Chapter 11.
Assessing the Economy-Wide Effects of the PSA Program

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11.1 Introduction

Large-scale policies such as Costa Rica's program of Payments for Environmental Services (*Pagos por Servicios Ambientales,* PSA) have the potential to generate a series of complex spillovers and feedbacks across many different economic markets. Over the last several decades, computable general equilibrium (CGE) models have emerged as a widely accepted method for conducting empirical analyses of such policies because of their ability to integrate economic theory with real-world data. Advances in numerical simulation techniques have allowed modelers to move from simple partial-equilibrium models to general-equilibrium models with more sectors and more complex behaviors. Particularly for policies without historical precedents, or for those with potentially varying impacts over time, CGE models can evaluate policy impacts in a theoretically consistent fashion that can be impractical for other modeling frameworks.

For this analysis, a dynamic CGE model of Costa Rica is developed that contains the details regarding current and expected future land-use patterns needed to model potential impacts of the PSA Program. Land markets and land values are handled in an endogenous fashion by the model in order to evaluate how altering forest cover may affect different components of Costa Rica agricultural and timber industries. Interactions between these industries and the rest of the economy are also represented so that spillover effects from limiting agricultural production on other sectors can be evaluated. Overall, the CGE model estimates that macroeconomic impacts of the PSA Program are likely to be quite small. However, they are not restricted solely to specific industries because of their effects on labor markets, household income, and other factors. Important future work to be conducted on this topic includes consideration of the numerous benefits of the PSA Program to Costa Rica and other nations.

The next section considers why a CGE model might be the appropriate modeling tool to evaluate a policy such as the PSA program. The following two sections then briefly discuss CGE modeling in general and models that have been applied to Costa Rica in particular. Section 11.5 summarizes the economic forces within the country that led to deforestation in the past and provides a picture of Costa Rica's economy today. Section 11.6 then describes the CGE model used to evaluate the PSA Program and its characterization of land markets, followed by estimated historical results in Section 11.7, projected future impacts in Section 11.8, and conclusions plus thoughts for future extensions in Section 11.9.

11.2 Why use a CGE model to evaluate the PSA Program?

Although researchers can potentially capture a wide spectrum of interactions among people and markets when conducting evaluations of programs such as the PSA Program, the size and scope of a proposed policy typically provides some guidance on the type of modeling approach used for evaluations. The ultimate choice should be driven several considerations:

- What is the size of the policy shock?
- Are economically important sectors impacted?
- How many markets are affected by the policy change?

If the proposed policy is limited to a small set of individuals or firms within a single industry, researchers have traditionally relied on standard supply and demand analysis that considers a policy's impact on a single market in isolation and ignores other interactions (Berck and Hoffman, 2002). This partial equilibrium approach can be valuable and has been used, for example, to inform planning of land trust conservation strategies (Armsworth and others, 2006). If the proposed policy is large (that is, it affects significant number of economic sectors or the cost of the policy represents a substantial share of the economy's total output), researchers have increasingly relied on economy-wide CGE models that include a variety sector links and economic interactions. By tracing out the full effects of policies, CGE models can identify important feedbacks associated with interactions that produce unintended and unanticipated policy outcomes.

The use of CGE models has been most influential when the analysis is transparent and serves as one component of a broad set of analytical tools (Sadoulet and de Janvry, 1995; Devarajan and Robinson, 2002). For example, Persson and Munasinghe's (1995) analysis of the effects of higher stumpage fees in Costa Rica confirms the partial equilibrium story that higher stumpage fees reduce deforestation by increasing logging production costs. However, the CGE model identifies an important feedback that dampens the policy's effectiveness. Stumpage fees cause the logging sector to contract, and total deforestation increases because capital and labor prices fall in response to declines in factor demand. Lower factor prices in turn provide incentives to expand agriculture production because they lower the costs of clearing land. This is one of many examples of the policy relevance of CGE 'laboratories' discussed by Devarajan and Robinson (2002), where rich descriptions of the causal chains between policy choices and outcomes can all be described in terms of parameters, data, sector links, and other behavioral specifications.

