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A framework for ex-ante analysis of public investment in forest-based development: An application to the Brazilian Amazon

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ABSTRACT

This paper develops a framework for evaluating the ex-ante economic impacts of public investments in forest-based development. Computable General Equilibrium (CGE) models provide a powerful approach for evaluating public investments in sectors with strong inter-sectoral linkages and for capturing dynamic economy-wide effects. Results of CGE analysis may be analyzed in a social cost-benefit framework typically used by the public sector and multilateral development banks to assess investment viability and trade-offs between alternatives. In this paper, a dynamic CGE is developed to evaluate the impact of a development loan to promote natural forests, forest plantations and agroforestry development in the Amazonian state of Acre, Brazil. Results of the analysis demonstrate the positive impact the expansion forest-based development activities generates and the potential the approach has for comprehensive analysis of the direct, indirect and induced benefits of public forest sector investment.

1. Introduction

Ex-ante economic analysis of loans is a standard practice among multilateral development banks and typically involves a cost benefit analysis (CBA) and a financial sustainability analysis. Increasingly, Computable General Equilibrium (CGE) models are being used to assess the economic and employment benefits of public investments in sectors with strong intersectoral linkages. The use of CGE models in assessing public investments in tourism at the Inter-American Development Bank (IADB), for example, is often the recommended approach (Banerjee et al., 2016c; Banerjee et al., 2015; Banerjee et al., 2016b; Taylor, 2010; Taylor and Filipski, 2014). Public investment in water and irrigation related infrastructure is another area where CGE models are increasingly applied (Banerjee, 2015; Wittwer and Banerjee, 2015).

Some forest sector investments also impact multiple sectors and have dynamic effects on economies and local communities (Banerjee and Alavalapati, 2010). This paper develops a framework for ex-ante economic analysis of public forest-sector investments and applies it to the analysis of the second phase of the Acre Sustainable Development Program (PDSA II), an investment in forest-based development in the state of Acre, Brazil. Prior to the 1990s, Acre was in a state of chronic poverty with poor governance and infrastructure, and unsustainable land use with de facto open access to public forestland. This seemingly untenable situation began to improve in 1999 with the launch of a bold economic development strategy fundamentally rooted in forest-based development. One component of this strategy was the first phase of PDSA which invested in strengthening environmental governance, land regulation and critical infrastructure. Between 2002 and 2009, improvements in governance contributed to reducing the deforestation rate from 111,000 ha/year to 22,000 ha/year (Lima et al., 2012).[1]

PDSA II is a US$187.4 million investment with some support from the IADB to build on the successes and lessons learned of PDSA I with the goal of increasing the contribution of the forest sector to economic growth and poverty reduction, while controlling levels of deforestation. In the design and preparation of PDSA II, an ex-ante economic assessment was undertaken. This paper presents the public forest investment analytical framework developed for this analysis which combines the strengths of CGE modeling with CBA, and reports some of the key results of the analysis.

The section that follows provides background on forestry in the state of Acre, its key development challenges, and how PDSA II was designed to address these challenges. Section 3 describes the methodological approach and data used in the investment which includes a static one-period CGE model and a dynamic multi-period model. Section 4 presents results and Section 5 evaluates the results in a benefit cost

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[1] A review of some of the factors that led to Brazil's success in reducing deforestation may be found in Banerjee, O., Macpherson, A. J., & Alavalapati, J. R. R. (2009). Toward a Policy of Sustainable Forest Management in Brazil: a Historical Analysis. *Journal of Environment & Development*, 18(2), 130–153.

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framework. Section 6 concludes with a summary of the key findings and considerations for the use of this framework in subsequent analyses.

2. Background

2.1. The state of acre

The Brazilian state of Acre is located in the north west of Brazil and in the south west of the Brazilian Amazon. The state's surface area is 164,221 km^2 which is equivalent to 1.9% of Brazil's land base. Acre has over 790 thousand inhabitants, over 72% of which are urban dwellers largely concentrated in the state capital of Rio Branco. A large proportion of Acre's inhabitants were migrants from the drought-stricken north east of Brazil, many of which were lured by the region's rubber boom between 1850 and 1920. Most Acreanos, as the local inhabitants are called, live in traditional settlements and extractivist settlement projects. Many traditional and indigenous communities reside in protected areas and settlements.

Deforestation in Acre has largely been driven by agriculture and ranching during the 1970s and 1980s. Fig. 1 depicts deforestation in the state since 1988. Between 1988 and 2012, approximately 12,723 km^2 were deforested. Agriculture and cattle ranching occurred in parallel to unregulated land use and land grabbing, primarily along the BR-364 and BR-317 highways that were also established during this period. The last decade has seen a decline in deforestation as Acre and Brazil overall have shifted to a paradigm of sustainable forest management (Banerjee et al., 2009). Deforestation in Acre fell from 547 km^2 in 2000 to 199 km^2 in 2013; over the same period, deforestation in the Amazon fell from 18,226 km^2 to 5843 km^2.

One of the Government of Acre's goals is to maintain at least 80% of the state in forest cover with 25% under sustainable forest management systems with 1.5 million hectares of forests dedicated to the production of timber and non-timber forest products. In 2011, the state produced 1,064,195 m^3 of roundwood valued at 75.4 million reais.

Forest management in Brazil is guided by Forestry Code, Law 12.651 of May 2012. In the case of the Legal Amazon, the Forestry Code establishes that 80% of private land holdings must be kept in forest. Permanent Preservation areas serve to protect vulnerable areas on stream and river banks and areas susceptible to erosion. Brazil's Public Forest Management Law (Law 11284 of 2006) authorizes the establishment of forest concessions on public forestland which may be offered to private enterprises of various sizes. Management of State forests is regulated under Acre's Forest Law of 2001 (Law 1.426). This law sets out a framework for conservation and sustainable forest resource use with three mechanisms. Forests may be used as public productive forests or offered as concessions for communities or private enterprises. State forests may be managed by state public entities or private enterprises.

