11). Aggregate domestic output is allocated to domestic and foreign markets with producers maximizing revenues subject to a constant elasticity of transformation (CET) function. Demand for exports is infinitely elastic at fixed world prices. Domestic consumer demand is for a composite commodity composed of imports and domestic output. In determining domestic demand, the Armington assumption is utilized where consumers minimize costs subject to imperfect substitutability between domestically produced and imported goods. International supplies of goods are infinitely elastic at fixed prices. The Armington assumption allows for some flexibility between domestic and world prices thereby assuring that the domestic market clears.

Macroeconomic Balances

There are three macroeconomic balances in the model: the government current account balance, the current account of the balance of payments, and the savings and investment balance. Decisions regarding these balances are known as closure rules which are required to maintain a balanced economic environment. Amartya Sen (1963 in Dewatripont & Michel, 1986, p. 65) determined that the assumption of equality of savings and investment is not guaranteed in an economy where labor is fully employed, factors of production are paid up until their marginal productivity, household consumption is solely a function of real income, and there is a fixed amount of investment. In order for economic equilibrium to be achieved, one of the four of these conditions must be relaxed. In essence, the system is over-determined with one more equation than variable.

With regards to the government account, tax rates may be fixed with government savings calculated as a flexible residual. Alternatively, government savings may be fixed and direct tax rates flexible. The current account of the balance of payments may be maintained by a flexible

real exchange rate and fixed foreign savings which implies a fixed trade balance. Alternatively, the real exchange rate may be fixed allowing for a flexible current account deficit and trade balance.

There are three main types of closures for the savings and investment balance: a balanced closure, the Johansen closure and a neoclassical closure. The balanced closure is a variation of the investment-driven closure where investment and government consumption shares are fixed while the quantities are flexible. Changes in absorption are distributed between household and government consumption, and investment. Nominal absorption shares of investment and government consumption are fixed at their base year levels. With other investment-driven closures, government consumption is fixed in real terms. The balanced closure is preferable for examining the probable economic impacts of policy shocks since it is a more accurate representation of how real world economies have tended to behave (Lofgren et al., 2002, p. 16).

The Johansen closure is investment-driven where the real quantity of investment is fixed and savings rates for non-government institutions adjust to equal the investment cost. It combines fixed foreign savings, fixed real investment, and fixed real government consumption and is often used to examine the welfare implications of policies (Lofgren et al., 2002, p. 16). It is assumed that the government implements policies to generate sufficient non-government domestic institutional savings to cover the cost of the investment bundle (Lofgren et al., 2002, p. 15).

The neoclassical closure is savings-driven where investment is the sum of private, government and foreign savings. In this case, investment is flexible while all non-government institutions have fixed marginal propensities to save. Changes in absorption are largely absorbed by investment (Lofgren et al., 2002, p. 15). The savings and investment market is cleared by

assuming that an interest adjustment mechanism exists outside of the model (Bandara, 1991, p. 17).

The choice of closure rules can have a significant impact on model behavior (Dewatripont & Michel, 1987, p. 66). Robinson (1988, in Kraev, 2003, p. 16) determined that the sectoral distribution of income is sensitive to the closure rule adopted. The Johansen closure for example, avoids the misleading result of household welfare improving as a function of increased foreign savings and decreased investment (Lofgren et al. 2002, p. 16). Given the potential sensitivity of model behavior to the closure rules chosen, it is good practice to model policy shocks in a number of macroeconomic closure settings.

Scenario Design

Brazil's 2007-2008 Annual Forest Granting Plan (SFB, 2007c), the government's first annual declaration of priority areas for forest management on public land, identifies 3.96 million hectares of public forests in the Amazon as priority areas for forest concessions. Of this area, it is estimated that 1 million hectares will be allocated to forest concessions in 2008. Annual production from these first concessions is estimated at 610,000 m^3 of roundwood and 670,000 m^3 of logging residuals, generating gross revenues of $120 million reais per year and creating 8,600 jobs[6]. With over 2.1 million hectares of forest with active Sustainable Forest Management Plans in 2003, establishing concessions on 1 million hectares of public forestland implies a 47% increase in available forestland. This scenario is modeled by increasing the factor supply of forestland in Brazil's northern region by an equivalent amount. Given the potential influence macroeconomic closures may have on model results, the factor supply shock is examined under a balanced closure, neoclassical closure, and Johansen closure.

With regards to factor closures, since the current analysis is short-run, it is appropriate to segment the labor and capital markets where each sector employs the base-year quantity of

capital and labor (Lofgren et al., 2002, p. 9). In this case, economy-wide wages are fixed and activity-specific wages and supply are flexible. Forestland and agricultural land are fixed and mobile between sectors. A flexible real exchange rate is chosen for the rest of the world closure which reflects current Brazilian government policy. The government closure fixes direct tax rates while government savings are flexible. The domestic price index is chosen as the numeraire.

Simulation Results

Comparing Simulation Results under Balanced, Neoclassical and Johansen Closures

The gross domestic product at market prices under the balanced, neoclassical and Johansen closures were very similar (0.01%, 0.00%, and 0.01%, respectively; Appendix B, Table B-1). Under the balanced and Johansen closure, the consumer price index increased, while for the neoclassical closure, the index decreased (0.02%, 2.00% and -1.19%, respectively). The Brazilian currency depreciated under the balanced and neoclassical closures (-0.01% and -0.91%, respectively) and appreciated under the Johansen closure (2.00%).

The government savings to GDP ratio remained unchanged in the balanced closure and increased under the neoclassical and Johansen closures (0.00%, 4.10% and 2.60%, respectively; Table B-1). Fixed investment was not affected under the balanced and Johansen closures and increased under the neoclassical closure (0.39%). The investment to GDP ratio remained unchanged under the balanced closure and increased in the neoclassical and Johansen closures (0.00%, 4.70% and 0.50%, respectively). Household marginal propensity to save increased for mid-income and high-income households and the enterprise under the balanced and neoclassical closures (balanced closure: 0.57%, 0.04% and 0.01%, respectively; neoclassical closure: 0.01%, 0.15% and 0.41%, respectively), and decreased for mid-income and high-income households and the enterprise under the Johansen closure (-218.82%, -14.11% and -5.35%, respectively).

Low-income, mid-income and high-income household consumption expenditures were unchanged under the balanced closure. In the neoclassical and Johansen closures, low and mid-income household consumption increased (neoclassical: 2.10% and 0.20%, respectively; Johansen: 0.70% and 0.10%, respectively; Table B-1) while high-income household consumption decreased in the neoclassical and Johansen closures (-0.90% and -0.20%, respectively). All household classes and the enterprise earned more under the balanced closure (0.05%, 0.05%, 0.04% and 0.01% for low, mid and high-income households and the enterprise, respectively; Table B-2). Under the neoclassical and Johansen closures, low income households and the enterprise earned more while mid-income and high-income households earned less (neoclassical: 0.96%, 4.88%, -0.99% and -2.13%; Johansen: 0.49%, 0.92%, -0.07% and -0.80%, respectively). Equivalent variation remained unchanged under the balanced closure; it increased for low-income and mid-income households and decreased for high income households under the neoclassical and Johansen closures (neoclassical: 2.10%, 0.20% and -0.90%, respectively; Johansen: 0.70%, 0.10% and -0.20%, respectively; Table B-3)[7].

Labor income increased for all labor classes under the balanced closure, but decreased for all but low-skilled informal labor in the neoclassical and Johansen closures (Table B-4). Capital income was greatest under the neoclassical closure, compared with the balanced and Johansen closures (5.30%, 0.13% and 0.98%, respectively). Factor income for forestland and agricultural land were generally quite similar between closures.

Under the Johansen closure, all composite good prices except for forest products and public services (-6.54% and -15.04%, respectively; Table B-5) increased by between 1.88% and 3.22%. Composite good prices were similar between the balanced and neoclassical closures with the exception of construction goods and public services.

With regards to the factor price for a particular activity, the most notable differences were found between the balanced and neoclassical closures for all labor skill classes in the construction sector (Table B-6) and between the balanced closure when compared to the neoclassical and Johansen closures for all labor skill classes in the public services sector. The change in the price of capital was also much higher in the neoclassical closure for the construction sector and lower in the neoclassical and Johansen closures for the public services sector.

Levels of domestic activity, the quantity of factor demand by industry and the quantity of domestic sales were quite similar under all three closures (Tables B-7, B-8, and B-9, respectively). Changes in exports were also similar under all three closures with the exception of construction exports. The change in quantity of composite goods and services supply was very similar between closures (Table B-10).

In summary, with few exceptions, the price of composite goods, factor demand, factor prices, factor income with the exception of labor, levels of domestic activity, domestic sales, exports, and the quantity of composite goods supply were very similar between closures. Gross domestic product at factor prices was identical between closures. The greatest variations in results were in savings and investment behavior and were driven by the manner in which savings and investment were brought into balance.

As previously discussed, under a balanced closure, changes in absorption are distributed between household and government consumption and investment, while nominal absorption shares of investment and government consumption are fixed at base year levels. As a result, changes in absorption have a noticeable effect on institutional marginal propensity to save and private consumption.

The neoclassical closure is savings-driven where investment is the sum of private, government, and foreign savings, while investment is flexible. With changes in absorption compensated for by adjustments in investment, there is an increase in the investment to GDP ratio and in fixed investment (4.10% and 0.39%, respectively) which is met by increases in mid and high-income household and enterprise marginal propensity to save, and an increase in the government savings to GDP ratio. As a result of increased private savings, private consumption declines overall.

In the case of the investment-driven Johansen closure, the real quantity of investment is fixed while household and enterprise savings rates adjust to purchase the investment bundle. Government consumption in this closure is fixed in real terms. Under this closure, overall, households consume more and save less. The increase in the investment to GDP ratio is largely met by an increase in the government savings to GDP ratio.

Simulation Results and Interpretation in a Balanced Macroeconomic Environment

Simulations undertaken in a balanced macroeconomic closure environment are preferable for evaluating the real-world impacts of policies and to aid the design of complimentary policies. This section presents detailed results of the forest concessions policy experiment in a balanced macroeconomic environment.

Gross domestic product at market and factor prices increased by 0.01% (Table 3-8). There was a small increase in the consumer price index (0.02%) indicating potential inflationary pressure. The Brazilian currency depreciated by -0.01%. Absorption increased by 0.01%. Imports declined by -0.01% while exports were unaffected. Real government consumption and the government to GDP savings ratio remain unchanged.

Private consumption increased by 0.02% (Table 3-8). Low, mid, and high-income household income increased (0.05%, 0.05% and 0.04% respectively: Table 3-9). Enterprise

income increased by 0.01%. The marginal propensity to save of mid and high-income households and the enterprise increased (0.57%, 0.04% and 0.01% respectively; Table 3-8). Equivalent variation remained unchanged for all households (Table 3-10).

Labor became significantly more expensive for the natural forest management sector in the north (143.65%; Table 3-13); the price of labor for the natural forest management sector in other regions dropped by between -9.40% and -14.82%. The price of labor increased for the processed wood and pulp and cellulose sectors (2.68% and 2.50%, respectively); it also increased for the deforestation sector in the north (18.84%) and decreased in the north east and center west (-6.96% and -5.89%, respectively). The price of labor decreased by a small amount for the agricultural sector in the north, north east and center west, and increased in the south east and south (-0.13%, -0.11%, -0.13%, 0.54% and 0.32%, respectively). With regards to the forest plantations sector, the price of labor decreased substantially in all regions (-13.57%, -14.40%, -20.43%, -26.08% and -15.99% in the north, north east, south east, south and center west, respectively). The price of labor increased marginally for all other sectors with the exception of the mining and petroleum and commerce sectors. The price of capital followed the aforementioned trends. The price of forestland for the forestry and deforestation sectors decreased by the same amount for both sectors (-64.47%, -14.25%, -9.40%, -9.54% and -11.14 in the north, north east, south east, south and center west, respectively). The price of agricultural land for the agriculture and forest plantations sectors decreased for both sectors by the same amount in the north, north east, south east, south and center west (-0.17%, -0.38%, -6.79%, -1.81% and -0.17%, respectively).

Both labor and capital factor income increased between 0.07% and 0.13% (Table 3-11). Forestland factor income declined in the north, north east, south east, south and center west (-

48.13%, -14.25%, -9.40, -9.54% and -11.14%, respectively). Agricultural land income in the north, north east, south east, south and center west declined, particularly in the south east (-0.17%, -0.38%, -6.79%, -1.81% and -0.17%, respectively).

There was a substantial decline in forest product prices and a very small decline in the price of processed wood and pulp and cellulose (-8.44%, -0.01% and -0.01%, respectively; Table 3-12). The composite good prices of agriculture, mining and petroleum, and commerce decreased by a small margin while the prices of industrial goods and services, processed food, utilities, construction, transportation, private services, and public services increased by a small amount.

In terms of the natural forest management sector's level of domestic activity, there was a large expansion in the north, a small contraction in the north east and center west, and no change in the south and south east (24.68%, -0.02%, -0.01%, 0.00% and 0.00%, respectively; Table 3-14). As a result of the implementation of forest concessions in the north, there was a simultaneous contraction of the forest plantation sector, particularly in the south and south east (-3.71% and -2.40%, respectively) and to a lesser degree in the north, north east and center west (-0.56%, -0.62% and -1.29%, respectively). Deforestation expanded in the north, north east and center west (1.20%, 0.14% and 0.09%, respectively). In the agricultural sector, there was an expansion in all regions except the north on the order of between 0.01% and 0.19%. All other sectors exhibited no change in their level of activity. There were small changes in the quantity of composite goods supply, the most significant of which was for forest products (0.37%; Table 3-17). The supply of all other goods and services were little affected.

Domestic sales of agricultural products, forest products, industrial products and processed food all increased (0.05%, 1.95%, 0.01% and 0.02%, respectively; Table 3-16) while there were

no changes in the domestic sales of all other goods and services. Agricultural product and forest product exports increased by 0.31% and 14.55%, respectively. There were small contractions in industrial, processed food, construction, transportation and private services exports on the order of between -0.04% and -0.09%, and no change in all other sectors.

Forest sector demand for forestland increased in the north (46.97%; Table 3-15), decreased in the north east (-0.13%) and center west (-0.01%) and presented no change in the south east and south. Deforestation demand for forestland increased in the north, north east and center west (6.22%, 0.41% and 0.29%, respectively). Forest plantations demanded less agricultural land in the north, north east, south east, south and center west (-2.84%, -2.99%, -3.11%, -5.52% and -3.39%, respectively). Agriculture demanded more agricultural land in the north, north east, south east, south and center west (0.01%, 0.06%, 1.83%, 0.52% and 0.01%, respectively).

In summary, the forest concessions policy resulted in an increase in gross domestic product as well as household income and private consumption. As a result of the expansion of forestlands for natural forest management in the north and taking into consideration the full employment assumption for land in the model, the overall demand for forestland in the north increased by the simulated amount of 47%. As a consequence, the price of forestland, particularly in the north, dropped significantly with the reduced scarcity. The large increase in forest sector activity in the north resulted in higher labor and capital costs for this sector, taking into consideration the segmented labor and capital markets. With a fixed economy-wide wage for labor and capital, a full factor employment closure, and increased scarcity due to the forest concessions policy, both labor and capital income increased.

A significant implication of the forest concessions policy is the simultaneous expansion of natural forest management in the north and the contraction of forest plantations in all regions.

Smaller contractions in the natural forest management sector also occurred in the north east and center west. As a result of this contraction, labor, capital, forestland and agricultural land became substantially less expensive for the forest plantations sector in all regions as well as for the natural forest management sectors in all regions with the exception of the north.

Increased natural forest management activity in the north resulted in a decrease in forest product prices and an increase in sales, particularly in forest product exports which increased by almost 15%. The reduction in forest product prices was not completely transferred to its principal intermediate consumers, the processed wood and pulp and cellulose sectors. This is in part attributable to the higher capital and labor costs incurred by these sectors as a result of the forest concessions policy.

As a consequence of the contraction of the forest plantation sectors in all regions, these sectors demanded less agricultural land. Given the full-employment assumption for land, this supply was taken up by the agricultural sector which simultaneously increased activity and output in all regions, in particular in the south east and south where forest plantation production was concentrated. The reduction in forest plantation's demand for agricultural land also translated into a reduction in the price and income of agricultural land in all regions, which had implications for levels of deforestation. The reduction in agricultural product prices benefited consumers to some degree, however, this reduction in price was not transmitted to the processed food sector which produced a more expensive composite good. This result is partially explained by the increased labor and capital costs that this sector confronted. Increased labor and capital income, however, enabled households to cope with a general price increase as reflected by the consumer price index.

Implications for Deforestation

In the base year of 2003, there were 125,307 hectares legally deforested in the north and 68,263 and 16,462 hectares legally deforested in the north east and center west respectively for a total of 210,032 hectares. Simulation results indicated that the deforestation sector's demand for forestland increased by 6.22%, 0.41% and 0.29% in the north, north east and center west respectively. Overall, the forest concessions policy resulted in a 3.8% increase in legal deforestation. This result may be explained by the interaction of the returns to agricultural and forestland, the price of forest products and the deforestation sector's output of forest products. The price of agricultural and forestland declined in all regions due to the forest concessions policy. While the deforestation sector's output of forest products increased in the north, north east and center west, the price of forest products declined. While the reduction in agricultural land income and the value of forest product output reduced the amount of income perceived by the deforestation institution, the decrease in the price of forestland rendered deforestation cheaper. As a result, the reduction in income was more than offset by the reduction in the price of forestland and the deforestation sector increased output of its composite good (forest products and cleared land).

Conclusions

The forest sector is an important component of the Brazilian economy, accounting for 3.5% of gross domestic product and 8.4% of exports, and generating 2 million formal jobs. Over 500,000 families settled in the Brazilian Amazon depend on forestry as a component of their livelihood system. Though the majority of the legal timber harvest is currently conducted on private land, over 1 million km² of public forestland has been identified as suitable for the production of forest goods and services. Brazil's Public Forest Management Law which passed in 2006 includes a framework for establishing forest concessions on these public forestlands.

Such a framework for promoting natural forest management in Brazil is unprecedented and presents a tremendous opportunity for forest-based socio-economic development.

In light of the proposed scale of forest concessions in the Amazon, the importance of the forestry sector to the economy and to the region's inhabitants, analysis of the forest concessions policy in a quantitative framework can provide important clues as to the potential impacts of the policy and indications of complimentary policies that may serve to counteract unintended negative consequences of policy implementation. As such, a computable general equilibrium model was developed to analyze the socio-economic and environmental impacts of forest concessions.

Simulating the implementation of forest concessions in a general equilibrium framework, three general conclusions are made:

1. Household income and private consumption increase with the implementation of forest concessions. Though there is a general increase in the price of consumer goods, households are able to cope with this increase due to their increased income.

2. The expansion of natural forest management in the north results in a significant contraction of forest plantation production in all regions and to a lesser degree, natural forest management in the north east and center west. The increased output from the north squeezes out plantation production by bringing less expensive timber to the market. As the forest plantation sector demands less agricultural land for production, the price of agricultural land decreases. The excess supply of agricultural land is taken up by the agricultural sector, which pays less for the land and consequently is able to produce more of a less expensive agricultural product.

3. The implementation of forest concessions results in an increase in legal deforestation by 3.8% in Brazil, with the greatest percentage increase in the north, followed by the north east and center west. This may be explained by the interaction of agricultural land prices, forest product prices and forestland prices. The deforestation institution perceived less income from agricultural land due to the drop in its price. Although the deforestation sector's output of forest products increased, the decline in forest product prices also resulted in a reduction in forest product income. These results, all other things being equal, would imply a reduction in the level of deforestation. However, with the substantial drop in the price of forestland in all regions, the reduction in the deforestation institution's income was more than offset by the reduced expenditure on forestland. Thus, the net effect was that the deforestation sector expanded its deforestation and forest product output.

What this analysis does not consider explicitly are the illegal forestry and illegal deforestation sectors and how they may be expected to behave with the implementation of the forest concessions. In order to more realistically and fully evaluate the potential socio-economic and environmental impacts of forest concessions, the chapter that follows disaggregates and models an illegal forestry and illegal deforestation sector. To enable the updating of agricultural land stocks resulting from deforestation and to consider the medium-term implications of the policy, a recursive dynamic computable general equilibrium modeling framework is developed and employed.

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[1] The average exchange rate in 2006 was 2.2 reais to the US dollar.

[2] Brazil's administrative regions are north, north east, south east, south, and center west. The northern region is composed of the states of Rondônia, Acre, Amazonas, Roraima, Pará, Amapá, and Tocantins. The north eastern region is Maranhão, Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe, and Bahia. The south east is Minas Gerais, Espírito Santo, Rio de Janeiro, and São Paulo. The south is Paraná, Santa Catarina, and Rio Grande do Sul. The center west is Mato Grosso do Sul, Mato Grosso, Goiás, and the Distrito Federal.

[3] Expenditure on transportation is deducted since Cattaneo employs a different treatment of transportation margins.

[4] For the full disaggregated version of the social account matrix developed for Brazil, please contact the author.

[5] The closures employed in the modeling experiments to follow are detailed in the Scenario Design section.

[6] The average exchange rate for the first 210 days of the year 2008 was 1.7 reais to the US dollar.

[7] Equivalent variation is measured at the level of prices and income present prior to the implementation of a policy. It is the minimum payment the consumer would need to forgo the policy change. In other words, it is the amount the consumer would need to receive to be as well-off if the policy had been implemented. A positive equivalent variation indicates an improvement in welfare.

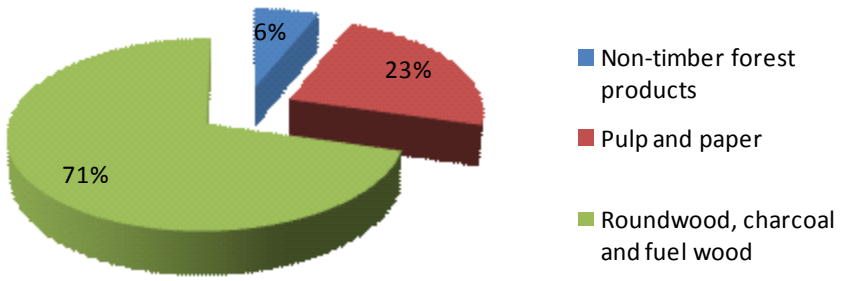

Figure 3-1. Relative output value of forest products. Source: IBGE, 2007a

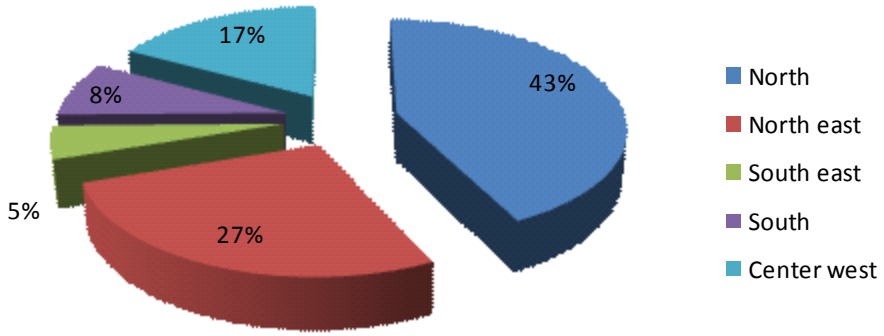

Figure 3-2. Regional distribution of roundwood, charcoal and fuelwood production value from natural forests. Source: IBGE, 2007a

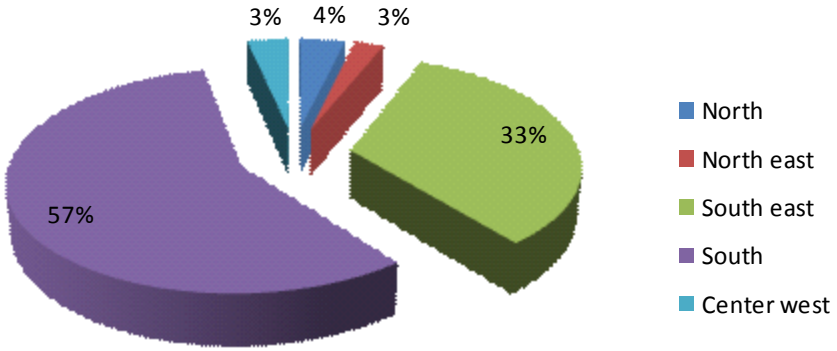

Figure 3-3. Regional distribution of wood, charcoal and fuelwood production value from forest plantations. Source: IBGE, 2007a

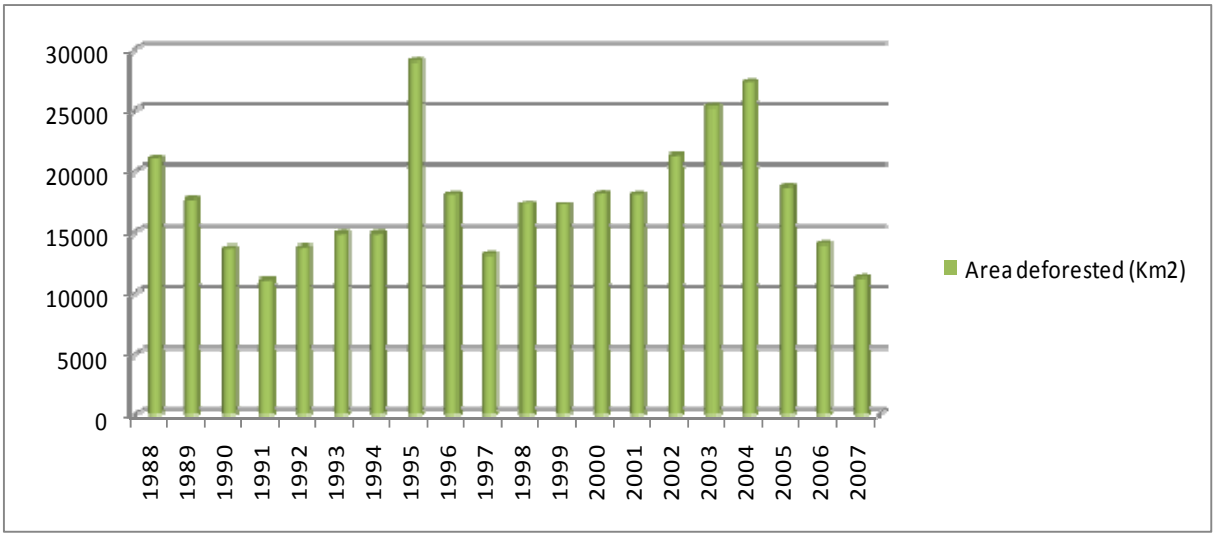

Figure 3-4. Area deforested 1988 to 2007. Source: INPE, 2007

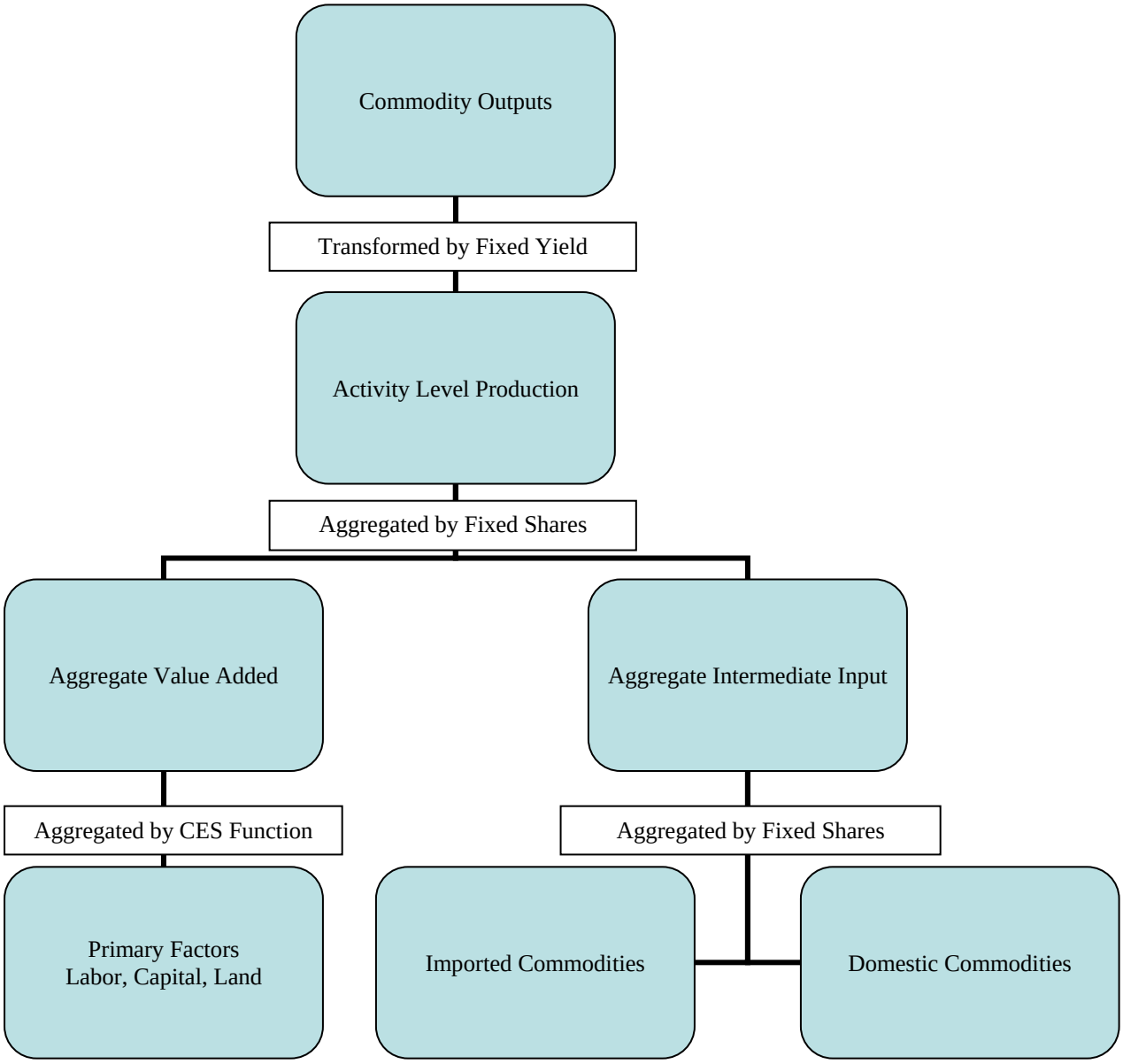

Figure 3-5. Structure of production

Table 3-1. Areas with forest management plans and areas with deforestation authorizations

Region	Forest management plan (Ha)	(%)	Deforestation authorization (Ha)	(%)
North	1959976	91.9	125307	59.7
Northeast	5117	0.2	68263	32.5
Center west	166863	7.8	16462	7.8
Total	2131956	100.0	210032	100.0

Source: MMA, 2008a.