These guidelines lead us to three reasons for using CGE to evaluate PSA Program impacts. First, the total dollar value of the payment system relative to agricultural output is significant. In 2006, Costa Rica allocated approximately US$16 million to the PSA Program, which was approximately one percent of agricultural Gross Domestic Product (GDP). Second, the PSA Program competes for a key factor of production used in agriculture, namely land. Agriculture remains an important sector of Costa Rica's economy, accounting for nearly 10 percent of GDP in 2003 and employing approximately 20 percent of the labor force. Changes in agricultural markets may indirectly affect other sectors of the economy that employ labor, as well as household income. Finally, the source of PSA Program funding might have independent effects of it own. By considering the influence that PSA Program expenditures have on land markets while simultaneously considering the source of PSA Program funding, our CGE model of Costa Rica provides an internally consistent framework for counterfactual simulations of the PSA Program and estimates the ultimate distribution of impacts across stakeholders.

11.3 CGE models

Designing a CGE structure to examine the impact of the PSA Program begins with a set of equations based on economic theory that describe interactions among businesses, households, governments, and regions. Within their structure, CGE models capture all flows of goods and factors of production (labor, capital, and natural resources) in the economy. The 'general equilibrium' nature of these models implies that all sectors in the economy must be in balance and all economic flows must be accounted for within the model. A simplified version of these circular flows in an economy is shown in Figure 11.1. Households own factors of production and sell them to firms, which generates incomes for households. Firms produce output by combining productive factors with intermediate inputs of goods and services from other industries. The output of each industry is purchased by other industries or households using the income received from sales of factors. Goods and services can also be exported, and imported goods can be purchased from other countries. Capital moves among regions as they run trade deficits or surpluses. In aggregate, all markets must clear, meaning that supplies of commodities and factors of production must equal their demands, and the income of each household must equal its factor endowments plus any net transfers received.

[Figure 11.1 about here]

Economic data specifying these circular flows are contained in a balanced social accounting matrix (SAM), which provides a baseline characterization of all interactions in the economy. The SAM contains data on the value of output, payments for factors of production, and intermediate input purchases by each industry, household income and consumption patterns, government purchases, investment, and trade flows. These data reflect technologies currently used by firms to manufacture goods and households' preferences for consumption goods. The theoretical structure of the CGE model, along with its parameter estimates, then determines how production and consumption will change in response to new policies.

In this theoretical structure, households are typically assumed to maximize utility received from consumption of goods and services, subject to their budget constraints. Constant-elasticity-of-substitution (CES) functions are typically used to describe these utility functions, which show how willing and able households are to substitute among consumption goods in response to price changes. Firms are assumed to be perfectly competitive and maximize profits, which are the difference between revenues from sales and payments for factors of production and intermediate inputs. Profit maximization is done subject to constraints imposed by available production technologies, which are also typically specified using CES functions that describe how different types of inputs can be substituted for each other. The extent of these substitutions is determined by elasticity parameters that control how easily trade-offs among inputs can be made.

As the result of their ability to consider all these aspects of the economy, CGE models are now widely used to develop counterfactual simulations of policies that effect a large number of economic sectors or when policy makers need to understand and evaluate policy induced structural changes in the economy (for example, sector employment or output) or the distribution of welfare impacts across stakeholders (Devarajan and Robinson, 2002).

Applications of CGE models to land use and the forest sector

Given the potential interactions between nonforest policies and deforestation, and the complex nature of these interactions, CGE models have been used in a few policy simulations—

see Xie and others (1996) for a review of early papers. In many cases, while the studies indicate that a CGE framework can capture impacts ignored by partial-equilibrium approaches, detailed characterizations of land use were relatively unexplored. Panayotou and Sussangkarn (1991), Cruz and Repetto (1992), and Coxhead and Jayasuriya (1994) develop standard CGE models that represent land use in a static (or single time period) setting where it is similar to other factors of production. Others (Dee, 1991; Thiele and Wiebelt, 1993) focus on steady-state representations of forest harvest patterns with limited characterizations of land mobility and the overall dynamics needed to examine a policy such as the PSA program. More recent papers have developed additional techniques for modeling land use and mobility, with an emphasis on the consequences of climate change mitigation policies. Darwin and others (1995) proposed methods for including land heterogeneity, which were then adopted in CGE modeling by Burniaux and Lee (2003) and Lee (2004). Golub and others (2006) examined long-run modeling of land use characterized by different sectors, land productivity measures, and land mobility features.

