Environmental Effects of Economywide Policies: Case Studies of Costa Rica and Sri Lanka

by

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To my parents, Margit and Edgar Persson
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ABSTRACT:

Traditional approaches to modeling environmental resources with insecure or ill-defined property rights are based on partial equilibrium models. This dissertation takes the view that since insecure tenure arrangements may be difficult to remedy, effects of national and sectoral policies should be analyzed in a general equilibrium framework in order to take unintended side effects on the utilization of environmental resources into account. Specifically, two case studies on deforestation in Costa Rica and land degradation in Sri Lanka are developed. The main conclusions of this exercise is that although partial models may be useful in analyzing policies aimed directly at the environmental resource in question or reforms in the property rights system, economywide policies and sectoral policies aimed at other sectors may have large effects on environmental resource utilization. When the environmental quality is a concern, a general equilibrium framework should be used.

In the Case of Costa Rica, the results indicate that policies such as minimum wage legislation and capital taxation have significant effects on deforestation. The deforestation effects should be taken into account in policy making, and measures to mitigate deforestation should accompany these policies. Similar results hold for the case study of land degradation in Sri Lanka.
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1. INTRODUCTION AND OVERVIEW.

The purpose of this dissertation is to trace unwanted side effects of government policies on the environment and natural resources, when markets for these resources are incomplete. Economic analyses of environmental problems often pose some difficulties not often encountered in standard economic theory. This is partly because standard first best theory often is not valid.

Public policy in the area of environment is essentially concerned about correcting the market failure\(^1\) often inherent in environmental areas. As a general example, the industrial emissions of for example sulfur dioxide into the air may harm trees and lakes as the sulfur is deposited on the ground or in surface water as acid rain. Regulations for industry behavior or the imposition of emission charges both constitute means for correcting the inherent lack of property rights to the air. The foundation of the above policy decisions is the notion that although there is no market for air per se, other individuals have rights to the resource of clean air. However, policies aimed at areas other than the environment may also generate positive or negative environmental spill-over effects, because these policies affect the relative prices in the economy and thus the production and consumption decisions.

This study will focus on the incomplete markets for forests in Costa Rica and for

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\(^1\) Bator (1958) introduces three types of market failures. Broadly, these three types are: (1) When all the relevant variables to production and consumption are not traded in markets, (2) Technical problems, which occur when resources are not easily dividable (e.g. dams, powerlines, and highway), and (3) The presence of externalities. However, a more useful definition is provided by Arrow (1969), who states that market failure occurs when any of the following is present: (1) inability to exclude, (2) lack of the necessary information to permit market transactions to be concluded, and (3) supply and demand are equated at zero.
land in Sri Lanka. In both cases, the property rights system can be considered to be an important factor behind environmental degradation.

In the following chapters I attempt to shed some light on the theoretical problems that occur in connection with economic modeling in the presence of incomplete markets for environmental resources. I also try to provide a framework in which environmental consequences of economic policies can be analyzed. My hope is that the models and the results presented here also may be of some practical use in policy design.

Chapter 2 provides a discussion of different property rights regimes, as well as brief summaries of some empirical case studies of the various regimes. A short background is given to the property rights regimes for forests in Costa Rica and agricultural land in Sri Lanka. Traditional and more recent approaches for modeling the common property and open access property rights regimes are discussed. Thereafter, a model for the analysis of the property rights regime in the Costa Rican forests is developed. Chapter 3 provides a discussion about environmental analysis in a general equilibrium context, and a brief survey of some general equilibrium models applied to environmental analysis. Chapter 4 provides a background of the Costa Rican economy, and factors other than the property rights structure that may affect deforestation in Costa Rica. The findings of Chapter 2 are used as a foundation for the general equilibrium models for deforestation in Costa Rica constructed in chapter 5.

Taking the results of the modeling exercise in the previous chapters into account, a new case study on land degradation in Sri Lanka is developed in chapters 6 and 7. This model is constructed taking a dynamic approach, as soil conservation is seen fundamentally as an investment problem. Finally, in chapter 8, general policy conclusions and broader modeling lessons are drawn.
2. PROPERTY RIGHTS

There are many different types of property rights systems, and many different policy options depending on the property rights regime at hand. We therefore begin this section by identifying and discussing the concept of property rights, and looking at some empirical studies of property rights regimes.

After discussing the property rights framework in the country case studies of Costa Rica and Sri Lanka examined here, we move on to looking at some of the recent analytical developments in the analysis of property rights regimes. A framework for modeling the complicated property rights structure of the Costa Rican forests is then developed.

2.1 THE CONCEPTS OF PROPERTY RIGHTS AND PROPERTY RIGHTS REGIMES

Bromley (1991, p. 15) defines a right as “the capacity to call upon the collective to stand behind one’s claim to the benefit stream”. This is a very useful definition to keep in mind while studying the complex area of property rights regimes. The above definition of rights demands that there is an authority structure in place, which can be used to protect the claims to a resource by an individual, firm, or a group of people. A further implication of this statement is, as Bromley points out, that a right is not a relationship between an object or a resource and an individual. Instead, it is a relationship between individuals with respect to the object.

The literature distinguishes among four basic types of property rights regimes with regards to land (Bromley and Cernea 1989, Bromley 1991, Feder and Feeny 1991, Hanna et al. 1995). These are open access property, common property, private property and state
First, there is open access, where rights to the resource are nonexclusive. This regime is the basis for Hardin’s “tragedy of the commons”\textsuperscript{3}. There is no defined owner (or group of owners) to the resource, and the benefit stream is available to anyone. The users cannot protect the resource against exploitation by other users (Bromley 1991). Each user will therefore take advantage of the resource, without taking the impact of his or her actions on the stock of the resource (the crowding effect) into account, until he or she can no longer profit from additional extraction\textsuperscript{4}. Under this regime, claims to the resource are realized at the time of capture (Hanna et al. 1995). This may result in overutilization of the land and lack of conservation incentives. A traditional example of an open access resource is overfishing.

Second, there is communal property where exclusive rights to the land are assigned to a group of people. There is no reason this system can not generate sustainable management of the land, depending on how effective the institutional structure of land management is (Bromley 1991, Feder and Feeny 1991). Communal property represents private property owned by a group, and the owners can therefore exclude others from using the resource. Tribal groups, extended families, neighborhood groups and kin systems are all possible examples of communal property rights systems. They can hold a customary ownership right, for example, to natural resources such as land or water resources (Bromley

\textsuperscript{2}There is some confusion in the use of the term common property resources, and the literature discussing it is extensive. In summary, common property has been used to characterize all of these property rights regimes except for private property. For a more extensive discussion on this subject see, for example, Bromley (1989) and Schlager and Ostrom (1992).

\textsuperscript{3}Hardin, Garret (1968). “The tragedy of the commons”, Science, 162, 1243-48. Although this is a much cited example of an open access problem, and very useful in this respect, it has frequently been criticized by other authors, see for example Dasgupta (1982), Cox (1985), McCay and Acheson (1987), Berkes et al (1990), Feeny et. al. (1990).

\textsuperscript{4}In more mathematical terms, this means that each user will take advantage of the resource until all rents are extracted, i.e. until the price equals average cost, whereas if the user owned the resource he would extract until price equals marginal cost, which allows for positive profits. See section 2.4 for a more extensive discussion.
and Cernea 1989, Dasgupta 1993a). In their use, these resources are often complementary to private property resources. Dasgupta (1993a) finds that they are often used as an insurance mechanism in times of economic stress, as they can be the only resources except for labor that are at the land-less poor’s disposal.

Third, under private property rights, the rights to the land are assigned to an individual or firm. The private owner has the rights to exclusively use the land, and to transfer his rights to another individual. This form of property is likely to be sustainably managed, since the impact of the owner’s actions on, for example, the stock of land is reflected in the stream of benefits to the owner of the land. (Bromley and Cernea 1989, Bromley 1991, Feder and Feeny 1991, Hanna et al. 1995). This is the most well known type of property rights, and it hardly warrants a more extended discussion.

Fourth, under state property, the rights to the land are under the management of the public sector (Bromley and Cernea 1989, Bromley 1991, Feder and Feeney 1991, Hanna et al. 1995). Individuals or groups may be able to use the resources, but only with the permission of the state. Examples can include national parks, or military reservations (Bromley and Cernea 1989, Bromley 1991). The state can either directly manage and control the state property through government agencies, or it can lease the property to individuals, firms or groups of users. They are then given the rights for a specific amount of time (Bromley 1991).

In the context of property rights, it is important to distinguish between de jure and de facto rights to a resource. If rights are enforced by the government, which explicitly grants rights to the resource, the property rights are de jure rights. On the other hand, de facto rights may be defined within groups of users. Users then act as if they have the property rights to the resource, and enforce these rules among themselves. De facto rights of access tend to be less secure than de jure rights (Schlager and Ostrom 1992).

These four types of property rights are ideal analytical types, and can sometimes be difficult to distinguish in practice. For example, if the group that has been assigned
exclusive communal rights is sufficiently large, the difference between open access land and communal property is likely to be small. If private property rights are not being enforced adequately, or are not regarded as legitimate, the private property from a judicial point of view may become a de facto open access resource. The same is true for state property. On the other hand, a clearly defined group of users who have exclusive communal land use rights would have the same incentives for sustainable management of the resource as in a system of private property rights.