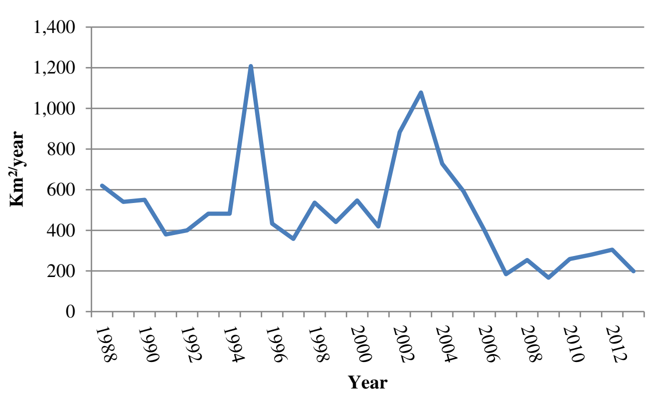

Fig. 1. Acre deforestation. Source: data from INPE, 2013; authors' own elaboration.

2.2. The acre sustainable development program—PDSA I

In the 1990s, Acre suffered from chronic poverty, poor infrastructure, low productivity, a lack of governance and nearly open access to forest resources. In 1999 with Jorge Viana, a forest engineer, assuming the governorship, Acre embarked an economic development program based on the sustainable management of forest resources. The government identified three critical challenges to enhancing forest-based development and livelihood opportunities. These challenges were: (i) open access nature of forest resources; (ii) low economic returns to traditional agricultural activities, and; (iii) a lack of adequate transport and energy infrastructure which has a direct bearing on economic competitiveness.

In a partnership forged between the IADB and the Government of Acre, a program to help to address some of these challenges was developed and PDSA I was designed. The goal of PDSA I was to improve the quality of life of the local population and ensure the sustainability of the region's natural resources. Specifically, PDSA I sought to: (i) modernize environmental governance and efficient use of natural resources; (ii) increase agricultural-sector growth and employment, and; (iii) reduce transport costs and increase access to electrification in rural areas.

Lines of action were developed along each of the three strategic directions. Aligned to the first, efforts included land administration, establishing protected area management, strengthening the state system for environmental management and promoting the preservation of local cultures and traditions. To increase agricultural-sector growth and employment, actions were directed to transfer appropriate technologies, support small producers, improve phytosanitary measures, support sustainable forest management and promote business development. Along the final strategic direction, investment was concentrated on improving land and river-based transportation networks and promoting alternative energy. The implementation of PDSA, valued at $108 million USD began in 2002 and concluded in 2010.

PDSA has a number of successes to report. While initially lacking in institutional capacity for environmental management, Acre's Environmental Information System (SEAIM) was developed, management was decentralized and Acre's Environmental-Economic Zoning was improved. To reduce the open access nature of forest resources, PDSA supported best practices in land use planning, tenure policy, administration and regularization. The state's core infrastructure has improved markedly, reducing transport costs and increasing competitiveness. The forest and agricultural sector have increased their importance to the state economy; forestry alone accounts for 18.6% of state gross domestic product (GDP), 60% of exports and supports 36% of rural livelihoods.

PDSA provided insight for future environmentally sustainable economic development of the state. While the construction of roads has historically been associated with increased deforestation, PDSA has demonstrated that if protected areas are strategically located and aligned with road construction, deforestation may be reduced. Second, the establishment of protected areas can gain local support if displaced livelihood activities are substituted with other attractive opportunities, which may be forest-based (Lima et al., 2012).

While PDSA concluded in 2010, a number of challenges remained. Some areas of public forests remain illegally occupied while there is a significant stock of degraded area, both of which could be used for forest-based and restoration activities. To encourage the development of forest-based economies the emergence of rural supply chains requires further support. Finally, continued institutional capacity building was required. To address these challenges the IADB and the state government of Acre formulated a phase II of PDSA; PDSA II is comprised of 3 main components: (i) expanding and consolidating protected areas, including areas eligible for forest management; (ii) developing competitive value chains, and; (iii) capacity building and enhanced governance.

The first component is comprised of 2 subcomponents; the first is designed to expand and consolidate state forests for production which include land regularization and further consolidation of existing state forests. This subcomponent also aims to develop the state forest concession system and investment in applied research to increase productivity. The second subcomponent focuses on supporting community forest management through improving infrastructure, planning and capacity building. The second component has three subcomponents. The first is to promote forestry and agroforestry businesses by improving marketing information systems, while the second subcomponent aims to support value chain development and finance technical assistance for developing business management plans. The third subcomponent is comprised of a private equity fund to leverage financial resources for investment in forest-based development. The third and final component of PDSA II is geared toward enhancing the policy and regulatory environment for forestry and agroforestry, increasing institutional capacity and enhancing stakeholder engagement.

In this paper, we focus on components one and two which invest in expanding forestry and agroforestry operations and improving productivity. Specifically, the following investment components are considered in the analysis: (i) the establishment of 240,000 ha of state forest concessions; (ii) the operationalization of 5000 ha of concessions in the state forest Antimary; (iii) the establishment of 180,000 ha of community forests; (iv) the implementation of 15,000 ha of commercial forest plantations, and; (v) the establishment of 19,000 ha of agroforestry operations.

3. Study methods

CGE modeling is rooted in the well-known input-output (I-O) framework developed by economist Wassily Leontief in the 1930s (Dixon et al., 1992). A CGE model is a mathematical representation of the theoretical structure of an economy, formalized by equations representing demand for commodities, intermediate and factor inputs. Additional equations relate prices to costs and clear markets for factors and commodities. 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.

Improving upon I-O models, CGE models incorporate an endogenous demand and price system, input and factor substitutability, optimization of agent behavior, resource scarcity/constraints, and a more detailed treatment of institutions and the macroeconomic environment. Models are customized with regard to the structure of production and consumption, the macroeconomic environment, and institutional interactions, enabling a more robust and realistic evaluation of an economy of interest (Alavalapati et al., 1998). CGE models are particularly effective in capturing the distributional aspects of policy changes (Buetre et al., 2003). CGE models have become widely used for evaluating environmental policy and natural resource management issues expected to have general equilibrium effects (Bergman, 2005), including forest policy issues and their economic and environmental impacts (Banerjee and Alavalapati, 2010).