Limitations of CGE models

Although CGE models offer innovative ways to identify and/or provide quantitative estimates of important spillover effects associated with policy, it is important to acknowledge that they are not without criticism, especially in developing country applications. Nearly a decade ago, Angelsen and Kaimowitz (1995, p.80) noted the following limitations in their review of economic models examining deforestation:

> CGE models can be criticized for the poor quality of their data and the parameters commonly used, their questionable assumptions about perfect markets, and (particularly in the case of the forest rotation approach) their descriptions of farmers' or loggers' behavior. In such models the conclusions depend heavily on the responsiveness of the variables to changes in prices and income, and these elasticities are often chosen rather arbitrarily.

Xie and others (1996) identify other key existing weaknesses in the forestry CGE models during their literature survey. They include:

- failure to capture dynamic aspects of the economy;
- inadequate modeling of the relationships between forestland; agricultural land, and other types of land (if modeled at all); and
- exclusion of the environmental benefits of forest conservation.

11.4 CGE models of the Costa Rican economy

There have been several previous CGE models of the Costa Rican economy (Table 11.1). For example, Persson (1995) develops a two period CGE model that analyzes the timing of factor and output tax policies under different property right regimes. She concludes that unintended consequences of polices, particularly in the presence of poorly defined property rights, can be counterintuitive and missed by partial equilibrium analysis. For example, a temporary land subsidy in the first period leads to lower rates of forest cover loss because it indirectly increases wages of unskilled workers. This change in relative prices reduces agriculture output which leads to decreased deforestation.

Other CGE applications for Costa Rica have been designed to address other policy or modeling questions. Abler and others (1999) use a CGE model to examine the relationship between labor force growth and the environment. They find that higher population growth increases deforestation by 0.5 to 1.8 percent because it increases food demand and increases incentives to clear land for agriculture. A similar model by Abler and others (1998) specifically addresses parameter uncertainty questions in a CGE analysis of environmental impacts associated with macroeconomic and sector policies. They find that predictions regarding policy induced changes in environmental indicators are robust to changes in parameter values.

Cattaneo and others (1999) examine trade liberalization policies and find that reducing tariffs could increase GDP growth, particularly in the agriculture sector. These policy changes also lead to modest improvement in income distribution. One of the key claims, however, is that benefits from trade may be offset to varying degrees depending on whether governments respond to the revenue loss by reducing spending or by replacing revenue with a sales or capital tax. Dessus and Bussolo (1998) also use a CGE model to examine the trade-offs between trade liberalization and environmental quality. Their results suggest that, under free trade, pollution-intensive production becomes more attractive, leading to higher levels of pollution in Costa Rica.

Finally, Rodriguez-Vargas (1994) uses a static CGE model to analyze selected trade and tax policies in Costa Rica and considers the environment changes associated with model predictions. All trade policy scenarios resulted in land use changes that were either mixed or adverse for the environment while land taxation policies resulted in land use changes that likely benefit environmental quality. One of the study's interesting claims is the absence of large aggregate impacts associated with the policies examined.

[Table 11.1 about here]

All existing CGE applications in Costa Rica have one or more of the limitations mentioned above, as summarized in Table 11.1, and so would have incomplete capabilities in attempting to analyze the effectiveness of the PSA Program in their current form. One of the most obvious limitations is the absence of land markets. Only three studies explicitly consider land use decisions. Another critical limitation is that only two studies use some form of intertemporal choice framework.

Keeping in mind these critiques, this chapter develops a new CGE model of Costa Rica that links the PSA Program to economic outcomes in ways that extend previous representations of land markets and movement among uses, and does this in a dynamic framework to evaluate policy impacts over time.

11.5 The Costa Rican economy and its interactions with forests

Over the last fifty years, economic forces at work in Costa Rica have been directly linked to variations in its forest cover. In 1950, forests covered approximately 50 percent of Costa Rica's total land area. As a result of changes in the economy, this had fallen to only 25 percent by the late 1970s, a trend that continued through the 1980s. Among the economic motivations driving deforestation were Costa Rica's titling laws, rapid population growth, and its agricultural production and associated pasture conversion.

