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# A computable general equilibrium analysis of forest concessions in Brazil

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ABSTRACT

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 historically 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 ( Veríssimo 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 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 ha of forest concessions by the end of the decade, such 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.
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. Results indicate that household income and private consumption increase with the implementation of forest concessions. With the expansion of natural forest management in the north, forest plantations contract significantly in all regions and to a lesser degree, natural forest management in the north east and center west. As forest plantations demand less agricultural land for production, the price of agricultural land decreases and the excess supply is taken up by the agricultural sector which pays less for the land and consequently produces more of a less expensive product. The implementation of forest concessions results in a 3.8% increase in legal deforestation with the largest increase in the north, followed by the north east and center west.


## 1. 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.[1] While the government has historically 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 (Veríssimo 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 ha of forest concessions by the end of the decade, such 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 et al., 1997 as cited in Pinedo-Vasquez et al., 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 region 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 while greater transparency in the regulatory environment further reduces risks and

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[1] The Legal Amazon consists of the states of Acre, Amapá, Amazonas, (west of 44ºW) Mato Grosso, Pará, Rondônia, Roraima, and Tocantins.

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costs. Forest concessions, as in the case of protected areas, may also act as a barrier to deforestation and encroachment (Nepstad et al., 2006, p. 72). To provide insight into the short run socioeconomic and environmental implications of implementing forest concessions and identify potential complimentary policies to maximize positive policy outcomes, we evaluate the implementation of forest concessions in a static computable general equilibrium (CGE) framework.

Following this introduction, the second section provides a brief overview of the Brazilian forest sector while the third describes key components of the PFML. The fourth section is an overview of CGE models and their applications in forestry. Next, the data is described and the basic structure of the CGE model is developed. The scenario design and simulation results are then presented. The paper concludes with a discussion of the key findings and policy implications.

### 1.1. 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); it 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 and Veríssimo, 2007, p. 22). In 2006, the value of forest sector output was over 10.9 billion reais.[2] Forest plantations were responsible for 66% of this output while natural forest management and non-timber forest products accounted for 34% (Instituto Brasileiro de Geografia e Estatística [IBGE], 2007a). Roundwood, charcoal and firewood made up the majority of this output (71%) with pulp and paper, and non-timber forest products accounting for 23% and 6%, respectively. 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. Natural forest-based production occurs mostly in the Legal Amazon while forest plantations are more concentrated in the south and south east.[3] Total roundwood, charcoal and fuelwood production from natural forests amounted to 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. In the Legal Amazon, approximately 14 .6 million $m^3$ of timber (excluding charcoal and fuelwood) valued at over 1.4 billion reais were harvested from natural forests.

In 2006, over 600,000 ha of forest plantations were established representing a 13% increase in relation to the previous year. The majority of new plantations were established in the south east (44%) and south (28%) (MMA, 2008b). 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. Forest plantations in the Legal Amazon produced 4 million $m^3$ of timber (excluding charcoal, fuelwood and wood for pulp and paper) valued at 187 million reais.

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

In 2003, there were 2.1 million ha of forest with approved management plans over 91% of which were located in the north (Table 1). Also in 2003, over 210 thousand ha of forest were 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., 2005, p. 72).

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., 2005, p. 29). Between 2004 and 2007, deforestation dropped from 27,379 $km^2$ to 11,224 $km^2$ (Fig. 1). Data for 2008, however, show a small increase to 11,968 $km^2$. Some estimates suggest that 80–90% of timber in Brazil is produced illegally. More conservative figures estimate that illegal logging accounted for approximately 56% of production in 2003 (Banerjee, 2008, p. 129).

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

### 1.2. The Public Forest Management Law

Brazil's 1934 Forestry Code included provisions for the concession of forest management on public land, though forest concessions were never implemented. Motivated by the need to control the illegal use of public lands and promote socio-economic development, a draft forest concessions law was submitted to the Office of the President by the government of Fernando Henrique Cardoso in 2002. 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 refine the proposal. After a 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

**Table 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.

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

[3] 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.