Table 3-2. Area reforested in 2006

Region	Area planted (Ha)	Percent area planted (%)
North	34500	6
North east	94500	15
South east	275000	44
South	175000	28
Center west	48000	8
Total	627000	100

Source: MMA, 2008b.

Table 3-3. Brazilian social accounting matrix mapping of activities to national accounts

BRASAM sector	BRASAM sector code	National accounts sector	National accounts sector code
Agriculture, livestock, ranching and fishing	A-AGR	Agriculture, silviculture, forest harvesting	101
		Ranching and fishing	102
Natural forest management	A-FOR	Agriculture, silviculture, forest harvesting	101
Forest plantations	A-PLNT	Agriculture, silviculture, forest harvesting	101
Deforestation	A-DEF	Based on other data	
Mining, other extractive industries, petroleum and natural gas	A-MINPET	Iron mining	202
		Other extractive industries	203
		Petroleum and natural gas	201
Manufacturing	A-IND	Cement	319
		Other products of non-metallic minerals	320
		Manufacture of steel and derivatives	321
		Metallurgy of non-iron metals	322
		Metal production except machinery and equipment	323
		Machines and equipment including maintenance and repair	324
		Electro domestic appliances	325
		Electric machines, equipment and materials	327
		Office machines and informatics equipment	326
		Electronic equipment and communications equipment	328
		Medical equipment and instruments	329
		Cars, pick-up trucks and jeeps	330
		Trucks and buses	331
		Parts and accessories for motor vehicles	332

Table 3-3. Continued

BRASAM sector	BRASAM sector code	National accounts sector	National accounts sector code
		Other transportation equipment	333
		Plastic and rubber articles	318
		Alcohol	310
		Chemical products	311
		Agricultural pesticides/herbicides	314
		Paint, varnish, enamels and lacquers	316
		Diverse chemical products	317
		Resin and elastomers	312
		Petroleum and coke refining	309
		Pharmaceutical products	313
		Perfume, hygiene and cleaning products	315
		Textiles	303
		Clothing and accessories	304
		Leather goods and shoes	305
		Furniture and other diverse industries	334
		Newspapers, magazines and disks	308
Wood processing	A-SAW	Wood products, except furniture	306
Pulp and paper products	A-PULP	Cellulose and paper products	307
Food processing	A-FPR	Food and drinks	301
		Smoking products	302
Public utilities	A-UTI	Electricity, gas, water, sewage and urban cleaning	401
Construction	A-CON	Construction	501
Commerce	A-COM	Commerce	601
Transportation, storage and postal services	A-TRN	Transportation, storage and postal services	701

Table 3-3. Continued

BRASAM sector	BRASAM sector code	National accounts sector	National accounts sector code
Private services	A-SER	Information services	801
		Maintenance and repair services	1101
		Food and shelter services	1102
		Services rendered to enterprises	1103
		Private education	1104
		Private health	1105
		Other services	1106
		Finance and insurance brokers	901
		Real estate and rental services	1001
Public services	A-ADM	Public education	1201
		Public health	1202
		Public administration and social security	1203

Notes: BRASAM is the Brazilian social accounting matrix, reference year 2003.

Table 3-4. Brazilian social accounting matrix mapping of products to national accounts

BRASAM product	BRASAM product code	National accounts product	National accounts product code
Agricultural products	P-AGR	Rice	010101
		Corn	010102
		Wheat and other cereals	010103
		Sugar cane	010104
		Soybean	010105
		Other agricultural products and services	010106
		Yucca	010107
		Tobacco	010108
		Cotton	010109
		Citric fruits	010110
		Coffee	010111
		Cattle and other animals	010201
		Milk	010202
		Swine	010203
		Birds	010204
		Eggs	010205
		Fish and aquaculture	010206
Forest products	P-FOR	Forest products	010112
Deforestation product	P-DEF	Based on other data	
Mining, petroleum and natural gas	P-MINPET	Petroleum and natural gas	020101
		Iron mining	020201
		Coal	020301
		Non-iron mining	020302
		Non-metallic minerals	020303
Industrial goods	P-IND	Cotton processing	030301
		Textiles	030302
		Other textiles	030303
		Garments and accessories	030401
		Leatherwork except shoes	030501
		Shoes	030502
		Paper and packaging	030702
		Newspapers, magazines and disks	030801
		Liquefied gas from petroleum	030901
		Automobile gasoline	030902
		Gas-alcohol blend	030903
		Combustible oil	030904

Table 3-4. Continued

BRASAM product	BRASAM product code	National accounts product	National accounts product code
		Diesel oil	030905
		Other refined petroleum products and coke	030906
		Alcohol	031001
		Inorganic chemicals	031101
		Organic chemicals	031102
		Resins and elastomers	031201
		Pharmaceutical products	031301
		Agricultural chemicals	031401
		Beauty and hygiene products	031501
		Paint, varnish, enamel and lacquer	031601
		Diverse chemicals	031701
		Rubber goods	031801
		Plastic goods	031802
		Cement	031901
		Other non-metallic mineral products	032001
		Pig iron	032101
		Steel tubes and sheets	032102
		Metallurgical non-iron products	032201
		Casted steel	032202
		Metal products except equipment and machines	032301
		Machines and equipment including maintenance and repair	032401
		Electro domestic products	032501
		Office machinery	032601
		Machines, equipment and electronic materials	032701
		Electronic and communication equipment	032801
		Medical and optical instruments	032901
		Automobiles, pick-up trucks and wagons	033001
		Trucks and buses	033101
		Auto parts	033201
		Other transportation equipment	033301
		Furniture and other diverse industrial products	033401
		Scrap iron	033402
Wood products	P-SAW	Wood products except furniture	030601

Table 3-4. Continued

BRASAM product	BRASAM product code	National accounts product	National accounts product code
Pulp and paper	P-PULP	Cellulose and pulp	030701
Processed food	P-FPR	Animal slaughter and preparation	030101
		Fresh or frozen swine	030102
		Fresh or frozen birds	030103
		Industrialized fish	030104
		Preserved fruits and vegetables	030105
		Soybean derivatives	030106
		Other vegetable and animal oils except corn	030107
		Refined soybean oil	030108
		Refrigerated, sterilized and pasteurized milk	030109
		Milk products and ice cream	030110
		Processed rice and derivatives	030111
		Wheat flour and derivatives	030112
		Yucca flour and others	030113
		Corn oil, starch and rations	030114
		Refined sugar and related products	030115
		Toasted and ground coffee	030116
		Instant coffee	030117
		Other food products	030118
		Beverages	030119
		Tobacco products	030201
Utilities	P-UTI	Electricity, gas, water, sewage and urban sanitation	040101
Construction	P-CON	Construction	050101
Commerce	P-COM	Commerce	060101
Transportation	P-TRN	Freight transport	070101
		Passenger transport	070102
		Mail	070103
Private services	P-SER	Information services	080101
		Financial intermediary services and insurance	090101
		Real estate services	100101
		Imputed rent	100102
		Maintenance and repair services	110101
		Housing and alimentary services	110201

Table 3-4. Continued

BRASAM product	BRASAM product code	National accounts product	National accounts product code
		Services provided by businesses	110301
		Commercial education	110401
		Commercial health	110501
		Family services	110601
		Associated services	110602
		Domestic services	110603
Public services	P-ADM	Public education	120101
		Public health	120201
		Public and social services	120301

Notes: BRASAM is the Brazilian social accounting matrix, reference year 2003.

Table 3-5a. Brazilian national accounts sources for the social accounting matrix

	Act	Com	Lab	Cap	Hh	Itax	Dtax	Tar	Ctax	Int	Ent	Gov	Row	S-i	Dstk	Tot
Act		1														2
Com	3				4							4	4	4	4	5
Lab	6															7
Cap	8															9
Hh			10	11						12	13	13	13			14
Itax	15		16													17
Dtax					18						18					19
Tar		20														21
Ctax		22														23
Int											24	24				25
Ent				26												27
Gov						28	29	30	31							32
Row		33	34							12						35
S-i					36						36	36	37			38
Dstk														39		40
Tot	41	42	43	44	45	46	47	48	49	50	51	52	53	54	40	

Notes: Numbers in this table refer to the Brazilian national accounts sources described in table 3-5b. Key to abbreviations: Act: activities; Com: commodities; Lab: labor; Cap: capital; Hh: households; Itax: indirect taxes; Dtax: direct taxes; Tar: tariffs; Ctax: commodity taxes; Int: interest; Ent: enterprises; Gov: government; Row: rest of the world; S-i: savings and investment; Dstk: change in stocks; Tot: total.

Table 3-5b. Key to table 3-5a

Reference number	Brazilian national accounts source
1	T1: Activity production (includes margins)
2	Activity income
3	T2: Intermediate activity consumption
4	T2: Final demand
5	Demand
6	T2: Value added (salaries)
7	Labor income
8	T2: Value added (gross operating surplus and mixed income)
9	Capital income
10	T2: Value added (salaries net of social security payments)
11	T2: Value added (gross operating surplus and mixed income)
12	CEI: Property income
13	Calculated as a residual
14	Household income
15	T2: Value added (effective social security contributions and other production taxes net of subsidies)
16	Private contributions to official social security system
17	Indirect tax receipts
18	CEI: Current income and property taxes
19	Direct tax receipts
20	T1: Supply of goods and services (import tax)
21	Tariff receipts
22	T1: Supply of goods and services
23	Commodity tax receipts
24	CEI: Property income
25	Interest receipts
26	T2: Value added (gross operating surplus and mixed income)
27	Enterprise income
28	Transfer of total indirect tax to government account
29	Transfer of total direct taxes to government account
30	Transfer of total tariffs to government account
31	Transfer of total commodity taxes to government account
32	Government income
33	T1: Goods and services imports
34	CEI: Labor payment from the rest of the world
35	Foreign exchange outflow
36	CEI: Gross savings
37	CEI: Current account balance
38	Savings
39	T2: Final demand
40	Change in stocks
41	Activity expenditure
42	Supply expenditure

Table 3-5b. Continued

Reference number	Brazilian national accounts source
43	Labor expenditure
44	Capital expenditure
45	Household expenditure
46	Indirect tax transfers
47	Direct tax transfers
48	Tariff transfers
49	Commodity tax transfers
50	Interest transfers
51	Enterprise expenditure
52	Government expenditure
53	Foreign exchange inflow
54	Investment

Notes: T refers to table. CEI refers to Integrated Economic Accounts. Households include non-government institutions. Enterprises include financial enterprises.

Table 3-6. Brazilian social accounting matrix accounts, reference year 2003

Account	Description
A-NAGR	Agricultural sector north
A-NEAGR	Agricultural sector north east
A-SEAGR	Agricultural sector south east
A-SAGR	Agricultural sector south
A-CWAGR	Agricultural sector center west
A-NFOR	Natural forest management sector north
A-NEFOR	Natural forest management sector north east
A-SEFOR	Natural forest management sector south east
A-SFOR	Natural forest management sector south
A-CWFOR	Natural forest management sector center west
A-NPLNT	Forest plantation sector north
A-NEPLNT	Forest plantation sector north east
A-SEPLNT	Forest plantation sector south east
A-SPLNT	Forest plantation sector south
A-CWPLNT	Forest plantation sector center west
A-NDEF	Deforestation sector north
A-NEDEF	Deforestation sector north east
A-CWDEF	Deforestation sector center west
A-MINPET	Mining, petroleum and natural gas
A-IND	Manufacturing sector
A-SAW	Wood processing sector
A-PULP	Wood pulp sector
A-FPR	Processed food sector
A-UTI	Utilities
A-CON	Construction
A-COM	Communications
A-TRN	Transportation
A-SER	Private services
A-ADM	Public administration
P-AGR	Agricultural products
P-FOR	Forestry products
P-DEF	Deforestation product
P-MINPET	Mining, petroleum and natural gas products
P-IND	Manufactured products
P-SAW	Wood products
P-PULP	Pulp products
P-FPR	Processed food products
P-UTI	Utilities
P-CON	Construction
P-COM	Communications

Table 3-6. Continued

Account	Description
P-TRN	Transportation
P-SER	Private services
P-ADM	Public services
F-LF	Low-skilled formal labor
F-LIF	Low-skilled informal labor
F-MF	Mid-skilled formal labor
F-MIF	Mid-skilled informal labor
F-HF	High-skilled formal labor
F-HIF	High-skilled informal labor
F-CAP	Capital
F-NAGLD	Agricultural land north
F-NEAGLD	Agricultural land north east
F-SEAGLD	Agricultural land south east
F-SAGLD	Agricultural land south
F-CWAGLD	Agricultural land center west
F-NFRLD	Forest land north
F-NEFRLD	Forest land north east
F-SEFRLD	Forest land south east
F-SFRLD	Forest land south
F-CWFRLD	Forest land center west
H-HL	Low-income household
H-HM	Mid-income household
H-HH	High-income household
H-DEFLND	Deforestation institution
INDTAX	Indirect tax
DIRTAX	Direct tax
TAR	Tariffs
COMTAX	Commodity taxes
INT	Interest
ENT	Enterprises
GOV	Government
ROW	Rest of the world
S-I	Savings and investment
DSTK	Change in stocks

Table 3-7. Aggregated social accounting matrix for Brazil, reference year 2003

	Aagr	Afor	Aroe	Pagr	Pfor	Pdef	Proe	Lab	Cap	Ald	Fld	Hh	Tax	Int	Ent	Gov	Row	S-i	Dstk	Tot
Aagr	0	0	0	163	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	176
Afor	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
Aroe	0	0	0	21	0	0	2777	0	0	0	0	0	0	0	0	0	0	0	0	2798
Pagr	18	0	108	0	0	0	0	0	0	0	0	35	0	0	0	0	20	10	7	197
Pfor	1	0	5	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	9
Pdef	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Proe	54	2	1353	0	0	0	0	0	0	0	0	1010	0	0	0	327	234	235	1	3216
Lab	27	1	500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	528
Cap	36	1	708	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	744
Ald	33	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35
Fld	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Hh	0	0	0	0	0	0	0	497	127	2	0	0	0	135	242	193	9	0	0	1205
Tax	7	0	123	8	0	0	221	31	0	0	0	58	0	0	90	0	0	0	0	539
Int	0	0	0	0	0	0	0	0	0	0	0	0	0	0	91	94	-50	0	0	135
Ent	0	0	0	0	0	0	0	0	617	34	1	0	0	0	0	0	0	0	0	652
Gov	0	0	0	0	0	0	0	0	0	0	0	0	539	0	0	0	0	0	0	539
Row	0	0	0	6	0	0	204	0	0	0	0	0	0	0	0	0	0	0	0	211
S-i	0	0	0	0	0	0	0	0	0	0	0	102	0	0	229	-75	-2	0	0	253
Dstk	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	7
Tot	176	7	2798	197	9	0	3216	528	744	35	1	1205	539	135	652	539	211	253	7	

Notes: Values are in 1,000,000,000 Brazilian reais.

Key to abbreviations:

Aagr: agricultural activity; Afor: forestry activity; Aroe: other activities; Pagr: agricultural products; Pfor: forestry products; Pdef: deforestation product; Proe: other products; Lab: labor; Cap: capital; Ald: agricultural land; Fld: forestland; Hh: households; Tax: tax; Int: interest; Ent: enterprises; Gov: government; Row: rest of the world; S-i: savings and investment; Dstk: change in stocks; Tot: total.

Table 3-8. Percent change in macroeconomic and institutional indicators

Indicator	Percent change
Absorption	0.01
Private consumption	0.02
Fixed investment	0.00
Change in stocks	0.00
Government consumption	0.00
Exports	0.00
Imports	-0.01
GDP at market prices	0.01
GDP at factor cost	0.01
Net indirect taxes	0.01
Real household consumption	
Low-income household	0.00
Mid-income household	0.00
High-income household	0.00
Deforestation enterprise	0.80
Consumer price index	0.02
Exchange rate	-0.01
Investment share of absorption	0.00
Foreign savings	0.00
Marginal propensity to save	
Mid-income households	0.57
High-income households	0.04
Enterprises	0.01
Investment to GDP ratio	0.00
Private savings to GDP ratio	0.00
Foreign savings to GDP ratio	0.00
Trade deficit to GDP ratio	0.00
Government savings to GDP ratio	0.00

Table 3-9. Percent change in institutional income

Institution	Percent change
Low income household	0.05
Mid-income household	0.05
High-income household	0.04
Deforestation institution	-0.24
Enterprises	0.01
Interest	0.02

Table 3-10. Equivalent variation

Institution	Percent change
Low-income households	0.00
Mid-income households	0.00
High-income households	0.00
Deforestation enterprise	0.80
Total	0.00

Table 3-11. Percent change in factor income

Factor	Percent change
Low-skill formal labor	0.08
Low-skill informal labor	0.07
Mid-skill formal labor	0.08
Mid-skill informal labor	0.07
High-skill formal labor	0.07
High-skill informal labor	0.08
Capital	0.13
Agricultural land north	-0.17
Agricultural land north east	-0.38
Agricultural land south east	-6.79
Agricultural land south	-1.81
Agricultural land center west	-0.17
Forest land north	-48.13
Forest land north east	-14.25
Forest land south east	-9.40
Forest land south	-9.54
Forest land center west	-11.14

Table 3-12. Percent change in price of composite good

Good or service	Percent change
Agriculture	-0.21
Forestry	-8.44
Deforestation	-1.07
Mining and petroleum	-0.01
Industrial	0.01
Processed wood	-0.01
Pulp and cellulose	-0.01
Processed food	0.02
Utilities	0.05
Construction	0.17
Commerce	-0.01
Transportation	0.09
Private services	0.05
Public services	0.04

Table 3-13. Percent change in price of factor F for activity A

Factor	Sector	Percent change
Low-skilled formal labor	Agriculture north	-0.13
Low-skilled formal labor	Agriculture north east	-0.11
Low-skilled formal labor	Agriculture south east	0.54
Low-skilled formal labor	Agriculture south	0.32
Low-skilled formal labor	Agriculture center west	-0.13
Low-skilled formal labor	Forestry north	143.65
Low-skilled formal labor	Forestry north east	-14.82
Low-skilled formal labor	Forestry south east	-9.40
Low-skilled formal labor	Forestry south	-9.54
Low-skilled formal labor	Forestry center west	-11.18
Low-skilled formal labor	Forest plantations north	-13.57
Low-skilled formal labor	Forest plantations north east	-14.40
Low-skilled formal labor	Forest plantations south east	-20.43
Low-skilled formal labor	Forest plantations south	-26.08
Low-skilled formal labor	Forest plantations center west	-15.99
Low-skilled formal labor	Deforestation north	18.84
Low-skilled formal labor	Deforestation north east	-6.96
Low-skilled formal labor	Deforestation center west	-5.89
Low-skilled formal labor	Mining and petroleum	-0.09
Low-skilled formal labor	Industry	0.01
Low-skilled formal labor	Processed wood	2.68
Low-skilled formal labor	Pulp and cellulose	2.50
Low-skilled formal labor	Processed food	0.65
Low-skilled formal labor	Utilities	0.06
Low-skilled formal labor	Construction	0.33
Low-skilled formal labor	Commerce	-0.03
Low-skilled formal labor	Transportation	0.10
Low-skilled formal labor	Private services	0.05
Low-skilled formal labor	Public services	0.03
Low-skilled informal labor	Agriculture north	-0.13
Low-skilled informal labor	Agriculture north east	-0.11
Low-skilled informal labor	Agriculture south east	0.54
Low-skilled informal labor	Agriculture south	0.32
Low-skilled informal labor	Agriculture center west	-0.13
Low-skilled informal labor	Forestry north	143.65
Low-skilled informal labor	Forestry north east	-14.82
Low-skilled informal labor	Forestry south east	-9.40
Low-skilled informal labor	Forestry south	-9.54
Low-skilled informal labor	Forestry center west	-11.18

Table 3-13. Continued

Factor	Sector	Percent change
Low-skilled informal labor	Forest plantations north	-13.57
Low-skilled informal labor	Forest plantations north east	-14.40
Low-skilled informal labor	Forest plantations south east	-20.43
Low-skilled informal labor	Forest plantations south	-26.08
Low-skilled informal labor	Forest plantations center west	-15.99
Low-skilled informal labor	Deforestation north	18.84
Low-skilled informal labor	Deforestation north east	-6.96
Low-skilled informal labor	Deforestation center west	-5.89
Low-skilled informal labor	Mining and petroleum	-0.09
Low-skilled informal labor	Industry	0.01
Low-skilled informal labor	Processed wood	2.68
Low-skilled informal labor	Pulp and cellulose	2.50
Low-skilled informal labor	Processed food	0.65
Low-skilled informal labor	Utilities	0.06
Low-skilled informal labor	Construction	0.33
Low-skilled informal labor	Commerce	-0.03
Low-skilled informal labor	Transportation	0.10
Low-skilled informal labor	Private services	0.05
Low-skilled informal labor	Public services	0.03
Mid-skilled formal labor	Agriculture north	-0.13
Mid-skilled formal labor	Agriculture north east	-0.11
Mid-skilled formal labor	Agriculture south east	0.54
Mid-skilled formal labor	Agriculture south	0.32
Mid-skilled formal labor	Agriculture center west	-0.13
Mid-skilled formal labor	Forestry north	143.65
Mid-skilled formal labor	Forestry north east	-14.82
Mid-skilled formal labor	Forestry south east	-9.40
Mid-skilled formal labor	Forestry south	-9.54
Mid-skilled formal labor	Forestry center west	-11.18
Mid-skilled formal labor	Forest plantations north	-13.57
Mid-skilled formal labor	Forest plantations north east	-14.40
Mid-skilled formal labor	Forest plantations south east	-20.43
Mid-skilled formal labor	Forest plantations south	-26.08
Mid-skilled formal labor	Forest plantations center west	-15.99
Mid-skilled formal labor	Deforestation north	18.84
Mid-skilled formal labor	Deforestation north east	-6.96
Mid-skilled formal labor	Deforestation center west	-5.89
Mid-skilled formal labor	Mining and petroleum	-0.09
Mid-skilled formal labor	Industry	0.01

Table 3-13. Continued

Factor	Sector	Percent change
Mid-skilled formal labor	Processed wood	2.68
Mid-skilled formal labor	Pulp and cellulose	2.50
Mid-skilled formal labor	Processed food	0.65
Mid-skilled formal labor	Utilities	0.06
Mid-skilled formal labor	Construction	0.33
Mid-skilled formal labor	Commerce	-0.03
Mid-skilled formal labor	Transportation	0.10
Mid-skilled formal labor	Private services	0.05
Mid-skilled formal labor	Public services	0.03
Mid-skilled informal labor	Agriculture north	-0.13
Mid-skilled informal labor	Agriculture north east	-0.11
Mid-skilled informal labor	Agriculture south east	0.54
Mid-skilled informal labor	Agriculture south	0.32
Mid-skilled informal labor	Agriculture center west	-0.13
Mid-skilled informal labor	Forestry north	143.65
Mid-skilled informal labor	Forestry north east	-14.82
Mid-skilled informal labor	Forestry south east	-9.40
Mid-skilled informal labor	Forestry south	-9.54
Mid-skilled informal labor	Forestry center west	-11.18
Mid-skilled informal labor	Forest plantations north	-13.57
Mid-skilled informal labor	Forest plantations north east	-14.40
Mid-skilled informal labor	Forest plantations south east	-20.43
Mid-skilled informal labor	Forest plantations south	-26.08
Mid-skilled informal labor	Forest plantations center west	-15.99
Mid-skilled informal labor	Deforestation north	18.84
Mid-skilled informal labor	Deforestation north east	-6.96
Mid-skilled informal labor	Deforestation center west	-5.89
Mid-skilled informal labor	Mining and petroleum	-0.09
Mid-skilled informal labor	Industry	0.01
Mid-skilled informal labor	Processed wood	2.68
Mid-skilled informal labor	Pulp and cellulose	2.50
Mid-skilled informal labor	Processed food	0.65
Mid-skilled informal labor	Utilities	0.06
Mid-skilled informal labor	Construction	0.33
Mid-skilled informal labor	Commerce	-0.03
Mid-skilled informal labor	Transportation	0.10
Mid-skilled informal labor	Private services	0.05
Mid-skilled informal labor	Public services	0.03
High-skilled formal labor	Agriculture north	-0.13

Table 3-13. Continued

Factor	Sector	Percent change
High-skilled formal labor	Agriculture north east	-0.11
High-skilled formal labor	Agriculture south east	0.54
High-skilled formal labor	Agriculture south	0.32
High-skilled formal labor	Agriculture center west	-0.13
High-skilled formal labor	Forestry north	143.65
High-skilled formal labor	Forestry north east	-14.82
High-skilled formal labor	Forestry south east	-9.40
High-skilled formal labor	Forestry south	-9.54
High-skilled formal labor	Forestry center west	-11.18
High-skilled formal labor	Forest plantations north	-13.57
High-skilled formal labor	Forest plantations north east	-14.40
High-skilled formal labor	Forest plantations south east	-20.43
High-skilled formal labor	Forest plantations south	-26.08
High-skilled formal labor	Forest plantations center west	-15.99
High-skilled formal labor	Deforestation north	18.84
High-skilled formal labor	Deforestation north east	-6.96
High-skilled formal labor	Deforestation center west	-5.89
High-skilled formal labor	Mining and petroleum	-0.09
High-skilled formal labor	Industry	0.01
High-skilled formal labor	Processed wood	2.68
High-skilled formal labor	Pulp and cellulose	2.50
High-skilled formal labor	Processed food	0.65
High-skilled formal labor	Utilities	0.06
High-skilled formal labor	Construction	0.33
High-skilled formal labor	Commerce	-0.03
High-skilled formal labor	Transportation	0.10
High-skilled formal labor	Private services	0.05
High-skilled formal labor	Public services	0.03
High-skilled informal labor	Agriculture north	-0.13
High-skilled informal labor	Agriculture north east	-0.11
High-skilled informal labor	Agriculture south east	0.54
High-skilled informal labor	Agriculture south	0.32
High-skilled informal labor	Agriculture center west	-0.13
High-skilled informal labor	Forestry north	143.65
High-skilled informal labor	Forestry north east	-14.82
High-skilled informal labor	Forestry south east	-9.40
High-skilled informal labor	Forestry south	-9.54
High-skilled informal labor	Forestry center west	-11.18
High-skilled informal labor	Forest plantations north	-13.57

Table 3-13. Continued

Factor	Sector	Percent change
High-skilled informal labor	Forest plantations north east	-14.40
High-skilled informal labor	Forest plantations south east	-20.43
High-skilled informal labor	Forest plantations south	-26.08
High-skilled informal labor	Forest plantations center west	-15.99
High-skilled informal labor	Deforestation north	18.84
High-skilled informal labor	Deforestation north east	-6.96
High-skilled informal labor	Deforestation center west	-5.89
High-skilled informal labor	Mining and petroleum	-0.09
High-skilled informal labor	Industry	0.01
High-skilled informal labor	Processed wood	2.68
High-skilled informal labor	Pulp and cellulose	2.50
High-skilled informal labor	Processed food	0.65
High-skilled informal labor	Utilities	0.06
High-skilled informal labor	Construction	0.33
High-skilled informal labor	Commerce	-0.03
High-skilled informal labor	Transportation	0.10
High-skilled informal labor	Private services	0.05
High-skilled informal labor	Public services	0.03
Capital	Agriculture north	-0.13
Capital	Agriculture north east	-0.11
Capital	Agriculture south east	0.54
Capital	Agriculture south	0.32
Capital	Agriculture center west	-0.13
Capital	Forestry north	143.65
Capital	Forestry north east	-14.82
Capital	Forestry south east	-9.40
Capital	Forestry south	-9.54
Capital	Forestry center west	-11.18
Capital	Forest plantations north	-13.57
Capital	Forest plantations north east	-14.40
Capital	Forest plantations south east	-20.43
Capital	Forest plantations south	-26.08
Capital	Forest plantations center west	-15.99
Capital	Deforestation north	18.84
Capital	Deforestation north east	-6.96
Capital	Deforestation center west	-5.89
Capital	Mining and petroleum	-0.09
Capital	Industry	0.01
Capital	Processed wood	2.68

Table 3-13 Continued

Factor	Sector	Percent change
Capital	Pulp and cellulose	2.50
Capital	Processed food	0.65
Capital	Utilities	0.06
Capital	Construction	0.33
Capital	Commerce	-0.03
Capital	Transportation	0.10
Capital	Private services	0.05
Capital	Public services	0.03
Agricultural land north	Agriculture north	-0.17
Agricultural land north	Forest plantations north	-0.17
Agricultural land north east	Agriculture north east	-0.38
Agricultural land north east	Forest plantations north east	-0.38
Agricultural land south east	Agriculture south east	-6.79
Agricultural land south east	Forest plantations south east	-6.79
Agricultural land south	Agriculture south	-1.81
Agricultural land south	Forest plantations south	-1.81
Agricultural land center west	Agriculture center west	-0.17
Agricultural land center west	Forest plantations center west	-0.17
Forestland north	Forestry north	-64.47
Forestland north	Deforestation north	-64.47
Forestland north east	Forestry north east	-14.25
Forestland north east	Deforestation north east	-14.25
Forestland southeast	Forestry south east	-9.40
Forestland south	Forestry south	-9.54
Forestland center west	Forestry center west	-11.14
Forestland center west	Deforestation center west	-11.14

Table 3-14. Percent change in level of domestic activity

Sector	Percent change
Agriculture north	0.00
Agriculture north east	0.01
Agriculture south east	0.19
Agriculture south	0.13
Agriculture center west	0.01
Forestry north	24.68
Forestry north east	-0.02
Forestry south east	0.00
Forestry south	0.00
Forestry center west	-0.01
Forest plantations north	-0.56
Forest plantations north east	-0.62
Forest plantations south east	-2.40
Forest plantations south	-3.71
Forest plantations center west	-1.29
Deforestation north	1.20
Deforestation north east	0.14
Deforestation center west	0.09
Mining and petroleum	0.00
Industry	0.00
Wood processing	0.00
Pulp and paper	0.00
Food processing	0.00
Utilities	0.00
Construction	0.00
Commerce	0.00
Transportation	0.00
Private services	0.00
Public services	0.00

Table 3-15. Percent change in quantity of factor demand by sector

Sector	Factor	Percent change
Agriculture north	Agricultural land north	0.01
Forest plantations north		-2.84
Agriculture north east	Agricultural land north east	0.06
Forest plantations north east		-2.99
Agriculture south east	Agricultural land south east	1.83
Forest plantations south east		-3.11
Agriculture south	Agricultural land south	0.52
Forest plantations south		-5.52
Agriculture center west	Agricultural land center west	0.01
Forest plantations center west		-3.39
Forestry north	Forest land north	46.97
Deforestation north		6.22
Forestry north east	Forest land north east	-0.13
Deforestation north east		0.41
Forestry south east	Forest land south east	0.00
Forestry south	Forest land south	0.00
Forestry center west	Forest land center west	-0.01
Deforestation center west		0.29

Table 3-16. Percent change in quantity of domestic sales and exports

Good or service	Percent change domestic sales	Percent change exports
Agriculture	0.05	0.31
Forestry	1.95	14.55
Deforestation	0.84	0.00
Mining and petroleum	0.00	0.00
Industrial	0.01	-0.04
Processed wood	0.00	0.00
Pulp and cellulose	0.00	0.00
Processed food	0.02	-0.07
Utilities	0.00	0.00
Construction	0.00	-0.09
Commerce	0.00	0.00
Transportation	0.00	-0.08
Private services	0.00	-0.04
Public services	0.00	0.00

Table 3-17. Percent change in quantity of composite goods supply

Sector	Percent change
Agriculture	0.03
Forestry	0.37
Deforestation	0.84
Mining and petroleum	0.00
Industrial	0.01
Processed wood	0.00
Pulp and cellulose	0.00
Processed food	0.02
Utilities	0.00
Construction	0.00
Commerce	0.00
Transportation	0.00
Private services	0.01
Public services	0.00

CHAPTER 4
RECURSIVE DYNAMIC COMPUTABLE GENERAL EQUILIBRIUM MODEL WITH ILLEGAL LOGGING AND DEFORESTATION

Introduction

The static CGE model evaluated the policy impact of forest concessions in the absence of illegality. Given the economic importance of illegality in the Brazilian forestry sector (56% of forest sector output in 2003), in order to more realistically and fully evaluate the potential socio-economic and environmental impacts of forest concessions, the analysis conducted herein disaggregates and models illegal forestry and illegal deforestation sectors. To enable the updating of agricultural land stocks resulting from deforestation and to consider the medium-term implications of the forest concessions policy, a recursive dynamic computable general equilibrium modeling framework is developed and employed.