Starting in the 1930s, squatters could obtain ownership of forest land by clearing it (Snider and others, 2003). Over the next several decades, national land ownership legislation continued to provide incentives to clear forests as a way of establishing property rights (de Camino and others, 2000). Rapid population growth also contributed to deforestation, as Costa Rica's population doubled between 1950 and 1970, and doubled again to nearly 4 million by 2000 (Snider and others, 2003).

Economic forces within agriculture also contributed to forest cover losses over this period. Strong international demand for beef made ranching quite profitable, and a system of price supports and loan programs for the cattle industry further encouraged pasture (de Camino and others, 2000). Government subsidies designed to support economic development through agricultural exports also played a role in forest conversion. As a result of these factors, pasture area increased from 0.8 million ha in 1950 to 2 million ha by 1980. Between 1979 to 1992, pasture conversions continued to cause losses of around 50,000 ha of forests per year.

Over the last decade, changes in economic policies and the structure of the Costa Rican economy have reduced the incentives that had led to deforestation. Cattle ranching has become less attractive as beef prices have fallen, agricultural price and export supports have decreased, and timber prices have risen. The contribution of agriculture to GDP has declined from around 25 percent in the early 1980s to less than 10 percent today, complemented by increases in the services and tourism industries. Government policies such as the establishment of national parks and development of the PSA Program have also emphasized conservation. Increased domestic and environmental awareness led to increases demand for international ecotourism.

Table 11.2 illustrates the outcome of these changes for Costa Rica's economy. Service industries contribute more than 60 percent of GDP, while agricultural commodities represent only five percent and livestock are another two percent. Although land earnings in the livestock industry have a greater absolute value than other agricultural sectors, this represents a much smaller per hectare return since the area in pastures is much larger—for example, there are more than 2 million ha of pastures, around 100,000 ha of coffee, and less than 50,000 ha of bananas. Agricultural exports have been overtaken in importance by tourism. This economic shift has happened rapidly as the number of inbound tourists increased from 785,000 in 1995 to 1.1 million by 2003, a 40 percent increase (World Bank, 2005). Tourism now generates the most export revenues (around US$1.4 billion, or nearly double the US$755 million in banana and coffee exports) (World Bank, 2005; SEPSA, 2004). Although not yet fully developed, the forest-products sector also continues to expand and now has export values similar to livestock exports (de Camino and others, 2000).

[Table 11.2 about here]

11.6 General equilibrium modeling of the PSA Program

The economy-wide implications of the PSA Program are investigated using the *Applied Dynamic Analysis of the Global Economy* (ADAGE) model—see Ross (2005) for details. ADAGE is a dynamic CGE model that combines a consistent theoretical structure with observed economic data covering all interactions among businesses and households. A classical Arrow-Debreu general equilibrium framework is then used to describe economic behaviors of these agents (Arrow and Debreu, 1954). In this framework, households are forward looking and can adjust their behavior today in response to future policy announcements. Decisions by households regarding the consumption of goods and the amount of their labor to supply are made to maximize overall welfare. Firms are assumed to maximize profits subject to their manufacturing technologies.

The version of the ADAGE model used in this paper represents Costa Rica as a small open economy, based on the data shown in Table 11.2 and additional information needed to generated a balanced set of social accounts. For this analysis of the PSA Program, production functions for the agricultural and forestry sectors of the economy have be expanded to include more detailed representations of land use than is in other versions of the CGE model, as discussed below.

Endogenous land use modeling

Representing land use changes in an endogenous fashion, especially on a hectares basis rather than solely in annual earnings per hectare, necessitates extensions to the CGE model not traditionally found in the literature. First, in contrast with most CGE models applied to natural resource and environmental policies in developing countries (including Costa Rica), ADAGE considers dynamic effects of policies by linking time periods through capital formation and adjustments in land markets. Second, typically these land markets are absent even in static CGE analyses or, if included, they only consider the land rental values shown in annual economic data. The approach in this paper addresses land-use issues by including hectares of forest and agricultural lands in ADAGE and linking land areas directly to crop production in ways that account for differential land productivity across crops. This enhances the CGE model's ability to characterize interactions among sectors competing for land and potential costs of reducing the available amount of land.

To evaluate land-use decisions, this version of the ADAGE model distinguishes three types of land: crop land, pasture land, and forest/timber land. Production functions that include land and other types of inputs (material goods, labor, capital, and energy) are specified for the different sectors of the economy. These functions show options for substituting among inputs and are designed to represent land as an essential fixed factor in production that is available in limited supply. The formulations maintain a distinction between output per hectare of land and output per unit of labor/capital. See Ross (2005) for additional information on these equations.