The framework developed here couples the analytical strengths of a CGE modeling approach with the transparency and rigor of CBA. In assessing the costs and benefits of PDSA II and ultimately the net present value (NPV) of the investment, we calibrate a CGE model for Brazil with regional disaggregation in the forestry, forest plantation and agricultural sectors. The shocks to the CGE model described below are implemented to estimate and project over the period of analysis, the direct, indirect and induced benefits of the investment. Since our perspective is that of a public institution, the indirect and induced benefits of the investment are of particular interest and are readily assessed through a CGE approach.

With the benefits of PDSA II estimated, these values are input into a CBA framework and compared alongside the costs of the investment. As the analysis is ex-ante, these costs are estimated based on PDSA II project documentation and estimations. In addition to the investment required to implement the forest-based development strategy, operations and maintenance costs are included in the analysis. Using a discount rate of 15%, the NPV of the investment is then calculated.

3.1. The data: the social accounting matrix

A social accounting matrix (SAM) is the fundamental data source for a CGE model; it is a square matrix representing a snapshot economy and empirically describes its structure of production and transactions among sectors, institutions, and factors of production. A SAM serves to both organize data and provide the statistical basis for the development of the economic modeling platform (King, 1985). SAMs are constructed based on national accounts data, government surveys such as household expenditure surveys and census data, and other data derived from secondary sources.

The Brazilian SAM developed for this analysis follows the framework presented in Lofgren et al. (2002), with activities distinguished from commodities, and activity and commodity account receipts valued at producer and consumer prices, respectively. Given this structure, any one activity can produce multiple commodities, while one particular commodity may be produced by more than one activity. Marketing margins are accounted for; margins represent the costs involved in shipping a product from the producer to the consumer (Lofgren et al., 2002).

The primary data sources used in the construction of the Brazilian SAM are national accounts data for 2003 (IBGE, 2004c). The year 2003 is the reference year because it was the most recent year for which definitive national and regional accounts data are available, along with national household survey and expenditure data (IBGE, 2004a, 2007b). This temporal consistency among data sources is required for constructing a consistent and representative SAM.

Agriculture and forestry were regionally disaggregated based on regional accounts for 2003 (IBGE, 2005) and IBGE data on production and extraction of forest products and silvicultural activities (IBGE, 2004b). Additional data sources include the 2000 demographic census (IBGE, 2003) and preliminary results from the 2006 agriculture and cattle ranching survey (IBGE, 2007a). The Research Institute for Applied Economics' (IPEA) 2003 SAM for Brazil (Tourinho et al., 2006) and Cattaneo's (2002) 1995 SAM for Brazil were also used to support the development of this SAM (Cattaneo, 2002).

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 estimated by aggregating sectors and commodities to 15 and 14, respectively. Data on institutional transfers, taxes, savings, and investment were derived from the national accounts' Integrated Economic Accounts (CEI) table and the IPEA SAM. Further development of the SAM required treatment of the forestry and related sectors, land, labor and households, and taxes, followed by a rebalancing of the SAM. The estimations conducted are discussed below.

3.2. The treatment of forestry and land in the model

In the national accounts, expenditures on land are aggregated with capital account expenditures. From Cattaneo (2002), approximately 20% of total agricultural and forestry expenditure is on land. The aggregate expenditure on land was therefore estimated as 20% of total agricultural and forestry expenditures on capital, which was then deducted from the capital account and attributed to expenditure on land.

In the national accounts, both natural and forest plantation management are aggregated with agriculture. To disaggregate forestry from agriculture, the following steps were followed:

(i) Indirect taxes on 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.

(ii) Forestry's expenditure on intermediate consumption and factor inputs was calculated. Total forestry expenditure less forestry expenditure on transportation in Cattaneo (2002) was calculated. The intermediate and factor consumption as a proportion of total forestry expenditure in Cattaneo (2002) was then calculated.

(iii) The proportions calculated in step ii 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 the Brazilian Institute of Geography and Statistics' (IBGE) production and extraction of forest products and silviculture survey (IBGE, 2004b) as well as documentation of deforestation authorization permits from Brazil's monitoring and control system for resources and forest products database (MMA, 2008). 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 for natural forest management, forest plantations, and deforestation sectors.

The 2003 Brazilian SAM is regionally disaggregated for the main sectors of interest for this analysis which are the natural forest management, forest plantations and agriculture sectors. This regional disaggregation is undertaken according to Brazil's five administrative regions which are the 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.

To determine regional agricultural expenditure on labor, the product of the number of people employed in agriculture by region (IBGE, 2007a) and the average wage in agriculture by region (IBGE, 2003) was taken. The proportion of agriculture's expenditure on labor by region was calculated and applied to agriculture's total expenditure on labor. Agriculture's regional expenditure on capital was calculated as the product of the proportion of tractors by region (IBGE, 2007a) and agriculture's total expenditure on capital. Agriculture's regional expenditure on land was calculated as the product of agricultural land area by region (IBGE, 2007a) and the average regional price of land (Reydon and Plata, 2000). This sector's proportional expenditure on land for each region was calculated and applied to agriculture's total expenditure on land.

Agriculture's regional expenditure on intermediate consumption was calculated as the proportion of intermediate consumption by region based on regional accounts data (IBGE, 2005) and applied to agriculture's total intermediate consumption. For indirect taxes, the proportion of regional agriculture was calculated from the regional accounts (IBGE, 2005). These proportions were applied to agriculture's total indirect tax payment to obtain regional indirect taxes. Regional agricultural receipts were calculated as receipts from each product as a proportion of agriculture's total receipts. These proportions were applied to agriculture'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, 2008) and the average regional price of land (Reydon and Plata, 2000) was calculated. The proportion of this product by region was applied to the natural forest management sector's expenditure on forestland to obtain regional expenditure on forestland. The product of the area in forest plantations by region (BRACELPA, 2003) and the average regional price of land (Reydon and 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 estimate forest plantation's regional expenditure on agricultural land. To obtain the deforestation sector's regional expenditure on forestland, the product of the area deforested by region (MMA, 2008) and the average regional price of land (Reydon and Plata, 2000) was calculated. The proportion of this product by region was calculated and applied to the deforestation sector's expenditure on forestland for the deforestation sector's regional expenditure on land.