Following this introduction, illegal logging is defined and its key causes and effects are summarized[1]. Next, illegal logging in Brazil is discussed and estimates of its magnitude and level of prosecution are provided. Treatment of illegality in CGE models is then reviewed. Following this review, dynamics in CGE models are introduced. Next, the recursive dynamic extension to the IFPRI Standard CGE Model in GAMs is presented. The experimental design of the modeling exercise is developed and is followed by simulation results. The chapter concludes with a discussion of the key findings.

Illegal Logging

Illegal logging can be characterized as consisting of illegal logging activities, the illegal movement of forest products, and the evasion of taxes and forestry related payments. Following Callister (1999, p. 7), illegal logging activities include logging without authorization on public or private land, logging in breach of contractual obligations, logging that does not respect forestry law, and the illegal attainment of timber harvest rights. The illegal transport of forest products

includes the import and export of tree species protected or banned under national and international law, the unauthorized transport of specified amounts of timber across within-country and between-country borders, and the illegal transportation of logs from the forest to the market. The evasion of taxes and other forest-related payments includes the evasion of fees and duties through incorrectly reporting timber grades and dimensions, the evasion of license fees, royalties, taxes and other government fees, and false declarations of input and output costs (Callister, 1999, p. 8). In this chapter, illegal logging is defined similarly to Callister (1999) with the exception that the illegal import and export of timber across international borders is not considered.

Corruption is a special form of illegality; it is closely linked with illegal logging since each facilitates the presence of the other (Amacher, 2006, p. 86). Corruption involves engaging public officials and involves public property or power; it is conducted for private gain and is intentional and clandestine (Contreras-Hermosilla, 2002, p. 9). Corruption enables illegal logging to take place or allows it to continue without consequence.

Numerous reasons for the presence of illegality in the forest sector are cited in the literature. The Food and Agriculture Organization (FAO, 2005) reports 5 root causes of forest sector illegality, namely: flawed policies and legal frameworks, low enforcement capacity, insufficient data on the characteristics of the forest resource and illegal activities, corruption, and high demand for timber.

The legal framework for forestry can create incentives for illegal operations when laws are unrealistic and their implementation and enforcement are not supported by sufficient human and financial resources (FAO, 2005, p. 7). Laws that are too complex or burdensome can create a significant barrier for producers' legal compliance, particularly in the case of producers of a

smaller stature. Often these frameworks were developed with little public and industry participation (FAO, 2005, p. 7). Where governments have low implementation and enforcement capacity, particularly in highly regulated environments, incentives are created for producers to engage in illegal activities given the low probabilities of detection and subsequent punishment (FAO, 2005, p. 9). A lack of information on the forest resource in question and its potential remoteness render monitoring, detection, and enforcement difficult (FAO, 2005, p. 9). Corruption and a lack of transparency can induce a mutually beneficial relationship between illegal operators and government officials (FAO, 2005, p. 12). Corruption is bred through faulty legal frameworks and programs, weak government and non-government institutions, few checks and balances resulting in low levels of accountability and transparency, and low public sector wages (FAO, 2005, p. 11). High levels of demand for timber due to excess processing capacity create incentives for the illegal acquisition of wood (Contreras-Hermosilla, Doornbosch & Lodge, 2007, p. 21). Furthermore, road building into previously inaccessible areas can significantly lower the costs of illegal logging in the absence of mechanisms of control and incentives for sustainable forest management (Contreras-Hermosilla et al., 2007, p. 23).

It is thus reasonable to assume that with the price of illegal and legal wood practically equal, economic incentives for operating illegally are created. Rational profit maximizing firms that base decisions on purely economic criteria will choose to engage in illegal logging when the benefits are greater than the costs, penalties, and associated risks of operating in illegality (Tacconi, Boscolo & Brack, 2003, p. 8).

Illegal logging results in negative socio-economic and environmental outcomes. Firms that evade forestry related payments such as royalties are able to produce an identical and cheaper product compared to those that operate legally. The world price reduction in forest

products due to illegal logging is estimated between 7% and 16% (Seneca Creek Associates & Wood Resources, 2004). Consequently, firms operating legally suffer from reduced profits, are discouraged from investing in forest management and ultimately may be forced out of business (Contreras et al., 2007, p. 19). Depressed prices also create perverse incentives for inefficient harvesting operations (Gutierrez-Velez & MacDicken, 2008, p. 249; Seneca Creek Associates & Wood Resources, 2004, p. 55). Illegal logging can lead to future forest productivity losses with firms operating in illegality shirking the higher management standards required by law (Gutierrez-Velez & MacDicken, 2008, p. 249).

Society as a whole tends to suffer from the effects of illegal logging. The government loses a potentially important source of revenue and its ability to provide social services is reduced (Callister, 1999, p. 19). Lost revenue from illegal logging in developing countries is estimated at over US$15 billion per year (Contreras-Hermosilla et al., 2007, p. 18). For Brazil, illegal logging costs the state and society upwards of US$1.1 billion per year (Gutierrez-Velez & MacDicken, 2008, p. 254). Furthermore, a forest's capacity to produce critical environmental services is diminished due to inappropriate logging practices, including increased residual damage and the logging of sensitive areas and protected species.

Finally, illegal operations can have a negative employment effect; legal operations require minimum salaries and working conditions whereas illegal operations do not (Gutierrez-Velez & MacDicken, 2008, p. 249). Short-term employment may be created by illegal logging, however, the boom and bust nature of these operations does not lend to community stability.

Illegal Logging in Brazil

Illegal logging in Brazil is a function of flawed policies and legal frameworks, low enforcement capacity, insufficient data on the characteristics of the forest resource and illegal activities, corruption, and high demand for timber as discussed in the previous section. Rhodes,

Allen and Callahan (2006, p. 3) argue that illegal logging's pervasiveness in Brazil is largely due to the absence of the rule of law where petty corruption prevails. The authors assert that in many cases, firms once operating legally were forced into illegality due to increasingly uncertain property rights, a changing policy environment creating new restrictions on forest operations, and a lack of forestland on which firms may operate legally (Rhodes et al., 2006, p. 3).

Estimates on the extent of illegal logging in Brazil tend to vary considerably. Smeraldi (2004, p. 39) reports that the classification and analysis of forest harvesting, commerce, and illegal logging in Brazil began in the early 1990s. A report prepared in 1994 by the environmental NGO Amigos da Terra reported that all mahogany harvested in the Brazilian Amazon was harvested illegally. A second paper prepared by the NGO reported that illegal harvesting activities were advancing on to public forests and conservation areas in 1994. A confidential government report leaked to the media in 1997 estimated that 80% of all the timber in the Brazilian market prior to 1997 was harvested illegally (Smeraldi, 2004, p. 40); this figure has subsequently been cited in numerous publications (Lele, Viana, Veríssimo, Vosti, Perkins & Husain, 2000, p. 20; Marquesini & Edwards, 2001, p. 1; Tacconi et al., 2003, p. 8). Seneca Creek Associates and Wood Resources International (2004, p. 11) report estimates of between 20-90% of wood harvested in Brazil is done so illegally. More recently, considering roundwood consumption and the volume authorized through deforestation authorizations and forest management plans for 2004, over 43% of the timber volume harvested was done so illegally (calculation based on Lentini et al., 2005a). This figure includes wood sourced from both selectively logged and deforested areas.

With the approval of Brazil's Environmental Crimes Law in 1998 and a supporting Decree in 1999 (Federal Law 9.606/98 and Federal Decree 3.179/99, respectively), efforts to

punish illegal logging have increased dramatically. The number of fines applied since 1999 has increased substantially, though their collection has remained low. The fine for illegal deforestation is approximately US$700 per hectare (Barreto, Souza, Noguerón, Anderson & Salomão, 2006, p. 20) while the fine for illegally transporting wood products ranges from US$28.50 to US$143.00 per cubic meter (Brito, Barreto and Rothman, 2005, p. 13).

An estimated US$16.2 billion in fines were issued in 2001 which is 8 times the fines issued in 1997; the percentage of these fines collected was 6% (Macqueen, Grieg-Gran, Lima, MacGregor, Merry, Prochnick, Scotland, Smeraldi & Young, 2003, p. 54). In 1999, The Brazilian Institute of the Environment and Natural Resources (IBAMA) collected 14% of the value of fines owed between 1998 and 1999. Between 2001 and 2004, the total value of fines issued by IBAMA increased 180% from US$103 million to US$290 million. Only 2% of the fines issued for environmental crimes during this period were collected, however. During the same period, the illegal timber harvest reportedly fell from 47% to 43% (Brito & Barreto, 2006, p. 2).

Brito et al. (2005, p. 13) conducted an analysis of a sample of 55 judicial actions for forestry violations committed in Pará and filed with the Federal Court of Belém between 2000 and 2003. Of this sample, 98% of the cases involved illegally taking, acquiring, selling, storing, or transporting wood, firewood, charcoal, and other forest products (art. 46 of the Environmental Crimes Law). Illegal transport and storage accounted for 48% and 24% of the crimes committed, respectively (Brito et al., 2005, p. 9) while only 8% of the crimes involved illegal logging (6%) and deforestation (2%; Brito et al., 2005, p. 10). With regards to fine collection, 9% of the cases or 2% of the value of the fines assessed were paid. In 2003, the average civil liability in 3 cases

was US$0.70 per cubic meter while the average criminal liability was US$45.00 per cubic meter for an overall average of US$45.70 per cubic meter (Brito et al., 2005, p. 13).

Treatment of Illegal Behavior in Computable General Equilibrium Models

Illegal activities in CGE models have received little attention in the literature. The closest parallel to modeling illegality has involved distinguishing between formal and informal activities and labor. Informal sector activities and labor are characterized by firms and individuals that do not comply with regulations and tax codes. Informality emerges where the government imposes excessive regulations and taxes and lacks the capacity to enforce them (Loayza, 1997, p. 2). Alternatively, informality may occur when state officials or interest groups profit from informality and as such they create a regulatory environment that renders operating in the informal sector beneficial or unavoidable (Loayza, 1997, p. 3). Costs involved in engaging in the informal sector include fines and penalties, lack of access to public services, unenforceable property rights on capital and output, and the inability to enter into legally binding contracts including access to capital markets and insurance (Loayza, 1997, p. 3).

Kelley (1994) analyzed the macroeconomic implications of informal sectors and informal labor in Peru considering an increase in government and investment demand, and the impact of an increase in formal sector wages and informal sector productivity. In this model, a shortage of formal employment results in a parallel informal sector, employing informal labor and producing a similar, though imperfectly substitutable good or service. Kelley (1994) characterized informal sector production as organized around an individual, family, or small group where the producer receives the net product from production rather than a wage, and pays little or no taxes. Informal sector production technology is labor intensive to reflect capital scarcity. Output from parallel formal and informal sectors is aggregated into a composite good; relative prices and imperfect substitutability between the two similar goods determine output levels. Full labor employment is

assumed which is made possible through adjustments in the level of informal employment (Kelley, 1994, p. 1395).

Gibson (2004) developed a dynamic model with an informal sector to evaluate the long-run effects of macroeconomic and trade reform policies on growth, distribution, human capital formation, and poverty (Gibson, 2004, p. 61). In this model, non-traded goods sectors have parallel informal sectors which serve as an employer of last resort, absorbing surplus labor during recessions and supplying labor in expansionary periods (Gibson, 2004, p. 62). The price of informal sector output is determined by the formal sector. The informal sector always operates at full capacity and as in Kelley (1994), informal sector income is earned by the operator (Gibson, 2005, p. 65).

Fortin, Marceau and Savard (1997) evaluated the effect of taxation and wage controls in an economy with informal sectors. The informal sector is distinguished from the formal sector by technological and organizational factors which are reflected through the scale of the firm, a wage differential between formal and informal workers, and regulatory evasion. In their model, firms operating in the informal sector do not comply with minimum wage and tax laws. Informal firms face the risk of being detected and fined unless they engage in a costly activity to avoid detection. The authors assume that firms would rather pay a sure cost to avoid the risk of being detected; this sure cost function is described by an inverted L curve where the cost of detection is zero until firm size reaches a critical limit and the cost of informality rises to infinity (Fortin et al., 1997, p. 298).

The Australian Bureau of Agricultural and Resource Economics' model of Papua New Guinea incorporated a kidnapping and informal sector in their modeling framework with

unskilled labor as the primary input to these sectors. Fines applied to the criminal sector are treated as production taxes in the model (Levantis & Fairhead, 2004, p. 15).

Dynamics in Computable General Equilibrium Models

Policy makers are often interested in how current decisions will affect future socioeconomic outcomes. Static models provide an indication of the order of magnitude and direction of effect of a policy shock and are typically either short-run or long-run depending on the factor and macroeconomic closures chosen by the modeler. In contrast, dynamic models are used to simulate the impact of a policy on the economy for a definite time period. The main advantages of this class of models is their ability to shed light on the economic transition path resulting from a policy shock and the short-term costs and longer-term gains resulting from policy implementation (Cattaneo, 1999, p. 17). Furthermore, dynamic models typically involve a deeper treatment of investment behavior and enable the modeler to update key growth parameters such as population, labor force, factor productivity, world prices, and government consumption as well as rates of capital depreciation. Dynamic models are thus a useful tool for informing policy decisions.

Four main approaches to dynamic modeling may be distinguished. Following Dixon and Parmenter (1996, p. 24), the distinction between approaches is based on the treatment of investment and capital accumulation. In the first approach, investment is modeled exogenously with agent expectations modeled as static. Agents exhibiting static expectations assume no changes in decision parameters over time. This type of model is recursive dynamic where the inter-temporal trajectory of the economy is determined by calculating a series of static equilibria which are related to each other by capital formation processes and exogenous changes in growth parameters (Pereira & Shoven, 1988, p. 402).

The second approach differs from the first in that investment is modeled endogenously and agent investment behavior is based on adaptive expectations. Agents with adaptive expectations use information on previous rates of return to capital to inform their current investment decisions. This class of models is also solved recursively.

Third, investment may be modeled endogenously where agents engage in forward-looking investment behavior. These agents consider both the present and future to inform their current investment decisions (Springer, 1999, p. 5). In this case, an agent's expectations about expected rates of return to capital for a given year are equal to the actual rates of return for that year. Differing from recursive dynamic models, this class of models is solved simultaneously for all time periods.

In the final case, investment behavior is optimized and modeled as an inter-temporal decision where inter-temporal substitution possibilities exist (Dixon & Parmenter, 1996, p. 25-36; Springer, 1999, p. 6). This class of models is also solved simultaneously for all time periods.

Since perfect foresight is not generally representative of how investment behaves in the real world, the model in the next section follows the second approach, where investment behavior is based on adaptive expectations and the model is solved recursively.

Dynamic Extension to the Standard Computable General Equilibrium Model in GAMS

The Recursive Dynamic Computable General Equilibrium Model is a dynamic extension to the IFPRI Standard CGE Model in GAMS and was developed by Robinson and Thurlow (no date). The within period (year) specification of the model is identical to that of the Standard IFPRI model described in Chapter 3. The between period specification contains adjustments to account for endogenous investment, and exogenous population and labor force growth, depreciation, and changes in total factor productivity (Robinson & Thurlow, no date, p. 1). The sectoral allocation of capital is modeled as a function of the rate of capital depreciation and the

differential in profits between sectors from the previous period (Thurlow, 2004, p. 11). Endogenous adjustments to account for capital accumulation and exogenous adjustments to population, labor force and total factor productivity are discussed in turn.

Capital supply is based on the previous period's capital stock and allocation of investment spending. Investment is carried out in proportion to a sector's share in economy-wide capital income and is adjusted by the ratio of a sector's rate of profits and the economy-wide average rate of profit. This specification implies that a sector with higher than average profits will receive a larger share of investment than its average share in aggregate capital income (Robinson & Thurlow, no date, p. 4; see Appendix A, equations 50 to 54).

Population growth has a direct and positive impact on household consumption expenditure with the quantity of income-independent consumption increasing at the same rate as population growth (Robinson & Thurlow, no date, p. 2). The level of minimum household consumption expenditure also increases proportionally with population growth. Growth affects average rather than marginal consumption demand implying that new consumers share the same preferences as existing consumers (Robinson & Thurlow, no date, p. 3). The parameter γ_{ch}^{m}, the subsistence consumption of marketed commodity c for household h, and $\gamma_{ac'h}^{h}$, the subsistence consumption of home commodity c from activity a for household h, are both adjusted upwards by the rate of population growth (see Appendix A).

With regards to labor force growth, with a fixed labor supply, flexible nominal wages and full employment, the between period levels of labor supply are adjusted according to the rate of labor force growth (Robinson & Thurlow, no date, p. 4; see Appendix A). The parameter $\overline{QFS}_f$, the quantity of factor supply, is adjusted upwards by the rate of labor force growth.

Changes in total factor productivity are imposed exogenously by introducing a technological parameter in the model equations for the calculation of the quantity of aggregate value-added (Robinson & Thurlow, no date, p. 6; see Appendix A). The parameter α_a^{va}, the efficiency parameter in the Constant Elasticity of Substitution value-added function, is adjusted upwards by total factor productivity growth.

The dynamic extension to the Standard CGE Model in GAMS is programmed and solved as a mixed complementarity problem using the General Algebraic Modeling System and the PATH solver.

Customizing the 2003 Social Accounting Matrix for Brazil to Describe Illegal Forestry and Illegal Deforestation

Illegal forestry and illegal deforestation activities are not explicitly described in the national accounts data from which the SAM for Brazil was constructed. Expenditures and receipts from these activities are aggregated with those of the legal forestry sector, however, since once timber is extracted from the forest, it is presented to consumers as a legal product and accounted for as such. Therefore, in customizing the SAM to describe illegal forestry and illegal deforestation activities, expenditures are disaggregated from the legal forestry sector (with two exceptions noted below). The following subsections describe the procedures used in disaggregating illegal forestry and illegal deforestation in the Brazilian SAM and provide a summary of the key assumptions made.

Illegal Deforestation

The starting point for disaggregating the illegal deforestation sector in the SAM is to estimate the total area illegally deforested in 2003. Illegal deforestation in this analysis is defined as the removal of timber and the subsequent clearing of forests in the absence of a valid deforestation authorization and the illegal transport of timber from the forest to the mill. As with

the legal deforestation considered in Chapter 3, illegal deforestation occurs in Brazil's north, north east and center west regions.

Total deforestation in Brazil's Legal Amazon in 2003 was 2,528,200 hectares (The National Institute for Space Research's [INPE] Program for the Calculation of Deforestation in Amazonia [PRODES]). Deducting legally authorized deforestation registered with Brazil's monitoring and control system for resources and forest products database (SISPROF; 210,032 Ha), illegal deforestation in 2003 was approximately 2,318,168 hectares (MMA, 2008a).

Forest product output from illegal deforestation is calculated next. It is reasonable to assume that only timber harvested in proximity to new logging centers can be fully utilized since the difficult access and the state's reduced monitoring and enforcement capabilities decrease the probability that illegality will be detected and penalized (Lentini, 2008, personal communication)[2]. Therefore, it is assumed that illegal deforestation produces the same amount of timber per unit area as legal deforestation only in proximity to new logging centers. To calculate the area deforested in proximity to these centers, levels of deforestation by municipality were obtained from the PRODES online server while the location of new logging centers was extracted from Lentini et al. (2005a, p. 63). Illegal deforestation in municipalities in which new logging centers are located amounted to 15.7% and 27.1% of total illegal deforestation in the north and center west, respectively. Therefore, illegal deforestation produces 15.7% and 27.1% of the timber that the legal deforestation sector produces per unit area in the north and center west, respectively[3]. Given the lack of data on logging centers in the north east and its easier access, it is assumed that illegal deforestation in this region produces 10% of the timber per unit area when compared with legal deforestation.

The illegal deforestation sector's expenditures on intermediate consumption, labor and capital for producing forest products is identical to that of the legal deforestation sector's expenditure per unit area. These expenditures, along with the value of the illegal deforestation sector's forest product output value are deducted from the legal forestry sector.

The treatment of the illegal deforestation sector's expenditure on forestland and its payments to the indirect tax account differs from that of the legal deforestation sector's expenditures and payments. First, with regards to forestland, it is assumed that illegal deforestation operations occurring on 50% of Special Areas (military zones, quilombola communities which are areas settled by the descendents of slaves, Environmental Protection Areas, and rural settlements) and on private land in dispute and terra devoluta make reduced forestland payments. This is a reasonable assumption since, private land aside, most illegality occurs on land with these tenure types. Furthermore, it is assumed that these illegal operations pay 75% of the legal deforestation sector's forestland rent per unit of output. The rationale for this reduced payment is that firms that acquire land illegally are assumed to pay less than those that do so legally due to weaker property rights guarantees and the risks inherent in the illegal acquisition of land. To calculate the percentage reduction in forestland payments, the total area in Special Areas, private land, private land in dispute, and terra devoluta is calculated based on IBGE data (1996; cited in Lentini et al., 2005a, p. 32). Based on this value, the proportion of area in 50% of Special Areas, private land in dispute, and terra devoluta is calculated and represents the proportion of production that is subject to reduced forestland payments (0.76, 0.57 and 0.34 in the north, north east and center west, respectively). These proportions are multiplied by 0.75 and each region's legal forest sector payment to forestland for a given unit of forest product

output to determine the illegal sector's forestland payment per unit of forest product output by region[4].

With regards to activity taxes, the illegal deforestation sector does not pay activity taxes. Illegal deforestation operations are, however, subject to fines if their illegal activities are detected and they are successfully prosecuted. It is therefore necessary to estimate the value of fines issued in 2003 as well as the collection rate for the same year. The value of fines issued to the illegal sectors is extrapolated from IBAMA and Macqueen et al. (2003, p. 54) data. Based on estimates from Macqueen et al. (2003, p. 54), Brito et al. (2005, p. 10), Brito and Barreto (2006, p. 3), and IBAMA data, a conservative estimate of 6% of the rate of collection for fines issued is made and applied to the estimate of the value of fines issued. The value of fines paid by region is distributed according to the weight of the value of each region's illegal output of forest products. Under the balanced macroeconomic closure used in the modeling experiments to follow, government savings are flexible and tax rates are fixed (i.e. the activity tax or fine is treated as a fixed share parameter and is calibrated from the SAM). Treating the fine as a fixed share implies that as an illegal sector's output increases, so does the amount of the fine that it pays.

Next, the additional expenditures on labor for clearing forestland are accounted for. From Cattaneo (2002), clearing one hectare of forestland requires half a month of low-skilled labor. The cost of labor for forest clearing is thus the product of half of the average monthly wage for the forestry sector and the forest area cleared. The imbalance in expenditure on labor which is generated as a result of this additional labor payment is distributed among all sectors in accordance with the weight of each sector's labor expenditure. The imbalance created in the indirect tax account resulting from the illegal sector's payment of fines is distributed among all sectors according to the weight of each sector's indirect tax expenditure.

The difference between the illegal deforestation sector and the legal deforestation sector's expenditure to produce a unit of output is referred to as the deforestation product in the SAM. This is considered to be the level of above normal profits earned for operating illegally and is allocated according to an assumption matrix which describes how these profits are distributed to each labor class.

Finally, adjustments to the SAM are made to account for the consumption of the deforestation product. With the disaggregation of the illegal deforestation sector, the size of the deforestation product is larger than when only legal deforestation was considered. The sole consumer of the deforestation product is the deforestation institution. This institution derives all of its income from the returns to agricultural land. To provide the additional income that the deforestation institution requires to consume the deforestation product, the value of the deforestation product is deducted from the total agricultural land rent distributed to households and enterprises. This amount is deducted according to the weight of each institution's share of agricultural land rent and is then reallocated as income to the deforestation institution.

Illegal Forestry

The starting point for disaggregating an illegal forestry sector in the SAM is to calculate the Legal Amazon's total illegal forest product output. First, the total volume of timber authorized through forest management plans and deforestation authorizations in 2003 is calculated. Next, total roundwood consumption for 2003 is extrapolated from data for 1998 and 2004 (Lentini et al, 2005a, p. 69; Lentini et al., 2005b, p. 1). The authorized volume is deducted from total consumption revealing that the illegal harvest volume from illegal deforestation and illegal forestry was 56% of total output in 2003. The difference between total illegal forest product output and the illegal deforestation sector's forest product output is the illegal forestry sector's output.

The illegal forestry sector's expenditures on intermediate consumption, labor and capital are assumed to be the same as that of the legal forestry sector's expenditures per unit of output. These expenditures are deducted from the legal forestry sector's expenditures. The illegal forestry sector's payments to forestland and its payments of fines are calculated in the same way as for the illegal deforestation sector. Since the illegal sector generally pays less forestland rent and makes smaller payments to the indirect tax account (interpreted as fines), the illegal sector's expenditure for a given unit of output is less than that of the legal sector. As in the case of the illegal deforestation sector, this difference is interpreted as above normal profits and is distributed to labor in the same manner as in the case of the illegal deforestation sector.

Summary of Key Assumptions

1. Illegal deforestation produces less timber per unit area than the legal deforestation sector.
2. The illegal deforestation and illegal forestry sectors pay less for forestland per unit of forest product output than their legal counterparts.
3. The illegal deforestation and illegal forestry sectors do not pay activity taxes rather they pay fines based on the amount of fines and the collection rate estimated for 2003.
4. The deforestation institution derives all of its income from the returns to agricultural land which enables it to finance the production of forest products and the clearing of forestland.
5. The difference between an illegal and legal sector's (for both forestry and deforestation) expenditure to produce a unit of forest product output is considered to be the level of above normal profits earned for operating illegally; this profit is allocated to labor.

Scenario Design

Two scenarios are simulated in this chapter. The baseline scenario projects the Brazilian economy from the base year of 2003 to 2018 in the absence of forest concessions. The policy shock scenario uses the results of the base year projection and simulates the establishment of forest concessions in the Brazilian Amazon from 2008 to 2018. The difference between the

baseline and policy shock scenarios is the policy impact of forest concessions on the Brazilian economy. This section develops the baseline and policy shock scenarios in detail.

In contrast to the static CGE model of Chapter 3, the recursive dynamic model enables the updating of factor stocks. In both the baseline and the policy shock scenarios, labor supply is updated based on the estimated labor force growth rate. Capital stocks are updated endogenously based on the previous period's allocation of investment and the rate of capital depreciation[5]. In both the baseline scenario and the policy shock scenarios, the stock of agricultural land is also updated each year. Since the legal and illegal deforestation sectors clear forestland, the quantity of forestland cleared in one year is used to update the factor supply of agricultural land in the subsequent year and is thus made available to the agricultural and forest plantations sectors[6]. Figure 4-1 represents the relationship between natural forest management, forest plantations, agriculture, forestland, and agricultural land. Equation 4-1 demonstrates the updating of the agricultural land stock based on the previous period's level of deforestation using the stock of agricultural land in the north as an example.

$$QFS_{agriland\ north,a,t+1} = QFS_{agriland\ north,a,t} + QF_{forestland\ north,legal\ deforestation\ north,t} + QF_{forestland\ north,illegal\ deforestation\ north,t} \quad 4\text{-}1$$

Where:

$QF_{f,a,t}$	= Quantity of factor f demanded by activity a in time t.
$QFS_{f,a,t}$	= Quantity of factor supply for activity a in time *t*.

In the policy shock scenario, the forest concessions policy is simulated as an increase in the factor supply of forestland in the north. Of the 193.8 million hectares of public forests registered in Brazil's National Registry of Public Forests, 43.7 million hectares (22.5%) are legally eligible to be designated as forest concessions; 99.8% of these forests are located in the

Legal Amazon. Of this area, 11.6 million hectares may be designated as Management Units for forest concessions for the 2007 to 2008 period, over 99% of which are located in Brazil's northern administrative region (i.e. in the Legal Amazon with the exception of the state of Mato Grosso). The state of Pará alone accounts for over 82% of this area. The majority of these forests are National Forests with approved forest management plans or National Forests with management plans that are in the process of development. Of the 11.6 million hectares of forest, 3.9 million hectares were designated as priority areas for forest concessions, all of which are located in the states of Pará and Rondônia. One million hectares of this area in 2008 are expected to be designated as Management Units and put up for bidding as forest concessions (SFB, 2007, p. 30). Over the next 10 years, the maximum area that the state plans to designate as forest concessions is 13 million hectares or 3% of Amazônia (MMA, 2005, p. 5). Taking a more conservative estimate of 10 million hectares over the next 10 years, the policy scenario introduces 1 million hectares of forestland stock per year in the north beginning in 2008, with the final 1 million hectares introduced in 2017[7].