Additional enhancements have also been added to ADAGE for this investigation. First, the economic data include multiple crops (see Table 11.2) so it is necessary to track land use, both earnings and hectares, for different commodities. Second, the silviculture, or timber, industry is separated from other crops since its use of land and dynamic characteristics are different than other agricultural crops (there is a stronger reliance on land and more limited options for improving productivity through use of additional non-land inputs). Finally, equations are specified to control mobility of, and competition for, land across different uses.

A variety of modeling techniques have been used to evaluate competition for land across potential uses (Golub and others, 2006). The simplest approach is to assume land is homogeneous across crops, livestock, and forestry, implying a single land rental rate. This, however, can result in significant shifts in land as demand or supply changes in one sector of the economy. Alternatively, land heterogeneity can be introduced into a CGE model through equations that transform a generic stock of land into land destined for specific uses or through more complex nested equations that are distinguished by type of land. Darwin and others (1995) first proposed this approach, and it has been incorporated in some more recent CGE modeling (Burniaux and Lee, 2003; Lee, 2004). Either approach is helpful in restricting unrealistic movements of land and in evaluating how land rental rates in different sectors may be affected by policies.

In this analysis, land use is modeled through nested equations, which also have the benefit of allowing a policy to be expressed in terms of physical units (hectares). In the presence of a new policy, transformations of land across uses are determined by the CGE model based on estimated changes in rental returns and historical data on transformation tendencies (for example, the tendency of forest lands to be largely converted into pastures, some pastures to turn into crop land, and vice versa). The extent of the estimated changes are influenced in part by assumptions regarding the willingness and ability of land owners to shift their land use, which are represented by a land transformation elasticity controlling movements across uses in the CGE model. Along with other influences, in a dynamic setting where agents possess foresight, land rental values over time will be linked by past adjustments and anticipated effects of future policies.

Modeling of the PSA Program

Along with the techniques used to model land use, estimated impacts of the PSA Program will depend on assumptions regarding how the policy is modeled. In this analysis, it has been conservatively assumed that all enrollment in the program constitutes a real change in land-use patterns. Thus, the PSA Program is effectively decreasing the available supply of land for agricultural and silviculture production by maintaining the enrolled area in forest cover that is not used to produce tangible goods for the economy. However, as discussed in Chapters 9 and 10, there is evidence that some of the enrolled land might have remained in forests in the absence of the program. The implication is that this analysis represents the best case for the effectiveness of the program, but also that its economic impacts will be overestimated to the extent that enrolled land would not actually have productive value if it entered agricultural land markets. Representing these simplifying assumptions on policy effectiveness in the CGE model requires an exogenous calculation of the area assumed to be covered under the PSA Program, which is based on available funds as described below.

We focus the analysis on the forest conservation contract, which accounted for some 95 percent of total area enrolled in the PSA Program. We do not examine the much smaller reforestation, forest management, and agroforestry components of the Program.

Our analysis also does not consider how land in the PSA program turns into *environmental services* provided to the global or Costa Rican national economy. Two major data limitations prevent any attempts to conduct such an analysis. First, we do not have good quantitative estimates of the amount of benefits generated by each conserved hectare. For example, we do not know the per hectare watershed services (in terms of either water quantity or quality). The preliminary ordinal analysis completed to date (see Chapter 10 and Wünscher and others, 2006; Hererra, 2002; Alpizar and Madrigal, 2005; Imbach Bartol, 2005) is inadequate. Second, we are unable to map these services into sectors currently included the Costa Rican SAM. Returning to the watershed services example, we would need to know exactly how the households (final consumers) and or the utilities sector would be impacted by these services. Furthermore, an average estimate of these services – even if it were available – could be misleading because of the spatial heterogeneity of these services (Sills and others, 2007). However, anything more precise would imply constructing a spatially explicit CGE model that is beyond the scope of much of the CGE literature. We return to this issue in the conclusion because it remains a key area for future work.