Each forest sector's expenditure on indirect taxes was calculated proportional to the value of output of the natural forest management, forest plantation, and deforestation sectors. All of these 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, while capital expenditures were calculated proportional to capital expenditures in Cattaneo (2002).

The deforestation product, an innovative feature of this modeling framework which allows for the year-on-year accounting of forested land converted to agricultural land, was calculated as a function of the product of the price differential between forested and agricultural land (Reydon and Plata, 2000) and the area deforested (MMA, 2008). This amount was summed with the deforestation sector's forest product output to represent the deforestation sector's total receipts.

3.3. Disaggregating labor and households

Labor was disaggregated into six types based on skill level and formal/informal participation in the labor market according to Tourinho et al. (2006). Formal labor makes indirect tax payments in the form of social security contributions, while informal labor does not. Low-skilled workers possess 0 to 8 years of schooling, mid-skilled workers from 9 to 11 years, and high-skilled workers have more than 11 years of education.

Households were disaggregated into three income categories, namely 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 given household earns per month. The low-income household earns from 1 to 3 minimum wages per month, the mid-income household earns 4 to 10 minimum wages/month, and the high-income household earns 11 or more minimum wages/month. 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. A sector's payment to a labor skill class follows the proportion of that labor class employed in that activity in the IPEA SAM (Tourinho et al., 2006).

Distribution of land rent to households and the enterprise was based on the IPEA SAM as well as inferred from national household survey data (IBGE, 2004a). Tourinho et al. (2006) hypothesize that the large number of informal low-skilled workers in the agricultural sector earning up to one minimum wage per month and the large number of informal low-skilled workers in the agricultural sector earning over 20 minimum wages is due to many of these workers' claiming land rent as income. On this basis, it was assumed that families earning up to six minimum wages do not receive land rent, while those earning seven or more minimum wages do earn rent from land. The amount of land rent included in returns to labor is calculated as the difference between declared labor income and the average labor income of families earning up to six minimum wages. This value provides the imputed value of land rent for each household income class participating in agriculture, forestry, and forest plantations, and the proportional receipt of land income for each household class (Tourinho et al., 2006).

Household consumption by income class was based on national household expenditure survey data (IBGE, 2007b) with a household class' share of the total consumption of each product based on the IPEA SAM. With regards to savings, it was assumed that households earning six or less minimum wages per month have negligible or no savings (Tourinho et al., 2006).

3.4. Taxes

In the Brazilian SAM, indirect taxes on activities are the sum of social security contributions and other production taxes, all net of subsidies. Commodity taxes are treated as 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 represent taxes on current income and property.

3.5. Balancing the social accounting matrix

Constructing a SAM from a variety of data sources invariably leads to small imbalances between symmetrical row and column sums. To eliminate these imbalances, cross-entropy balancing was undertaken (Robinson, Cattaneo and El-Said, 2001). The balancing algorithm was executed in the General Algebraic Modeling System (GAMS), a software system designed for solving mathematical programming and optimization problems (GAMS Development Corporation, 2013).

4. The model

The static model developed in this paper is based on the International Food Policy Research Institute's (IFPRI) Standard CGE Model. The dynamic model developed in this paper is an extension to the IFPRI Standard CGE developed by Robinson and Thurlow (2004). This extension contains additional parameters, variables, and equations to introduce model dynamics (Robinson and Thurlow, 2004). Both the static and dynamic models are implemented in GAMS and solved as mixed complimentary problems using the PATH solver. Although the basic version of the model is well documented in Lofgren et al. (2002) and Robinson and Thurlow (2004), the basic model structure and its dynamics are presented here.

While the SAM is a numerical representation of the equilibrium payments and receipts between economic agents, the CGE model describes the behavior of agents in the economic environment (Robinson and Thurlow, 2004). 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 macroeconomic environment. 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). The model may be broken into a series of blocks, namely production, factor markets, institutions, commodity markets, and macroeconomic balances. These model blocks are discussed in turn.

4.1. Production

In the model, producers maximize profits subject to nested technological constraints where at the bottom of the technology nest, domestic and imported commodities are aggregated into a composite intermediate input according to fixed shares (Fig. 2).

Value-added is created by a constant elasticity of substitution (CES) aggregation of primary factor inputs, enabling non-unitary though constant price elasticities, non-zero but constant substitution elasticities, and a unitary income elasticity (Annabi et al., 2006). Producers use primary factors until the marginal revenue product for each factor is equal to its price. The price paid to a particular factor can vary for each sector depending on the factor market closure chosen (Lofgren et al., 2002).

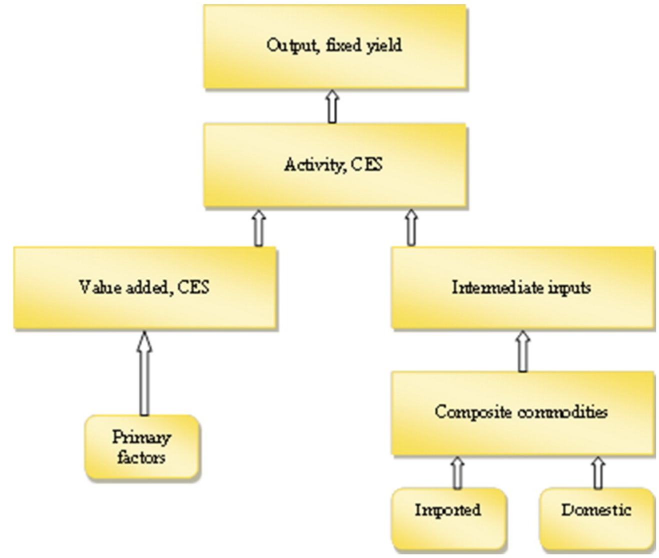

Fig. 2. Schematic representation of the structure of production. Source: authors' own elaboration.

Intermediate and value-added inputs are aggregated according to Leontief 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.

4.2. Factor markets

Factor market closures describe how the supply of a factor equilibrates with the demand for its use. The model allows for three main factor market closures. The first closure fixes the quantity of a factor at the benchmark level, allowing the economy-wide wage to adjust, while the factor is fully employed and mobile between sectors. The second closure is a Keynesian closure in which the economy-wide factor wage is fixed and the factor may be underemployed. The third closure is a segmented closure in which industries hire base year factor quantities. 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). This third closure is frequently applied in short-run analysis.