A mathematical formulation of this addition of forestland is as follows. The sum of all activities' demand for a given factor is equal to the total factor supply as given by equation 4-2. For simplicity, the element of time is dropped.

$$\sum_{a \in A} QF_{f,a} = QFS_f \qquad 4\text{-}2$$

Where:

$QF_{f,a}$ = Quantity of factor f demanded by activity a.
QFS_f = Quantity of factor supply.
$QFS0_f$ = Initial quantity of factor supply.

As an example, in the first year of forest concessions implementation, forestland supply is increased by 46% in the north. Given equation 4-3, this increase enters the model as in equation 4-4.

Since:

$$QFS_f = QFS0_f \qquad 4\text{-}3$$

$$QFS_{forestland\ north} = 1.46 \cdot QFS0_{forestland\ north} \qquad 4\text{-}4$$

Illegal forestry operations produce less timber and generate more wood waste than their legal counterparts. Following Gutierrez-Velez and MacDicken (2008, p. 252), planned logging is used as a proxy for legal forestry and unplanned logging is used as a proxy for illegal forestry. Barreto, Amaral, Vidal and Uhl (1998, p. 13) found that planned forestry operations harvest 30% more timber than unplanned operations due to less waste during felling and skidding. To account for inefficiencies in illegal operations as well as the increasing scarcity of forestland available for use by the illegal logging and illegal deforestation sectors in the north, a yield distortion parameter is introduced into the illegal forestry and illegal deforestation sectors' equations for forest and deforestation product output per unit of activity. Equation 4-5 is a mathematical representation of the impact of the distortion parameter on a sector's activity level. In this equation, as a sector's activity level increases, its output increases at a slower rate as determined by the yield distortion parameter.

$$QXAC_{ac} + \sum_{h \in H} QHA_{ach} = \varphi_{ac} \cdot \theta_{ac} \cdot QA_a \qquad 4\text{-}5$$

Where:

QHA_{ach} = Quantity of household home consumption of commodity c from activity a for household h.

$QXAC_{ac}$ = Quantity of marketed output of commodity c from activity a.

φ_{ac} = Yield distortion parameter for activity a and

	commodity c.
θ_{ac}	= Yield of output of c per unit of activity a.
QA_a	= Activity level.

In order to calculate the distortion parameter, the area of forest concessions established each year is deducted from the total federal public forests eligible for forest concessions. The proportion of the value calculated above and the total federal public forests eligible for forest concessions is calculated and is interpreted as the distortion parameter. With 1 million hectares of public forests designated as forest concessions per year, this distortion parameter is smaller in value and larger in effect year upon year[8].

With regards to model closure rules, in both the baseline and policy shock scenarios, the modeling experiment is run in a balanced macroeconomic environment where investment and government consumption shares are fixed while the quantities are flexible. Nominal absorption shares of investment and government consumption are fixed at their base year levels. With regards to factor closures in the baseline and policy shock scenarios, labor, capital, agricultural land, and forestland are fully employed and mobile between sectors. A flexible real exchange rate is chosen for the rest of the world closure while the government closure fixes direct tax rates enabling flexible government savings. The domestic price index is chosen as the numeraire.

Results

Changes in macroeconomic indicators in the baseline scenario are presented in Table 4-1. The annual compound percent change (ACPC) in real GDP at market prices is 5.5%. The annual ACPC in household consumption, investment, government consumption, exports, and imports are 5.9%, 6.2%, 4.4%, 5.1%, and 5.8%, respectively. Slight deflationary pressure is reflected in the ACPC of the consumer price index (-0.2%). There is a reduction in private savings as a percentage of GDP (-0.6%) which is compensated for by an increase in government savings

(0.6%). There is an increase in the ACPC in low-income, mid-income and high-income households' consumption (3.7%, 5.6% and 6.6%, respectively). The welfare of all households improves; the ACPC in equivalent variation is 5%, 8.6% and 11.2% for low, mid and high-income households, respectively.

The impact of the forest concessions policy on the economy is calculated as the difference between the value of indicators in the baseline scenario and the policy shock scenario. The policy impact on real GDP at market prices is positive for all years with the exception of 2009 (Figure 4-2). The policy impact on other macroeconomic indicators is small with the exception of the deforestation institution's consumption and welfare (Table 4-1). This institution's consumption in the baseline grows at 3.3%; it decreases with the concessions policy scenario at a rate of -9.2% per annum for a difference of -12.5%. Equivalent variation in the baseline grows at 17.3% and decreases by -3.0% in the policy scenario for a yearly average difference of -20.3%.

A large and positive impact on activity levels is experienced by the legal and illegal forestry sectors in the north (Figure 4-3). The policy has a small negative impact on legal forestry in the north east, south east and south, and on illegal forestry in the north east. There is a small positive effect on the legal and illegal forestry sectors in the center west. Forest concessions have a large positive impact on the average annual growth rate (AAGR) of legal forestry activity in the north and center west while they have a negative effect on the AAGR of activity levels in the north east, south east and south (13.53%, 4.09%, -2.22%, -0.08% and -0.04%, respectively; Table 4-2). The impact on illegal forestry's AAGR in activity is positive and the highest in the north and center west and negative in the north east (10.59%, 2.93% and -2.78%, respectively).

With regards to policy impacts on legal deforestation activity levels, there is a positive effect, the largest of which occurs in the north, followed by the center west and north east (Figure 4-4). The policy has a very small negative impact on illegal deforestation in the north east and a large negative impact in the north, followed by the center west. The policy has a large and positive effect on the AAGR of legal deforestation's activity level; the effect is the greatest in the center west, followed by the north east and north (10.22%, 9.92% and 8.74%, respectively; Table 4-2). Illegal deforestation's AAGR in activity is negatively impacted, most dramatically in the north, followed by the north east and center west (-26.08%, -7.47% and -5.19%, respectively).

The policy impact on forest plantation activity is negative and the largest in the south, followed by the north east, north, center west and south east (Figure 4-5). The policy negatively affects the AAGR of the forest plantations sector's activity, with the largest effect in the center west followed by the north, north east, south and south east (-3.28%, -3.11%, -2.65%, -2.56% and -1.87%, respectively; Table 4-2).

There is a large positive effect on pulp and cellulose and wood processing activities (Figure 4-6). The processed wood and pulp and cellulose AAGR in activity levels is positively impacted (0.38% and 0.75%, respectively; Table 4-2).

The forest concessions policy has a relatively large and positive impact on agricultural activity in all regions but the center west (Figure 4-7). The impact on the AAGR of agricultural activity levels is also positive in the north, north east, south east and south, and negative in the center west (0.45%, 0.36%, 0.09%, 0.18% and -0.05%, respectively; Table 4-2).

The policy impact on composite commodity supply for agricultural and forest products, processed wood, and pulp and cellulose is positive and most pronounced for agricultural product

supply (Figure 4-8). The effect on the AAGR in composite commodity supply is positive for agricultural and forestry products, processed wood, and pulp and cellulose (0.09%, 0.47%, 0.14% and 0.76%, respectively; Table 4-3); the supply of all other goods and services is also positively impacted with the exception of commercial services.

Figure 4-9 reveals that the policy has a considerable positive impact on domestic demand for agricultural and forestry products. Domestic demand for processed wood and pulp and cellulose, and export demand for agricultural and forest products also increase. The AAGR for domestic demand of agricultural and forestry products, processed wood, and pulp and cellulose increases by 0.10%, 1.10%, 0.15% and 0.76%, respectively; the AAGR in exports increases by 0.21%, 2.53%, 0.86% and 0.74% for agricultural and forestry products, processed wood, and pulp and cellulose, respectively (Table 4-4).

With regards to composite commodity prices, the forest concession policy has a large negative impact on forest product prices, a smaller negative impact on processed wood and agricultural product prices, and a negligible effect on pulp and cellulose prices (Figure 4-10). The policy impact on the AAGR for agricultural and forest products prices, processed wood, and pulp and cellulose is -0.09%, -0.94%, -0.32% and 0.00%, respectively (Table 4-5).

Figure 4-11 and 4-12 depict the policy impact on the stock of agricultural land and forestland in the north, north east and center west. The policy impact is positive for agricultural land stocks in the north and the north east as a result of deforestation and negative in the center west. Forestland stock in the north increases beginning in 2008 as forest concessions are established.

The policy impact on the legal deforestation sector's demand for forestland in the north east is positive and pronounced after 2008 and remains relatively constant thereafter (Figure 4-

13); the effect on the illegal and legal forestry sectors' demand is negative. There is a small negative effect on the illegal deforestation sector's demand for forestland in the north east; there is no policy impact on demand in the south and south east. In the north east, the AAGR of legal deforestation's demand for forestland increases while legal and illegal forestry and illegal deforestation demand decrease (9.93%, -2.16%, -2.77% and -7.45%, respectively; Table 4-6); there is no effect on demand in the south and south east.

The legal and illegal forestry sectors' demand for forestland in the north is positively and strongly affected by the forest concessions policy, though the latter to a lesser degree (Figure 4-14). The legal deforestation sector's demand for forestland in the north is positively impacted by a small degree while the illegal deforestation sector's demand is negatively affected. In the center west, the legal forestry, legal deforestation and illegal forestry sectors' demand for forestland is positively affected while the illegal deforestation sector is negatively impacted. The policy impacts on the AAGR in demand for forestland are positive for legal forestry, illegal forestry and legal deforestation in the north, while illegal deforestation in the north suffers a marked negative impact (13.69%, 10.67%, 8.92% and -25.78%, respectively; Table 4-6). The AAGR of legal forestry, illegal forestry and legal deforestation demand for forestland in the center west is positively affected while illegal deforestation's demand is negatively affected (4.14%, 2.95%, 10.27% and -5.10%, respectively).

Figure 4-15 describes the policy impact on demand for agricultural land in the north east, south east and south. The agricultural sector's demand for land in the south is the most positively affected of these 3 regions, followed by the agricultural sector in the north east and south east. The forest plantations sector is the most negatively impacted of these 3 regions in the south followed by the south east and north east. The agricultural sector's demand for agricultural land

in the north is positively impacted to a large degree and negatively affected in the center west (Figure 4-16). The forest plantation sector's demand for land is negatively impacted the most in the center west and then in the north. The effect on the agricultural sector's AAGR in demand for agricultural land is positive in the north, north east, south east and south; it is negative in the center west (0.48%, 0.50%, 0.18%, 0.22% and -0.04%, respectively; Table 4-6). The forest plantation sector's AAGR in demand for land is negatively impacted in all regions (-3.06%, -2.54%, -1.87%, -2.55% and -3.27% in the north, north east, south east, south and center west, respectively).

The policy impact on household income is depicted in figure 4-17. High-income household income is the most positively affected, followed by enterprise and mid-income and low-income household income. From 2009 to 2012 and 2009 to 2010, the policy impact on low-income and mid-income households, respectively, is negative; the impact on high-income households is always positive, though the difference between the baseline and the policy shock also dips slightly in 2009. The AAGR in income increases for low-income, mid-income and high-income households and the enterprise (0.01%, 0.02%, 0.03% and 0.02%, respectively; Table 4-7). Policy impacts on household expenditures follow the same trends as those described for household income (Figure 4-18).

Figure 4-19 describes the policy impact on labor and capital income. Low-skilled labor income in the policy scenario is less than in the baseline from 2009 to 2016, though the effect becomes positive after 2016. Mid-skilled and high-skilled labor and capital experience a negative impact on their income in 2009, though the effect is positive thereafter. The policy impact on the AAGR for low-skilled, mid-skilled and high-skilled labor, and capital income is positive (0.01%, 0.03%, 0.03% and 0.03%, respectively; Table 4-8).

Forestland income in the north increases dramatically with the implementation of forest concessions (Figure 4-20). Forestland income in other regions changes little in comparison, though it tends to be generally negatively affected as a result of the policy. The policy impact on the AAGR in forestland income increases markedly in the north and declines in the north east, south east, south and center west (5.39%, -0.66%, -1.32%, -1.14% and -2.39%, respectively; Table 4-8).

In figure 4-21, the policy impact on agricultural land income is depicted. The policy effect in the north is negative in 2008, positive in 2009, negative from 2010 to 2014, and positive thereafter. In the north east, the effect is negative in 2008, positive in 2009 and negative in all subsequent years. In the south east, south and center west, it is negative for all years. The policy impact on the AAGR in agricultural land income in the north is positive, while it is negative in the north east, south east, south and center west (0.08%, -0.49%, -0.47%, -0.30% and -0.14%, respectively; Table 4-8).

Figure 4-22 depicts the policy impact on labor wages and the price of capital. The effect on low-skilled labor wages is negative and quite pronounced from 2009 to 2016; the effect becomes positive after 2016. The impact on mid-skilled labor wages is negative only for 2009. Mid-skilled and high-skilled labor experience a positive impact on their wages as a result of the policy while the price of capital is positively affected to a much lesser degree. The impact on the AAGR in low-skilled, mid-skilled and high-skilled labor wages and the price of capital is positive (0.01%, 0.03%, 0.03% and 0.02%, respectively; Table 4-9).

The impact on the price of forestland in the north east spikes positively in 2009 and declines steadily thereafter; the effect is negative in 2008, positive from 2009 to 2014 and negative thereafter (Figure 4-23). The impact is negative in all other regions with the greatest

effect on forestland prices in the north followed by the center west. The policy impact on the AAGR in forestland prices is negative in all regions (-6.20%, -0.66%, -1.32%, -1.14% and -2.39% in the north, north east, south east, south and center west, respectively; Table 4-9).

The policy impact on agricultural land prices is negative for all regions (Figure 4-24). Prices are negatively affected the most in the south east and north east, and less dramatically in the south and north. Although prices are negatively affected in the center west, this effect is less pronounced than in other regions. The impact on the AAGR in agricultural land prices is negative in all regions (-0.36%, -0.78%, -0.47%, -0.30% and -0.07% in the north, north east, south east, south and center west, respectively; Table 4-9).

Discussion

The baseline model results reveal a 5.5% rate of real GDP growth over the time horizon (Table 4-1). This figure is a reasonable estimate when compared to other real GDP growth projections that vary between 4% and 5% (Jaeger, 2006, p. 1; Ministério de Minas e Energia, no date; Patusco, 2002; Purushothaman, no date; The World Bank, 2008, p. 22).

In the baseline scenario, legal forestry in the north and center west contract while expanding in all other regions (Table 4-2). With forest concessions implemented in 2008, the opposite becomes true- the policy impact is positive in the north and center west and negative in other regions. This is an indication of the current scarcity of forestland for forest management. The increased availability, however, results in greater growth in the illegal forestry sector in the north and center west rather than the contraction experienced in the baseline. Illegal forestry grows at a slower rate than the legal forestry sector given the increasing scarcity of forestland for illegal activities with the establishment of forest concessions.

With increased activity and output resulting from forest concessions, the policy impact on the forest plantation sector, although it continues to grow, is negative in all regions (Table 4-2).

This result, however, does not take into consideration investments that have already been made in forest plantations which are yet to bear their full economic impact.

Legal deforestation in the baseline expands in the north and contracts in the north east and center west. The policy impact, however, leads to positive and faster growth in all regions. Illegal deforestation grows in the north and center west and contracts in the north east in the baseline; the policy impact, however, results in a contraction in all regions. This contraction in illegal deforestation is a function of the increasing scarcity of forestland on which firms may operate illegally and the reduced returns to agricultural land which fund the deforestation institution (Table 4-2). In summary, the policy impact of forest concessions on illegality is to reduce the rate of growth of illegal forestry in the north east and the rate of illegal deforestation in all regions.

As a result of the forest concessions policy, the rate of agricultural growth increases in all regions with the exception of a small decrease in the center west. While the greater rate of expansion in the north and north east are a result of faster rates of legal deforestation and therefore the production of agricultural land, the decline in the center west appears to be the result of a relatively large decrease in illegal deforestation, given the importance of this sector in generating agricultural land.

Various economic indicators such as real GDP, household income, agricultural and forest product supply and forest plantation activity exhibit a positive or negative spike in 2008 or 2009 as a result of the forest concessions policy. Where these spikes occur in 2008, they are the result of the increased availability of forestland in the north. Where they occur in 2009, it is reasonable to assume that this variation is the result of the combined economic impact of greater forestland

availability in the north as well as increased scarcity in forestland for illegal activities. These spikes represent a brief period of economic adjustment to policy implementation.

With a growing population and labor force, it is expected that through time, the domestic demand for aggregate sectoral output will increase. In the baseline, this is the case with domestic demand growing between 3% and 6% (Table 4-4). This is also true in the forest concessions policy scenario where the largest impacts on domestic demand are for forestry and agricultural products, processed wood, and pulp and cellulose; in the case of exports, the policy impact is also positive for these products. With regards to composite commodity prices, forestry and agricultural product as well as processed wood product prices increase in the baseline (Table 4-5); the policy impact of forest concessions, however, results in a reduced rate of growth in these prices.

Just as the level of activity of the legal and illegal forestry sectors in the north and center west are positively affected by the policy, growth in their demand for forestland also increases. In the case of illegal deforestation in the north and center west, the growth in demand for forestland is positive in the baseline; the policy, however, results in a negative rate of growth for this activity's demand for forestland. In the north east, the policy impact on growth in demand for forestland is positive although still decreasing.

The policy impact on the rate of growth in the agriculture sector's demand for agricultural land increases in all regions but the center west. This increased growth in demand is met by a reduced rate of growth in the forest plantations sectors' demand for land and an increase in the rate of growth of legal deforestation and therefore an increasing stock of agricultural land.

With regards to household income, there is a positive overall policy impact on income levels (Table 4-7). With high and mid-income households receiving a greater share of income from deforestation among other things, their incomes also grow at a faster rate. Low-income and mid-income households experience an adjustment period to the policy shock with their incomes being negatively affected in comparison to the baseline for 4 and 2 years, respectively; high-income households are positively affected throughout the simulation period.

Through time, in the baseline, labor and capital income increases; forest concessions have a positive impact on the income of all labor classes as well as capital (Table 4-8). The policy impact on growth of forestland income is large and positive in the north and negative in other regions. With the price of forestland negatively impacted by the policy in all regions (Table 4-9), the increase in forestland income in the north is explained by the increase in the stock and demand for forestland in the north. The greatest negative effect on forestland prices is in the north followed by the center west.

With regards to agricultural land income, the average rate of growth is increasing in the baseline; in the policy shock scenario, the policy impact is negative in all regions but the north (Table 4-8). With agriculture in all regions with the exception of the center west exhibiting greater growth in demand for agricultural land as a result of the policy, the negative impact on agricultural land income is due to the magnitude of the negative impact of the policy on the price of agricultural land in all regions (Table 4-9). Interestingly, in the north, the impact on agricultural land income is negative in 2008 and from 2010 to 2014. This is an indication that the policy impact on agricultural land income is mixed initially requiring a number of years for adjustments to take place.

[1] Although beyond the scope of the current discussion, the drivers of deforestation are reviewed in Kaimowitz & Angelsen (1998); a literature review of the drivers of deforestation may be found in Glantz, Brook &Parisi (1997).

[2] New logging centers were established less than 10 years ago (as of 2004) and are located primarily in western Pará and the extreme north west of Mato Grosso (Lentini et al., 2005a, p. 37); these centers form an arc from the BR-163 highway in western Pará to the extreme north west of Mato Grosso until the southern reaches of the state of Amazonas close to the Trans-Amazon highway (Lentini et al., 2005a, p. 62).

[3] In the case of the center west, given the high levels of deforestation and the large number of new logging centers, this value is further adjusted downwards since calculated as described above, illegal deforestation on its own would account for over 53% of the total (legal deforestation, legal logging and illegal logging) forest sector output.

[4] As better data becomes available, a closer approximation of illegal sectors' payments to forestland will be possible.

[5] Estimates on population and labor force growth rates were obtained from the Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat. Projections on the depreciation rate and total factor productivity growth rates were taken from the Organisation for Economic Co-operation and Development's [OECD] Economic Surveys (2006). The average capital to output ratio was obtained from Morandi and Reis (2004).

[6] Deforestation driven by land speculation may not necessarily be put towards a productive use. Furthermore, deforested areas that are put towards production may be later abandoned due to low productivities. These processes are beyond the scope of the present analysis, however (see Cattaneo (2002) for the incorporation of land degradation in a static CGE framework).

[7] Forestland in the model is treated as homogenous, specifically, it is not distinguished by tenure type. As a result, forestland that enters the model as forest concessions is technically available to both legal and illegal forestry and deforestation sectors. Deforestation is of course not permitted by law on forest concessions and the illegal deforestation of forest concessions is not likely to occur at any significant level given a concessionaire's vested interest in prohibiting encroachment by third parties. It is thus assumed that within the aggregate forestland base, deforestation occurs on non-concessioned forestland.

[8] The yield distortion parameter calculated in this way likely underestimates the inefficiency of illegal operations as well as the increasing scarcity of forestland for illegal operations as forest concessions expand. As data on the real economic effects of forest concessions become available, the ability to estimate this parameter will improve. Though beyond the scope of this research, as with all model parameters, systematic sensitivity analysis may be conducted to examine the sensitivity of results to changes in the assumptions embodied in exogenous parameter inputs. Furthermore, confidence intervals may also be generated for any endogenous variables in the model (see Alavalapati, Adamowicz & White, 1999 and Arndt & Pearson, 1998, for details).

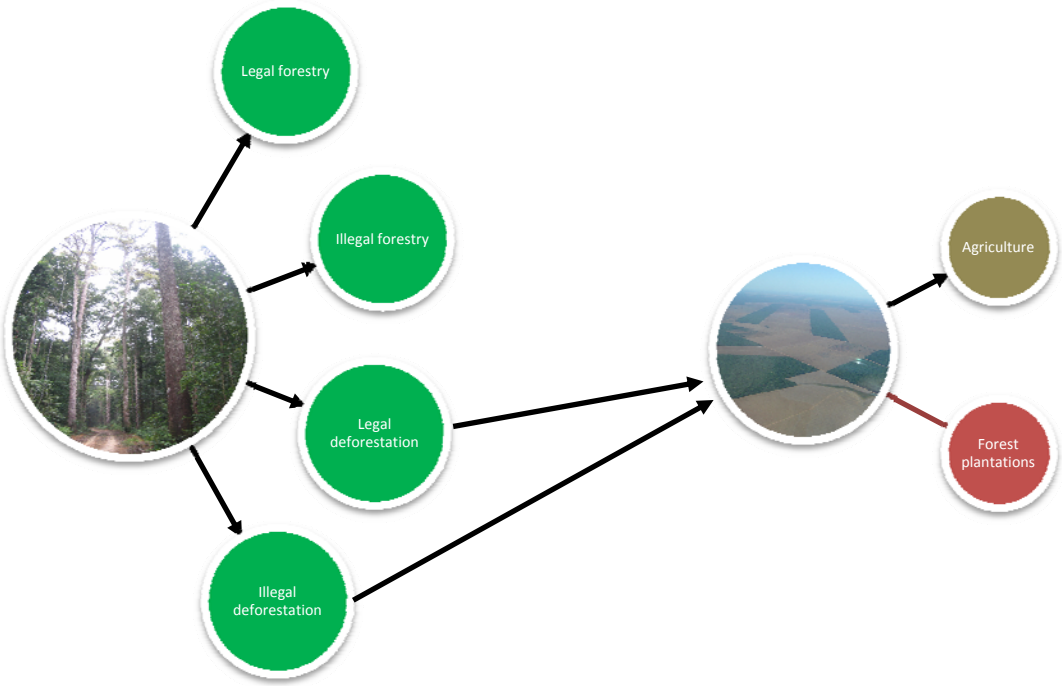

Figure 4-1. Relationship between forestry, deforestation, forest plantations, agriculture, forestland and agricultural land

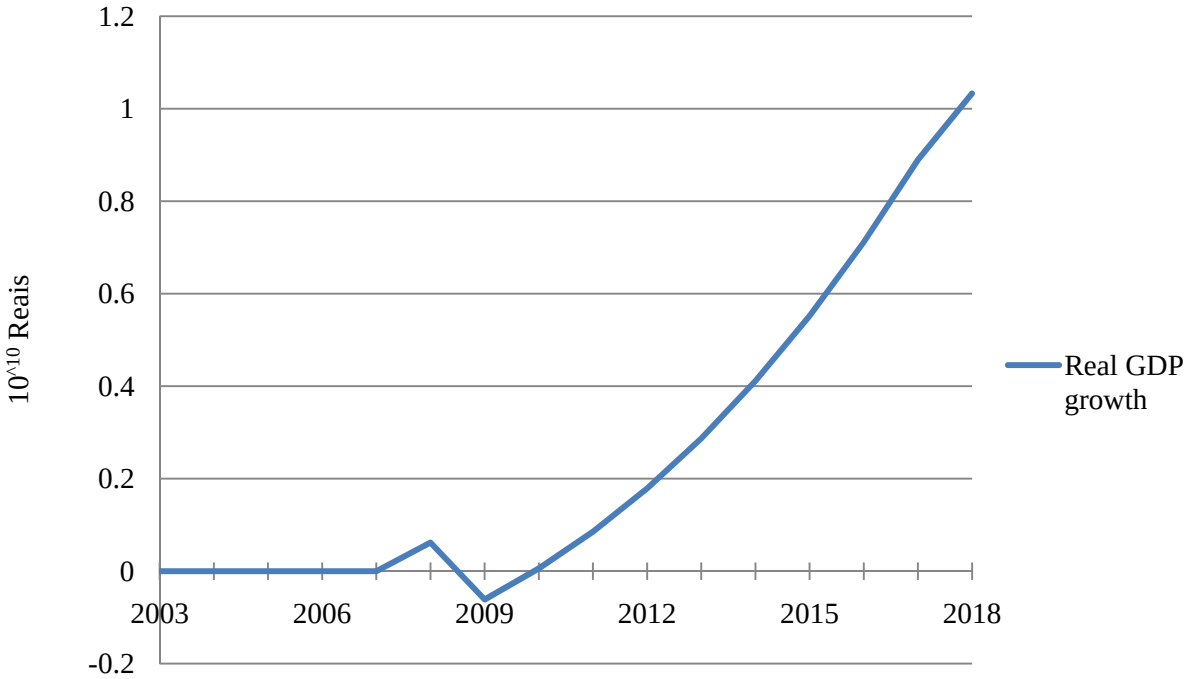

Figure 4-2. Policy impact on real GDP growth

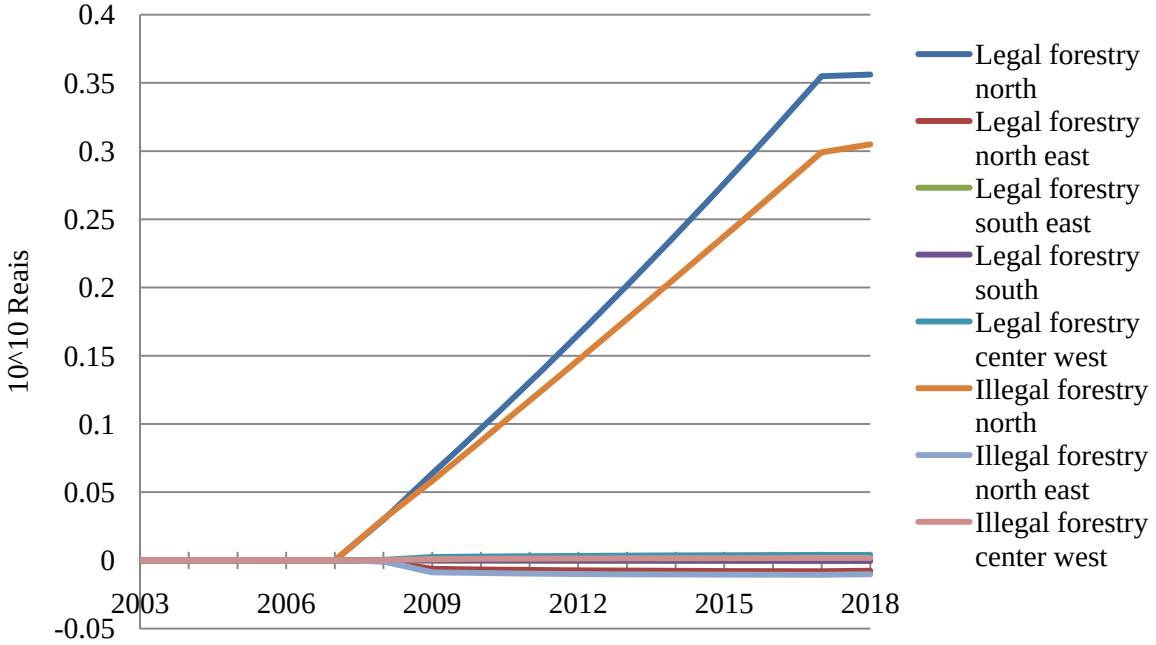

Figure 4-3. Policy impact on the level of legal and illegal forestry activity in the north, north east, south, south east and center west

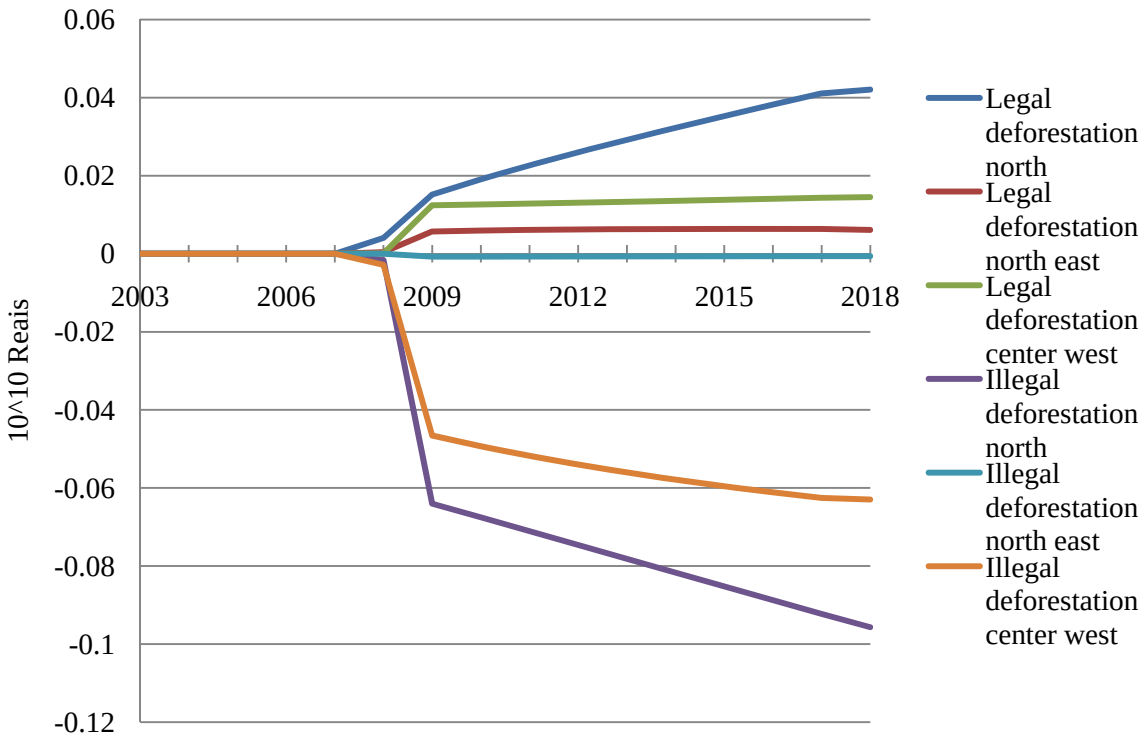

Figure 4-4. Policy impact on the level of legal and illegal deforestation activity in the north, north east and center west