11.7 Effects of the PSA Program from 1997 to 2005

This section and the next discuss the sources and levels of funding for the PSA Program and then present findings from the CGE model on their estimated economic impacts. We begin by examining the effects of the PSA Program as it was implemented in the period from 1997 to 2005, in comparison to a 'baseline' case where it is assumed that the Program didn't exist, so that forests were not enrolled in the program and thus were able to enter land markets. In the next section we will then examine the impacts of several possible evolutions of the Program, involving new levels of funding and also possible changes in land payments.

Since its inception in 1997, the PSA Program has been financed primarily from a tax on fossil fuels (see Chapter 3). After initially varying from year to year, this funding source has provided an average of about US$11.3 million per year in the last five years. Additional funding has been received from a GEF grant under Ecomarkets, which contributed about US$1 million per year from 2000 to make payments, from a KfW grant, which has contributed about US$2 million per year in the last few years, from sale of Certified Tradable Offsets of carbon, which generated one-time funding of US$2 million (see Chapter 6), and from a growing number of voluntary agreements with water users, which by 2005 were generating US$0.5 million a year (see Chapter 5). For the purpose of this analysis, we ignore the specific details of the year-to-year variation in funding and assume an initial budget of US$4 million in 1997, rising linearly to US$14.8 million in 2005; fully reflecting the year-to-year variability would have added complication without enhancing understanding. We assume that transaction costs reduce the gross funding amounts by around 10 percent before they reach the program participants, which lowers the area enrolled in the PSA program. During this period, the Program offered payments for forest conservation of US$40-45/ha/yr. At this price level, the Program was fully subscribed, with applications to participate in any given year usually far exceeding the available budget. For this analysis, we assume a constant price level of US$45/ha/yr for forest conservation.

It is necessary to define a counterfactual, or Baseline, scenario against which effects of the PSA Program can be compared. In this case, we have chosen to define the baseline for the model that assumes the PSA program was not instituted in 1997. As a result, no forest lands were enrolled, thus the land remained free to enter the agriculture and silviculture sectors of the economy. No international funds were received either in the past or future, and hence no finance repayments are necessary (these costs are included in the PSA scenario). The baseline scenario provides a point of comparison to evaluate how the PSA Program might have affected growth in the economy.

With the assumed funding and payment levels, the PSA Program enrolls a growing area of land, reaching 275,000 ha in 2005. As discussed above, we assume this entire area represents additional forest, compared with the model baseline of no PSA Program. As a consequence of preventing this deforestation, the program restricts the supply of land in agricultural sectors of the economy, thus the quantity of agricultural land will be lower in the policy case than in the baseline. This change has direct impacts on the area used in each crop, the land values and associated earnings, and agricultural output. The model also evaluates indirect effects caused by these direct impacts as changes flow through the economy.

Based on endogenous interactions among agricultural sectors, historical patterns of land-use change, and land conversion costs, the CGE model estimates that the majority of land in the conservation program would otherwise have been used for pasture. Of the 275,000 ha enrolled by 2005, around 256,000 ha would have been in pastures, 16,000 ha would have been used as crop land, and the remaining 3,000 ha in the silviculture industry (note that this lack of effect on silviculture occurs because the modelling is focused on the forest protection component of PSA and does not consider the more complicated dynamics of any reforestation efforts).

Figure 11.2 illustrates the impacts of these changes in land use within the agriculture sector in 2005, compared to the baseline without the Program. Limiting the supply of pasture land (a large component of what occurs under the PSA Program) drives up returns to existing land of this type and actually increases overall earnings by land owners in this sector, demonstrating how land heterogeneity in the model can influence rates of return across uses. The more limited supply of land, however, implies that output of livestock is lower than it would have been in the baseline without the PSA Program. Ignoring the reforestation program, the silviculture industry experiences similar effects. The supply of land to other types of agriculture is not altered as much, and thus both land earnings and output are less affected.

[Figure 11.2 about here]

As the result of conserving forests under the PSA Program, aggregate economic activity is slightly lower in 2005 than if those forests had entered agricultural industries, as shown in Figure 11.3. This leads to slightly lower wage rates and thus household income (on the order of one-tenth of one percent by 2005). Although such changes are modest, they provide one mechanism by which impacts on agriculture spill over into the rest of the economy.