Quoting Hanna et al. (1995, p. 19), three general principles of sustainable property management regimes have been established to date:

1. Property rights regimes do not exist as two opposing types but rather as combinations along a spectrum from open access to private ownership.
2. Property rights regimes are not in themselves sufficient conditions for resource sustainability, but they are necessary conditions. Without specified rights to resource benefits, ownership is realized only upon capture. If the assurance to future claims to the resource benefits is absent, no incentive exists to limit current use.
3. No single type of property rights regime can be prescribed as a remedy for problems of resource degradation or overuse. Both effective control and ineffective control can exist under any kind of regime. Effective property rights regimes are well-specified, context-specific, and enforceable.”

### 2.2 SOME EMPIRICAL EXAMPLES OF DIFFERENT PROPERTY RIGHTS REGIMES

Schlager and Ostrom (1992) give an example of a de facto open access fishery in the Valenca estuary in Brazil. Fishing communities held de jure rights to the rights of access and extraction, and the common property management worked well because no other fishers expressed interest in fishing in the area. Then, in an effort to modernize the country’s fishing industry, the Brazilian government began subsidizing loans for nylon nets. Although

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5 This article also gives example of sustainable fisheries management in a communal property rights regime.
the local fishers did not qualify for the loans, wealthy people in the surrounding areas did, and new fishers invaded the estuary. This resulted in overharvesting, and the fishing grounds were eventually abandoned.

There are many empirical studies of communal management regimes, of which only a fraction are discussed here. Berkes (1986) studies fisheries management in several locations in Turkey, where there is no licensing in the fisheries industry. In villages where there is little commercial pressure on the fishing resources, a communal management system works well. In the case of one lagoon fishery, where the local community had sufficient control of the lagoon, closed-access was institutionalized through a lottery of fishing sites, which took place repeatedly. In another area, the traditional fishing techniques were augmented with the development of a trawling fleet in the 1970’s. Overfishing resulted as there were no means to mediate between small-scale traditional fishers and the commercial fisheries. W. Cruz (1986) gives a similar example from the Philippines. In Cruz’s case, de jure rights to the resource existed, but since the rights could not be enforced the result was a de facto open access resource.

Common lands in traditional Japanese villages were communal lands with identifiable communities of co-owners. The villages developed elaborate regulations and even written codes for their commons, and misuse was punished. These common lands were in use, sustainably managed, well into the 1950’s. Since then, pressures stemming from commercial farming as opposed to subsistence use of the land, have caused the commons to disappear and private property rights have evolved instead (McKean 1992).

Gardner and Ostrom (1991) describe a successful communal management system in West Bengal. During the fishing season, fishers settle temporarily on the island of Jambudwip, and set nets in semi-permanent locations for the duration of the fishing season. The basic rule used on the island is that the first fishing team to set a net in one location has the right to continue using that location throughout the season, even if the nets have been moved intermittently due to changing directions of shoals of fish.
Another successful communal management system is illustrated by the Cree Indians in James Bay, Canada. There, sustainable resource management is incorporated both into the religious belief system and into hunting practices. The Cree Indians shift prey and fishing areas according to declining catch per effort, and the rotational use of hunting and fishing areas has proved both economically and ecologically efficient (Berkes 1995).

An example of state management of natural resources is the management of India’s biological diversity, which currently formally resides entirely within the state. The government takes a sectoral approach to biodiversity, and there is little coordination between the state agencies involved in this issue. In addition, biodiversity has been viewed as conflicting with the basic subsistence needs of local people, resulting in small support for the government’s conservation efforts (Gadgil and Rao 1995). Gadgil and Rao give the example of conservation of the Bharatpur wetlands as an example. These wetlands were designated as one of the first wildlife sanctuaries in the country after independence. They were also used for irrigation and livestock grazing by the local population, a practice that continued after the area became a sanctuary. At the demands of conservationists studying migratory birds in the area, the government banned grazing in the area in 1983, while no provisions were made for the villagers using the land. This resulted, predictably, in serious conflicts between the government and the villagers. Ironically, it turned out that in the absence of grazing, grass grew unchecked, choking the wetland, and bulldozers are now used to keep the grass under control.

After World War II, Poland maintained a large private sector in agriculture, in addition to the socialized farms. Gemma (1991) analyzes productivity growth in both sectors, and concludes that the growth in total factor productivity was much higher in the private sector. In Mexico, Heath (1992) studies the impacts of land reform in Mexico, and finds no significant difference in productivity between the Mexican ejido sector and the private agricultural sector. He explains this by low overall productivity in Mexican agriculture, but also with efficient communal property management in the ejido sector, and relatively equal access to credit for the two ownership forms. These results are to some
extent confirmed by Deininger and Minten (1996). They find that common property management improves with the degree of cooperation in the *ejidos*.

From these empirical studies, we can conclude that private property rights generally result in good resource management, whereas the environmental results of communal property management depend on the extent to which the user group is well-defined, and can exclude others from using the resource. Open access resources, on the other hand, are not likely to be sustainably managed.

### 2.3 Property rights in the case studies

In Sri Lanka, all large estates in the treecrops sector are owned by the government. The management of the plantations is leased out to management companies, although they have no stake in the equity of the plantations. The lengths of the leases are five years, with an option of renewal after this time depending on profitability. The short time horizons provide incentives for mining of the land. There are also smallholders active in the treecrops sector, but the size of private landholdings is limited by law, and the land cannot be freely transferred on land markets. Use rights for smallholder land are generally secure, even though they are not transferable. Soil degradation is a problem for all treecrops. The government of Sri Lanka is now taking steps to privatize some of the equity in the plantations.

Although the Costa Rican government is legislating in order to mitigate deforestation, in the past it was possible to gain property rights to forested land by clearing the land. Forests were considered to be of little value to development, and land clearing was considered in Costa Rica to be a land improvement, as was the case in many other Latin American countries. Rosero-Bixby and Palloni (1996) found that between 1973 and 1984, more than 80% of the forested area located near forest edges or roads was deforested. Forest clearing varies between the climatic zones in the county. In tropical dry zones, the probability of forest clearing was 97%, compared to 20% in montane rain forests, while the lowest deforestation rates could be found on land less suitable for agriculture.
Formally, with the introduction of the Forestry law of 1969, it was no longer possible to gain rights to land by converting forested land to land suitable for agricultural purposes. There is, however, still a problem in enforcing these laws. When the legislation was introduced, there were provisions made for land cleared under the previous system that was not yet titled. The new legislation requires proof, such as neighbors testifying to the time of clearing, that the land was cleared prior to the introduction of the new laws. However, the legislative process moves slowly, and in addition to recollection problems there are incentives for neighboring squatters to aid each other in testifying to the time of land clearing (Hartshorn et. al., 1982). Rosero-Bixby and Palloni (1996) found in their analysis that landless peasants is the group most likely to clear forests in Costa Rica between 1973 and 1984. M. Cruz (1992) finds that in the 1980’s, migration by squatters to forested areas increased, and that forests and marginal lands were increasingly being colonized by landless peasants. She continued to suggest that this is now the leading cause of environmental degradation in Costa Rica.

Loggers must have a permit for every tree harvested, and the trees are then marked. Informal accounts of the share of logs properly marked in the sawmills places this share at around only 20%. According to Hartshorn et. al. (1982), only about 35% of all logs harvested in 1980 had the proper permit.

Lutz and Daly (1990) note that the following four groups can be seen as responsible for deforestation in Costa Rica:

1. The timber industry may be responsible for deforesting as much as 20,000 hectares annually. Logging requires a special permit from the government, but about half of the trees are cut illegally.

2. Banana firms and other companies are expanding their plantations rapidly.

3. Cattle ranchers have expanded their activities rapidly at the expense of forested areas in recent decades. However, this type of land conversion may be limited now since most of the land that can be sustainably used for pasture has already been cleared.
4. *Squatting* is taking place on both privately owned and government land. Some of the squatters produce agricultural outputs, but others sell the cleared land to cattle ranchers or other land owners. Buyers who buy "in good faith" from squatters are not prosecuted. About twice as much is paid for cleared land as is paid for forests. Lutz and Daly, however, believe that squatting is no longer a major force behind deforestation, though it may be locally important.

Carrière (1991) describes the process of deforestation in Costa Rica as taking place in several stages. First, a logging company involved in high-grading clears a vehicle track to extract lumber. Thereafter, the road is improved by the government due to pressures from lobbying groups. This in turn enables local peasant families to clear and use the remaining forest for subsistence agriculture until the decreasing yields force them to sell or abandon the land, depending on whether it is titled or not. However, the land is still suitable for pasture and is therefore assembled by urban-based real estate companies and sold to cattle ranchers. After a few years, the land is almost completely degraded and unsuitable for any kind of economic use. This view is shared by Keogh (1984).

Thus, in the case of Costa Rica, the property rights situation is more a problem of insecure land tenure than a problem of traditional undefined property rights. If ownership to the land may be obtained with no costs other than the clearing of the land (i.e., without internalizing the externality of deforestation), the forests can be perceived to be a *de facto* common property, while the cleared land is perceived as private property. However, while deforestation occurs, the area being deforested is exclusive to the logger. This implies that there is no crowding effect, but instead a form of short term property right persists while deforestation occurs. There are no incentives for the individuals or logging firms to take the value of forest conservation into account.\(^6\)

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\(^6\) Dasgupta (1993a) p. 284 discusses this subject more extensively. A similar approach is taken in Chichilnisky (1993).
2.4 MODELING THE IMPLICATIONS OF COMMON PROPERTY AND OPEN ACCESS REGIMES ON RESOURCE EXTRACTION

The property rights system in Sri Lanka is quite straightforward. In general, land is owned by the state, which leases it out to the private sector on leases with different maturities. Though the length of the lease will probably have environmental implications, this is not a complicated problem in terms of modeling the incentives.