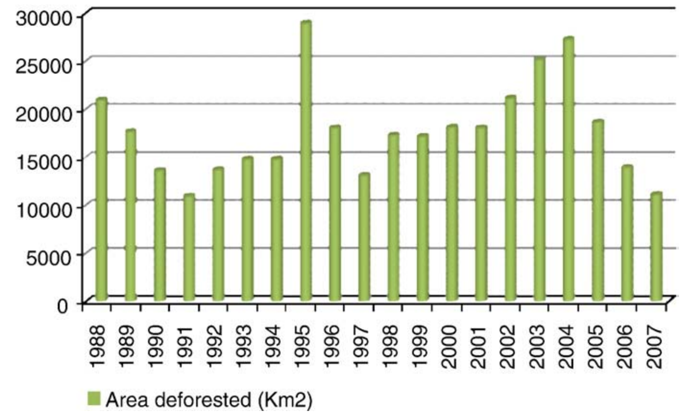


**Fig. 1.** Area deforested 1988 to 2007. Source: INPE, 2007.

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 in public forests. This right is conferred through a competitive bidding process. The winning bidder must comply with all criteria in the published request for proposals 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 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 hold only 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).

### *1.3. Overview of CGE models*

CGE models have their roots in the input–output (I–O) framework developed by the economist Wassily Leontief in the 1930s (Dixon et al., 1992, p. 19). 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). Despite their popularity, I–O models have a number of limitations which led to 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 irresponsive to changes in relative prices (Bandara, 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, factors of production and intermediate 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 et al., 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 and 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 and Round, 1985, p. 17). A SAM is typically constructed based on national accounts data and government surveys such as household expenditure surveys and census data.

### *1.4. CGE applications in forestry*

CGE models are frequently used to study international trade, taxes and economic policy packages such as structural adjustment programs (Stenberg and 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 et al. (1997) studied forest management options when non-timber values are considered in the model. Alavalapati et al. (1998b, p. 349) evaluated the impact of land use restrictions on a resource dependent economy in Canada. Dufournaud et al. (2000, p. 15) examined the economic impact of an export ban and an increase in royalties and export taxes. Gan (2004) studied 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 price of logs (Persson and 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 and Munasinghe, 1995, p. 266).

Cattaneo (2001, 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.

## 2. The database and model

### 2.1. The data: a 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 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 as well as national household survey and expenditure data for the same year (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 forest sector output (IBGE, 2004c). Additional data sources include the 2000 demographic census (IBGE, 2003), preliminary results from the 2006 agricultural survey (IBGE, 2007c), The Research Institute for Applied Economics' (IPEA) 2003 SAM for Brazil (Tourinho et al., 2006) and Cattaneo's (2002) 1995 SAM for Brazil.

The 2003 national accounts feature supply-use tables with 55 sectors and 110 goods and services. Since for the purposes of the present analysis such detail was not required, an aggregate SAM was created by aggregating sectors and commodities to 15 and 14, respectively. This procedure was applied to the supply-use tables for goods and services, production and imports (Table 1 of the national accounts), and to the supply-use tables for intermediate consumption, final demand and value added (Table 2 of the national accounts). Data on institutional transfers, taxes, and savings and investment were obtained from the national account's Integrated Economic Accounts (CEI) table and the IPEA SAM.

### 2.2. The CGE model

#### 2.2.1. Overview

The model developed herein is based on the International Food Policy Research Institute's (IFPRI) Standard CGE model which was developed by IFPRI to facilitate the use of CGE models in developing countries (Lofgren et al., 2002, p. vi). The model is implemented in GAMS and is solved as a mixed complimentary problem using the PATH solver. Although thoroughly documented in Lofgren et al. (2002), the basic model structure is presented here. While the SAM is a numerical representation of the equilibrium payments and receipts between agents in the economy, a CGE model describes 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

**Table 2**
Percent change in macroeconomic and institutional indicators.

| Indicator | Percent change |
|---|---|
| Absorption | 0.01 |
| Private consumption | 0.02 |
| Imports | −0.01 |
| Exports | 0.00 |
| GDP at market prices | 0.01 |
| Consumer price index | 0.02 |
| Exchange rate | −0.01 |
| *Marginal propensity to save* | |
| Mid-income households | 0.57 |
| High-income households | 0.04 |
| Enterprises | 0.01 |
| *Income* | |
| Low income household | 0.05 |
| Mid-income household | 0.05 |
| High-income household | 0.04 |
| Enterprises | 0.01 |

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. Following Lofgren et al. (2002), these are discussed in turn.