4.3. Institutions

The model contains seven institutions, including three household income classes, 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). In a LES, households use their income to first consume a minimum level of subsistence goods and services, and then with the income that remains, households purchase goods and services according to a linear relationship between income and consumption. LES functions differ from CES functions in that LES functions have non-unitary income elasticities (Annabi et al., 2006). All households pay direct income and property taxes, and receive income from labor and capital. Only mid- and high-income households receive income from returns to agricultural and forestland, and save. Households receive transfers from social security benefits, interest as property income, transfers from the enterprise account which represents income from factors of production, and; transfers from 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 flexible (Lofgren et al., 2002).

The enterprise receives factor income from capital and agricultural and forestland and distributes it to households, pays both direct taxes and interest as property income, and saves. The enterprise does not consume goods and services. The interest account receives income from the government, the enterprise, and the rest of the world, and transfers its income to households.

The government receives income from tax and tariff accounts. The government consumes, specifically public goods and services produced by the public administration sector (e.g., public health, education, and public security) and private services. The government makes transfer payments to households which are indexed by the consumer price index and pays interest on property. Government savings may be negative and are treated as a flexible residual.

The rest of the world purchases exports, makes transfers to households, and receives income from interest. The rest of the world's savings represents the current account deficit. The current account deficit is the difference between a country's expenditures and receipts. The rest of the world receives income from imports (Lofgren et al., 2002).

4.4. Commodity markets

Outputs from a given sector are treated as imperfect substitutes to represent potential differences in the timing and quality of output, and distance to markets. As such, commodity prices are sector-specific. The demand for a sector's output is determined by minimizing the cost of supplying the commodity subject to the CES function (Lofgren et al., 2002). Aggregate domestic output is allocated to domestic and foreign markets, with producers maximizing revenues subject to a constant elasticity of transformation (CET) function, and export demand is infinitely elastic at fixed world prices. Domestic consumer demand is for a composite commodity composed of an aggregate of imports and domestic output. The Armington (1969) assumption is applied to domestic demand, where consumers minimize costs subject to imperfect substitutability between domestically produced and imported goods. This assumption allows for some flexibility between domestic and world prices, thereby assuring that the domestic market clears. International supplies of goods are infinitely elastic at fixed prices.

4.5. 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 on how these balances are maintained are called model closure rules and are required to create a balanced economic environment. Nobel Laureate Amartya Sen observed 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 (Dewatripont and Michel, 1987). Since the system is over-determined with one more equations than variables, in order for economic equilibrium to be achieved, one of the four conditions must be relaxed.

With regard 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, implying a fixed trade balance. Alternatively, the real exchange rate may be fixed to represent 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 in which investment and government consumption shares are fixed and 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).

The Johansen closure is investment-driven, in which 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. 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).

The neoclassical closure is savings-driven, in which 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 used by investment (Lofgren et al., 2002). The savings and investment market is cleared by assuming that an interest adjustment mechanism exists outside of the model (Bandara, 1991).

The choice of closure rules can have a significant impact on model behavior and the distribution of income (Dewatripont and Michel, 1987). The Johansen closure, for example, ensures that household welfare does not improve as a result of increased foreign borrowing and reduced domestic investment (Lofgren et al., 2002). 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.

4.6. Model dynamics

A CGE model can be one-period static model or multi-period dynamic model. Static models are used for estimating the order of magnitude and direction of effects of a policy shock. Static models roughly distinguish between a short term, where capital is immobile between regions, and a long term, where capital stocks are inter-regionally mobile. Assumptions with regards to labor are made as appropriate to the particular region modelled (Banerjee and Alavalapati, 2014). Comparative static models are used to ask 'what if' questions (Dixon and Rimmer, 2009). Dynamic models provide additional insight, portraying the transition path of an economy, which permits a more robust specification of investment behavior, the potential to introduce lags such as sticky wages and inter-regional labor migration, as well as the ability to customize the policy or environmental shock through time for greater realism.

In the case of forest sector investment analysis, program benefits and costs are incurred at different points in time over the course of the investment program. While a static model may be used to estimate the once-off benefits of an investment, a dynamic model is required for a more precise specification of costs and benefits and for model results to be used in a CBA. Furthermore, the dynamic framework enables the dynamic effects of direct, indirect and induced benefits to be captured.

The within-period (year) or static specification of the CGE model was described above. PDSA II is also evaluated in a dynamic CGE modeling framework. The dynamic extension explains the between-period model specification. This specification contains additional relationships to represent endogenous investment, and exogenous population and labor force growth, depreciation, and changes in total factor productivity. The sectoral allocation of capital is a function of the rate of capital depreciation and the differential in profits between sectors from those of the previous period (Robinson and Thurlow, 2004). What follows is a discussion of endogenous adjustments to account for capital accumulation and exogenous adjustments to population, labor force, and total factor productivity.

Capital supply is a function of the previous period's capital stock and how investment spending is allocated. Investment is undertaken proportionally to a sector's share in economy-wide capital income. This level of investment is adjusted by the ratio of a sector's rate of profits and the economy-wide average rate of profit. With this specification, sectors with higher than average profits will receive a larger share of investment than their average share in aggregate capital income (Robinson and Thurlow, 2004).

Population growth has a positive impact on household consumption expenditure. The quantity of income-independent consumption increases at the same rate as population growth.

Minimum household consumption expenditure increases proportionally with population growth. Growth affects average consumption demand, which implies that new consumers share the same preferences as existing consumers. Household consumption of commodities is adjusted upwards by the rate of population 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 and Thurlow, 2004). 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 quantity of aggregate value-added (Robinson and Thurlow, 2004). The efficiency parameter in the CES value-added function is adjusted upwards by total factor productivity growth.

The recursive dynamic model enables the updating of factor stocks. In both the baseline and policy shock scenario, labor supply is updated based on the estimated labor force growth rate, while capital stocks are updated endogenously based on the previous period's allocation of investment and rate of capital depreciation.[2]

The dynamic modeling experiment is conducted 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. The factors labor, capital, agricultural land, and forestland are fully employed and mobile among sectors in the baseline and policy shock scenarios. 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. Dynamic model elasticities used are the same as those used in the static model.