In Costa Rica, however, the situation is more complicated. In order to find a suitable approach for determining the implications of the property rights structure, an investigation of the applicability of traditional approaches for modeling common property rights systems is in order.

The traditional analysis of open access property rights regimes involves a straightforward maximization problem. New agents can, by definition, enter into the exploitation of an open access resource, and will do so as long as there are positive profits to exploiting the resource. The solution to each firm's profit maximization problem with respect to output, or with respect to inputs if the open access resource is an input, therefore generates the condition that the optimal level of extraction occurs when price equals average cost. Firms thus operate without taking the effects of their actions on the stock of the resource into account. The solution to this problem will equal the solution to the maximization problem of an agent who has exclusive rights to the resource only when the technology used exhibits constant returns to scale. A more common assumption would be decreasing returns to scale. This results in a higher level of extraction in the open access case than in a case of enforceable property rights as long as the marginal cost is higher than the average cost.

More recently, game theory has been used to analyze the implications of property

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7 For a more formal description see, for example, Stevenson (1991).
rights systems on resource extraction, in the cases of open access and communal resources. Approaches range from simple “prisoner’s dilemma” models to more complex models taking the dynamics of the stocks of resources and the intertemporal behavior of the players into account. An early game theoretical exploration of the implications of open access for species extinction is given in Dasgupta and Heal (1979). They discuss species extinction in the context of a dynamic model with free entry and exit of firms, and they show that profit levels are critical in determining the extent of overexploitation of the resource. Levhari and Mirman (1980) use a game theoretical approach to analyze the behavior of two countries competing for fishing resources. In their model, each country maximizes its net discounted utility, and the stock of fish follows a dynamic path. They show that if cooperation is not allowed, overfishing will occur. Plorde and Yeung (1989) extend this model to N players.

One interesting recent application of game theory to common property problems is presented by Gardner and Ostrom (1991). The objective of their paper is to investigate the impact of rule configurations on the equilibrium outcome of the game. Gardner and Ostrom analyze the non-cooperative one period game (a subgame perfect Nash equilibrium) of two fishers and two fishing spots. The fishers compete for spots, and they can inflict damage to each others' equipment in case of a conflict over a fishing spot. The different spots differ in quality. The game takes a simple prisoner's dilemma form. In an open access situation the outcome is thus determined by the value of the yield at each spot, and the potential damage caused by the other fisher. The authors proceed to change the rules of the game so that the game becomes cooperative. They can then analyze the

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8 A thorough presentation of the “Prisoner's dilemma” of common property resources in provided in Runge (1986) and Stevenson (1991).

9 Fudenberg and Tirole (1991 p. 74) defines a subgame perfect equilibrium in the following way: “A strategy profile $s$ of a multi-stage game with observed actions is in subgame-perfect equilibrium if, for every history $h^k$, the restriction $s|_{h^k}$ to $G(h^k)$ is a Nash equilibrium of $G(h^k)$, where $h^k$ is the history of moves before stage $k$, and $G(h^k)$ is the game from stage $k$ on with a history of $h^k$. See, for example, Fudenberg and Tirole (1991), Tirole (1991) or Reinganum and Stokey (1995) for a discussion.
communal management regime of the Indian fishers described earlier, where the first fisher to occupy a spot retains the exclusive right to fishing there, and the rules used by Brazilian fishers where the exclusive right to fishing belongs to the person first claiming that he will do so. Note, however, that the rules are exogenous to the game; an interesting extension in terms of the policy implications of this model would be to simulate the conditions under which cooperation would occur spontaneously.

2.5 Modeling property rights in the Costa Rican forests

From the discussion in section 2.3, we saw that forestry investments in Costa Rica are subject to substantial uncertainty. Other actors can in practice harvest forests formally belonging to other private actors or to the government because of traditionally insecure property rights. However, there are informal short term property rights in place as the forests are being harvested. The laws are changing and current government policies are now aimed at discouraging uncontrolled and unsustainable logging, although the legislative reforms are not rigorously enforced.

We will begin by exploring the implications of a traditional game-theoretical limited user model of deforestation, and its applicability to Costa Rica. Taking the shortcomings of this approach into account, a more accurate model of the incentives set in place by the actual property rights structure is constructed.

2.5.1 A simple prisoner's dilemma game for deforestation

To illustrate a situation with undefined property rights to the forests, and the implications of this property rights situation on forest conservation, we can apply a simple prisoner's dilemma game. Assume that we have two identical firms, which

\[\text{10 The prisoner's dilemma models presented here follows the approach outlined by Stevenson (1991).}\]

\[\text{11 The assumption of a constant number of players makes this game a limited user game, and hence not an open access situation. With a limited number of players, all rents will not necessarily be dissipated, as}\]
individually decide how much timber to harvest from a given amount of forest. Each logger can decide whether to harvest an additional tree, and the two loggers cannot collaborate in making this decision. Further, at the outset of the game the deforestation decisions are assumed to be at their optimal level. Assume that the harvesting of each additional tree (beyond the optimal level\textsuperscript{12}) today will generate revenue of $p$, whereas it will result in a discounted foregone revenue in the next time period of $q$\textsuperscript{13}. Since the players are identical, and make individual decisions on how many trees to harvest, the loss in revenue tomorrow from harvesting an additional tree today would be divided between the two firms, such that the loss in revenue for each firm would be $q/2$.

The necessary conditions for making this a prisoner’s dilemma problem are that

\[-\frac{q}{2} < -q \cdot p < p - \frac{q}{2}, \quad \text{and} \quad \left(p - \frac{q}{2}\right) - q < 0.\]

That is, the private net revenue from harvesting a tree today must be positive and smaller than the value of conserving the tree for harvesting in the next period. The total net revenue from harvesting today is negative and greater than the loss in future revenue to each individual logger. Further, if the second condition is not fulfilled, the gains from only one logger harvesting an extra tree would exceed the loss in revenue to the other logger. This would imply that fewer than optimal\textsuperscript{12} trees were being harvested at the beginning of the game.

\textsuperscript{12} The optimal level is here defined as the level that would be optimal if the firms cooperated, and maximized joint profits.

\textsuperscript{13} This is a conservative simplifying assumption. A more realistic assumption would be that losses per tree harvested over the equilibrium level would be increasing in the number of trees harvested. The general quantitative results of the simple prisoner’s dilemma game would still hold for this assumption in this more complete case.
The payoff matrix for this game is:

<table>
<thead>
<tr>
<th></th>
<th>Logger 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Logger 1</td>
<td>Harvest tree</td>
<td>Conserve tree</td>
</tr>
<tr>
<td>Harvest tree</td>
<td>(p-q, p-q)</td>
<td>(p-q/2, -q/2)</td>
</tr>
<tr>
<td>Conserve tree</td>
<td>(-q/2, p-q/2)</td>
<td>(0, 0)</td>
</tr>
</tbody>
</table>

The relevant question to ask then is what the dominant strategy would be for each logger, given the actions of the other logger. If logger 1 chooses to conserve a tree and logger 2 chooses to harvest a tree, logger 1 will lose half of the foregone value of conserving the tree for the next period (-q/2). If logger 1 chooses to harvest the tree and logger 2 also chooses to harvest the tree, logger 1 will gain the value of harvesting the tree today (p) less half of the foregone value of conserving both trees (-q). From our assumptions above, regardless of the actions of logger 2, logger 1 would always benefit from harvesting the tree today rather than conserving it. Logger 2 faces the same decision problem, and his dominant strategy would also be to harvest the tree today. However, if the two loggers could cooperate, they would both be better off conserving the tree as p-q < 0.

We can easily expand this game to an arbitrary number of actors, say n, as long as the number of actors is constant. Instead of the game between the above two players, the game will now occur between each individual logger and all other loggers. Assume that all individual loggers are identical, that each individual logger harvests an average of λ trees, and that the optimal solution is for a total number of λn = L trees to be harvested in the first period. By the earlier definition in footnote 12, the optimal solution results in the highest total net value of the forest, and thus the optimal allocation of harvesting between the two time periods. Assume that the decline in the total net value of the forest from harvesting an additional tree in the first period, rather than conserving it, is constant.

---

14 This particular game is known as Muhsam's game, see Stevenson (1991).
at $p-q$ (using the same notation as above, and maintaining the assumption that $p-q < 0$).

Overharvesting of logs in the first period occur if $\left(L+1\right) \left(1 + \frac{p-q}{q}\right) < L$, or, equivalently,

$$\frac{p-q}{q} > \frac{1}{L+1},$$

i.e. if the increase in total revenue from harvesting one more tree is smaller than the net value loss for the total value of the forest.

The individual logger decides whether to harvest one additional tree, whereas all other loggers decide whether to harvest $n-1$ additional trees.