*2.2.2. Production*

Producers maximize profits subject to nested technological constraints. 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. CES functions enable non-unitary though constant price elasticities (i.e. identical elasticities between all pairs of inputs), non-zero but constant substitution elasticities and unitary income elasticity (Annabi et al., 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, the proportion of each commodity produced by a particular sector is determined by fixed yield coefficients.

*2.2.3. Factor markets*

Factor market closures describe the mechanism by which factor supply equilibrates with demand. 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 sector-specific wages and supply are flexible. Forestland and agricultural land are fixed in supply and mobile between sectors.

*2.2.4. 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 they use their income to first consume a minimum level of subsistence goods and services. Supernumerary income, the income remaining after subsistence consumption, is used to purchase commodities according to a linear relationship between income and consumption. The difference between CES and LES functions 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). Only mid and high-income households save. All households receive income from labor and capital and transfers from social security benefits, the enterprise (i.e. indirect income from factors), the government and the rest of the world, and interest as property income. Mid and high-income households also receive income from the returns to agricultural and forestland. 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 earns 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 earns income from capital and agricultural and forest land. 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 purchases the majority of the public goods and services produced by the public administration sector (e.g. public health, education and security) and to a much lesser degree, private services. The government makes transfer payments to households which are indexed by the consumer price index; it pays interest on property and saves. Government savings may be negative and are treated as a flexible residual (Lofgren et al., 2002, p. 10). The rest of the world purchases exports, makes transfers to households, earns income from imports and pays or receives interest payments. The rest of the world's savings is the current account deficit, which is the difference between a country's expenditure and its receipts (Lofgren et al., 2002, p. 11).

*2.2.5. 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 particular 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 where producers maximize revenues subject to a constant elasticity of transformation (CET) function. Export demand 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.

*2.2.6. 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 and are required to maintain a balanced economic environment. What follows are the closure rules implemented in the model.

For the government account, tax rates are fixed and government savings are calculated as a flexible residual. The current account of the balance of payments is maintained by a flexible real exchange rate and fixed foreign savings which implies a fixed trade balance. A balanced closure for the savings and investment balance is chosen 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. This 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 domestic price index is chosen as the numeraire.

## 3. Simulation design and key findings

*3.1. Scenario design*

Brazil's 2007–2008 Annual Forest Plan (SFB, 2007c), the government's first annual declaration of priority areas for forest management on public land, identifies 3.96 million ha of public forests in the Amazon as priority areas for forest concessions. Of this area, it is estimated that 1 million ha 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,

**Table 3**
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 |

generating gross revenues of $120 million reais per year and creating 8600 jobs.[4] With over 2.1 million ha of forest with active Sustainable Forest Management Plans in 2003, establishing concessions on 1 million ha 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. In the current analysis, the impact of forest concessions on levels of deforestation is explicitly considered only for legal deforestation.

### 3.2. Key findings

Gross domestic product at market prices, the consumer price index and absorption increased while the Brazilian currency depreciated and imports declined (0.01%, 0.02%, 0.01%, −0.01% and −0.01%, respectively; Table 2). Exports were unaffected.

Private consumption increased by 0.02% (Table 2). Low, mid, and high-income household income increased (0.05%, 0.05% and 0.04%, respectively) while 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). Equivalent variation remained unchanged for all households.

Both labor and capital income increased by between 0.07% and 0.13% (Table 3). Forestland 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).

Labor became significantly more expensive for the natural forest management sector in the north (143.65%) and dropped by between −9.40% and −14.82% in other regions. The price of labor increased for the processed wood and pulp and cellulose sectors (2.68% and 2.50%, respectively). The price of labor increased for the legal 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 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.

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

**Table 4**
Percent change in composite commodity price, quantity of domestic sales and exports.

| | | Percentage change | |
|---|---|---|---|
| Good or service | Price | Domestic sales | Exports |
| Agriculture | −0.21 | 0.05 | 0.31 |
| Forestry | −8.44 | 1.95 | 14.55 |
| Mining and petroleum | −0.01 | 0.00 | 0.00 |
| Industrial | 0.01 | 0.01 | −0.04 |
| Processed wood | −0.01 | 0.00 | 0.00 |
| Pulp and cellulose | −0.01 | 0.00 | 0.00 |
| Processed food | 0.02 | 0.02 | −0.07 |
| Utilities | 0.05 | 0.00 | 0.00 |
| Construction | 0.17 | 0.00 | −0.09 |
| Commerce | −0.01 | 0.00 | 0.00 |
| Transportation | 0.09 | 0.00 | −0.08 |
| Private services | 0.05 | 0.00 | −0.04 |
| Public services | 0.04 | 0.00 | 0.00 |