5. Case study design

5.1. The static model

The one-period static CGE model is used to simulate the implementation of the core features of PDSA II. Specifically, the impact of: (i) establishing 240,000 ha of state forests in the Gregorio Complex; (ii) bringing 5000 ha of state forest in Antimary into production; (iii) establishing 180,000 ha of community forests. It is assumed that half of these community forestlands will be made available for harvest; (iv) establishing 15,000 ha of commercial forest plantations, and; (v) establishing 19,000 ha of agroforestry production systems. Returns to each of these productive activities are based on baseline levels of productivity for each activity.

As previously discussed, model closure rules can play an important role in driving modeling results. Model sensitivity to closure rules was explored in Banerjee (2008) and Banerjee and Alavalapati (2009) and the model was found to be robust to the closure assumptions made. The static model was run in a balanced macroeconomic environment where investment and government consumption shares are fixed while their quantities are flexible. Nominal absorption shares of investment and government consumption are fixed at their base year levels. For factor closures, labor and land are fully employed and mobile across sectors, while capital stock is fixed, sector-specific and fully employed. 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.

Elasticity parameters also influence modeling results. Elasticities are not calibrated from the SAM, rather they are typically derived from previous econometric research reported in the literature. Elasticities of factor substitution, output aggregation for commodities and the elasticity of substitution between aggregate factors and intermediate consumption are based on the widely used and tested GTAP model documented in Dimaranan (2006). Armington elasticities are based on Cattaneo (2002), Dimaranan (2006) and Tourinho et al. (2006). The Frisch parameter used in the linear expenditure system function follows from Annabi et al. (2006). The sensitivity of modeling results to the elasticity parameters selected was also explored in Banerjee (2008) and Banerjee and Alavalapati (2009), and the model was found to be robust to the elasticities used.

Table 1 presents an overview of PDSA II costs in USD. The total cost of PDSA II is $187,402,214. An additional 5% of this total is assessed annually, representing operations and maintenance costs for the life of the project.

5.2. Assessment through a dynamic model

Two model runs are conducted with the dynamic CGE model. The first run produces the forecast baseline which updates the Brazilian SAM from 2003 to the current year, and projects the Brazilian economy from the base year of the SAM, to the year 2030 in the absence of PDSA II or any other exogenous shocks. The second run is the policy scenario which introduces PDSA II to the model. The difference between the results of the policy scenario and the forecast baseline is the estimated impact of PDSA II.

The following shocks are introduced in the model to represent the implementation of PDSA II:

- In the Gregorio Complex, 240,000 ha of state forests are brought into production. This shock is implemented as an increase of 48,000 ha/yr of forestland from year 1 to year 5.
- In the Antimary state forest, 5000 ha of public forest are brought into production. This shock is implemented as an increase of 1250 ha/yr of forestland from year 1 to year 4.
- Community forestry operations are established on 180,000 ha of community lands. It is assumed that half of these community forestlands will be made available for harvest and therefore the shock is implemented as an increase of 22,500 ha/yr of forestland from year 1 to year 4.
- 15,000 ha of forest plantations are introduced into the model. Allowing time for the plantation timber to reach merchantable size, the harvest of these forests becomes possible from year 11 onwards. Forest plantations are implemented as an increase in the land available to the forest plantation sector.
- 19,000 ha of agroforestry systems are introduced into the model from 1 to year 4, as an increase in the land stock available to a diversified agricultural sector.

The economic viability of the investment will depend on the benefits estimated with the CGE assessed against the costs presented in Table 1, all discounted at a rate of 15%.

5.3. Implementing model shocks

A mathematical formulation of how an increase in forestland, and similarly the increase in agricultural land for forest plantations and

[2] 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 Organization for Economic Co-operation and Development's [OECD] Economic Surveys (2006). The average capital to output ratio was obtained from Morandi and Reis (2004).

Table 1
Costs and timeline associated with PDSA II.

Project component, subcomponent and result	Cost Days	Cost USD	Timeline (years) 1	2	3	4	5	6	7	8	9	10	11	…19
Component 1: Expansion of sustainable forest management	1456	$ 32,516,215												
1.1: Management of public forests	1456	$ 10,778,580												
1.2: Community forest management	1304	$ 16,540,830												
1.3: Capacity building	1218	$ 5,196,805												
Component 2: Forest plantations	1347	$ 56,529,999												
2.1: Implementation of Private Equity Fund	1020	$ 11,000,000												
2.2: Forestry/agroforestry value chain	1280	$ 38,599,999												
2.3: Enterprise promotion in value chains	1153	$ 6,930,000												
Component 3: Forest management	1304	$ 15,788,000												
Planning and management	195	$ 163,000												
Implementation	682	$ 4,270,000												
Other inputs	1174	$ 11,355,000												
Component 4: Administration	1521	$ 5,678,000												
Component 5: Auditing, monitoring and evaluation	1413	$ 1,440,000												
Operations and maintenance (5% of $187,402,214/yr; $9,370,111/yr)	6935	$ 178,032,103												

Source: Data supplied by the IADB; authors' own elaboration. Notes: Filled area indicates implementation period

agroforestry systems, is described by Eq. (1). Eq. (1) states that the sum of all activities' demand for a given factor is equal to the total factor supply. For simplicity, the element of time is dropped.

$$\sum_{a \in A} QF_{f,a} = QFS_f \tag{1}$$

where:

$QF_{f,a}$ is the quantity of factor *f* demanded by activity *a*
QFS_f is the quantity of factor supply
$QFS0_f$ is the initial quantity of factor supply.

As an example, a 10% increase of the stock of forestland in the north would be implemented as in Eq. (2).

Since:

$$\begin{aligned} QFS_f &= QFS0_f \\ QFS_{forestland\ \ north} &= 1.10 \cdot QFS0_{forestland\ \ north} \end{aligned} \tag{2}$$

6. Results

6.1. Static model results

Fig. 3 reports percentage change in macroeconomic indicators in response to the implementation of PDSA II. GDP, investment, private consumption, and exports are all impacted positively (0.0076%, 0.0179%, 0.0101%, and 0.0186%, respectively) while government consumption and imports are negatively impacted (−0.0069% and −0.0225%, respectively).