The payoff matrix for logger $i$'s game and the game for all other loggers can then be calculated:

**Payoff matrix for logger $i$**

<table>
<thead>
<tr>
<th>Logger $i$</th>
<th>Harvest tree</th>
<th>Conserve tree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvest tree</td>
<td>$(p-q)(L+\lambda)/q + 1/(L+1)$</td>
<td>0</td>
</tr>
<tr>
<td>Conserve tree</td>
<td>$(p-q)(L-\lambda)/q$</td>
<td>0</td>
</tr>
</tbody>
</table>

**Payoff matrix for all other loggers**

<table>
<thead>
<tr>
<th>Logger $i$</th>
<th>Harvest tree</th>
<th>Conserve tree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvest tree</td>
<td>$(n-1)(1+(p-q)(n+L)/q)$</td>
<td>$(p-q)(L-\lambda)/q$</td>
</tr>
<tr>
<td>Conserve tree</td>
<td>$(n-1)(1+(p-q)(n-1)/q)$</td>
<td>0</td>
</tr>
</tbody>
</table>

Again, the dominant strategy for logger $i$ will be to harvest an additional tree. However, the optimal strategy for the collective of all other loggers differs from that of the individual logger. If the individual logger does not harvest an additional tree, all other loggers (as a collective) will incur a loss from harvesting additional trees as long as

---

15 For example, the net benefit for logger $i$ if all loggers, including himself, harvest an additional tree in the first time period will be $(\lambda + 1) \left(1 + \frac{p-q}{q}\right)^n - \lambda = 1 + \frac{p-q}{q} \left(n + L\right)$. 
1/((n-1)(\lambda + 1)) < -(p-q)/q. If the individual logger harvests an additional tree, it is more profitable for the collective of all other loggers to conserve trees for the next period as long as 1/((n-1)(\lambda + 1)) < -(p-q)/q. Given that these conditions hold, it would be in the best interest of the collective of all other loggers not to increase deforestation, regardless of the actions of the individual logger. It would also be in the best interest of the individual logger not to harvest an additional tree, but his dominant strategy would still be to harvest. Recall that all loggers are assumed to be identical, and the individual logger is representative of all individual loggers. The result of this game would therefore be for all loggers to overharvest in the first period. If the loggers could cooperate, forests would be conserved for the next period, and deforestation would be at the collectively optimal level.

Although the prisoner's dilemma games presented here are useful in order to illustrate the implications of undefined property rights to a resource, they are based on the very stylized assumption that the entire stock of the resource is available for harvesting, and that whoever decided to harvest can do so. To better illustrate the incentives for deforestation in Costa Rica, where the property rights to the forests are insecure rather than stylized open access, we need a framework that incorporates the dynamics of this property rights system.

2.5.2 A more accurate model of incentives arising from the property rights system in Costa Rica

In Costa Rica, we know that there is uncertainty as to whether a forest owner will have access to forests not harvested in the first period, in the second period. Following Arrow and Hahn (1971), the loggers' production vector in the second period will be

16 These conditions will be true for most parameter values, as they are approximately equal to the definition of overharvesting given earlier.
contingent on the "state of the world"\(^{17}\) in the second period. Then, the forest owner can only benefit from his conservation and reforestation efforts if he has the option to harvest in the second period\(^{18}\).

In the simple two period model to be developed here, the firms know what land they have been allocated and can harvest in the first period. Thus, the state of the world in that period is known with certainty. In the second period, however, there are two possible states of the world: either the firm will retain the plot it possessed in the first period, or that plot has been occupied by another firm. Firms will only be able to benefit from their reforestation and forest conservation efforts if they possess the same plot in period 1 as in period 0. Therefore, the benefits from reforestation and forest conservation will depend on the state of the world in the second period, and the likelihood that the firm can retain the same plot in both periods. Even if benefits from conservation and reforestation are very high, the firms are not likely to engage in these activities if the likelihood that they will return to the same plot in the second period is sufficiently small.

If property rights are well defined, the stock of forests available for harvesting in the plot owned by a firm in the second period is determined only by the actions of that same firm in the first period. On the other extreme, if the forest is an open access resource, the stock available for harvesting on the plot occupied by a firm in the second period is outside the control of that firm. Finally, if there is uncertainty in the property rights system, the expected amount of forest available for deforestation in period 1 on the plot owned by the same firm in period 0 will depend on the probability that the firm can retain the plot in both periods.

\(^{17}\) Defined by Arrow and Hahn (1971, p.122) as "a description so complete that, if known to be true, it would completely define all endowments and production possibilities".

\(^{18}\) This concept is known as Arrow-Debreu contingent claims. It defines a good not only by the usual type of good (such as apples or oranges, or forested land), but also by the time the good is supplied and the location in which it is supplied. The concept was developed by Arrow and Debreu, and is discussed in several publications by both authors, see for example in Debreu (1959) and Arrow and Hahn (1971).
The relationship between the amounts of available forest in the two periods is assumed to be simple. First, assume that the forest grows at a constant rate in the first time period, and the growth of the forest is available for timber production in the second period. Then, the amount of forest available for extraction in the second period is the initial amount of forest, plus the growth, and less the amount that was harvested in the previous period (regardless of whether the plot belongs to the same logger in both periods or not). In addition, the logger/owner in the first period can plant additional forest on the plot he owns in the first period. The amount planted in the first period is also available for harvesting in the second period, by the logger who owns the plot in the second period. The logger will therefore have two decisions to make in his intertemporal profit maximization problem: How much to harvest in the first period, and how much forest to plant for use in the second period.

In this context, it is interesting to investigate the impacts of different degrees of uncertainty in the property rights system for the forests, on deforestation. Below, a simple two-period model of the logging sector is constructed in order to investigate the implications of different property rights systems on the operations of the timber industry. In the case of land clearing from agriculture, the results would be parallel to those presented below for the logging sector, except that the price of output (cleared land) would not be determined by the world market price, since land is only traded on the domestic market. Instead, the price of land would be endogenously determined, and it would depend on the stock of land available for deforestation.

Assume that we have \( N \) identical firms, and that the total resource base is limited to

\[
L = \sum_{i=1}^{N} L_i
\]

---

\(^{19}\) For a discussion, see for example Dasgupta (1993 b).
where $L_i = L/N$ is forest biomass owned by firm $i$ in the first period and $L$ is total forest biomass. Assume further that each plot of forested land has an equal amount and uniform density of forest biomass, and that each firm will retain the same plot of land in period 1 as in period 0 with probability $\mu$.

Each firm is assumed to have a decreasing returns to scale technology for deforestation, reflecting that parts that are easier to clear of forests will be cleared first. In order to simplify the problem, the production function is assumed to be a function only of the extent of forest that is cleared to produce timber:

$$x'_i = f(A'_i)$$

where $x'_i$ is timber output for firm $i$ in period $t$, $A'_i$ is the input of forest into firm $i$'s production in period $t$, and $f$ is the production function. The production function is assumed to have decreasing returns to scale technology.

Secure property rights

If property rights are secure, each firm can retain the same plot in both periods with probability one ($\mu=1$). Each firm maximizes profits subject to the constraint that the harvest can not exceed the existing forest biomass in any of the periods:

$$\max p_0 f(A_i^0) - w_0 A_i^0 - q_0 d_i^0 + \frac{1}{1+r} \left( p_1 f(A_i^1) - w_1 A_i^1 \right)$$

s.t. $f(A_i^0) \leq L_i$

$$f(A_i^1) \leq (1+g)L_i - f(A_i^0) + d_i^0$$

where $p_t$ is the price of output in period $t$, $f$ is the production function for timber, $A_i^t$ is the input of forest into production by firm $i$ in period $t$, $w$ is the input price of forest in period $t$, $q_t$ is the price of reforestation in period $t$, $g$ is the growth rate of the forest, $d_i^t$ is area reforested by firm $i$ in period $t$, $r$ is the interest rate, and $L_i$ is the stock of forest owned by firm $i$. From profit maximization we obtain the following first order conditions:
where $\lambda_0$ and $\lambda_1$ are the shadow prices of forests in the first and second periods, respectively. These shadow prices can also be interpreted as Hotelling prices on the resource, and they give an expression for the intertemporal arbitrage conditions of the resource. If the available forest in the first period exceeds timber demand in that period, $\lambda_0$ equals zero.

Production in the first period will take place until the marginal revenue from deforestation minus the marginal cost of deforestation in the first period, less the expected discounted value of the marginal revenue minus marginal cost in the second period, equals the shadow price of forest resources in the first period. Reforestation will take place until the marginal cost of reforestation equals the discounted marginal revenue of harvesting in the second period. Production will not take place in the timber industry if the marginal cost exceeds the marginal revenue or if profits are negative. The third condition will not be binding if demand for timber extraction from firm $i$ in the second period is less than the size of its share of the forest.

Using the common assumption of decreasing returns to scale (i.e. $f' > 0$), the term in parenthesis in the first order conditions for $d_i^0$ will cancel out only if there are no additional profits to be obtained in timber extraction, i.e. if $\lambda_1$ equals zero. This implies that if reforestation does take place, there are profits to be obtained from timber extraction in the second period, and the marginal revenue exceeds the marginal cost. Further, from the first order conditions for $A_i^0$, it follows that profits to timber extraction must be
positive also in the first period if reforestation takes place. The first order condition for $A_j^p$ implies that the optimal level of deforestation for the firm is less than the optimal level of deforestation when the optimization problem concerns one period only, where we would get the standard result that deforestation would take place until marginal cost equals marginal revenue.

If property rights are secure, the firm will retain the same plot of land in next period with probability 1. The solution to the firm’s maximization problem then equals the solution to a social planner’s maximization problem (assuming that prices not are distorted, but reflect the true marginal social value), and reforestation will take place as long as the marginal cost of reforestation does not exceed the marginal revenue. No reforestation will take place if the size of the available forest is very large, prices in the second period are expected to be very low, or wages are expected to be very high.

**Insecure property rights**

There are different possible levels of uncertainty in the ownership of resources. Below, the implications of probabilities between zero and one of the firm retaining the plot in the second time period are investigated. Two cases are examined: a scenario where entry of new firms is restricted, and next the case of free entry of firms into timber harvesting in the second period.