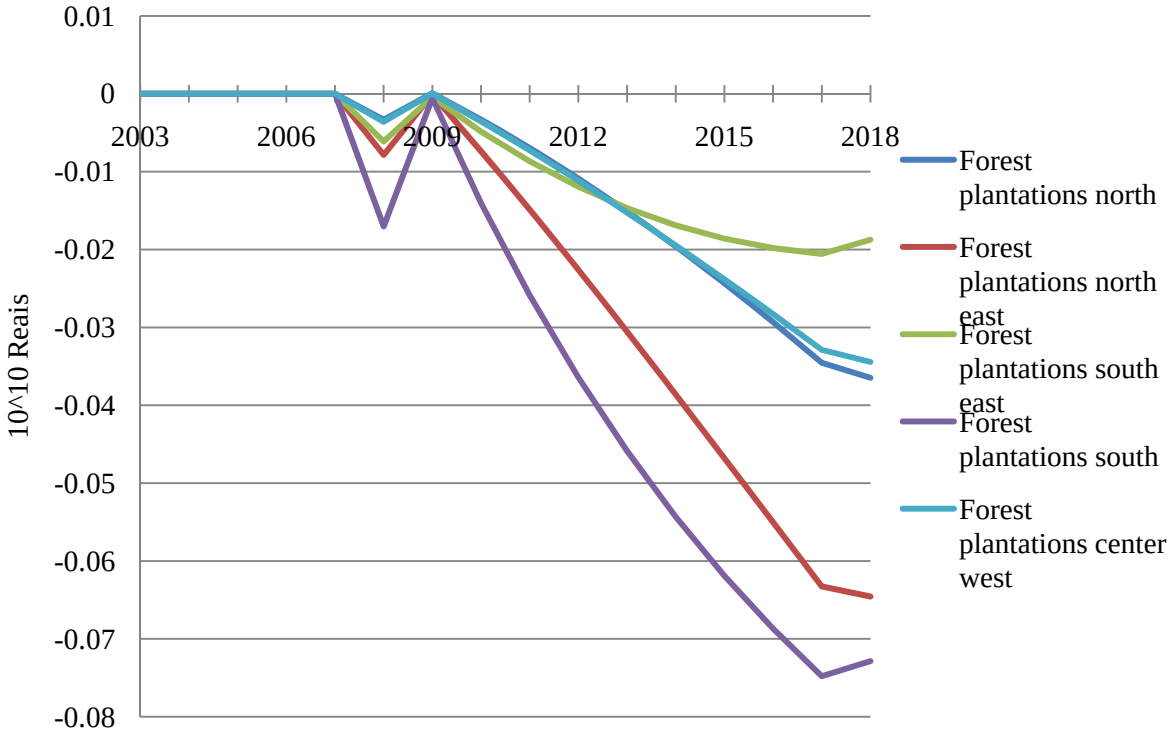

Figure 4-5. Policy impact on level of forest plantation activity in the north, north east, south east, south and center west

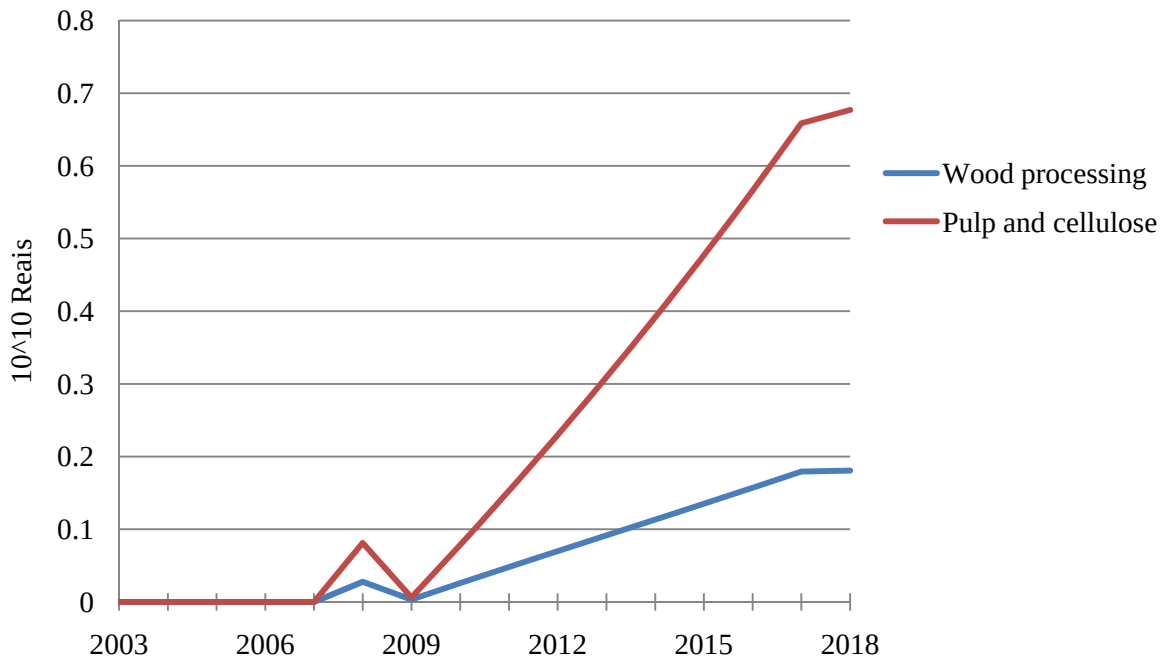

Figure 4-6. Policy impact on the level of wood processing and pulp and cellulose activity

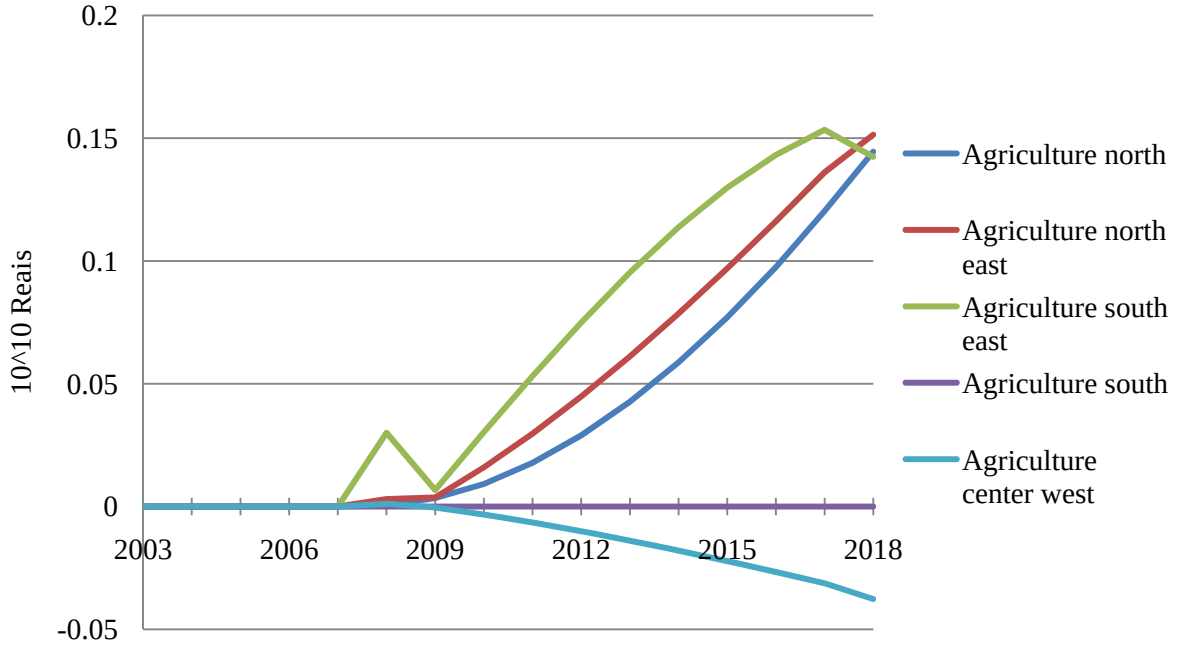

Figure 4-7. Policy impact on the level of agricultural activity in the north, north east, south east, south and center west

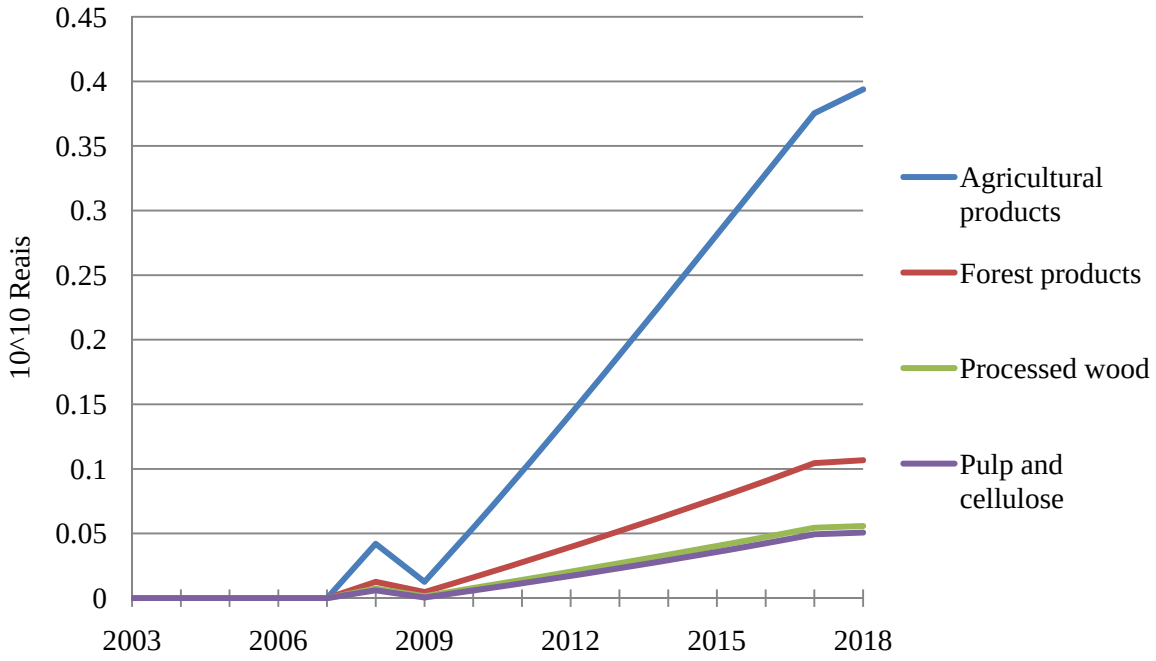

Figure 4-8. Policy impact on composite commodity supply of agricultural, forest, processed wood, and pulp and cellulose products

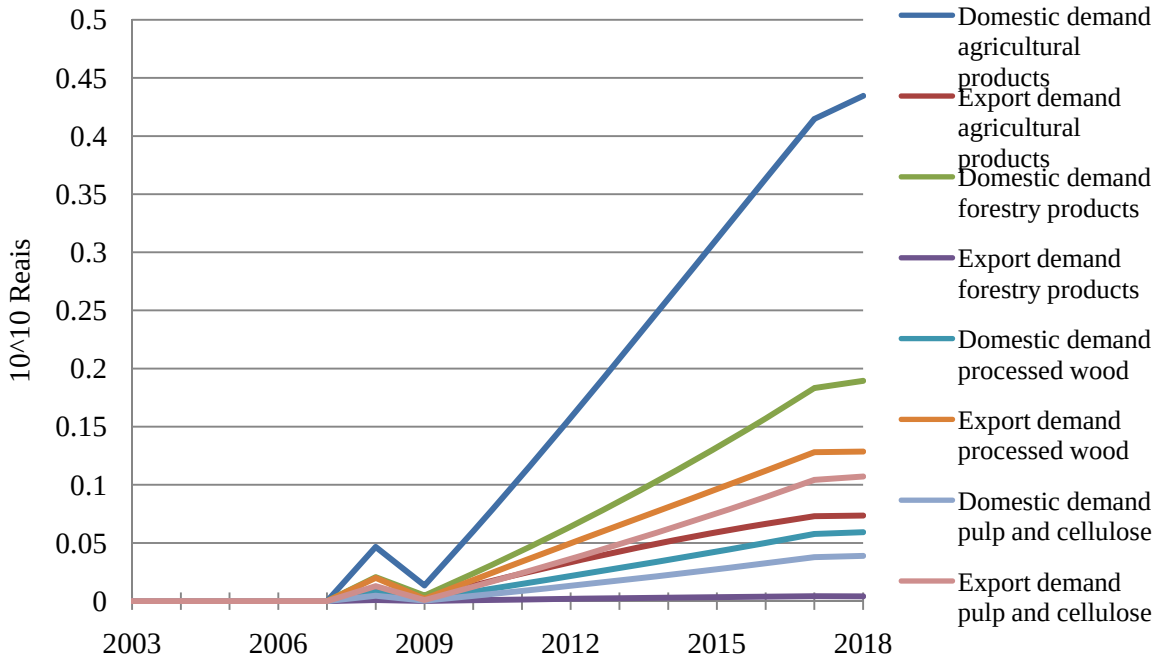

Figure 4-9. Policy impact on domestic and export demand for agricultural, forest, processed wood, and pulp and cellulose products

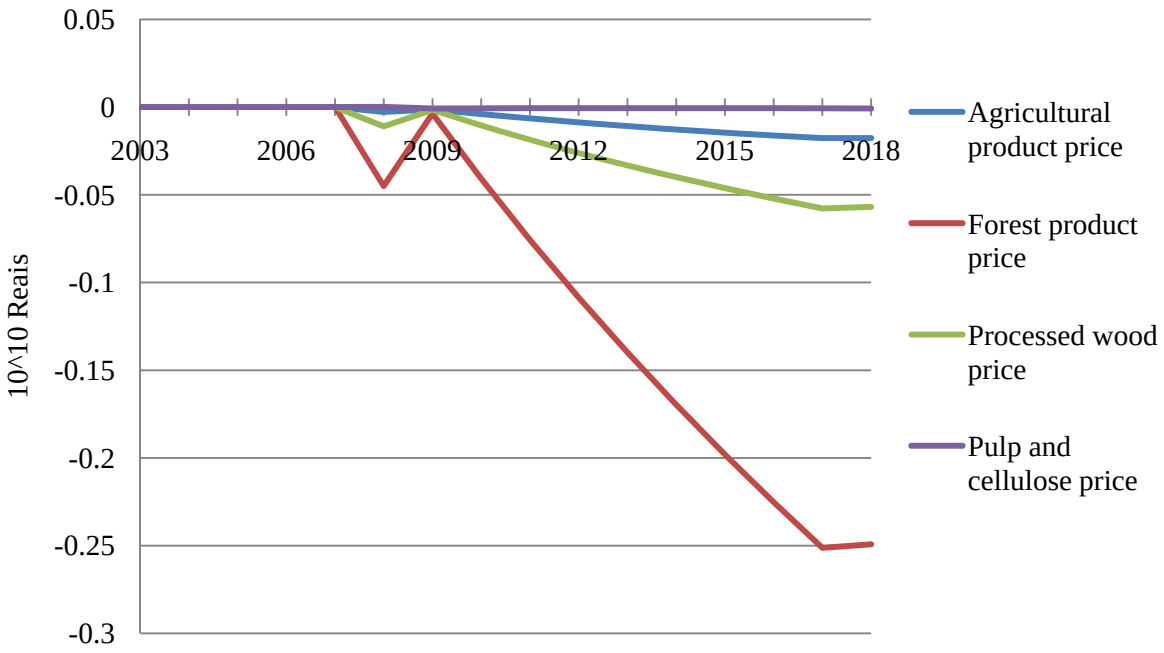

Figure 4-10. Policy impact on composite commodity prices of agricultural, forest, processed wood, and pulp and cellulose products

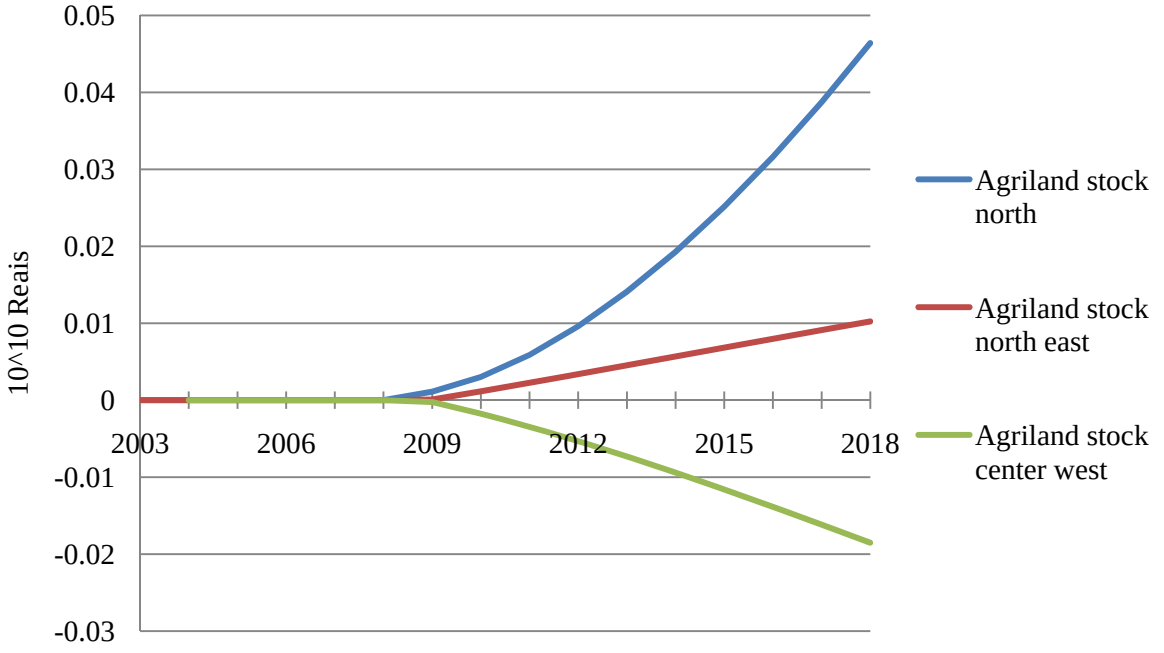

Figure 4-11. Policy impact on agricultural land stock in the north, north east and center west

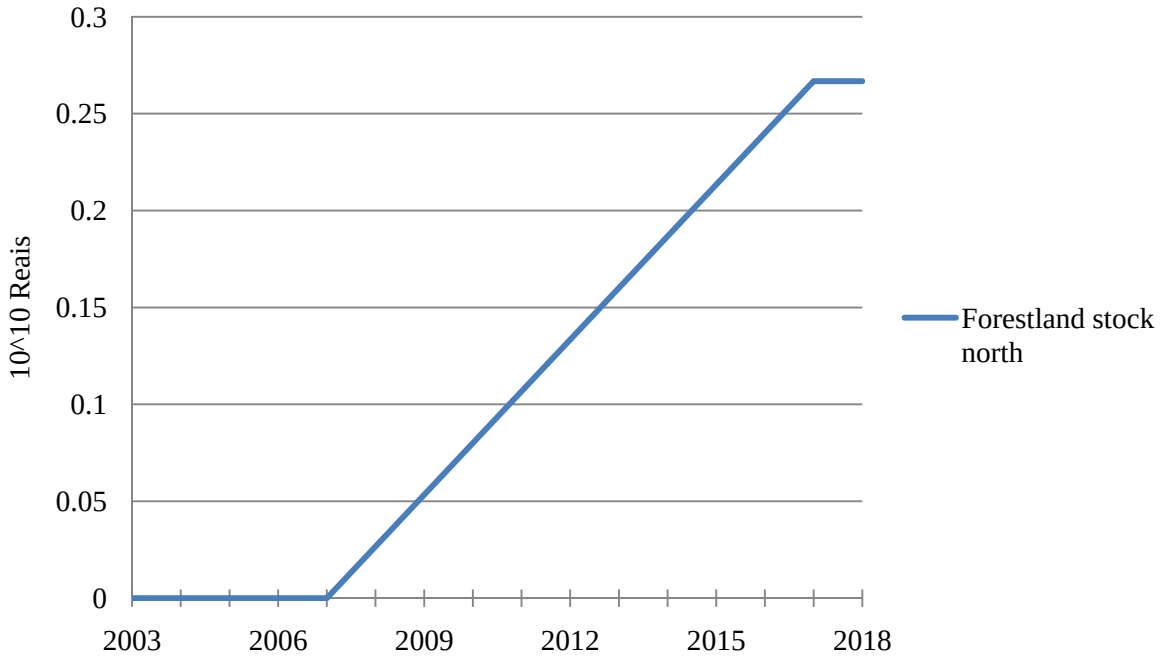

Figure 4-12. Policy impact on forestland stock in the north

Figure 4-13. Policy impact on forestland demand in the north east, south east and south

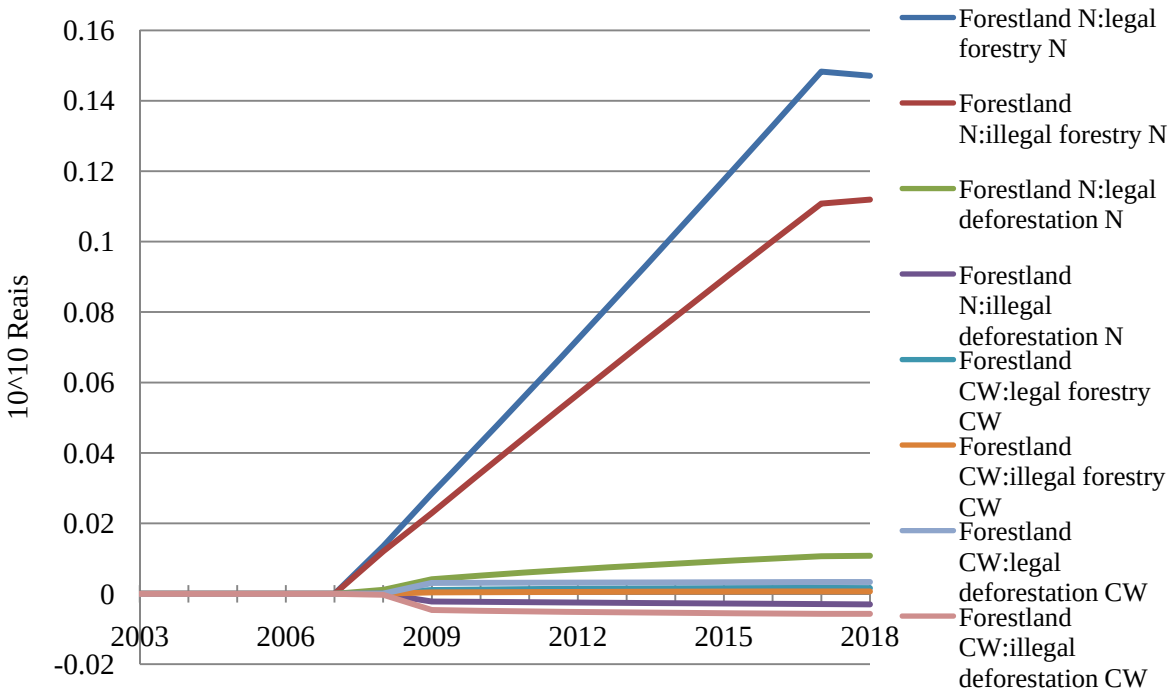

Figure 4-14. Policy impact on forestland demand in the north and center west

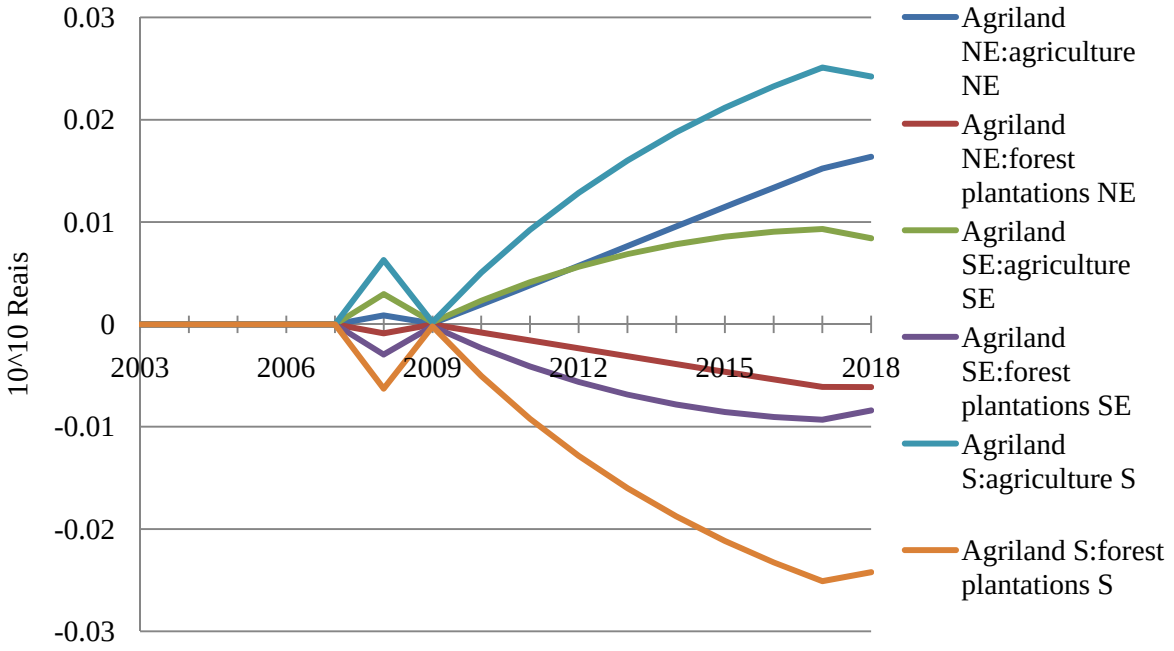

Figure 4-15. Policy impact on agricultural land demand in the north east, south east and south

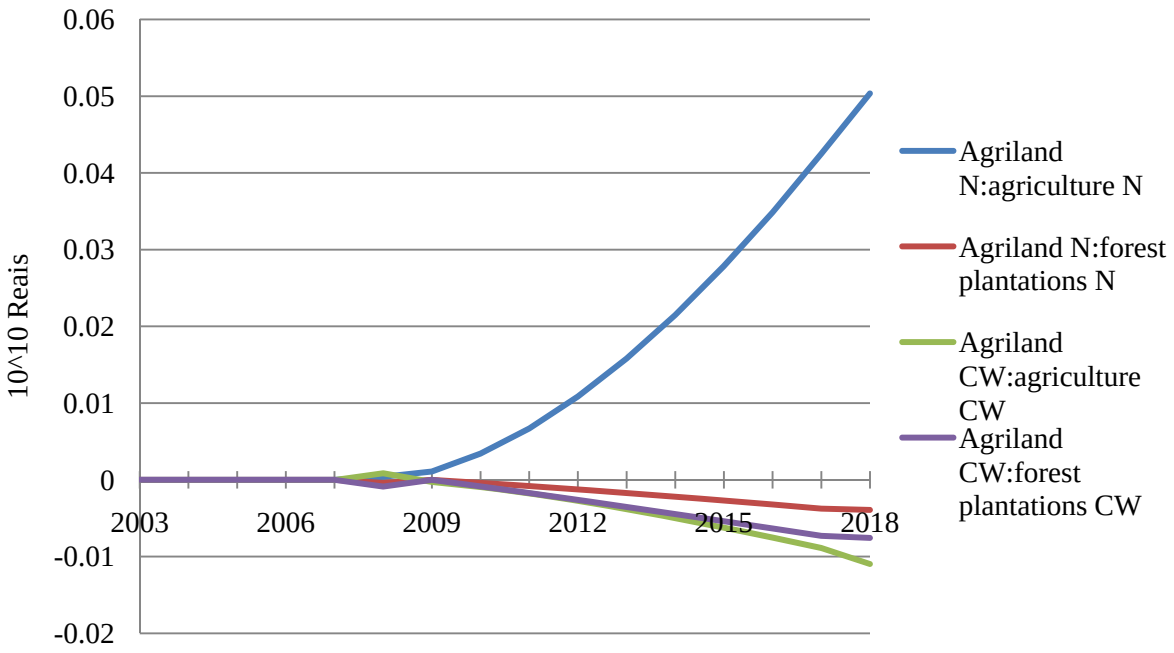

Figure 4-16. Policy impact on agricultural land demand in the north and center west