[Figure 11.3 about here]

Outside of agriculture, one industry estimated to have experienced effects is food processing, since it relies on agricultural goods and also supplies the majority of its output to domestic households (see Table 11.2). Petroleum refiners and electricity/water suppliers have also been affected through the domestic taxes used to raise funds for the PSA program. Although small in percentage terms, the largest dollar impact has been on the services industry, which is estimated to have gross output that is around US$23 million lower in 2005 than without the Program (total industry output declines around US$56 million). Exports, especially of agricultural goods, are slightly lower in 2005 in response to increases in domestic prices (as a small open economy, Costa Rica does not have any pricing power to influence international markets). These changes are more pronounced in the livestock and silviculture industries, which are most directly affected by the conservation policy's restriction of available land.

Despite these sector-specific results, estimated changes in overall macroeconomic conditions are quite small relative to total economic activity in Costa Rica. Estimated GDP losses from the PSA Program are around 0.05 percent initially in 1997 and reach 0.19 percent by 2005. Deviations in household consumption are similarly small (around 0.10 percent). As mentioned above, export changes are largely driven by policy effects on producer prices. Import demands are more a function of household income, which shows some slight decreases as wage rates decline. In spite of these income effects, the CGE model's measure of total welfare change (Hicksian equivalent variation, or EV) suggests the conservation program has had little impact on households even without considering the unmeasured benefits from ecotourism, watershed services, and any future carbon sequestration or bio-prospecting returns (the relative decline in annual Hicksian EV is estimated at less than 0.10 percent in 2005).

11.8 Effects of possible future evolution of the PSA Program

The future impact of the PSA Program is likely to change as overall funding levels and payment levels change. In this section, we examine the impacts that might be experienced under several possible scenarios concerning future funding and payments to participants.

As of 2005, funding for the PSA Program came largely from a domestic tax on fossil fuels, which is assumed to continue raising around US$11.3 million annually in the future (see Table 11.3), along with another US$0.5 million continuing from the voluntary agreements with water users. In addition, as of 2005 a total of approximately US$6.0 million remained from past

KfW funding, which has been used previously at a rate of around US$2 million per year. Past GEF contributions of about US$1 million annually through the Ecomarkets Project have concluded. However, additional new funding sources are also possible in the future. Domestic tariffs on water are expected to raise around US$5.0 million annually by 2012 (see Chapter 5), while international payments for biodiversity conservation and carbon sequestration may contribute another US$1.0 million each (see Chapters 6 and 7). In this analysis, we assume that these new funding sources enter in a linear fashion over time. We again assume that transaction costs reduce the gross funding amounts by around 10 percent.

[Table 11.3 about here]

Based on these funding sources and amounts, plus the area protected, we define several scenarios to simulate in the CGE model. Once again, it is necessary to define a counterfactual, or Baseline, scenario against which effects of future evolutions of the PSA Program can be compared. As nobody is proposing winding down the PSA Program, the best baseline in this case would be a simple continuation of the current program. We have thus defined as the baseline for these projections a model that assumes the PSA program continues with current funding levels and pre-2005 price levels, leading to the following list of policy runs in the model:

- ***Baseline (Current funding at US$45/ha/yr)*** – This scenario assumes that the PSA Program is funded at current levels of around US$13.8 million per year, dropping to US$11.8 million per year once the KfW funding is used up. Based on payments of US$45/ha/yr, this permits a total long-term enrollment of around 235,000 ha.
- ***Current funding at US$63/ha/yr*** – This scenario also assumes that the PSA Program is funded at current levels of around US$13.8 million per year dropping to US$11.8 million per year. However, it assumes payments of US$45/ha/yr for current enrollees and US$63/ha/yr for new enrollees, which reduces the area that can be enrolled to 170,000 ha per year.
- ***New funding at US$45/ha/yr*** – This scenario assumes that the PSA Program receives the new funding, which reaches US$18.8 million per year by 2012. Based on payments of US$45/ha/yr, this would permit a total enrollment of 375,000 ha in 2012.
- ***New funding at US$63/ha/yr*** – This scenario also assumes that the PSA Program receives the new funding, which reaches US$18.8 million per year by 2012. However, it assumes payments of US$45/ha/yr for current enrollees and US$63/ha/yr for new enrollees, which permits an ongoing enrollment of 265,000 ha in 2012.