If property rights are insecure, the firm will retain the same plot in the second period with a probability less than one. First, we will examine the case when entry of firms into timber extraction is restricted in the second period. For simplicity, assume that no new firms can enter into timber production in the second period, so that $N_0 = N_1$. Further, assume that the probability of the firm returning the same plot is proportional to the inverse of the number of firms.

The profit maximization problem is then:
Max \[ p_0 f(A^0) - w_0 A^0 - p_1 f_1(A^1) - w_1 A^1 + \left(1 - \frac{1}{N_1}\right) \frac{1}{1+r} \left( p_1 f(A^1) - w_1 A^1 \right), \quad i \neq j \]

s.t. \[ f(A^0) \leq L^0 \]
\[ f(A^1) \leq \left(1 + d_i\right) L_i - f(A^0) + d_i = L_i \]

The first order conditions for each firm’s maximization problem are now

\[ A^0_i: \quad p_0 f'(A^0) - w_0 - \frac{1}{N_1} \frac{1}{1+r} \left( p_1 f'(A^1) - w_1 \right) = \lambda_0 \], \quad \lambda_0 \geq 0
\[ A^1_i: \quad p_1 f'(A^1) - w_i = \lambda_1 \], \quad \lambda_1 \geq 0
\[ d^0_i: \quad -q_0 + \frac{1}{N_1} \frac{1}{1+r} \left( p_1 f'(A^1) - w_1 \right) \leq 0 \]
\[ \lambda_0: \quad f(A^0) - L_i \leq 0 \]
\[ \lambda_1: \quad f(A^1) - f(A^0) - \left(1 + d_i\right) L_i \leq 0 \]

From the above first order conditions, assuming non-negative profits, it follows that deforestation in the first period will be higher than deforestation in the case of secure property rights if forests are scarce (i.e., \( \lambda_0 > 0 \)), as the last term in the first order conditions for \( A_0 \) is only \( 1/N_1 \) compared to the same term in the case of secure property rights. The marginal benefit from reforestation has declined by \( (N_1-1)/N_1 \) compared to the situation of well-defined property rights. However, as long as there is a positive probability of the firm retaining the same plot in the second time period, it will still be profitable for the firm to engage in reforestation if expected output prices are sufficiently high, and the interest rate and expected wages in the second period are sufficiently low. The result that there must be positive profits to timber extraction if reforestation takes place still holds. Thus, the higher the number of firms engaged in timber extraction on a
fixed land area, the lower the level of reforestation for a given set of prices, wages and interest rates.

Second, we examine the case when entry of new finns into timber extraction in the second period is unrestricted. In this context, it is interesting to first examine under what conditions additional firms would be interested in entering the market. If new firms enter the market, \( N_t > N_0 \), and the share of land allocated to firm \( i \) will decline so that \( L_t^i = \frac{L}{N_t} < L_t^0 \). Assuming that timber extraction and reforestation take place uniformly in the forest allocated to firm \( i \) in the first period, the probability that extraction or reforestation decisions in the first period will affect production in the second period (given that the firm is allocated a piece of land that is contained in the land it cultivated in the first period) becomes:

\[
m = 1 - \frac{N_t - N_0}{N_0}
\]

The maximization problem is now:

\[
\begin{align*}
\text{Max} & \quad p_o f (A_t^0) - w_o d_t^0 - q_o d_t^0 + m \frac{1}{N_t} \left( \frac{1}{1 + r} \left( p_i f (A_t^i) - w_i A_t^i \right) + \right) \\
& \quad \left( 1 - m \right) \left( 1 - \frac{1}{N_t} \right) \frac{1}{1 + r} \left( p_i f (A_t^i) - w_i A_t^i \right) \\
\text{s.t.} & \quad f (A_t^0) \leq L_t \\
& \quad f (A_t^i) \leq \left( (1 + g) + d_t^0 \right) mL_t^0 - f (A_t^0)
\end{align*}
\]

The first order conditions for the profit maximization problem become:
From the previous discussion we have that as long as there is a positive probability of the firm retaining the same plot in the second period, and if \( f' > 0 \), there are positive profits to deforestation if reforestation takes place. Thus, new firms would have incentives to enter into production until all profits have been extracted, and deforestation levels would increase. In turn, this would remove the incentives for reforestation, because as \( N_i \) increases the expected benefit from reforestation to each firm operating in the first period declines. As \( N_i \) approaches infinity, the benefits of forest conservation or reforestation for the firm using the plot in period 0 are eliminated. In this context, it is important to note that the benefits from conservation will decline more rapidly than the inverse of the number of firms entering the market in the second period, as the entry of new firms also diminish the amount of forest available for each firm. Therefore, if new firms can enter the market at no cost, the property rights situation will approach the open access situation.

Open access

An open access property rights situation is characterized by many small identical actors who harvest the resource without taking the impacts of their actions on the stock of the resource into account. Given the assumed behavior of all other firms, each firm will attempt to maximize its own profits. In the example of forests, this would imply that the likelihood that the firm would be able to take advantage in the second period of the forest
conservation and reforestation undertaken on the plot it was managing in the first period approaches zero as discussed in the above section, if property rights are undefined.

We are assuming that all loggers are identical, and competitive input and output markets. Logger $i$ will then harvest forests at the rate of the average product, and total output is determined as the sum of outputs from all firms.

Since all firms are identical, the first order conditions to each firms maximization problem become:

$$A_i^0: \quad p_0 - \frac{w_0 A_i^0}{f(A_i^0)} = 0$$

$$A_i^1: \quad p_1 - \frac{w_1 A_i^1}{f(A_i^1)} = 0$$

$$d_i^0: \quad -q_0 \leq 0 \quad \text{if} \quad d_i^0 \geq 0$$

i.e., marginal revenue equals average cost in each time period. Reforestation will not take place since there cannot be positive rents to deforestation in an open access situation. As the timber extractor does not expect to retain the same plot in the second period, he has no incentives to take into account the effects of his actions today on the stock of the forest tomorrow. Therefore, no conservation for the next period will take place in the first period. More interestingly, levels of deforestation in the first period will increase compared to the case of secure property rights.

Implications of the property rights structure

The approach with insecure property rights would seem to be the approach most relevant to the situation in Costa Rica. In this approach, there is no uncertainty as to what the endowment available to each forester is in the first period. The uncertainty does not arise until in the second period, when the spot occupied by a firm in the first period may
have already been occupied by another firm.

In terms of the model presented in this chapter, it is important to note that there are several extensions that may be interesting in view of the general implications of the property rights system. For example, a model with an infinite time horizon and restricted entry of new firms may generate different results than the ones obtained here, in terms of forest management. This is, however, outside the scope of this paper. It may well be, if the results of the Folk theorem are applicable to this particular game\textsuperscript{20}, that the optimal strategy for the firms would be to engage in optimal forest management, as the probability that the firm will return to the same plot some time in the future approaches one as time approaches infinity\textsuperscript{21}. However, that is a complicated problem, and as our main interest here is to investigate the current situation in Costa Rica where new agents can enter the market, we proceed to the analysis of the implications of government policies for deforestation, taking the current property rights system as given, and limiting the property rights analysis to the two extreme cases: open access forests and perfectly secure property rights.

From the above model, we can draw the conclusion that secure property rights are qualitatively important if sustainable forest management and forest investments are to be encouraged. Lacking secure property rights, forestry investment is not likely to take place, and timber extraction will exceed the amounts extracted when property rights are secure. However, there are many difficulties in monitoring and enforcing an improved property rights system. From the above discussion, we see that as long as new firms can

\textsuperscript{20} The Folk theorem is extensively discussed in the literature of game theory, and asserts that if discounts rates are sufficiently low, any feasible, individually rational payoffs in the one-shot game can be enforced as an equilibrium in the repeated game with an infinite time horizon. See, for example, Tirole (1988). However, it has to my knowledge not been proven that the Folk theorem applies to this game, which is a dynamic game rather than a repeated game, and which has different probabilities of returning to the same spot.

\textsuperscript{21} For a discussion about the importance of the length of the time period in game-theoretic analysis of natural resource extraction, see Reinganum and Stokey (1985).
enter the market, deforestation is likely to be higher than in the case of securely defined property rights. This is because the dynamics of the problem lead to a situation approaching the open access property rights system. This is illustrative of the situation in Costa Rica, where legislation has changed but enforcement is not entirely successful.

We can also draw some conclusions about the direct effects of other policy options. Assuming that input supply is price inelastic, and that the output price is exogenous, a subsidy on the direct inputs into timber extraction would result in higher levels of deforestation in all of the above property rights cases. We can also determine that the effects of higher output prices would increase deforestation. However, a change in input prices, or in the timber price, is likely to affect other prices and thereby production in other sectors of the economy as well as consumption decisions. These relative price changes may in turn affect production in the logging sector. Policies targeted at other sectors of the economy will have similar effects, as will macro economic policies such as exchange rate reforms and other stabilization measures. In this model, or in any sectoral model for that matter, it is not possible to take these effects into account, and yet they are considered to be important factors behind deforestation.22

In view of the government’s commitment to reducing deforestation levels in Costa Rica and the difficulties in enforcing private and state property rights, a different modeling approach, where the sustainability of forest management is integrated into macroeconomic policy as a whole, would be needed. The effects of policies (other than improving the tenure system) on deforestation should be analyzed in that context, as these policies also are likely to have significant spillover effects on the rest of the economy, and on deforestation. Further, the effects of forest degradation must be incorporated into the production functions. The demand effects of relative price changes may be critical in determining, for example, timber demand. In the following chapters, computable general equilibrium models incorporating deforestation in Costa Rica are developed, and

conclusions about the impacts of selected policies on deforestation as well as other economic variables are drawn. In addition, soil conservation in Sri Lanka’s treecrop sectors (where land is state property leased out to the private sectors on contracts with different maturities) will be analyzed in a general equilibrium context.
3. GENERAL EQUILIBRIUM MODELS AND THE ENVIRONMENT

This chapter focuses on recent developments of general equilibrium modeling for the analysis of environmental issues\textsuperscript{23}.