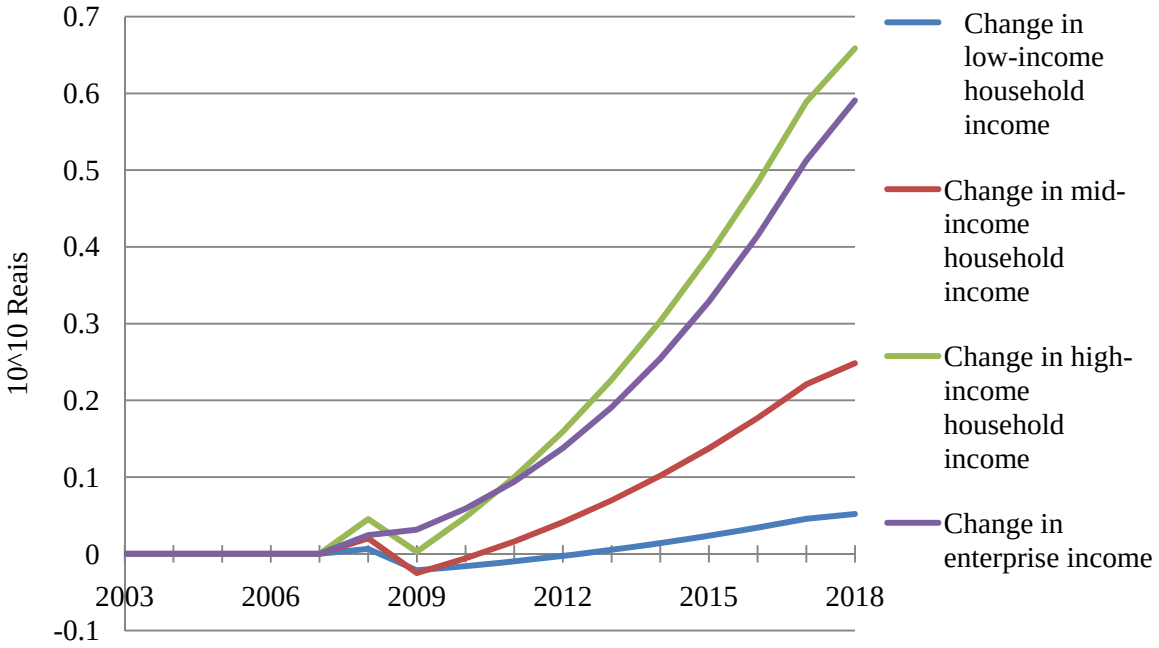

Figure 4-17. Policy impact on household and enterprise income

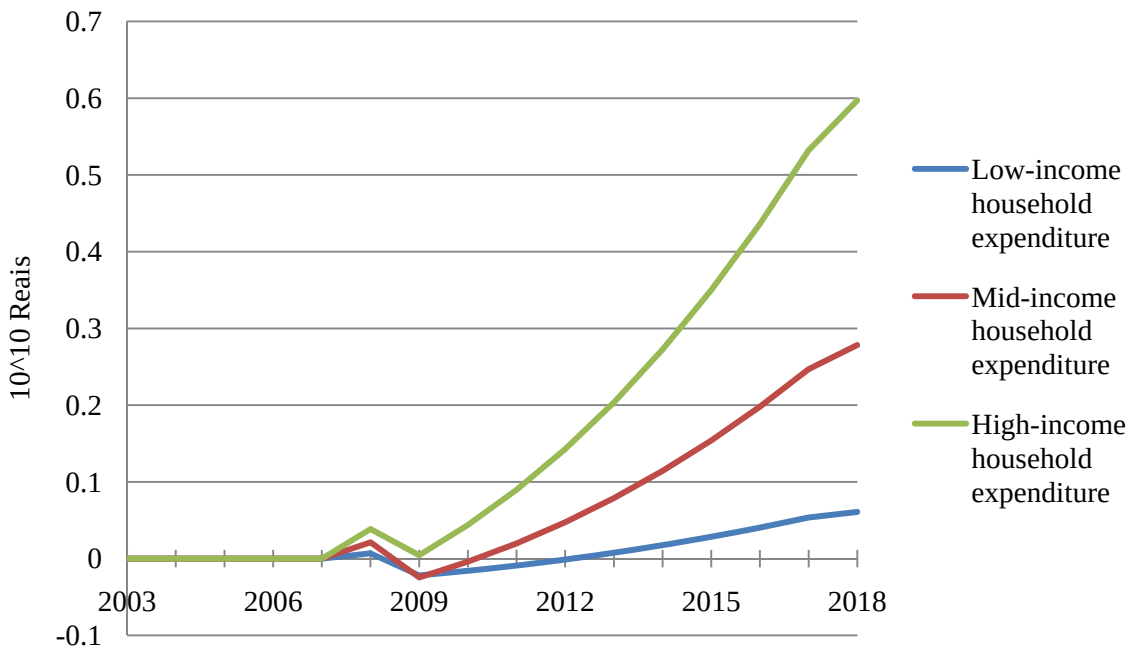

Figure 4-18. Policy impact on household expenditures

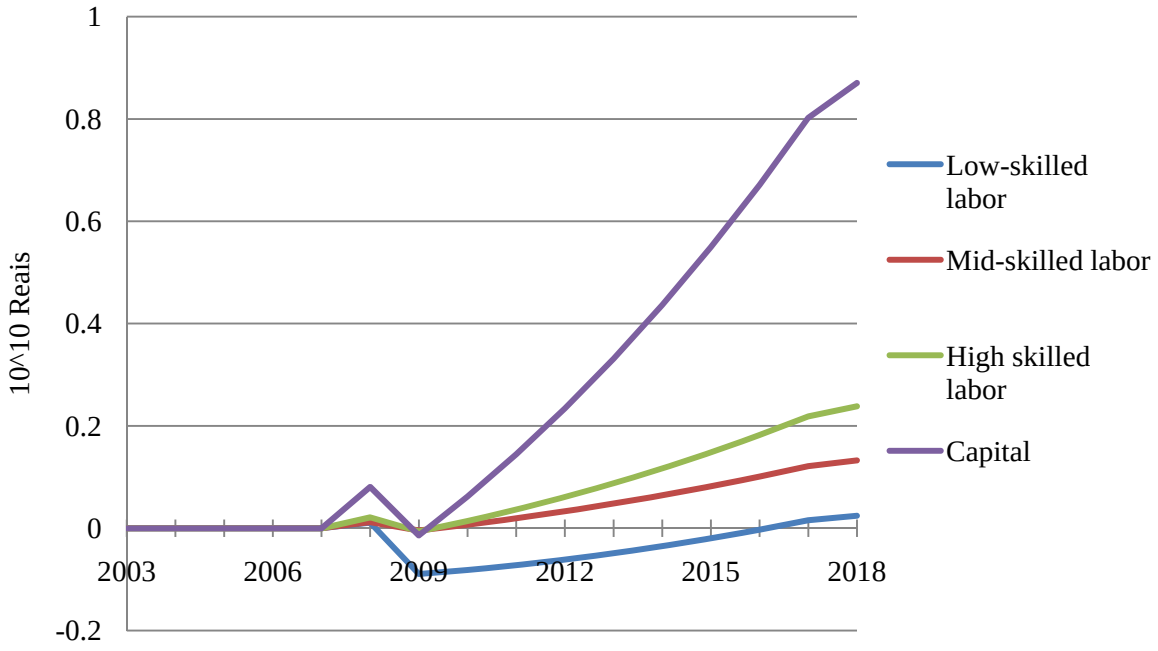

Figure 4-19. Policy impact on labor and capital income

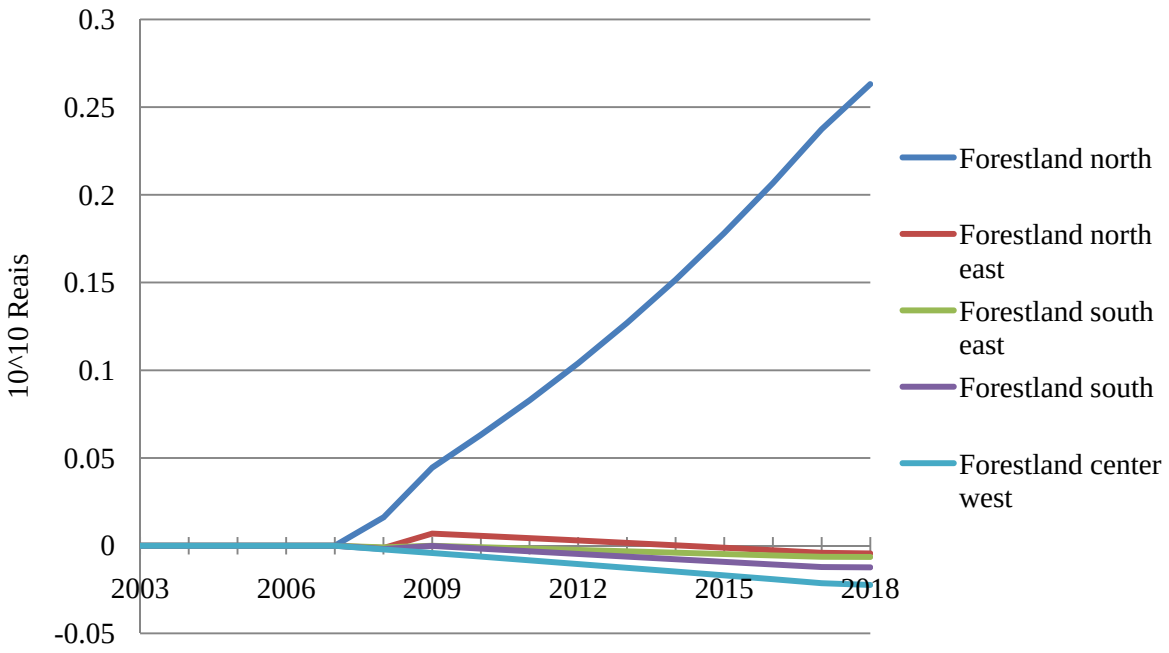

Figure 4-20. Policy impact on forestland income in the north, north east, south east, south and center west

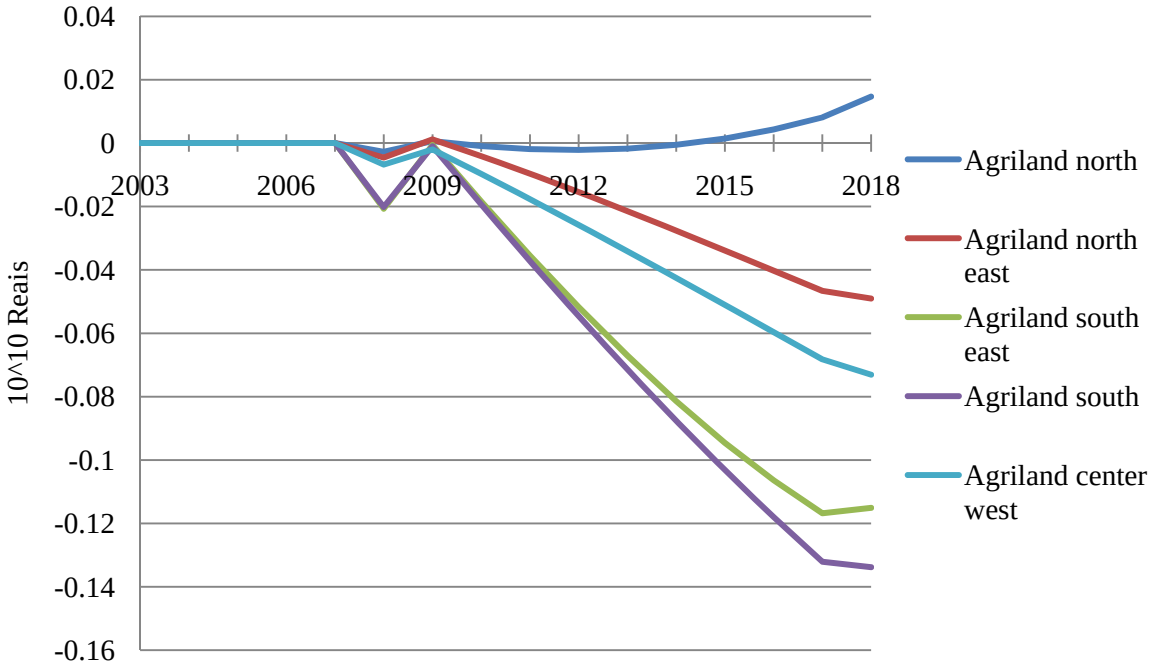

Figure 4-21. Policy impact on agricultural land income in the north, north east, south east, south and center west

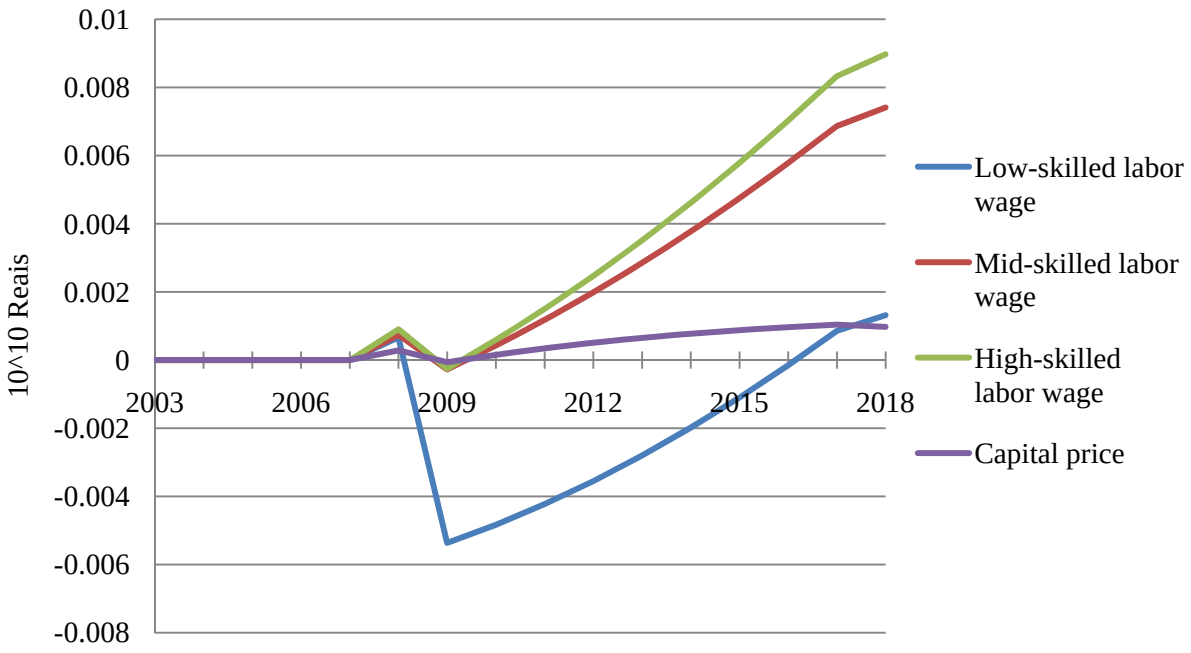

Figure 4-22. Policy impact on labor wages and the price of capital

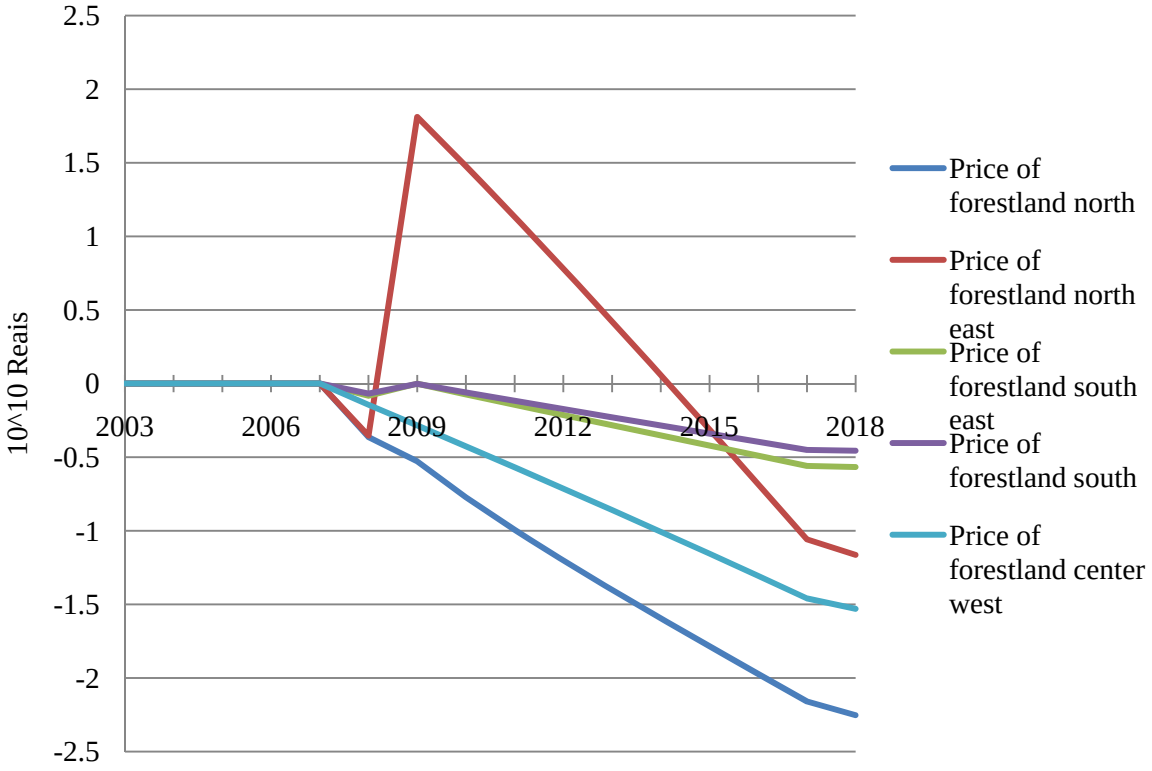

Figure 4-23. Policy impact on price of forestland in the north, north east, south east, south and center west

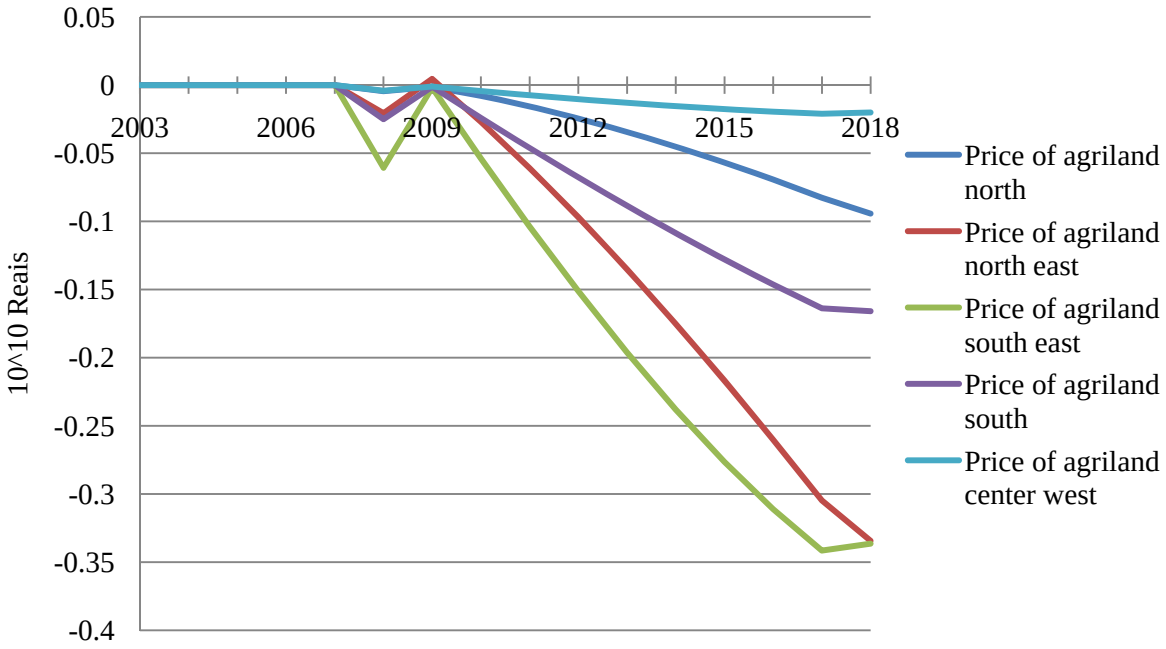

Figure 4-24. Policy impact on the price of agricultural land in the north, north east, south east, south and center west

Table 4-1. Annual compound percent change in macroeconomic and institutional indicators between 2003 and 2018

Indicator	Baseline	Policy shock	Difference
	Annual compound percent change		
Real household consumption (LCU at base prices)	5.9	5.9	0.0
Real investment (LCU at base prices)	6.2	6.2	0.0
Real government consumption (LCU at base prices)	4.4	4.4	0.0
Total real exports (LCU at base prices)	5.1	5.1	0.0
Total real imports (LCU at base prices)	5.8	5.8	0.0
Purchasing Power Parity real exchange rate (LCUs per FCU)	-0.3	-0.3	0.0
Consumer Price Index (100 for base)	-0.2	-0.2	0.0
Investment (% of nominal GDP)	0.0	0.0	0.0
Private savings (% of nominal GDP)	-0.6	-0.6	0.0
Foreign savings (% of nominal GDP)	0.0	0.0	0.0
Trade deficit (% of nominal GDP)	0.1	0.1	0.0
Government savings (% of nominal GDP)	0.6	0.6	0.0
Direct tax revenue (% of nominal GDP)	0.0	0.0	0.0
Real household consumption			
Low-income household	3.7	3.7	0.0
Mid-income household	5.6	5.6	0.0
High-income household	6.6	6.6	0.0
Deforestation enterprise	3.3	-9.2	-12.5
Equivalent Variation			
Low-income household	5.0	5.0	0.0
Mid-income household	8.6	8.7	0.1
High-income household	11.2	11.2	0.0
Deforestation enterprise	17.3	-3.0	-20.3
Nominal GDP at market prices	5.5	5.5	0.0
Nominal GDP at factor cost	5.6	5.6	0.0
Real GDP at market prices	5.5	5.5	0.0
Real GDP at factor cost	5.5	5.6	0.0

Notes: LCU and FCU are local and foreign currency units respectively

Table 4-2. Average annual growth rate in the level of domestic activity between 2003 to 2018

Activity	Baseline (%)	Policy shock (%)	Difference (%)
Agriculture north	1.85	2.29	0.45
Agriculture north east	1.69	2.05	0.36
Agriculture south east	5.06	5.15	0.09
Agriculture south	2.00	2.17	0.18
Agriculture center west	1.65	1.60	-0.05
Legal forestry north	-0.02	13.51	13.53
Legal forestry north east	5.91	3.69	-2.22
Legal forestry south east	1.18	1.10	-0.08
Legal forestry south	1.03	0.99	-0.04
Legal forestry center west	-3.67	0.42	4.09
Illegal forestry north	1.65	12.24	10.59
Illegal forestry north east	5.37	2.58	-2.78
Illegal forestry center west	-2.13	0.80	2.93
Forest plantations north	14.40	11.28	-3.11
Forest plantations north east	12.40	9.75	-2.65
Forest plantations south east	-7.31	-9.19	-1.87
Forest plantations south	2.84	0.27	-2.56
Forest plantations center west	12.40	9.12	-3.28
Legal deforestation north	0.28	9.02	8.74
Legal deforestation north east	-10.52	-0.60	9.92
Legal deforestation center west	-0.55	9.67	10.22
Illegal deforestation north	5.07	-21.01	-26.08
Illegal deforestation north east	-0.70	-8.17	-7.47
Illegal deforestation center west	3.19	-2.00	-5.19
Mining and petroleum	6.28	6.25	-0.02
Industry	5.72	5.73	0.01
Wood processing	4.05	4.43	0.38
Pulp and cellulose	3.49	4.24	0.75
Food processing	3.61	3.71	0.10
Utilities	5.92	5.94	0.02
Construction	6.04	6.07	0.03
Commerce	6.86	6.79	-0.08
Transportation	5.91	5.92	0.01
Private services	5.96	5.97	0.01
Public services	4.39	4.39	0.00

Table 4-3. Average annual growth rate in the quantity of composite supply between 2003 and 2018

Activity	Baseline (%)	Policy shock (%)	Difference (%)
Agriculture	3.90	3.98	0.09
Forestry	3.98	4.45	0.47
Deforestation	3.34	-9.19	-12.52
Mining and petroleum	5.72	5.74	0.01
Industrial	5.77	5.80	0.03
Processed wood	5.21	5.34	0.14
Pulp and cellulose	3.82	4.58	0.76
Processed food	4.72	4.78	0.05
Utilities	5.85	5.87	0.02
Construction	6.04	6.07	0.03
Commerce	6.42	6.37	-0.05
Transportation	5.90	5.91	0.01
Private services	5.94	5.95	0.01
Public services	4.39	4.39	0.00

Table 4-4. Average annual growth rate in the quantity of domestic and export sales between 2003 and 2018

Good or service	Baseline Domestic sales (%)	Policy shock Domestic sales (%)	Difference Domestic sales (%)	Baseline Exports (%)	Policy shock Exports (%)	Difference Exports (%)
Agriculture	3.56	3.66	0.10	0.91	1.12	0.21
Forestry	2.17	3.27	1.10	-4.28	-1.75	2.53
Deforestation	3.34	-9.19	-12.52	0.00	0.00	0.00
Mining and petroleum	5.95	5.95	0.00	7.03	6.96	-0.07
Industrial products	5.82	5.84	0.02	6.10	6.07	-0.03
Processed wood	5.16	5.31	0.15	2.36	3.22	0.86
Pulp and cellulose	3.78	4.54	0.76	3.39	4.13	0.74
Processed food	4.67	4.73	0.05	1.01	1.16	0.15
Utilities	5.91	5.92	0.02	0.00	0.00	0.00
Construction	6.04	6.07	0.03	6.25	6.27	0.02
Commerce	6.04	6.03	0.00	5.35	5.43	0.08
Transportation	5.90	5.91	0.01	6.10	6.08	-0.02
Private services	5.96	5.97	0.01	6.12	6.11	-0.01
Public services	4.39	4.39	0.00	0.00	0.00	0.00

Table 4-5. Average annual growth rate in composite commodity prices between 2003 and 2018

Good or service	Baseline (%)	Policy shock (%)	Difference (%)
Agriculture	1.68	1.59	-0.09
Forestry	4.23	3.29	-0.94
Deforestation	2.54	15.02	12.49
Mining and petroleum	-0.78	-0.76	0.02
Industrial products	-0.43	-0.43	0.01
Processed wood	0.89	0.57	-0.32
Pulp and cellulose	-0.20	-0.20	0.00
Processed food	0.86	0.81	-0.04
Utilities	-1.01	-0.99	0.02
Construction	-0.75	-0.75	0.00
Commerce	0.52	0.41	-0.11
Transportation	-0.59	-0.56	0.02
Private services	-0.55	-0.54	0.02
Public services	1.29	1.31	0.02

Table 4-6. Average annual growth rate in the quantity of factor demand by industry between 2003 and 2018

Activity	Factor	Baseline (%)	Policy shock (%)	Difference (%)
Agriculture north	Agricultural land north	0.91	1.39	0.48
Forest plantations north		13.41	10.35	-3.06
Agriculture north east	Agricultural land north east	-0.05	0.45	0.50
Forest plantations north east		10.84	8.30	-2.54
Agriculture south east	Agricultural land south east	2.25	2.43	0.18
Forest plantations south east		-8.45	-10.31	-1.87
Agriculture south	Agricultural land south	-0.15	0.07	0.22
Forest plantations south		1.60	-0.95	-2.55
Agriculture center west	Agricultural land center west	0.56	0.51	-0.04
Forest plantations center west		11.34	8.07	-3.27
Legal forestry north	Forestland north	-1.13	12.56	13.69
Illegal forestry north		0.75	11.42	10.67
Legal deforestation north	Forest land north	-0.69	8.24	8.92

Table 4-6. Continued

Activity	Factor	Baseline (%)	Policy shock (%)	Difference (%)
Illegal deforestation north		4.01	-21.78	-25.78
Legal forestry north east	Forestland north east	3.55	1.40	-2.16
Illegal forestry north east		4.19	1.42	-2.77
Legal deforestation north east		-11.56	-1.64	9.93
Illegal deforestation north east		-1.92	-9.37	-7.45
Legal forestry south east	Forestland south east	0.00	0.00	0.00
Legal forestry south	Forestland south	0.00	0.00	0.00
Legal forestry center west	Forestland center west	-4.75	-0.61	4.14
Illegal forestry center west		-3.02	-0.07	2.95
Legal deforestation center west		-1.51	8.76	10.27
Illegal deforestation center west		2.15	-2.96	-5.10

Table 4-7. Average annual growth rate in institutional income between 2003 and 2018

Institution	Baseline (%)	Policy shock (%)	Difference (%)
Low income household	3.11	3.12	0.01
Mid-income household	4.79	4.81	0.02
High-income household	5.54	5.57	0.03
Deforestation institution	5.28	5.25	-0.04
Enterprises	5.88	5.90	0.02
Interest	5.28	5.31	0.03

Table 4-8. Average annual growth rate in factor income between 2003 and 2018

Factor	Baseline (%)	Policy shock (%)	Difference (%)
Low-skill labor	4.86	4.86	0.01
Mid-skill labor	5.03	5.05	0.03
High-skill labor	5.23	5.26	0.03
Capital	5.79	5.82	0.03
Agricultural land north	4.97	5.05	0.08
Agricultural land north east	8.04	7.55	-0.49
Agricultural land south east	11.09	10.61	-0.47
Agricultural land south	9.09	8.79	-0.30
Agricultural land center west	5.48	5.35	-0.14
Forest land north	9.22	14.61	5.39
Forest land north east	14.38	13.71	-0.66
Forest land south east	8.29	6.96	-1.32
Forest land south	7.64	6.50	-1.14
Forest land center west	9.69	7.30	-2.39

Table 4-9. Average annual growth rate in factor wages and prices between 2003 and 2018

Factor	Baseline (%)	Policy shock (%)	Difference (%)
Low-skill labor	3.69	3.70	0.01
Mid-skill labor	3.86	3.89	0.03
High-skill labor	4.07	4.10	0.03
Capital	-1.46	-1.44	0.02
Agricultural land north	3.97	3.61	-0.36
Agricultural land north east	7.62	6.84	-0.78
Agricultural land south east	11.09	10.61	-0.47
Agricultural land south	9.09	8.79	-0.30
Agricultural land center west	4.87	4.80	-0.07
Forest land north	9.22	3.02	-6.20
Forest land north east	14.38	13.71	-0.66
Forest land south east	8.29	6.96	-1.32
Forest land south	7.64	6.50	-1.14
Forest land center west	9.69	7.30	-2.39

CHAPTER 5
CONCLUSIONS

Historical analysis suggests that forest policies of countries with significant forested frontiers transition through stages of forest policy development reflecting the orientation of governments toward economic development on the frontiers, namely: settlement, protective custody and management. To present, with regards to the forests of the Amazon, Brazil is no exception. The period of settlement as the name suggests was characterized by land clearing to provide raw materials and establish farms and ranches. Policy makers could not, however, ignore the apparent devastation that resulted, particularly in the Atlantic Forest Region, and passed the first Forestry Code in 1934. A basic framework for forest concessions was included in the law, although they were never implemented. With government priorities focusing on colonization and agricultural expansion, the destruction continued largely unabated.