The magnitudes of the impacts of PDSA II are presented in Fig. 4. GDP increases by over $126 million BRL, investment by $44 million BRL, private consumption by $105 million BRL, and exports by $47 million BRL, while government consumption falls by over $22 million BRL and imports by $47 million BRL.

Fig. 4 suggests that the household income increases for low, mid and high-income households by 0.0165%, 0.0177%, and 0.0176%, respectively. Commodity output increases for almost all commodities, including agricultural, forestry, sawmilled goods, pulp and paper, and processed food products, by 0.0296%, 0.3338%, 0.1279%, 0.3512%, and 0.0186%, respectively. The generally positive impact is a result of the introduction of increased forestland for management, the income opportunities that this generates and greater productivity.

PDSA II's impact on sectoral activity is mixed. Where the forestry sectors are concerned, the northern forestry sector expands considerably, as would be expected, while contracting by a small amount in other regions. Agriculture expands in all regions. Production from natural forests tends to crowd out forest plantation activity in all regions by a small margin. The price of those commodities most closely linked to PDSA II decline somewhat, including agricultural, forest, sawmilled, pulp and paper, and processed food products (−0.0602%, −2.7399%, −0.2615%, −0.0018%, and −0.0175%, respectively) due to increased supply. PDSA II's impacts on exports are mixed, though exports do increase for agricultural, forest, sawmilled, pulp and paper, and processed food products as some of the increased supply is designated to export

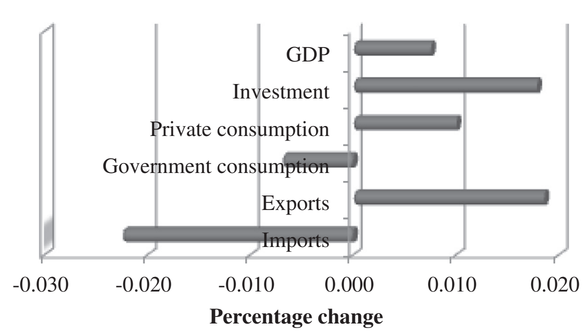

Fig. 3. Percentage change in macroeconomic indicators in response to PDSA II. Source: model results; authors' own elaboration.

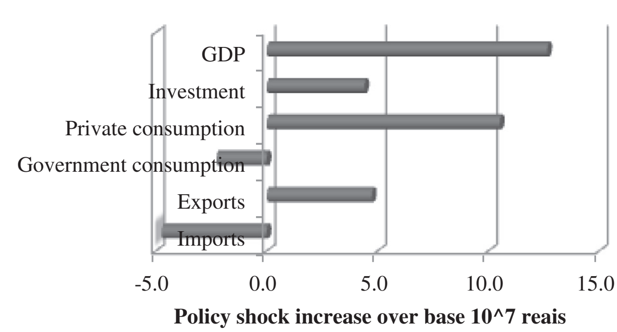

Fig. 4. Magnitude of increase over base. Source: model results; authors' own elaboration.

markets (0.1000%, 4.6374%, 0.7137%, 0.3209% and 0.0395%, respectively).

6.2. Dynamic model results

The results presented in this section represent PDSA II's impact as deviations from the forecast baseline in the average annual growth rate (AAGR). As with the static model results, dynamic model results indicate that the PDSA II has a positive impact on the AAGR of real GDP, imports, exports, government consumption, private consumption, and investment (0.0010%, 0.0006%, 0.0005%, 0.0004%, 0.0011%, and 0.0015%, respectively). Although these percentages appear small, given the size of the Brazilian economy, the increased rates of growth attributable to PDSA II are significant.

Fig. 5 shows the increased growth between the baseline and PDSA II scenario for macroeconomic indicators including exports, government consumption, private consumption, investment and GDP. In magnitude, the increase in GDP resulting from PDSA II is estimated at $1.9 billion BRL greater than the baseline in the final year. Exports, government consumption, fixed investment, and private consumption are $144 million, $119 million, $474 million, and $1.3 billion BRL greater than in the forecast baseline in the final year, respectively.

With enhanced income opportunities, household income grew faster for all three income classes, especially in the case of high income households (0.0001%, 0.0013% and 0.0014% for low, mid, and high income households, respectively). Faster income growth for low-income households is expected to have poverty-alleviating impacts.

With regard to composite commodity output, pulp and paper, forestry, and sawmilled goods experience the greatest increase in AAGR (0.0230%, 0.0114% and 0.0033%, respectively). Domestic output grew faster for various sectors, including forestry and agriculture in the north (0.6031% and 0.0066%, respectively). Although growth accelerated in most other sectors, rates of growth slowed for a few sectors including forest plantation activity in all regions.

In terms of magnitude, the increase in domestic forestry activity is estimated at over $283.8 million BRL greater than in the final year; agricultural activity in the north is valued at $35.2 million BRL greater than in the final year. Domestic activity in the final year is also greater than baseline figures by as much as $114.8 million BRL, $514.8 million BRL, and $317.9 million BRL for the sawmilling, pulp and paper production, and food processing sectors, respectively.

Fig. 6 shows that the composite price of key goods such as processed food, sawmilled goods, pulp and paper, forestry products, and agricultural products grows at a slower rate as a result of PDSA II (−0.0002%, −0.0084%, −0.0002%, −0.0208% and −0.0009%, respectively). Increased production possibilities increase the price competitiveness of these producers.

PDSA II results in increased export growth in a number of key commodities. Although for forest products, growth in exports slows in the forecast baseline, the introduction of PDSA II reverses this trend. The differences between policy and baseline AAGR are 0.0032%, 0.0920%, 0.0225%, 0.0231%, and 0.0015% for agriculture, forestry, sawmilling, pulp and paper, and processed food commodities, respectively.

6.3. Cost benefit analysis

Results from dynamic model simulations were evaluated in a CBA framework. It is estimated that PDSA II has an NPV on the order of USD$1.9 billion considering a discount rate of 15%. Accounting for only the direct benefits generated by the forestry, forest plantation and agriculture/agroforestry sectors, the NPV is equivalent to USD$266 million.