The rationale for using a general equilibrium approach while analyzing environmental impacts stems from the need to account for spill-over effects of policies. Although specific policy measures aimed directly at, for example, the forestry (or deforesting) sectors are likely to have significant effects, they are more easily analyzed in a partial equilibrium framework. However, other general policies, such as taxation policies, trade policies and stabilization policies may have significant effects on the incentives for sustainable use of the environment and of natural resources, by affecting incentives and prices throughout the economy\textsuperscript{24}. In using general equilibrium models to simulate the behavior of the entire economy, assumptions are made about the utility functions of the consumers and the production technology of the producers. Consumers are assumed to maximize utility, and producers maximize profits, subject to the constraints facing each. Prices, wages, and consumed and produced quantities of each good are then determined endogenously. In this framework, the effects of for example increased taxation of industrial output on incomes, production in other sectors, and deforestation or soil erosion, can be traced through the economy.

\textsuperscript{23} This chapter does not attempt to provide a general introduction to computable general equilibrium models, nor does it give a history of the evolution of the incorporation of environment into macro economic models. An excellent introduction to CGE models is provided by Dervis et. al. (1982), and for a brief history on the integration of environment into macro economic modeling see Fersund (1985).

\textsuperscript{24} See, for example, Hyde and Newman (1991).
3.1 Some General Equilibrium Models Previously Applied to Environmental and Natural Resource Issues

A useful theoretical framework for the incorporation of environmental issues into a general equilibrium framework is provided by Mäler (1974). Mäler develops a model with the environment as a public good, in which an environmental management agency maximizes net environmental benefits, producers maximize profits, and consumers maximize utility subject to their budget constraint, and where the utility functions incorporate environmental quality. Both consumption and production activities generate residuals that are discharged into the environment. By pricing waste disposal into the environment, as well as providing clean-up services to consumers and producers, the environmental management agency controls the level of environmental damages. The environmental protection agency also buys inputs used for environmental treatment from the producers. The resulting equilibrium is a Lindahl equilibrium, introduced by Erik Lindahl in 1919 in his Ph.D. dissertation, which Mäler (1985) shows to be a Pareto-efficient allocation of resources. Coxhead and Jayasuriya (1994) develop a general equilibrium model focusing on the impacts of policies and technical progress on land use patterns, distinguishing between upland and lowland regions. The environmental effects are then deduced from the changes in cropping patterns, but they do not feed back into the production decisions of the farmers.

Computable general equilibrium (CGE) models have been applied before to environmental problems -- mainly issues involving air pollution and pollution taxes. A

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25 One area which has been rather frequently studied is the impact on economies of the discovery of oil, the so called "Dutch disease". Such models are not so relevant to our work, since they focus primarily in the economic impact of windfall foreign exchange earnings, not on the environmental management issues. Examples of such models are Alsabah (1985) which deals with oil findings in Kuwait, and Benjamin et al. (1989) and Benjamin (1990) which investigate the effect of oil sector earnings in the Cameroon.

26 This model is also discussed in Mäler (1985).

27 Introduced by Erik Lindahl in 1919 in his Ph.D. dissertation.

survey of models in this area is provided by Bergman (1988)\textsuperscript{29}. Two models with applications to air pollution are Bergman (1990) and Jorgenson and Wilcoxen (1990).

Bergman's (1990) model is designed to simulate the effects of environmental regulation and energy policy on the Swedish economy. The model has seven producing sectors and four types of primary production factors: labor, capital, electricity generated in existing hydro electric and nuclear power plants, and roundwood. Electricity can also be produced in fossil fuel plants when energy demand exceeds the supply. The cost of emission permits for carbon dioxide, sulfur and nitrogen are incorporated in the cost functions, and a market for emission permits is postulated. The prices of the permits are derived endogenously in the model, while total emission limits are determined exogenously by the government.

Jorgenson and Wilcoxen (1990) analyze the economic impact of environmental regulations on the US economy. This is done by simulating long term growth with and without environmental regulations. The model is dynamic, and runs between 1974 and 1985. The share of abatement costs in total costs is estimated for each industry, as well as the share of investment in pollution control equipment and the cost of pollution control devices in motor vehicles. The model is run with and without these costs, to estimate the economic impacts. The results include the finding that the motor vehicle and the coal industries are hardest hit by environmental regulations, at the same time that real GNP and consumption rise in the country.

There are only a few examples of CGE models dealing with the impact on the economy of overexploitation of forests. Panayotou and Sussengkern (1992) construct a model against the background of environmental problems in Thailand. The sources of

\textsuperscript{29} For a survey on early Input-Output models incorporating environmental pollution, see James et. al. (1978). Leontief and Ford (1972) provide, to my knowledge, the first example of applied input-output analysis to the disposal of pollutants into the environment, applied to the United States. Førsund and Strøm (1976) provide an early empirical input-output model with industrial emissions for Norway.
environmental degradation are economic growth, exchange rate misalignments, government policies such as agricultural policies and taxation, and the land tenure system, all of which combine to promote deforestation. The approach taken in the paper implies that every unit of production in each producing sector produces, for example, a fixed amount of air pollution or deforestation. The environmental impacts are not part of the model per se -- the environmental degradation or improvement is not fed back into the model so as to affect future production and consumption decisions. The results include the finding that export taxes on rice and rubber increase investments in soil conservation, increases the use of agrochemicals, and shifts land from rubber to rice. W. Cruz and Repetto (1992) use a similar approach to examine the environmental impacts of structural adjustment and stabilization policies in the Philippines.

Thiele and Wiebelt (1993) use a standard CGE model, amended with a forestry submodel, to investigate impacts of policy changes on deforestation in Cameroon. The forestry submodel is a traditional optimal rotation model for forests, amended by the introduction of a minimum harvest age. Foresters choose the optimal harvest age of the tree so as to maximize the present value of returns from current and future harvests. Logging technology is described by Leontief functions combining land and other inputs. Thiele (1995) applies the same approach to deforestation in Indonesia.

3.2 Property Rights and General Equilibrium Models

There has not been much previous work on the modeling of undefined property rights in a general equilibrium context. Mäler (1985, p.33) shows that the resulting Lindahl equilibrium discussed previously is incompatible with the Coase theorem, unless legal rights to the environment are granted to the environmental management agency or a social planner. Without these defined legal rights, the large number of agents -- typical in environmental problems -- would result in a Pareto-inefficient Nash equilibrium.

Devarajan (1990) suggests that a fruitful analytical approach may be to incorporate a partial equilibrium model in the general equilibrium framework. The intention is to model
the market the way it is actually working, and not to apply standard assumptions about well-functioning markets when this is not the case. This can, for example, be done by removing the first order condition that labor must be paid the value of its marginal product in some sectors, and replace it with a condition that reflects the suboptimal behavior of the sector. This would in turn enable, for example, an analysis of the effects on deforestation of policy interventions. It is emphasized that the model has to be dynamic in order to take account of both the stock and the flow effects of deforestation.

Unemo (1993) models the suboptimal use of land in Botswana, caused by overgrazing of cattle due to undefined property rights of the land. Land is seen as an open access resource, and the effects of overgrazing are incorporated in the cattle owner's production function as crowding effects. The quantity of output is determined not only by the number of cattle the individual owns, but by the whole population of cattle grazing on the land. The results include the finding that a fall in the price of diamonds considerably increases pressure on land, as mining becomes less profitable relative to cattle ranching.
4. COSTA RICA

4.1 STATUS OF FORESTS IN COSTA RICA

Deforestation in Costa Rica is proceeding at a rapid pace, and there is growing concern about this both inside the country and in environmental organizations around the world. Ministerio de Recursos Naturales, Energia y Minas (1990) mentions the following economic and ecological benefits that Costa Rica may lose if deforestation continues: access to construction materials and other wood products; unknown species of plants and animals that may have possible future uses in consumption and industrial production; recreation and ecotourism; control of erosion and sedimentation; and education and research possibilities. Also, other countries and environmental organizations may have concerns about Greenhouse effects and the loss of rich biological diversity in Costa Rica.

Deforestation and erosion are the main environmental problems in the country (Blomström & Lundahl 1989 and Foy and Daly 1989). Originally, most of Costa Rica was forested, but in 1977 only 31 percent (16,000 km$^2$) remained covered with forests according to Foy and Daly (1989), although other studies have reported very different results. Blomström and Lundahl (1989) estimate that in 1983 fourteen percent of the area was still covered with forests. Solórzano et al. (1991) give the more conservative estimate that about 40 percent of the land is still covered with forests. These discrepancies are probably due to differences in what types of forests were investigated. The lower estimates are probably only for primary forests, whereas the higher estimates include secondary forests and intervened forests (Sader and Joyce 1988).