As forests in the Atlantic region continued to be reduced in quantity and quality and with the poor implementation record of the 1934 Forestry Code, policy makers began to develop a New Forestry Code which was subsequently approved in 1965. This New Code was significantly more protectionist and marks the transition in forest policy development to the protective custody phase. An important feature of this code is the limitation placed on private property rights. During this period, protective legislation flourished, along with the creation of large protected areas; initiatives to promote the development of the natural forest management sector were lacking, however. With the forest plantation sector feeding the nation's metal and mineral industries, the provision and management of incentives for forest plantations was a substantial component of forest policy. Institutions and programs during this period were weak and underfunded, however, and although the forest policy framework developed significantly more than in the previous period, the state's prioritization of industrialization and integration of the

Amazon into the national economy resulted in the marginalization of forest policy rendering it largely ineffectual. As such, the protectionist stage of Brazilian forest policy lived out primarily on paper

Signs of change in the relevance of forestry and environmental policy began with the political opening in 1974 when the seeds of an environmental movement were sown. The movement, aligning itself with already established democratic and international environmental movements, was successful in creating political space for the assertion of environmental interests. Brazil's democratization, the growing influence of environmental movements and civil society's effective engagement in political affairs pushed forest policy towards the management stage of policy development by the beginning of the millennium. This transition is marked by various forest and environment sector initiatives such as the National System of Nature Conservation Units (SNUC), The National Forest Program (PNF), incentives for the development of the natural forest management sector, and the Public Forest Management Law (PFML). The PFML is of considerable interest; a significant component of the law involves the authorization of forest concessions on public lands, whereas previous forest policies relating to timber extraction were focused on the regulation of forestry on private land. Taking the PFML as a proximate indicator of the transition to the management stage of forest policy development, the variables that led to the political opening for the approval of the law are important to understand.

First, levels of deforestation reached historic heights in 1995 and 2002. With greater transparency and domestic and international concern for the Amazon region, the state was pushed to act in defense of the forest resources of the region and develop frameworks to combat deforestation. Escalating violence caused by land tenure disputes, changes in the regulatory framework for natural forest management, the ensuing scarcity of forestland for legal forestry,

and the resulting forest sector crisis urged the government to send the PFML proposal to Congress as a constitutional emergency. Aided by the left-leaning Worker's Party and greater representation for the interests of forestry-based communities, the law passed swiftly through Congress and was approved in March of 2006.

The level of success that is experienced in the implementation of the PFML will reveal whether the new policies and institutions established since 2000 represent a break with the past with regards to the low levels of policy implementation that characterized the protective custody period. There are convincing reasons to believe that the management stage of forest policy will be significantly more effectively implemented. Efforts to delimit public lands and state-civil society partnerships are making progress in regulating public land use. With a globalized civil society and media, the economic and political costs of the illegal exploitation of forest resources are becoming a significant obstacle to illegality in the forest sector. The state has committed unprecedented institutional support and funding towards gaining control of forest resources in the Amazon. Various contradictory extra-sectoral policies have been eliminated. Furthermore, the economic opportunities presented by sustainable forest management are increasing. Payments for environmental services, carbon credits for carbon sequestration, and incentives for avoided deforestation may serve to increase the value of standing, managed forests as opposed to an agricultural alternative. The outlook for a transition to management that is lived out in practice is decidedly optimistic.

Taking the PFML and the establishment of forest concessions in particular as a proximate indicator of a substantive transition to the management phase of forest policy development, the economic, welfare, and environmental response to concessions provides an indication of the degree to which, if fully implemented, forest policy will be accepted and supported by society.

Using a static computable general equilibrium model, the short-run socio-economic and environmental implications of implementing forest concessions in the Brazilian Amazon were evaluated.

Simulating the establishment of 1 million hectares of forest concessions in Brazil's northern administrative region, three conclusions with regards to socio-economic and environmental impacts are made. First, households experience growth in their income with the implementation of forest concessions. Although prices of goods and services increase somewhat, households are more than able to cope with their increased income.

Second, forest plantations contract as a result forestry expansion in the north. With the decline in the price of forestland in the north, the forestry sector is able to produce a less expensive product thus squeezing out some of the production from the forest plantations sector. The contraction in the forest plantations sector results in a reduction in its demand for agricultural land which in turn depresses the price of agricultural land. This less expensive land is taken up the agricultural sector, enabling it to produce a more affordable agricultural product.

Finally, the forest concessions policy results in an increase in legal deforestation, with the largest increase occurring in the Amazon. The deforestation institution perceives less income from returns to agricultural land, and although the sector's output of forest products increases, the depression in forest product prices also results in a reduction in its forest product income. All other things being equal, levels of deforestation would also decline as a result of the policy. However, with the price of forestland also depressed, the sector's reduced income was more than offset by the decline in the price of forestland, enabling the deforestation institution to acquire more forestland, clear more land, and produce more forest products.

Given the significant economic importance of the illegal forestry and illegal deforestation sectors in Brazil and to more realistically evaluate the socio-economic and environmental impacts of forest concessions, illegal forestry and illegal deforestation sectors are disaggregated and modeled. A recursive dynamic computable general equilibrium modeling framework is chosen to consider the medium-term implications of the implementation of forest concessions. Advantages of the dynamic modeling framework include: the ability to update the factor supply of agricultural land based on annual levels of deforestation; the model sheds light on the economic transition path resulting from the policy shock; and, it provides information on the short-term costs and longer-term gains resulting from policy implementation. The baseline scenario projects the Brazilian economy from 2003 to 2018 by accounting for growth in the labor force, population, and total factor productivity, as well as accounting for capital accumulation and depreciation. The policy shock scenario uses the results of the baseline scenario and introduces the forest concessions shock into the economy. The difference between the value of indicators in the baseline and the policy shock scenario is the net policy impact of forest concessions.

The overall policy impact of forest concessions on the Brazilian economy is relatively small with the exception of the negative welfare impact on the illegal deforestation institution. In the absence of forest concessions, legal forestry activities contract in the north and center west. Increased demand for forest products is met by relatively large growth in forest plantations with the exception of the south east. Introducing the concessions policy, legal forestry in the north and center west expand, which may be an indication of the current scarcity of forestland for legal forestry operations. Illegal forestry activities increase in the baseline in the north and north east and decrease in the center west; in the policy scenario, growth in activity increases dramatically

in the north and to a slightly lesser degree in the center west, while growth is reduced in the north east.

Legal deforestation in the baseline expands slightly in the north and contracts in the north east and center west. The policy impact, however, leads to faster growth in all regions. It should be noted that although growth rates in legal deforestation activities are large, the legal deforestation sector's output of forest products and demand for forestland is initially quite small. Illegal deforestation grows in the north and center west and contracts in the north east in the baseline; the policy impact, however, results in a contraction in all regions. This contraction in illegal deforestation is a function of the increasing scarcity of forestland on which firms may operate illegally and the reduced returns to agricultural land which fund the deforestation institution. In addition, since legal deforestation is able to more fully utilize timber prior to land clearing, it is able to out-compete the illegal deforestation sectors in terms of forest product output. The overall policy impact of forest concessions on illegality is to reduce the rate of growth of illegal forestry in the north east and reduce the level of illegal deforestation in all regions; the legal deforestation sectors grow faster as a result of the policy.

As a result of increased forest product output from legal and illegal forestry and legal deforestation in the north, the forest plantations sectors experience a negative policy impact in all regions. Nonetheless, forest plantation activities continue to grow with the exception of the south east. With increased supply of raw materials from forest product producing sectors, the processed wood, and pulp and cellulose sectors grow at a faster rate as a result of the policy. Both domestic and export demand increase for forestry, agricultural, processed wood, and pulp and cellulose products. Agricultural and forest product prices grow at a slower rate as a result of forest concessions.

Agricultural activity grows in all regions in the baseline; the policy impact is positive in all regions with the exception of a small reduction in growth in the center west. While the greater rate of expansion in the north and north east are a function of faster rates of legal deforestation (i.e. the production of agricultural land) as well as the forest plantations sectors' reduced demand for agricultural land, the decline in the center west appears to be the result of a relatively large decrease in illegal deforestation, given the importance of this sector in generating agricultural land.

With regards to household income, the policy impact is positive. Since high and mid-income households receive a greater share of income from legal and illegal deforestation among other things, their incomes grow at a faster rate. Low-income and mid-income households experience an adjustment period to the policy shock with their incomes negatively affected for a short period in comparison to the baseline. The overall impact on income growth over the time period, however, is positive.

In the baseline, labor and capital income increase; forest concessions have a positive impact on the income of all labor classes as well as capital due to increased growth in demand and higher rates of growth in wages. The policy impact on growth of forestland income is positive and large in the north and negative in other regions. With the price of forestland negatively impacted by the policy in all regions, the increase in income in the north is explained by the increase in the stock and demand for forestland. With regards to agricultural land income, the average growth rate in all regions is increasing in the baseline. The policy impact is large and positive in the north and negative in all other regions. With all regions experiencing growth in demand for agricultural land in the policy scenario with the exception of the center west, the

negative impact on agricultural land income in all regions but the north is explained by the magnitude of the decrease in the price of agricultural land.

The positive policy impact on household welfare and household income, and growth in the legal forestry and agricultural sectors revealed by the models in Chapters 3 and 4 are positive indicators of the potential societal acceptance of a new forest policy paradigm of management. If forest concessions are fully implemented as they are assumed to be in the modeling experiments, the management phase of policy development promises real and on balance, positive changes to the Amazon's economy and forest sector. The benefits that forest concessions can generate as suggested by these results, particularly in the legal forestry sector, will very likely serve to increase the relevance of forest policy as a tool for promoting socio-economic development.

The implementation of forest concessions presents favorable outcomes with regards to reducing illegality in the case of deforestation. The reduction in the levels of illegal deforestation in the north, north east and center west is certainly a palatable proposition from both a societal and political point of view. Less desirable, however, is the disappointing response of illegal forestry and legal deforestation to the forest concessions policy. Although forest concessions result in a reduction in the rate of growth in illegal forestry in the north east, the contraction of illegal forestry in the center west in the baseline is reversed and the sector expands. The illegal forestry sector in the north also experiences a considerable increase in growth in the policy scenario. In the case of legal deforestation, the contraction experienced in the baseline in the north east and center west is reversed in the policy scenario; in the north, legal deforestation expands at a faster rate. These policy impacts on illegal forestry and legal deforestation are likely not what policy makers and advocates for forest concessions would have desired.

The disappointing policy impact on illegal forestry must be qualified, however. In the modeling exercises, forest concessions are implemented in the absence of any increases in the detection and prosecution of illegality. Improved monitoring, enforcement and the subsequent successful prosecution of violators would increase the costs of doing business illegally. The consequences of improvements in this area are intuitive- higher costs of illegality would force firms into legal compliance (or out of business). Although this would result in an expansion of the legal forestry sector, the overall level of forestry activity when compared to the results of the policy experiment in Chapter 4 would likely be somewhat lower. The forest plantation sectors would probably not experience such a negative policy impact, and forest product prices might increase slightly. Complimentary policies to improve monitoring, enforcement and prosecution of illegality could go a long way in reducing illegality in the forestry sector.

Another result that signals the need for complimentary policies as forest concessions are implemented is the negative effect on low and mid-income households in the early years of policy implementation. From 2009 to 2012 and 2009 to 2010, the policy impact on low-income and mid-income households, respectively, is negative. This result is likely driven by the negative policy impact on low-skilled labor wages between 2009 and 2016. Economic development programs and social programs could be effective in counteracting the negative impacts on income growth experienced in the initial years of policy implementation.

Four limitations to the modeling approach adopted in this research should be mentioned. First is with regards to the policy impact of concessions on legal deforestation. The policy impact on legal deforestation resulted in increased rates of growth in the north and center west. Though initial levels of deforestation are low, this result is still troublesome and highlights a limitation in the simulation design. This increase in the rate of growth of deforestation is in part explained by

the fact that the legal deforestation sector is not constrained by increasing factor scarcity of private forestland, rather, it is constrained by the total supply of forestland. For deforestation to be legal, it must be legally authorized on private land. Private property owners in the Amazon are permitted by law to clear up to 20% of their forestland. The amount of forest area that can legally be cleared on private land, however, is likely somewhat scarce; reliable estimates of the size of this area are required to increase the realism of the simulation with regards to forestland constraints on the legal deforestation sector.

The second limitation is elucidated by the policy impact on the illegal forestry sector. The illegal forestry sector's use of forestland is constrained by the total supply of forestland. The potential increasing scarcity of forestland for illegal activities is modeled as reduced yields per unit of illegal forestry activity. With the implementation of forest concessions, the 1 million hectare per year increase in forestland stock is made available to all forest product producing sectors. With the implementation of forest concessions, however, both the state and the concessionaire have a vested interest in prohibiting the illegal logging or clearing of the concession by a third party. Illegal activities engaged in by the concessionaire aside (i.e. over-harvesting, under-reporting, harvesting in sensitive areas), it is expected that the level of monitoring and enforcement in the concession and in proximity to the concession would increase as a result of the policy. To some degree, this heightened vigilance is modeled by the illegal forestry sector's reduced yields per unit of activity. The real effect of concessions in reducing the availability of forestland for illegal operations is uncertain, however, though it is likely lower than that modeled in Chapter 4.

The third model limitation is with regards to the world prices of goods and services. World prices and therefore export prices remain constant in the dynamic modeling experiment.

Often, depending on the time horizon of analysis, world prices are updated according to projections made by industry experts. The highly aggregated social accounting matrix developed for this analysis, however, is not conducive to exogenously updating world prices. For example, the industrial sector produces everything from leather goods to motor vehicles, whose general rate of growth in prices may be quite different. To avoid erroneous conclusions that may be driven by the inflexibility in the world price system as modeled, a medium-term time horizon of 10 years was chosen. Since domestic prices are allowed some flexibility in the model due to imperfect substitution between imported goods and domestically produced goods, domestic prices tend to grow while export prices remain constant. The implications of fixed world prices on the modeling results are a likely lower growth rate in exports than would occur if world prices were updated according to industry projections.

Finally, the fourth limitation to the modeling approach involves the aggregation of households. Disaggregation of households according to region would be advantageous to understand the regional income impacts of policy implementation. As the results from Chapters 3 and 4 indicate, there is a small increase in aggregate household income and welfare. With a regional disaggregation of households, the policy impact on household income growth in the northern region would likely prove to be substantially greater than in other regions. Data limitations, however, restricted the current analysis of household income to the economy-wide aggregate level.

Three areas for promising future research may be mentioned. First, the policy experiment is conducted in the absence of potential increases in the detection and prosecution of illegal deforestation and illegal forestry. The computable general equilibrium framework applied in this research is conducive to iteratively and exogenously shocking the value of the fine paid per unit

of illegal output. Determining the level of fines that would be required to reduce illegal forestry and illegal deforestation to the socially optimal level would be useful to policy makers in their decisions on budgetary allocations for monitoring and enforcement.

Second, policy makers may be interested in the longer run (10+ years) socioeconomic and environmental impacts of forest concessions. The debate surrounding Reduced Emissions from Deforestation and Degradation can significantly increase the demand for this type of information. A greater disaggregation of the social accounting matrix for Brazil in terms of activities, commodities and households, as well as estimates on changes in the world price of goods and services would enable more realistic, longer-term analysis of the impacts of forest concessions.

Finally, the modeling exercises treat forestland as capable of producing the same quantity and quality of forest product output through time. Forestry law sets diameter, species and volume constraints on forest operations. Whether these limits, assuming they are followed, result in sustainable yields is an open question, though recent research appears to indicate that they are not. In the short and medium term as modeled in the current analysis, declining quantity and quality of timber stocks may not present any measurable impact. If the policy is modeled in the longer-term, however, interesting results may be borne out of modeling changes in the characteristics of the timber supply.

APPENDIX A
COMPLETE MODEL EQUATION LISTING

Table A-1. Model sets and parameters

Symbol	Explanation	Symbol	Explanation
Sets			
$a \in A$	Activities	$c \in CMN(\subset C)$	Commodities not in *CM*
$\propto \in ACES(\subset A)$	Activities with a CES function at the top of the technology nest	$c \in CT(\subset C)$	Transaction service commodities
$\propto \in ALEO(\subset A)$	Activities with a Leontief function at the top of the technology nest	$c \in CX(\subset C)$	Commodities with domestic production
$c \in C$	Commodities	$f \in F$	Factors
$c \in CD(\subset C)$	Commodities with domestic sales of domestic output	$i \in INS$	Institutions (domestic and rest of world)
$c \in CDN(\subset C)$	Commodities not in *CD*	$i \in INSD(\subset INS)$	Domestic institutions
$c \in CE(\subset C)$	Exported commodities	$i \in INSDNG(\subset INSD)$	Domestic non-government institutions
$c \in CEN(\subset C)$	Commodities not in *CE*	$h \in H(\subset INSDNG)$	Households
$c \in CM(\subset C)$	Imported commodities		
Parameters			
$cwts_c$	Weight of commodity c in the CPI	$\overline{qinv}_c$	Base-year quantity of private investment demand
$dwts_c$	Weight of commodity c in the producer price index	$shif_{if}$	Share for domestic institution i in income of factor f
ica_{ca}	Quantity of c as intermediate input per unit of activity a	$shii_{ii'}$	Share of net income of i' to i (i' ∈ INSDNG'; i ∈ INSDNG)
$icd_{cc'}$	Quantity of commodity c as trade input per unit of c' produced and sold domestically	ta_a	Tax rate for activity *a*
$ice_{cc'}$	Quantity of commodity c as trade input per exported unit of c'	te_c	Export tax rate
$icm_{cc'}$	Quantity of commodity c as trade input per imported unit of c'	tf_f	Direct tax rate for factor *f*
$inta_a$	Quantity of aggregate intermediate input per activity unit	$\overline{tins}_i$	Exogenous direct tax rate for domestic institution i

Table A-1. Continued

Symbol	Explanation	Symbol	Explanation
iva_a	Quantity of aggregate intermediate input per activity unit	$tins01_i$	0-1 parameter with 1 for institutions with potentially flexed direct tax rates
$\overline{mps}_i$	Base savings rate for domestic institution i	tm_c	Import tariff rate
$mps01_i$	0-1 parameter with 1 for institutions with potentially flexed direct tax rates	tq_c	Rate of sales tax
pwe_c	Export price (foreign currency)	$trnsfr_{i\,f}$	Transfer from factor f to institution i
pwm_c	Import price (foreign currency)	tva_a	Rate of value-added tax for activity *a*
$qdst_c$	Quantity of stock change		
$\overline{qg}_c$	Base-year quantity of government demand		
Greek letters			
α_a^a	Efficiency parameter in the CES activity function	δ_c^t	CET function share parameter
α_a^{va}	Efficiency parameter in the CES value-added function	δ_{fa}^{va}	CES value-added function share parameter for factor *f* in activity *a*
α_c^{ac}	Shift parameter for domestic commodity aggregation function	γ_{ch}^m	Subsistence consumption of marketed commodity c for household h
α_c^q	Armington function shift parameter	θ_{ac}	Yield of output c per unit of activity a
α_c^t	CET function shift parameter	ρ_a^a	CES production function exponent
β^a	Capital sectoral mobility factor	ρ_a^{va}	CES value-added function exponent
$\beta^h{}_{ach}$	Marginal share of consumption spending on home commodity c from activity a for household h	ρ_c^{ac}	Domestic commodity aggregation function exponent
β_{ch}^m	Marginal share of consumption spending on marketed commodity c for household h	ρ_c^q	Armington function exponent
δ_a^a	CES activity function share parameter	ρ_c^t	CET function exponent
δ_{ac}^{ac}	Share parameter for domestic commodity aggregation function	η_{fat}^a	Sector share of new capital (dynamic model)

Table A-1. Continued

Symbol	Explanation	Symbol	Explanation
δ_c^q	Armington function share parameter	υ_f	Capital depreciation rate (dynamic model)
$\varphi_{a,c}$	Yield distortion parameter		

Source: Lofgren et al. (2002); Robinson and Thurlow (no date).

Table A-2. Model variables

Variable	Explanation	Variable	Explanation
Exogenous variables			
$\overline{CPI}$	Consumer price index	$\overline{MPSADJ}$	Savings rate scaling factor (= 0 for base)
$\overline{DTINS}$	Change in domestic institution tax share (= 0 for base; exogenous variable)	$\overline{QFS}_f$	Quantity supplied of factor
$\overline{FSAV}$	Foreign savings (FCU)	$\overline{TINSADJ}$	Direct tax scaling factor (= 0 for base; exogenous variable)
$\overline{GADJ}$	Government consumption adjustment factor	$\overline{WFDIST}_{fa}$	Wage distortion factor for factor f in activity a
$\overline{IADJ}$	Investment adjustment factor		
Endogenous variables			
AWF_{ft}^a	Average capital rental rate in time period t (dynamic model)	QF_{fa}	Quantity demanded of factor f from activity a
$DMPS$	Change in domestic institution savings rates (= 0 for base; exogenous variable)	QG_c	Government consumption demand for commodity
DPI	Producer price index for domestically marketed output	QH_{ch}	Quantity consumed of commodity c by household h
EG	Government expenditures	QHA_{ach}	Quantity of household home consumption of commodity c from activity a for household h
EH_h	Consumption spending for household	$QINTA_a$	Quantity of aggregate intermediate input
EXR	Exchange rate (LCU per unit of FCU)	$QINT_{ca}$	Quantity of commodity c as intermediate input to activity a
$GOVSHR$	Government consumption share in nominal absorption	$QINV_c$	Quantity of investment demand for commodity
$GSAV$	Government savings	QM_c	Quantity of imports of commodity c
$INVSHR$	Investment share in nominal absorption	QQ_c	Quantity of goods supplied to domestic market (composite supply)
MPS_i	Marginal propensity to save for domestic non-government institution (exogenous variable)	QT_c	Quantity of commodity demanded as trade input
PA_a	Activity price (unit gross revenue)	QVA_a	Quantity of (aggregate) value-added

Table A-2. Continued

Variable	Explanation	Variable	Explanation
PDD_c	Demand price for commodity produced and sold domestically	QX_c	Aggregated quantity of domestic output of commodity
PDS_c	Supply price for commodity produced and sold domestically	$QXAC_{ac}$	Quantity of output of commodity c from activity a
PE_c	Export price (domestic currency)	RWF_f	Real average factor price (dynamic model)
$PINTA_a$	Aggregate intermediate input price for activity a	$TABS$	Total nominal absorption
PK_{ft}	Unit price of capital in time period t (dynamic model)	$TINS_i$	Direct tax rate for institution i (i ∈ INSDNG)
PM_c	Import price (domestic currency)	$TRII_{ii'}$	Transfers from institution i' to i (both in the set INSDNG)
PQ_c	Composite commodity price	WF_f	Average price of factor
PVA_a	Value-added price (factor income per unit of activity)	YF_f	Income of factor f
PX_c	Aggregate producer price for commodity	YG	Government revenue
$PXAC_{ac}$	Producer price of commodity c for activity a	YI_i	Income of domestic non-government institution
QA_a	Quantity (level) of activity	YIF_{if}	Income to domestic institution i from factor f
QD_c	Quantity sold domestically of domestic output	ΔK^a_{fat}	Quantity of new capital by activity a for time period t (dynamic model)
QE_c	Quantity of exports		

Source: Lofgren et al. (2002); Robinson and Thurlow (no date).

Table A-3. Model equations

$PM_c = pwm_c \cdot (1+tm_c) \cdot EXR + \sum_{c' \in CT} PQ_{c'} \cdot icm_{c'c}$	(1)
$PE_c = pwe_c \cdot (1-te_c) \cdot EXR - \sum_{c' \in CT} PQ_{c'} \cdot ice_{c'c}$	(2)
$PDD_c = PDS_c + \sum_{c' \in CT} PQ_{c'} \cdot icd_{c'c}$	(3)
$PQ_c \cdot (1-tq_c) \cdot QQ_c = PDD_c \cdot QD_c + PM_c \cdot QM_c$	(4)
$PX_c \cdot QX_c = PDS_c \cdot QD_c + PE_c \cdot QE_c$	(5)
$PA_a = \sum_{c \in C} PXAC_{ac} \cdot \theta_{ac}$	(6)
$PINTA_a = \sum_{c \in C} PQ_c \cdot ica_{ca}$	(7)
$PA \cdot (1-ta_a) \cdot QA_a = PVA_a \cdot QVA_a + PINTA_a \cdot QINTA_a$	(8)
$\overline{CPI} = \sum_{c \in C} PQ_c \cdot cwts_c$	(9)

Table A-3. Continued

$$DPI = \sum_{c \in C} PDS_c \cdot dwts_c \tag{10}$$

$$QA_a = \alpha_a^a \cdot \left(\delta_a^a QVA_a^{-\rho_a^a} + (1-\delta_a^a) \cdot QINTA_a^{-\rho_a^a}\right)^{\frac{1}{\rho_a^a}} \tag{11}$$

$$\frac{QVA_a}{QINTA_a} = \left(\frac{PINTA_a}{PVA_a} \cdot \frac{\delta_a^a}{(1-\delta_a^a)}\right)^{\frac{1}{1+\rho_a^a}} \tag{12}$$

$$QVA_a = QA_a \cdot iva_a \tag{13}$$

$$QINTA_a = QA_a \cdot inta_a \tag{14}$$

$$QVA_a = \alpha_a^{va} \cdot \left(\sum_{f \in F} \delta_{f\,a}^{va} \cdot \left(\alpha_{f\,a}^{vaf} \cdot QF_{f\,a}\right)^{-\rho_a^{va}}\right)^{-\frac{1}{\rho_a^{va}}} \tag{15}$$

$$W_f \cdot \overline{WFDIST}_{fa} = PVA_a \cdot \left(1 - tva_a\right) \cdot QVA_a \cdot \left(\sum_{f \in F'} \delta_{f\,a}^{va} \cdot \left(\alpha_{f\,a}^{vaf} \cdot QF_{f\,a}\right)^{-\rho_a^{va}}\right)^{-1} \cdot \delta_{f\,a}^{va} \cdot \left(\alpha_{f\,a}^{vaf} \cdot QF_{f\,a}\right)^{-\rho_a^{va}-1} \tag{16}$$

$$QINT_{ca} = ica_{ca} \cdot QINTA_a \tag{17}$$

$$QXAC_{ac} + \sum_{h \in H} QHA_{ach} = \theta_{ac} \cdot QA_a \tag{18}$$

$$QX_c = \alpha_c^{ac} \cdot \left(\sum_{a \in A} \delta_{a\,c}^{ac} \cdot QXAC_{a\,c}^{-\rho_c^{ac}}\right)^{-\frac{1}{\rho_c^{ac}-1}} \tag{19}$$

$$PXAC_{a\,c} = PX_c \cdot QX_c \left(\sum_{a \in A'} \delta_{a\,c}^{ac} \cdot QXAC_{a\,c}^{-\rho_c^{ac}}\right)^{-1} \cdot \delta_{a\,c}^{ac} \cdot QXAC_{a\,c}^{-\rho_c^{ac}-1} \tag{20}$$

$$QX_c = \alpha_c^{ac} \cdot \left(\sum_{a \in A} \delta_{a\,c}^{ac} \cdot QXAC_{a\,c}^{-\rho_c^{ac}}\right)^{-\frac{1}{\rho_c^{ac}-1}} \tag{21}$$

$$\frac{QE_c}{QD_c} = \left(\frac{PE_c}{PDS_c} \cdot \frac{1-\delta_c^t}{\delta_c^t}\right)^{\frac{1}{\rho_c^t-1}} \tag{22}$$

$$QX_c = QD_c + QE_c \tag{23}$$

$$QQ_c = \alpha_c^q \cdot \left(\delta_c^q \cdot QM_c^{-\rho_c^q} + (1-\delta_c^q) \cdot QD_c^{-\rho_c^q}\right)^{-\frac{1}{\rho_c^q}} \tag{24}$$

$$\frac{QM_c}{QD_c} = \left(\frac{PDD_c}{PM_c} \cdot \frac{\delta_c^q}{1-\delta_c^q}\right)^{\frac{1}{1+\rho_c^q}} \tag{25}$$

$$QQ_c = QD_c + QM_c \tag{26}$$

$$QT_c = \sum_{c' \in C'} \left(icm_{cc'} \cdot QM_c + ice_{cc'} \cdot QE_{c'} + icd_{cc'} \cdot QD_{c'}\right) \tag{27}$$

Table A-3. Continued

Institutions

$$YF_f = \sum_{a \in A} WF_f \cdot \overline{WFDIST_{fa}} \cdot QF_{fa} \tag{28}$$

$$YIF_{i\,f} = shif_{i\,f} \cdot \left[YF_f - trnsfr_{row\,f} \cdot EXR \right] \tag{29}$$

$$YI_i = \sum_{f \in F} YIF_{i\,f} + \sum_{i' \in INSDNG'} TRII_{i\,i'} + trnsfr_{i\,gov} \cdot \overline{CPI} + trnsfr_{i\,row} \cdot EXR \tag{30}$$

$$TRII_{i\,i'} = shii_{i\,i'} \cdot (1 - MPS_{i'}) \cdot (1 - \overline{tins}_{i'}) \cdot YI_{i'} \tag{31}$$

$$EH_h = \left(1 - \sum_{i \in INSDNG} shii_{i\,h} \right) \cdot \left(1 - MPS_h \right) \cdot (1 - \overline{tins}_h) \cdot YI_h \tag{32}$$

$$PQ_c \cdot QH_{ch} = PQ_c \cdot \gamma^m_{ch} + \beta^m_{ch} \cdot \left(EH_h - \sum_{c' \in C} PQ_{c'} \cdot \gamma^m_{c'h} - \sum_{a \in A} \sum_{c' \in C} PXAC_{ac'} \cdot \gamma^m_{ac'h} \right) \tag{33}$$

$$PXAC_{ac} \cdot QHA_{ach} = PXAC_{ac} \cdot \gamma^h_{ach} + \beta^h_{ach} \cdot \left(EH_h - \sum_{c' \in C} PQ_{c'} \cdot \gamma^m_{c'h} - \sum_{a \in A} \sum_{c' \in C} PXAC_{ac'} \cdot \gamma^m_{ac'h} \right) \tag{34}$$

$$QINV_c = IADJ \cdot \overline{qinv}_c \tag{35}$$

$$QG_c = \overline{GADJ} \cdot \overline{qg}_c \tag{36}$$

$$YG = \sum_{i \in INSDNG} \overline{tins}_i \cdot YI_i + \sum_{a \in A} ta_a \cdot PA_a \cdot QA_a + \sum_{c \in CMNR} tm_c \cdot pwm_c \cdot QM_c \cdot EXR + \tag{37}$$

$$\sum_{r \in R} \sum_{c \in CMR} tmr_{cr} \cdot pwmr_{cr} \cdot QMR_{cr} \cdot EXR + \sum_{c \in C} tq_c \cdot PQ_c \cdot QQ_c + \sum_{f \in F} YF_{gov\,f} + trnsfr_{gov\,row} \cdot EXR$$

$$EG = \sum_{c \in C} PQ_c \cdot QG_c + \sum_{i \in INSDNG} trnsfr_{i\,gov} \cdot \overline{CPI} \tag{38}$$

System constraints

$$\sum_{a \in A} QF_{f\,a} = QFS_f \tag{39}$$

$$QQ_c = \sum_{a \in A} QINT_{c\,a} + \sum_{h \in H} QH_{c\,h} + QG_c + QINV_c + qdst_c + QT_c \tag{40}$$

$$\sum_{c \in CMNR} pwm_c \cdot QM_c + \sum_{r \in R} \sum_{c \in CMR} pwmr_{cr} \cdot QMR_{cr} \cdot \sum_{f \in F} trnsfr_{row\,f} \tag{41}$$

$$= \sum_{c \in CENR} pwe_c \cdot QE_c + \sum_{r \in R} \sum_{c \in CER} pwer_{cr} \cdot QER_{cr} + \sum_{i \in INSD} trnsfr_{i\,row} + FSAV$$

$$YG = EG + GSAV \tag{42}$$

$$TINS = \overline{tins}_i \cdot (1 + \overline{TINSADJ} \cdot tins01_i) + \overline{DTINS} \cdot tins01_i \tag{43}$$

$$MPS_i = \overline{mps}_i \cdot (1 + \overline{MPSADJ} \cdot mps01_i) + DMPS \cdot mps01_i \tag{44}$$

$$\sum_{i \in INSDNG} MPS_i \cdot \left(1 - \overline{tins}_i \right) \cdot YI_i + GSAV + EXR \cdot FSAV = \sum_{c \in C} PQ_c \cdot QINV_c + \sum_{c \in C} PQ_c \cdot qdst_c \tag{45}$$

$$TABS = \sum_{h \in H} \sum_{c \in C} PQ_c \cdot QH_{ch} + \sum_{a \in A} \sum_{c \in C} \sum_{h \in H} PXAC_{ac} \cdot QHA_{ach} \tag{46}$$

$$+ \sum_{c \in C} PQ_c \cdot QG_c + \sum_{c \in C} PQ_c \cdot QINV_c + \sum_{c \in C} PQ_c \cdot qdst_c$$

Table A-3. Continued

$$INVSHR \cdot TABS = \sum_{c \in C} PQ_c \cdot QINV_c + \sum_{c \in C} PQ_c \cdot qdst_c \tag{47}$$

$$GOVSHR \cdot TABS = \sum_{c \in C} PQ_c \cdot QG_c \tag{48}$$

Capital accumulation (dynamic model)

$$AWF_{f\,t}^{a} = \sum_{a} \left[\left(\frac{QF_{f\,a\,t}}{\sum_{a'} QF_{f\,a'\,t}} \right) \cdot WF_{f\,t} \cdot WFDIST_{f\,a\,t} \right] \tag{49}$$

$$\eta_{f\,a\,t}^{a} = \left(\frac{QF_{f\,a\,t}}{\sum_{a'} QF_{f\,a'\,t}} \right) \cdot \left(\beta^{a} \cdot \left(\frac{WF_{f,t} \cdot WFDIST_{f\,a\,t}}{AWF_{f\,t}^{a}} - 1 \right) + 1 \right) \tag{50}$$

$$\Delta K_{f\,a\,t}^{a} = \eta_{f\,a\,t}^{a} \cdot \left(\frac{\sum_{c} PQ_{c\,t} \cdot QINV_{c\,t}}{PK_{f\,t}} \right) \tag{51}$$

$$PK_{f\,t} = \sum_{c} PQ_{c\,t} \cdot \frac{QINV_{c\,t}}{\sum_{c'} QINV_{c'\,t}} \tag{52}$$

$$QF_{f\,a\,t+1} = QF_{f\,a\,t} \cdot \left(1 + \frac{\Delta K_{f\,a\,t}^{a}}{QF_{f\,a\,t}} - \upsilon_{f} \right) \tag{53}$$

$$QFS_{f\,t+1} = QFS_{f\,t} \cdot \left(1 + \frac{\sum_{a} \Delta K_{f\,a\,t}}{QFS_{f\,t}} - \upsilon_{f} \right) \tag{54}$$

Source: Lofgren et al. (2002); Robinson and Thurlow (no date).