7. Discussion and conclusions

This paper develops a quantitative framework for the ex-ante evaluation of public investments in forest-based development. The framework employs the analytical power and advantages of a dynamic CGE models to capture the direct, indirect and induced benefits of public investments, and couples this with the rigor and transparency of a CBA. This framework is applied to a public investment of US$187.4 million in forest-based development in Acre, Brazil. For illustrative purposes, both a static and dynamic model are developed. Results from the static analysis provide an indication of the positive impact of the investment, though do not account for dynamic effects and are not amenable to analysis in a CBA framework. The dynamic CGE was used to evaluate PDSA II's impacts over the life of the project and show that the investment results in an NPV of over USD$1.9 billion at a discount rate of 15%. A more conservative estimation of the investment impact considering only the forestry, forest plantations and agroforestry/agricultural sectors in the state of Acre result in an NPV of USD$266 million.

At first glance, the results reported here may seem large compared with those typically generated by a traditional CBA for a similar size of investment. The primary reason for this is that the economy-wide analytical framework captures not only direct benefits, but indirect and induced benefits accruing to society as a whole. These indirect and induced benefits are not captured in partial equilibrium frameworks and are therefore not accounted for in subsequent CBA. The second reason is that PDSA II brings once-idle land into productive use. In most cases, tradeoffs or opportunity costs are involved in substituting one land use for another. In the case of PDSA II, however, bringing unproductive land into productive use has the effect of pushing outwards the production possibilities frontier, making possible the expansion of economic output.

There are a number of caveats to this analyses that should be noted. First, concerning the benefits, PDSA II is a diverse and complex investment with various components including improved infrastructure and

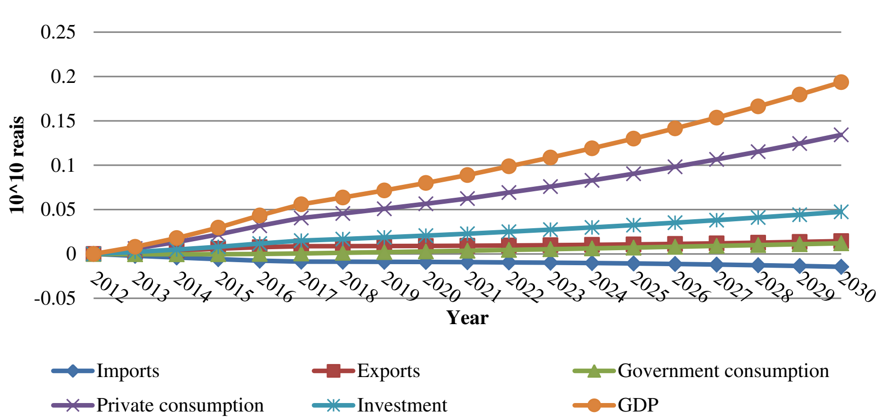

Fig. 5. Projected difference in AAGR between baseline and PDSA II scenario for selected macroeconomic indicators; Source: model results; authors' own elaboration.

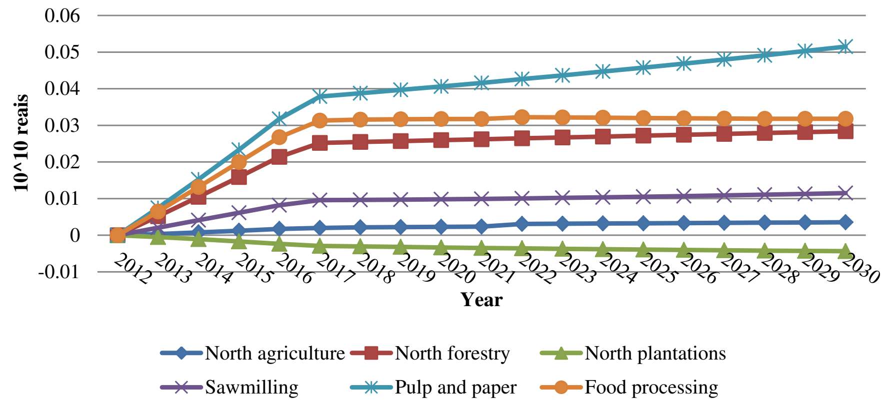

Fig. 6. Projected difference in AAGR between baseline and policy scenario in domestic activity. Source: model results; authors' own elaboration.

administration, supply chain development, and capacity building. These investments will likely result in productivity gains. Although assumptions could be made about their potential impacts, a conservative approach was taken here and these potential benefits were not accounted for.

Second, due to data availability, the results reported here are at a somewhat aggregated level. Greater regional as well as sectoral disaggregation would be desirable. This would enable more detailed analysis of the linkages among sectors and the flow-on effects of the investment in forestry, forest plantations, and agroforestry within the state of Acre, to other sectors of Acre's economy. More broadly, the linkages to other regions and sectors of Brazil could be traced more precisely. This regional and sectoral detail would be extremely useful for identifying supply chains, capacity constraints, bottlenecks, and conversely, areas where additional investment could significantly leverage the investment undertaken under PDSA II.

Third, in developing the forest sector representation in the SAM, various data sources were consulted including active forest management plans, estimates on regional prices of land, forest plantation industry data, and documentation related to deforestation permits. Integration of this data into the SAM required significant data reconciliation and assumptions which are a costly and time consuming exercise. With the recent publication of the first statistical standard for environmental-economic accounting, the System of Environmental-Economic Accounting (SEEA; UN et al., 2014), this data reconciliation and strong assumptions will no longer be necessary.

Given SEEA's compatibility with the System of National Accounts, the core data source for a SAM and CGE, data extracted from the SEEA can be readily integrated into a SAM. Availability of data collected under the SEEA will enable significant advances in public forest investment analysis and integrated economic-environmental modeling more generally (Banerjee et al., 2016a; Banerjee et al., 2016c). The forest accounts component of the SEEA will facilitate a more robust specification of the forest sector, and when coupled with other SEEA accounts such as energy and emissions, and water accounts, will provide a more comprehensive assessment of public investment impacts on the environment.

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