Most of the deforestation has occurred since 1950. If deforestation continues at the current rate, the commercial forests of Costa Rica will be exhausted within the next few
years. The life zones with the highest rates of deforestation are the tropical wet forests; these are also the life zones in which biodiversity levels are highest (Solórzano et al. 1991).

The Costa Rican government is taking steps to preserve the forests. More than 13,000 km² have been designated as national parks, although in the past deforestation had been encouraged to diversify the country's production away from coffee and banana crops (Biesanz et al. 1987 and Lutz and Daly 1990).

4.2 THE COSTA RICAN ECONOMY

4.2.1 The macro economy

During the 1960's and 1970's the Costa Rican economy was growing fast. The growth rate in real GNP between 1961 and 1979 was on average 6.5%. Both the agricultural sector and the industrial sector were expanding rapidly. Industrial production was encouraged by import subsidies, and by Costa Rica's membership in the Central American market. Between 1950 and 1980 the share of the labor force employed in the public sector grew from 6 percent of the work force to approximately 20 percent. Trade unions were strong in the public sector, and they were able to obtain relatively high wages for their members.

In 1974, when oil prices increased dramatically, the government started borrowing heavily from abroad. However, the prices of coffee and bananas were increasing, and Costa Rica's terms of trade improved as compared to before the oil crisis. This resulted in a booming economy. Despite this, the government continued borrowing from the rest of the world. The borrowed capital was used mainly to expand the public sector, which grew at the expense of the private sector during the seventies. Public enterprises had almost unlimited access to credit from the Central Bank, and between 1974 and 1978 they received 18

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30 This section draws heavily on Blomström and Lundahl (1989) and Economist Intelligence Unit (various years).
percent of domestic credits while contributing only 1.8 percent of GNP. With growing public expenditures, sinking coffee prices, and rising oil prices towards the end of the seventies, the country entered into a serious balance of payment crisis.

However, the industry lobby was strong and managed to maintain its import possibilities. Trade unions in the public sector blocked proposed budget cuts. In 1981, Costa Rica's GNP contracted by 2.3 percent in real terms, and the following year by a further 7.3 percent. The country suspended foreign debt payments in 1981. Domestic investments sunk in 1982 to less than half of investments in 1979, and capital transfers to abroad increased because of increased uncertainty. The government responded with strong fiscal measures, and following the successful adjustment, the economy recovered rapidly reaching an average growth rate of 4.3% between 1980 and 1990.

Until 1984, Costa Rica continued import substitution policies within the Central American common market. Because of the balance of payments crisis and increased political instability in the region, the government then decided to target the international market with "non-traditional exports.\textsuperscript{31} Exports were promoted by liberalizing the exchange regime allowing for significant devaluations of the currency, and lowering ad valorem duties on intermediate imports. Export contracts have been introduced in the industry sector. Costa Rica's foreign debt in 1989 was almost 100 percent of the countries GNP, or more than three times annual exports. As part of the liberalized regime, there are no foreign exchange controls, limits on dividend payments, or restrictions on capital repatriation.

The tax structure for income and property taxes is quite regressive. Sales taxes and other indirect taxes constituted 86 percent of total tax revenues in 1989 (Central Bank 1990), and there are indications that this figure may still be high. Although property taxes are low (in some cases about one percent of the actual market value), property and income

\textsuperscript{31} Examples are flowers, seeds, seafood, textiles, electronic components and plastic products.
tax evasion are problems that cost the country approximately 100 billion colones (or about 20% of GDP) per year (Lutz and Daly 1990).

4.2.2 The agricultural sector

The main products cultivated in Costa Rica are rice, coffee, fruits, sugar canes, beans, maize, and sorghum. Lutz and Daly (1990) note that erosion is visible in some areas, but that farmers "do not produce in obviously unsuitable ways to destroy the environment. -- For example, living fences are widely used, which reduce erosion, and protective forest cover is left intact next to creeks, on contours or steep slopes, etc."

According to Hugo et al. (1983), productivity per worker has increased in agriculture, industrial production and construction, and decreased in the other sectors. The productivity gains in the producing sectors to a large extent reflect productivity gains in the agricultural sector (food processing is the largest industrial sector in the country). Hugo et al suggest that the increase in labor productivity in agriculture may be a result of an increase in usable land. The gains from using techniques that demand more intensive use of other inputs have therefore increased. The increase in usable land is illustrated by an increase in permanently cultivated land from 512,000 hectares to 530,000 hectares (or about 4%) between 1982 and 1992. Crop production grew by 20% in the same time period (Economist Intelligence Unit 1995).

There are four major grain markets in Costa Rica. These are for white and yellow maize, beans and rice. Almost all yellow maize -- which is used for feeding cattle -- is imported. Costa Rica was until recently self sufficient in the production of the other grains (Hazell and Stewart 1993). In recent years, production patterns are changing towards non-traditional exports such as cut flowers, pineapples and tropical fruits (Economist Intelligence Unit 1995). Prices of grains are heavily regulated by the Consejo Nacional de

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32 Total tax income in 1989 amounted to about 16% of GDP (Central Bank 1990)
Produccion (CNP), which regulates imports and exports. The CNP also acts as a reserve fund to smooth out seasonal variations over the year, and buys grains from producers at prices that do not reflect the transportation costs. It is also involved in setting minimum producer prices and maximum consumer prices through its trading operations. These policies were established in the 1940's and are still in effect (Hazell and Stewart 1993).

In the 1950's and 1960's there was a large increase in investment in cattle, encouraged by foreign aid and investment, as well as government aid in the forms of credit and provision of infrastructure. The increase of cattle ranching caused rapid deforestation. The pasture trend boomed in the 1970's, but since then profits have decreased. More than 70 percent of available farmland is in pasture while only 2.5 percent is in coffee and 1.1 percent is in bananas (Biesanz et al. 1987). Between 1982 and 1992, the area under permanent pasture expanded with only 0.5% (from 2.2 million hectares to 2.3 million hectares), whereas livestock production grew by 19% (Economist Intelligence Unit 1995).

Studies on optimal land use (Biesanz et al. 1987 p 34) indicate that only 25 percent of the land in Costa Rica is suitable for intensive cultivation. An additional 25 percent may be used for extensive agriculture and the remaining 50 percent is suitable for forestry, including the rain forests. There is a trend towards an increase in pasture, although optimal land use would favor an increase in cultivation and forestry (Biesanz et al. 1987). Other studies, however, come up with somewhat different estimates -- Lutz and Daly (1990) and Solórzano et al. (1991) estimate that about 60 percent of Costa Rica's soils are useful for pasture or for cropping.

Traditionally, Costa Rica has been seen as "a small democracy of small landowners". However, about 46 percent of the farmers own farms smaller than five hectares, and they own altogether only two percent of the farmland area. In 1973, one percent of the number of landholdings were larger than 500 hectares, but they constituted 36 percent of all privately owned land (Biesanz et al. 1987).
4.2.3 The industry sector

Costa Rica is the most industrialized country in Central America with mining and manufacturing constituting 21.4% of GDP in 1993 (Economist Intelligence Unit 1995). The industrial sector is promoted by export subsidies on 'non traditional exports'. The direct export subsidy functions as a tax credit, and is worth approximately 15% of net exports (Hoffmaister 1992). In addition, intermediate import goods are free from taxes if they are used in the production of exported goods. There are no export taxes or income taxes on exported industrial products, and government subsidies are given up to 10 percent of the yearly increase in exports to stimulate industry exports (Blomström and Lundahl 1989). Food processing is the largest industry in the country, and textiles, chemical products and metal processing are also important (Economist Intelligence Unit 1995).

4.2.4 The logging sector

Domestically cut logs are processed locally and are used typically in construction. Imports and exports of logs were outlawed in 1986, and therefore no official statistics are available regarding continued illegal logging (Lutz et al. 1993). Official exports of wood and wood products are small, and imports are negligible.

The current import tariff on logs is 5 percent (Lutz and Daly 1990). Efficiency in the forestry sector is low, and only a few species are commercially utilized. About 54 percent of the logs are processed, and of these about half finally reach the market (Ministerio de Recursos Naturales, Energia y Minas 1990). The main part of the logs used in the timber industry are bought from sources other than the industry itself.

4.3 Property rights and domestic interest rates

In order to investigate the impact of property rights on domestic interest rates, we use a simple two period model. First, we investigate the case of secure property rights, and we then use the same model to analyze the implications of insecure property rights, and
compare the two results.

Assuming that property rights are secure, investors will continue to invest in a resource until

\[ f'(k_0) + P_1^k (1 - \delta) = P_0^k (1 + r_{\text{WM}}) \text{ or, equivalently} \]

\[ \frac{f'(k_0)}{P_0^k} + \frac{P_1^k (1 - \delta)}{P_0^k} = 1 + r_{\text{WM}} \]

where the price of output in the first period is exogenous and normalized to 1, \( P^k \), is the price of capital in period \( t \), \( f(k) \) is the production function, \( f'(k) \) is the marginal product of capital which is assumed to be declining in the capital stock, and \( r_{\text{WM}} \) is the world market interest rate.

The equilibrium price of capital in the first period will equal the value of the marginal product of capital in that period, i.e. the first term on the right hand side in the above equation equals one. The second term on the right hand side is the marginal return to investment, which by definition is the domestic interest rate (\( r \)):

\[ 1 + \frac{P_1^k (1 - \delta)}{P_0^k} = 1 + r = 1 + r_{\text{WM}}. \]

Let us now assume that there is a nontraded resource with insecure property rights, such as forests, included in the capital aggregate of the economy and change the notation so that when property rights are insecure the resource is denoted \( d \). We then have that each individual will continue to invest in the resources until

\[ \frac{f'(d_0)}{P_0^d} + \frac{\mu P_1^d (1 - \delta)}{P_0^d} = 1 + r^d. \]

where the output price again is normalized to one, and \( \mu \) is the probability that an agent will still own the resource in the second period.