APPENDIX B
STATIC MODEL RESULTS: COMPARING THE BALANCED, NEOCLASSICAL AND JOHANSEN CLOSURES

Table B-1. Percent change in macroeconomic and institutional indicators

	Balanced closure	Neo classical closure	Johansen closure
Absorption	0.01	0.00	0.01
Private consumption	0.02	-0.09	0.02
Fixed investment	0.00	0.39	0.00
Change in stocks	0.00	0.00	0.00
Government consumption	0.00	0.00	0.00
Exports	0.00	-0.11	-0.04
Imports	-0.01	-0.13	-0.04
GDP at market prices	0.01	0.00	0.01
GDP at factor cost	0.01	0.01	0.01
Net indirect taxes	0.01	0.00	0.01
Real household consumption			
Low-income household	0.00	2.10	0.70
Mid-income household	0.00	0.20	0.10
High-income household	0.00	-0.90	-0.20
Deforestation enterprise	0.80	0.80	0.80
Consumer price index	0.02	-1.19	2.00
Exchange rate	-0.01	-0.91	2.00
Investment share of absorption	0.00	30.77	3.32
Foreign savings	0.00	0.00	0.00
Marginal propensity to save			
Mid-income households	0.57	0.01	-218.82
High-income households	0.04	0.15	-14.11
Enterprises	0.01	0.41	-5.35
Investment to GDP ratio	0.00	4.70	0.50
Private savings to GDP ratio	0.00	0.60	-2.10
Foreign savings to GDP ratio	0.00	0.00	0.00
Trade deficit to GDP ratio	0.00	0.00	-0.10
Government savings to GDP ratio	0.00	4.10	2.60

Table B-2. Percent change in institutional income

Institution	Balanced closure	Neo classical closure	Johansen closure
Low income household	0.05	0.96	0.49
Mid-income household	0.05	-0.99	-0.07
High-income household	0.04	-2.13	-0.80
Deforestation institution	-0.24	-0.82	1.87
Enterprises	0.01	4.88	0.92
Interest	0.02	2.81	3.78

Table B-3. Percent change in equivalent variation

	Balanced closure	Neoclassical closure	Johansen closure
Equivalent variation			
Low-income households	0.00	2.10	0.70
Mid-income households	0.00	0.20	0.10
High-income households	0.00	-0.90	-0.20
Deforestation enterprise	0.80	0.80	0.80
Total	0.00	-0.10	0.00

Table B-4. Percent change in factor income

Factor	Balanced closure	Neo classical closure	Johansen closure
Low-skill formal labor	0.08	-2.24	-2.81
Low-skill informal labor	0.07	14.64	1.30
Mid-skill formal labor	0.08	-10.53	-6.50
Mid-skill informal labor	0.07	-1.51	-1.96
High-skill formal labor	0.07	-16.38	-10.58
High-skill informal labor	0.08	-9.29	-4.89
Capital	0.13	5.30	0.98
Agricultural land north	-0.17	-0.77	1.94
Agricultural land north east	-0.38	-0.94	1.73
Agricultural land south east	-6.79	-7.26	-4.81
Agricultural land south	-1.81	-2.37	0.27
Agricultural land center west	-0.17	-0.75	1.94
Forest land north	-48.13	-48.37	-47.03
Forest land north east	-14.25	-14.55	-12.37
Forest land south east	-9.40	-9.93	-7.51
Forest land south	-9.54	-10.06	-7.65
Forest land center west	-11.14	-11.59	-9.27

Table B-5. Percent change in price of composite good

Good or service	Balanced closure	Neo classical closure	Johansen closure
Agriculture	-0.21	-0.88	1.88
Forestry	-8.44	-9.03	-6.54
Deforestation	-1.07	-1.64	3.22
Mining and petroleum	-0.01	-0.91	2.00
Industrial	0.01	-0.92	2.01
Processed wood	-0.01	-0.91	2.00
Pulp and cellulose	-0.01	-0.91	2.00
Processed food	0.02	-0.74	2.12
Utilities	0.05	-0.95	2.12
Construction	0.17	69.40	2.00
Commerce	-0.01	-0.91	2.00
Transportation	0.09	-1.36	2.07
Private services	0.05	-1.53	1.95
Public services	0.04	-20.85	-15.04

Table B-6. Percent change in price of factor F for activity A

Factor	Sector	Balanced closure	Neo classical closure	Johansen closure
Low-skilled formal labor	Agriculture north	-0.13	-0.74	1.97
Low-skilled formal labor	Agriculture north east	-0.11	-0.68	2.01
Low-skilled formal labor	Agriculture south east	0.54	0.06	2.70
Low-skilled formal labor	Agriculture south	0.32	-0.27	2.44
Low-skilled formal labor	Agriculture center west	-0.13	-0.71	1.98
Low-skilled formal labor	Forestry north	143.65	142.52	148.80
Low-skilled formal labor	Forestry north east	-14.82	-15.10	-13.00
Low-skilled formal labor	Forestry south east	-9.40	-9.93	-7.51
Low-skilled formal labor	Forestry south	-9.54	-10.06	-7.65
Low-skilled formal labor	Forestry center west	-11.18	-11.63	-9.32
Low-skilled formal labor	Forest plantations north	-13.57	-13.98	-11.75
Low-skilled formal labor	Forest plantations north east	-14.40	-14.78	-12.59
Low-skilled formal labor	Forest plantations south east	-20.43	-20.87	-18.78
Low-skilled formal labor	Forest plantations south	-26.08	-26.29	-24.52
Low-skilled formal labor	Forest plantations center west	-15.99	-16.40	-14.23
Low-skilled formal labor	Deforestation north	18.84	18.15	22.68
Low-skilled formal labor	Deforestation north east	-6.96	-7.50	-4.34
Low-skilled formal labor	Deforestation center west	-5.89	-6.42	-2.92
Low-skilled formal labor	Mining and petroleum	-0.09	-3.44	1.99
Low-skilled formal labor	Industry	0.01	-1.22	2.02
Low-skilled formal labor	Processed wood	2.68	1.85	4.73

Table B-6. Continued

Factor	Sector	Balanced closure	Neoclassical closure	Johansen closure
Low-skilled formal labor	Pulp and cellulose	2.50	1.45	4.54
Low-skilled formal labor	Processed food	0.65	-0.15	2.84
Low-skilled formal labor	Utilities	0.06	-0.85	2.19
Low-skilled formal labor	Construction	0.33	136.64	1.99
Low-skilled formal labor	Commerce	-0.03	-0.80	2.03
Low-skilled formal labor	Transportation	0.10	-1.46	2.11
Low-skilled formal labor	Private services	0.05	-3.09	1.92
Low-skilled formal labor	Public services	0.03	-36.56	-25.72
Low-skilled informal labor	Agriculture north	-0.13	-0.74	1.97
Low-skilled informal labor	Agriculture north east	-0.11	-0.68	2.01
Low-skilled informal labor	Agriculture south east	0.54	0.06	2.70
Low-skilled informal labor	Agriculture south	0.32	-0.27	2.44
Low-skilled informal labor	Agriculture center west	-0.13	-0.71	1.98
Low-skilled informal labor	Forestry north	143.65	142.52	148.80
Low-skilled informal labor	Forestry north east	-14.82	-15.10	-13.00
Low-skilled informal labor	Forestry south east	-9.40	-9.93	-7.51
Low-skilled informal labor	Forestry south	-9.54	-10.06	-7.65
Low-skilled informal labor	Forestry center west	-11.18	-11.63	-9.32
Low-skilled informal labor	Forest plantations north	-13.57	-13.98	-11.75
Low-skilled informal labor	Forest plantations north east	-14.40	-14.78	-12.59
Low-skilled informal labor	Forest plantations south east	-20.43	-20.87	-18.78

Table B-6. Continued

Factor	Sector	Balanced closure	Neoclassical closure	Johansen closure
Low-skilled informal labor	Forest plantations south	-26.08	-26.29	-24.52
Low-skilled informal labor	Forest plantations center west	-15.99	-16.40	-14.23
Low-skilled informal labor	Deforestation north	18.84	18.15	22.68
Low-skilled informal labor	Deforestation north east	-6.96	-7.50	-4.34
Low-skilled informal labor	Deforestation center west	-5.89	-6.42	-2.92
Low-skilled informal labor	Mining and petroleum	-0.09	-3.44	1.99
Low-skilled informal labor	Industry	0.01	-1.22	2.02
Low-skilled informal labor	Processed wood	2.68	1.85	4.73
Low-skilled informal labor	Pulp and cellulose	2.50	1.45	4.54
Low-skilled informal labor	Processed food	0.65	-0.15	2.84
Low-skilled informal labor	Utilities	0.06	-0.85	2.19
Low-skilled informal labor	Construction	0.33	136.64	1.99
Low-skilled informal labor	Commerce	-0.03	-0.80	2.03
Low-skilled informal labor	Transportation	0.10	-1.46	2.11
Low-skilled informal labor	Private services	0.05	-3.09	1.92
Low-skilled informal labor	Public services	0.03	-36.56	-25.72
Mid-skilled formal labor	Agriculture north	-0.13	-0.74	1.97
Mid-skilled formal labor	Agriculture north east	-0.11	-0.68	2.01
Mid-skilled formal labor	Agriculture south east	0.54	0.06	2.70
Mid-skilled formal labor	Agriculture south	0.32	-0.27	2.44
Mid-skilled formal labor	Agriculture center west	-0.13	-0.71	1.98

Table B-6. Continued

Factor	Sector	Balanced closure	Neoclassical closure	Johansen closure
Mid-skilled formal labor	Forestry north	143.65	142.52	148.80
Mid-skilled formal labor	Forestry north east	-14.82	-15.10	-13.00
Mid-skilled formal labor	Forestry south east	-9.40	-9.93	-7.51
Mid-skilled formal labor	Forestry south	-9.54	-10.06	-7.65
Mid-skilled formal labor	Forestry center west	-11.18	-11.63	-9.32
Mid-skilled formal labor	Forest plantations north	-13.57	-13.98	-11.75
Mid-skilled formal labor	Forest plantations north east	-14.40	-14.78	-12.59
Mid-skilled formal labor	Forest plantations south east	-20.43	-20.87	-18.78
Mid-skilled formal labor	Forest plantations south	-26.08	-26.29	-24.52
Mid-skilled formal labor	Forest plantations center west	-15.99	-16.40	-14.23
Mid-skilled formal labor	Deforestation north	18.84	18.15	22.68
Mid-skilled formal labor	Deforestation north east	-6.96	-7.50	-4.34
Mid-skilled formal labor	Deforestation center west	-5.89	-6.42	-2.92
Mid-skilled formal labor	Mining and petroleum	-0.09	-3.44	1.99
Mid-skilled formal labor	Industry	0.01	-1.22	2.02
Mid-skilled formal labor	Processed wood	2.68	1.85	4.73
Mid-skilled formal labor	Pulp and cellulose	2.50	1.45	4.54
Mid-skilled formal labor	Processed food	0.65	-0.15	2.84
Mid-skilled formal labor	Utilities	0.06	-0.85	2.19
Mid-skilled formal labor	Construction	0.33	136.64	1.99
Mid-skilled formal labor	Commerce	-0.03	-0.80	2.03

Table B-6. Continued

Factor	Sector	Balanced closure	Neoclassical closure	Johansen closure
Mid-skilled formal labor	Transportation	0.10	-1.46	2.11
Mid-skilled formal labor	Private services	0.05	-3.09	1.92
Mid-skilled formal labor	Public services	0.03	-36.56	-25.72
Mid-skilled informal labor	Agriculture north	-0.13	-0.74	1.97
Mid-skilled informal labor	Agriculture north east	-0.11	-0.68	2.01
Mid-skilled informal labor	Agriculture south east	0.54	0.06	2.70
Mid-skilled informal labor	Agriculture south	0.32	-0.27	2.44
Mid-skilled informal labor	Agriculture center west	-0.13	-0.71	1.98
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Mid-skilled informal labor	Forestry south east	-9.40	-9.93	-7.51
Mid-skilled informal labor	Forestry south	-9.54	-10.06	-7.65
Mid-skilled informal labor	Forestry center west	-11.18	-11.63	-9.32
Mid-skilled informal labor	Forest plantations north	-13.57	-13.98	-11.75
Mid-skilled informal labor	Forest plantations north east	-14.40	-14.78	-12.59
Mid-skilled informal labor	Forest plantations south east	-20.43	-20.87	-18.78
Mid-skilled informal labor	Forest plantations south	-26.08	-26.29	-24.52
Mid-skilled informal labor	Forest plantations center west	-15.99	-16.40	-14.23
Mid-skilled informal labor	Deforestation north	18.84	18.15	22.68
Mid-skilled informal labor	Deforestation north east	-6.96	-7.50	-4.34
Mid-skilled informal labor	Deforestation center west	-5.89	-6.42	-2.92

Table B-6. Continued

Factor	Sector	Balanced closure	Neoclassical closure	Johansen closure
Mid-skilled informal labor	Mining and petroleum	-0.09	-3.44	1.99
Mid-skilled informal labor	Industry	0.01	-1.22	2.02
Mid-skilled informal labor	Processed wood	2.68	1.85	4.73
Mid-skilled informal labor	Pulp and cellulose	2.50	1.45	4.54
Mid-skilled informal labor	Processed food	0.65	-0.15	2.84
Mid-skilled informal labor	Utilities	0.06	-0.85	2.19
Mid-skilled informal labor	Construction	0.33	136.64	1.99
Mid-skilled informal labor	Commerce	-0.03	-0.80	2.03
Mid-skilled informal labor	Transportation	0.10	-1.46	2.11
Mid-skilled informal labor	Private services	0.05	-3.09	1.92
Mid-skilled informal labor	Public services	0.03	-36.56	-25.72
High-skilled formal labor	Agriculture north	-0.13	-0.74	1.97
High-skilled formal labor	Agriculture north east	-0.11	-0.68	2.01
High-skilled formal labor	Agriculture south east	0.54	0.06	2.70
High-skilled formal labor	Agriculture south	0.32	-0.27	2.44
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High-skilled formal labor	Forestry south east	-9.40	-9.93	-7.51
High-skilled formal labor	Forestry south	-9.54	-10.06	-7.65
High-skilled formal labor	Forestry center west	-11.18	-11.63	-9.32

Table B-6. Continued

Factor	Sector	Balanced closure	Neoclassical closure	Johansen closure
High-skilled formal labor	Forest plantations north	-13.57	-13.98	-11.75
High-skilled formal labor	Forest plantations north east	-14.40	-14.78	-12.59
High-skilled formal labor	Forest plantations south east	-20.43	-20.87	-18.78
High-skilled formal labor	Forest plantations south	-26.08	-26.29	-24.52
High-skilled formal labor	Forest plantations center west	-15.99	-16.40	-14.23
High-skilled formal labor	Deforestation north	18.84	18.15	22.68
High-skilled formal labor	Deforestation north east	-6.96	-7.50	-4.34
High-skilled formal labor	Deforestation center west	-5.89	-6.42	-2.92
High-skilled formal labor	Mining and petroleum	-0.09	-3.44	1.99
High-skilled formal labor	Industry	0.01	-1.22	2.02
High-skilled formal labor	Processed wood	2.68	1.85	4.73
High-skilled formal labor	Pulp and cellulose	2.50	1.45	4.54
High-skilled formal labor	Processed food	0.65	-0.15	2.84
High-skilled formal labor	Utilities	0.06	-0.85	2.19
High-skilled formal labor	Construction	0.33	136.64	1.99
High-skilled formal labor	Commerce	-0.03	-0.80	2.03
High-skilled formal labor	Transportation	0.10	-1.46	2.11
High-skilled formal labor	Private services	0.05	-3.09	1.92
High-skilled formal labor	Public services	0.03	-36.56	-25.72
High-skilled informal labor	Agriculture north	-0.13	-0.74	1.97
High-skilled informal labor	Agriculture north east	-0.11	-0.68	2.01

Table B-6. Continued

Factor	Sector	Balanced closure	Neoclassical closure	Johansen closure
High-skilled informal labor	Agriculture south east	0.54	0.06	2.70
High-skilled informal labor	Agriculture south	0.32	-0.27	2.44
High-skilled informal labor	Agriculture center west	-0.13	-0.71	1.98
High-skilled informal labor	Forestry north	143.65	142.52	148.80
High-skilled informal labor	Forestry north east	-14.82	-15.10	-13.00
High-skilled informal labor	Forestry south east	-9.40	-9.93	-7.51
High-skilled informal labor	Forestry south	-9.54	-10.06	-7.65
High-skilled informal labor	Forestry center west	-11.18	-11.63	-9.32
High-skilled informal labor	Forest plantations north	-13.57	-13.98	-11.75
High-skilled informal labor	Forest plantations north east	-14.40	-14.78	-12.59
High-skilled informal labor	Forest plantations south east	-20.43	-20.87	-18.78
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High-skilled informal labor	Deforestation north	18.84	18.15	22.68
High-skilled informal labor	Deforestation north east	-6.96	-7.50	-4.34
High-skilled informal labor	Deforestation center west	-5.89	-6.42	-2.92
High-skilled informal labor	Mining and petroleum	-0.09	-3.44	1.99
High-skilled informal labor	Industry	0.01	-1.22	2.02
High-skilled informal labor	Processed wood	2.68	1.85	4.73
High-skilled informal labor	Pulp and cellulose	2.50	1.45	4.54
High-skilled informal labor	Processed food	0.65	-0.15	2.84

Table B-6. Continued

Factor	Sector	Balanced closure	Neoclassical closure	Johansen closure
High-skilled informal labor	Utilities	0.06	-0.85	2.19
High-skilled informal labor	Construction	0.33	136.64	1.99
High-skilled informal labor	Commerce	-0.03	-0.80	2.03
High-skilled informal labor	Transportation	0.10	-1.46	2.11
High-skilled informal labor	Private services	0.05	-3.09	1.92
High-skilled informal labor	Public services	0.03	-36.56	-25.72
Capital	Agriculture north	-0.13	-0.74	1.97
Capital	Agriculture north east	-0.11	-0.68	2.01
Capital	Agriculture south east	0.54	0.06	2.70
Capital	Agriculture south	0.32	-0.27	2.44
Capital	Agriculture center west	-0.13	-0.71	1.98
Capital	Forestry north	143.65	142.52	148.80
Capital	Forestry north east	-14.82	-15.10	-13.00
Capital	Forestry south east	-9.40	-9.93	-7.51
Capital	Forestry south	-9.54	-10.06	-7.65
Capital	Forestry center west	-11.18	-11.63	-9.32
Capital	Forest plantations north	-13.57	-13.98	-11.75
Capital	Forest plantations north east	-14.40	-14.78	-12.59
Capital	Forest plantations south east	-20.43	-20.87	-18.78
Capital	Forest plantations south	-26.08	-26.29	-24.52
Capital	Forest plantations center west	-15.99	-16.40	-14.23
Capital	Deforestation north	18.84	18.15	22.68
Capital	Deforestation north east	-6.96	-7.50	-4.34
Capital	Deforestation center west	-5.89	-6.42	-2.92
Capital	Mining and petroleum	-0.09	-3.44	1.99
Capital	Industry	0.01	-1.22	2.02
Capital	Processed wood	2.68	1.85	4.73

Table B-6. Continued

Factor	Sector	Balanced closure	Neoclassical closure	Johansen closure
Capital	Pulp and cellulose	2.50	1.45	4.54
Capital	Processed food	0.65	-0.15	2.84
Capital	Utilities	0.06	-0.85	2.19
Capital	Construction	0.33	136.64	1.99
Capital	Commerce	-0.03	-0.80	2.03
Capital	Transportation	0.10	-1.46	2.11
Capital	Private services	0.05	-3.09	1.92
Capital	Public services	0.03	-36.56	-25.72
Agricultural land north	Agriculture north	-0.17	-0.77	1.94
Agricultural land north	Forest plantations north	-0.17	-0.77	1.94
Agricultural land north east	Agriculture north east	-0.38	-0.94	1.73
Agricultural land north east	Forest plantations north east	-0.38	-0.94	1.73
Agricultural land south east	Agriculture south east	-6.79	-7.26	-4.81
Agricultural land south east	Forest plantations south east	-6.79	-7.26	-4.81
Agricultural land south	Agriculture south	-1.81	-2.37	0.27
Agricultural land south	Forest plantations south	-1.81	-2.37	0.27
Agricultural land center west	Agriculture center west	-0.17	-0.75	1.94
Agricultural land center west	Forest plantations center west	-0.17	-0.75	1.94
Forestland north	Forestry north	-64.47	-64.63	-63.72
Forestland north	Deforestation north	-64.47	-64.63	-63.72
Forestland north east	Forestry north east	-14.25	-14.55	-12.37
Forestland north east	Deforestation north east	-14.25	-14.55	-12.37
Forestland southeast	Forestry south east	-9.40	-9.93	-7.51
Forestland south	Forestry south	-9.54	-10.06	-7.65
Forestland center west	Forestry center west	-11.14	-11.59	-9.27
Forestland center west	Deforestation center west	-11.14	-11.59	-9.27

Table B-7. Percent change in level of domestic activity

Sector	Balanced closure	Neo classical closure	Johansen closure
Agriculture north	0.00	0.00	0.00
Agriculture north east	0.01	0.01	0.01
Agriculture south east	0.19	0.19	0.19
Agriculture south	0.13	0.12	0.13
Agriculture center west	0.01	0.01	0.01
Forestry north	24.68	24.68	24.68
Forestry north east	-0.02	-0.02	-0.03
Forestry south east	0.00	0.00	0.00
Forestry south	0.00	0.00	0.00
Forestry center west	-0.01	-0.01	-0.01
Forest plantations north	-0.56	-0.56	-0.56
Forest plantations north east	-0.62	-0.61	-0.62
Forest plantations south east	-2.40	-2.41	-2.41
Forest plantations south	-3.71	-3.67	-3.71
Forest plantations center west	-1.29	-1.28	-1.29
Deforestation north	1.20	1.20	1.20
Deforestation north east	0.14	0.14	0.15
Deforestation center west	0.09	0.09	0.11
Mining and petroleum	0.00	0.00	0.00
Industry	0.00	0.00	0.00
Wood processing	0.00	0.00	0.00
Pulp and paper	0.00	0.00	0.00
Food processing	0.00	0.00	0.00
Utilities	0.00	0.00	0.00
Construction	0.00	0.00	0.00
Commerce	0.00	0.00	0.00
Transportation	0.00	0.00	0.00
Private services	0.00	0.00	0.00
Public services	0.00	0.00	0.00

Table B-8. Percent change in quantity of factor demand by industry

Sector	Factor	Balanced closure	Neo classical closure	Johansen closure
Agriculture north	Agricultural land north	0.01	0.01	0.01
Forest plantations north		-2.84	-2.82	-2.84
Agriculture north east	Agricultural land north east	0.06	0.06	0.06
Forest plantations north east		-2.99	-2.96	-2.99
Agriculture south east	Agricultural land south east	1.83	1.84	1.84
Forest plantations south east		-3.11	-3.12	-3.12
Agriculture south	Agricultural land south	0.52	0.51	0.52
Forest plantations south		-5.52	-5.47	-5.52
Agriculture center west	Agricultural land center west	0.01	0.01	0.01
Forest plantations center west		-3.39	-3.38	-3.40
Forestry north	Forest land north	46.97	46.97	46.97
Deforestation north		6.22	6.22	6.28
Forestry north east	Forest land north east	-0.13	-0.13	-0.14
Deforestation north east		0.41	0.40	0.44
Forestry south east	Forest land south east	0.00	0.00	0.00
Forestry south	Forest land south	0.00	0.00	0.00
Forestry center west	Forest land center west	-0.01	-0.01	-0.01
Deforestation center west		0.29	0.28	0.34

Table B-9. Percent change in quantity of sales

Good or service	Balanced closure Domestic sales	Neoclassical closure Domestic sales	Johansen closure Domestic sales	Balanced closure Exports	Neoclassical closure Exports	Johansen closure Exports
Agriculture	0.05	0.09	0.06	0.31	0.04	0.22
Forestry	1.95	1.96	1.95	14.55	14.17	14.45
Deforestation	0.84	0.84	0.85	0.00	0.00	0.00
Mining and petroleum	0.00	0.00	0.00	0.00	0.00	0.00
Industrial	0.01	0.00	0.00	-0.04	0.02	-0.02
Processed wood	0.00	0.00	0.00	0.00	0.00	0.00
Pulp and cellulose	0.00	0.00	0.00	0.00	0.00	0.00
Processed food	0.02	0.09	0.06	-0.07	-0.46	-0.30
Utilities	0.00	0.00	0.00	0.00	0.00	0.00
Construction	0.00	0.15	0.00	-0.09	-23.44	0.00
Commerce	0.00	0.00	0.00	0.00	0.00	0.00
Transportation	0.00	-0.01	0.00	-0.08	0.33	-0.05
Private services	0.00	-0.01	0.00	-0.04	0.41	0.03
Public services	0.00	0.00	0.00	0.00	0.00	0.00

Table B-10. Percent change in quantity of composite goods supply

Activity	Balanced closure	Neo classical closure	Johansen closure
Agriculture	0.03	0.09	0.05
Forestry	0.37	0.43	0.38
Deforestation	0.84	0.84	0.85
Mining and petroleum	0.00	0.00	0.00
Industrial	0.01	-0.01	0.01
Processed wood	0.00	0.00	0.00
Pulp and cellulose	0.00	0.00	0.00
Processed food	0.02	0.10	0.07
Utilities	0.00	0.00	0.01
Construction	0.00	0.32	0.00
Commerce	0.00	0.00	0.00
Transportation	0.00	-0.01	0.00
Private services	0.01	-0.07	-0.01
Public services	0.00	0.00	0.00

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BIOGRAPHICAL SKETCH

Onil Banerjee earned a Bachelor of Science in forest resources management from the University of British Columbia in Vancouver in 1999. Focusing on international forest management, he spent a semester at the Institute of Technology of Costa Rica's Department of Forest Engineering. Upon graduation, he worked in community development and natural resources planning in Mexico and in forest resources management in the USA and Canada. In 2002, he and a colleague established a firm, RMGEO Consultants Inc., for which he has undertaken various projects internationally in community-based resources management, forest plantations and geographic information systems development. After gaining professional experience at the grassroots level, he was inspired to learn more about the macro context in which development policy is imbedded; he returned to Canada to study for a master's degree in public administration from Carleton University in Ottawa, focusing on international development policy and practice. During his studies, he worked at the Canadian International Development Agency's America's Branch, conducting research on the economics of international trade and participated in strategic planning exercises. After graduation in 2004 and conducting work with indigenous communities in Paraguay, he commenced his Ph.D. in 2004 at the University of Florida's School of Forest Resources Management focusing on forest policy and economics in Brazil.