The price of forestland decreased in the north, north east, south east, south and center west (−64.47%, −14.25%, −9.40%, −9.54% and −11.14%, respectively). The price of agricultural land also decreased (−0.17%, −0.38%, −6.79%, −1.81% and −0.17% in the north, north east, south east, south and center west, respectively). There was a substantial decline in forest product prices and a small decline in the price of processed wood, pulp and cellulose, and agricultural commodities (−8.44%, −0.01%, −0.01% and −0.21%, respectively; Table 4). Domestic sales of agricultural products, forest products, industrial products and processed food all increased (0.05%, 1.95%, 0.01% and 0.02%, respectively) while there were no changes in the domestic sales of all other goods and services. Agricultural and forest product exports increased by 0.31% and 14.55%, respectively. There were small contractions in industrial, processed food, construction, transportation and private service exports on the order of between −0.04% and −0.09% and no change in all other sectors.

The natural forest management sector's level of domestic activity exhibited an 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 5). As

**Table 5**
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 |

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). Legal deforestation increased in the north, north east and center west (1.20%, 0.14% and 0.09%, respectively). The agricultural sector expanded in all regions with the exception of the north on the order of between 0.01% and 0.19%. All other sectors exhibited no change in their level of activity.

Forest sector demand for forestland increased in the north (46.97%; Table 6), decreased in the north east (−0.13%) and center west (−0.01%), and presented no change in the south east and south. Legal 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). The agricultural sector demanded more 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 GDP, household income and private consumption. As a result of the increased availability of forestland for 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 due to reduced scarcity. The large increase in forest sector activity in the north resulted in higher labor and capital costs for this sector, considering 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, an increase in sales and an over 14% increase in forest product exports. The reduction in forest product prices was not completely transferred to its principal intermediate consumers, the processed wood and pulp and cellulose sectors, and is in part attributable to the higher capital and labor costs incurred by these sectors.

**Table 6**
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 |

As a consequence of the contraction of the forest plantation sector in all regions, forest plantations 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, most notably 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 legal 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.

In the base year of 2003, there were 125,307 ha legally deforested in the north and 68,263 and 16,462 ha in the north east and center west, respectively for a total of 210,032 ha. 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 is explained by the interaction of agricultural land prices, forest product prices and forestland prices. The deforestation institution earned 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.

## 4. Discussion and conclusions

The forest sector is an important component of the Brazilian economy accounting for 3.5% of GDP, 8.4% of exports and responsible for 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 was approved 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 insight into the potential impacts of the law and indications of complimentary policies that may serve to counteract unintended negative consequences of implementation. As such, a computable general equilibrium model was developed to evaluate 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 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.

To offset the increase in deforestation as a result of forest concessions, complimentary policies may be required. As discussed above, the principal reason for the increase in deforestation is the reduction in the price of forestland, particularly in the north. Measures taken to maintain or increase the value of standing forest and thus the price of forestland can discourage deforestation. Programs aimed at creating markets for forest ecosystem services will aid in achieving this goal in the medium term. In the shorter run, introducing forest concessions at a slower rate could dampen the effect of forest concessions on the value of forestland. Critical in the formulation of such a measure is the consideration of its effect on the largely positive socioeconomic benefits resulting from the implementation of forest concessions; subsequent modeling experiments can shed light on this important question.

The reduction in forest plantation production as a result of forest concessions is also cause for concern. Substituting timber production from forest plantations with timber from natural forests may bear considerable political risk and jeopardize the sustainability of the forest concessions policy. Incentives for the establishment and management of forest plantations, diversification of plantation production and improving market access can bolster forest plantation productions' upward growth trajectory.

Given the economic importance of illegal logging and illegal deforestation in the Brazilian Amazon, we are currently engaged in research that seeks to capture the dynamics of these sectors and their legal counterparts. The dynamic framework employed in this work enables the updating of agricultural land stocks resulting from a previous year's level of deforestation to further elucidate the relationship between forestry, deforestation and agriculture. Furthermore, this framework adds considerable value when considering the medium to long-run implications of forest concessions on households, economic sectors and the Brazilian economy overall.

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