Figure 11.4 shows the land use changes that would result if either funding levels or payment levels are changed, relative to the baseline of the current PSA Program. As can be seen, if payments are increased from US$45/ha/yr to US$63/ha/yr with no increase in funding, the decline in total enrollment leads to additional land being used for pastures and crops (the changes shown for the "*Current Funding at US$63/ha/yr*" case). In the scenarios with new funding, total enrollment in the PSA Program can be increased, which protects additional lands from being converted to agricultural uses. More land can be protected at US$45/ha/yr than at US$63/ha/yr so changes in land use in the two cases with new funding have somewhat different magnitudes.

[Figure 11.4 about here]

With the exception of timber in the "*New Funding at US$45/ha/yr*" case, none of these changes in land use have impacts on agricultural output of over one percent. If enrollment declines because funding remains at current levels and payments per hectare are increased, there would be small increases in output across all commodities as more land is available. If both funding and payments are increased, there are modest drops in production of some crops, but all declines are less than 0.2 percent.

[Figure 11.5 about here]

Figure 11.6 examines how these potential changes to the PSA Program might affect the rest of the economy over time. Compared with the existing structure of the program, increasing payments to US$63/ha/yr without new funding would have very slight positive effects on GDP, consumption, and exports. Receiving additional new funding and maintaining payments of US$45/ha/yr would allow enrollment to increase more than under the other alternatives, which leads to declines in GDP and consumption, although these are less than 0.10 percent and 0.05 percent respectively. The impacts of new funding, when combined with higher payments, are essentially offsetting and very few macroeconomic effects are estimated as the result of the higher enrollment.

[Figure 11.6 about here]

11.9 Conclusions

Overall, the CGE model estimates that past and future macroeconomic impacts of the PSA program are likely quite small, regardless of the level of funding and amount of land involved. However, the effects are not restricted solely to specific industries, because of changes in labor markets, household income, and export demands. Sensitivity analyses to date have not indicated that results are particularly dependent on specific model parameters or assumptions. Model runs were also conducted on potential interactions between international tourism in Costa Rica and the nation's forest cover. Using estimates from de Camino and others (2000) that show the tourism value of a hectare of forests as US$16/ha/yr, the model results did not find significant ecotourism benefits from the PSA program. However, alternative estimates of this value could lead to different results. Additional work can be done on tying the ecotourism sector to forest cover. Alternatively, forest lands could enter the utility functions of Costa Rican households or those in other nations. These extensions would be consistent with emerging state-of-the-art techniques on non-market as well as market feedbacks in counterfactual simulations of large scale conservation policies. For example, Pattanayak and others (2007) use a CGE model to investigate how forest conservation can mediate the impacts of climate change on human health via land and labor markets.

Other market interactions such as links between forests and watershed services, carbon sequestration and bio-prospecting could also be evaluated. Internal benefits from ecotourism, watershed services, carbon sequestration, and bioprospecting could collectively easily exceed the costs. For example, it is conceivable that protecting 450,000 ha of forests (equal to 30 percent of current forest cover) could reduce electricity generation costs because of watershed services (electricity and water sector have a revenue base of US$500 million) or generate 'carbon revenues' because each hectare can easily sequester a metric ton of carbon or more, which could earn, for example, US$50 in the international market place in the future. Environmental services of these magnitudes could easily offset any GDP costs experienced by agricultural sector. Future research is planned on explicitly incorporating these types of environmental services into household consumption and production decisions, along the lines of Carbone and Smith (forthcoming), to provide a more 'complete' welfare analysis

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Table 11.1: Computable General Equilibrium models for Costa Rica

Model	*Research topic*	*Static or dynamic model*	*Includes a land market clearing condition?*	*Includes non-market interactions associated with forests?*
Persson and Munasinghe, 1995	Property rights; taxes/subsidies on logs, land, unskilled labor, capital	Static	Includes demands for cleared land	Limited to exogenous damage function
Persson, 1995	Limits on deforestation; factor and output taxes	Dynamic (2 periods)	Includes demands for cleared land	Limited to exogenous damage function
Abler and others, 1998	Parameter uncertainty	Static	No	No
Abler and others, 1999	Labor Growth	Static	No	No
Cattaneo and others, 1999	Trade and macro policies	Static	No	No
Dessus and Bussolo, 1998	Trade policy and pollution abatement	Dynamic (solved recursively)	No	No
Rodriguez-Vargas, 1994	Trade and land tax polices	Static	Yes	No