If the fact that property rights of a resource are insecure is not taken into account, the domestic interest rate is likely to be higher than if the insecure resource ownership was
taken into account:

\[ 1 + \frac{P^k(1-\delta)}{P^k_0} = 1 + r > 1 + \frac{\mu P^D(1-\gamma)}{P^D_0} = 1 + r^d. \]

In the Costa Rican national accounts (Banco Central de Costa Rica 1990), forests are not included in the fixed capital formation tables, though net deforestation at higher than socially optimal levels can be viewed as a form of capital depletion\(^{33}\). Taking the viewpoint that forests are natural capital, and should be viewed as such in a country's resource balance, the above analysis would indicate that domestic interest rates may be too high in Costa Rica, or that the marginal returns to traditional capital are artificially high.

Further, the impact of tropical forests stocks are often more significant in the long term than in the short term. The regenerative capacity of tropical forests is low, and the discounting of future environmental benefits is crucial in determining the optimal stocks of forests at any given time period. Forest investments, like replanting, take a long time to yield returns, and individuals and firms therefore find little benefit in conservation and reforestation activities when faced with high interest rates and uncertainty.

### 4.4 INCENTIVES FOR DEFORESTATION IN COSTA RICA

As may be concluded from the earlier discussion, possible reasons for excess deforestation in Costa Rica may be:

- Undefined property rights which make the private cost of deforestation lower than the social cost of deforestation. Because forests are not included as capital assets in the national accounts, and because of the property rights structure, domestic interest rates may be too high. Both of these factors imply that the gains from deforestation today is higher than they would be if property rights to the forests were secure.

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\(^{33}\) For a discussion regarding the inclusion of natural capital into the national accounts, applied to Costa Rica, see Solórzano et. al. (1991).
• Economywide policies such as the tax system, which may inadvertently create incentives that cause deforestation.

The next chapter investigates the causes of deforestation in Costa Rica, taking these factors into account.
5. GENERAL EQUILIBRIUM MODELS FOR THE ANALYSIS OF CAUSES OF DEFORESTATION IN COSTA RICA

A general description of the functioning of computable general equilibrium (CGE) models was provided in chapter 3.

The purpose of the CGE models analyzed in this chapter is to investigate the effects of economywide policies on natural resource use and the environment, and to determine the economic effects of an enforced allocation of property rights to Costa Rican forests. In addition, the impact of changes in interest rates and of taxes on factors of production -- labor, capital, land, logs -- and on final goods will be investigated. The models presented here are constructed so as to allow for side effects of government policies to spill over to other parts of the economy. Further, two models (one static and one dynamic) are constructed so as to capture the quantitative differences between the two approaches.

CGE models can be designed for different types of experiments. First, questions about optimal policies can be asked, such as what the optimal tax structure is in order to achieve a certain goal. Second, questions about the effects of exogenous policies can be investigated. For example, if we introduce a tax increase on a certain factor of production, what are the effects on other critical variables? The CGE models presented below are designed to investigate the second type of problem. To answer questions of the first type, such as what is the optimal tax on capital if we want to reduce deforestation to a certain level, the model would have to be designed differently and focus more on the functioning of the market affected by the tax.
5.1 General Features of the CGE Models

The models have two types of traditional producing sectors. The tradable producing sectors (T-sectors) forest, agriculture and industry are assumed to be price takers in the world market in the standard Heckscher-Ohlin fashion. The non-tradable producing sectors (N-sectors) are infrastructure and services. The aggregation of sub-sectors into production sectors is illustrated in Appendix 1. In addition, the models have two sectors that clear land. Loggers clear land to obtain logs for use in the forest industry and for exports, and squatters clear land and sell it to the agriculture sector. The traditional way of modeling environmental effects such as deforestation is through fixed coefficients or partial equilibrium models. Here, a different approach is used. Instead of deforestation as a fixed coefficient of agricultural production or production of forest products, substitution between land and logs, and, for example, capital is allowed.

A traditional Heckscher-Ohlin model is used to model trade, as the main focus of these models is the incentive structure in the logging and land clearing sectors and not the impacts of trade reforms. This trade model implies that a country will export commodities which are intensive in production factors that are abundant in the country, whereas it will import commodities which are intensive in production factors that are scarce in the domestic economy. Therefore, imports and exports cannot simultaneously take place in the same good. As land is not a tradable production factor, this modeling approach does not directly affect the incentives in the land clearing sector. Logs, however, are tradables in the model, as trade is likely to take place despite legal restrictions if the world market price is sufficiently high.

Using a Heckscher-Ohlin trade model is likely to generate very strong effects of policy experiments on production in the tradables producing sectors. Despite this, the Heckscher-Ohlin approach was chosen rather than Armington approach (developed in Armington, 1969), as there is no reason to believe that traded Costa Rican logs or agricultural produce would not be perfect substitutes for similar produce in other countries.
There are five types of domestic intersectorally mobile production factors in the models: unskilled labor (UL), skilled labor (SL), capital (K), logs (FL), and cleared land (DL). They are aggregated into a composite factor aggregate using nested constant elasticity of scale (CES) functions. Logs are used as an input only in the forest sector, and cleared land is used only in the sector agriculture. In Costa Rica, part of the land cleared by squatters is sold to the agriculture sector, and part of the cleared land is used for subsistence agriculture by the squatters themselves. However, since both subsistence agriculture and land transactions occur, the marginal revenue must be the same in both cases, and all land is therefore assumed to be “sold” to the agriculture sector in the model, even though some of the squatters may themselves join the agricultural sector and cultivate the land. Squatters are assumed to not sell the timber from their deforestation. Other uses of timber, such as for firewood, are assumed to be negligible and are therefore set to zero.

The technologies used by loggers and squatters for deforestation are assumed to exhibit constant returns to scale technology. The input of forested land is assumed to be exogenous. For simplicity, the input of forested land into the production functions is not modeled, resulting in decreasing returns to scale in other inputs.

No reforestation is possible in the general equilibrium models presented here. This is because the policy experiments conducted here concern a regime of undefined property rights. The results of the partial equilibrium analysis in chapter 2 of this dissertation show that the undefined property rights imply that no investments will take place in forests as the shadow price of investments in forests is zero.

5.2 THE STATIC MODEL OF DEFORESTATION IN COSTA RICA

The first model is a static CGE model of an open economy, although it has certain implicit intertemporal features as the discount rate is included in the future valuation of

34 “A more accurate model of deforestation in Costa Rica”, see p.18-
forested land. It differs from the standard approach of CGE modeling by including undefined property rights and by modifying the functioning of the markets for logs and cleared land.

If property rights are undefined, the squatter or logger has control over the management of the land in future periods only if the land is cleared. Therefore, when property rights are undefined, the deforester includes only the private cost of deforestation - i.e. costs for labor and capital -- in his cost function.

When property rights are well defined, squatters and loggers are assumed to own the forest and an additional term reflecting the opportunity value of forest conservation is included in the cost function. Thus, it is not necessary to deforest the land to gain property rights to the land in this case. This approach is parallel to the approach taken in chapter 2. The inclusion of the opportunity value reflects a probability of 1 for the logger to retain the same land in both periods (μ=1 in the terminology of chapter 2), whereas when property rights are undefined that probability is zero. The opportunity value is assumed to be the present value of forests in the next period, and is exogenous to the static model since the next period is not explicitly included. The opportunity value is discounted back to the present period. In the dynamic model presented in section 5.3, the opportunity value is made endogenous.

5.2.1 Formal Description of the Static Model

A complete list of all variables used in the CGE models of deforestation in Costa Rica is provided in Appendix 3. We begin with a detailed description of the deforestation components, as this is the main contribution of this chapter whereas the overall model structure is fairly standard.

5.2.1.1 Deforestation sectors

The supply of forests that can be cleared for land or logs is perceived as a free good
by squatters and loggers. Further, from an individual's point of view, it is perceived that as much forest as needed can be cleared by each logger or squatter.

**The logging sector**

The logging sector is assumed to have a capital intensive technology (Repetto 1988, Lutz et. al. 1993). Further, the technology is assumed to exhibit decreasing returns, as the input of forested land is excluded from the production function for simplicity. Production of logs is assumed to depend only on two factors of production: unskilled labor and capital. The log-linear production function is assumed to be:

\[
\log = (k^{log})^\alpha (l^{log})^\beta, \quad \alpha + \beta < 1
\]

where \( \log \) is deforestation by loggers, and \( k^{log} \) and \( l^{log} \) are the inputs of capital and unskilled labor in logging, and \( \alpha \) and \( \beta \) are the elasticities of output with respect to capital and labor, respectively.

From profit maximization we have that the demands for capital and unskilled labor when property rights are undefined (i.e., \( \mu = 0 \) in the model developed in chapter 2) are

\[
(k^{log}) = \left[ \frac{P_K}{\alpha P_{FL} (l^{log})^\beta} \right]^{\frac{1}{\alpha-1}}
\]

\[
(l^{log}) = \left[ \frac{P_U}{\beta P_{FL} (l^{log})^\alpha} \right]^{\frac{1}{\beta-1}}
\]

where \( P_K \) is the price of capital excluding taxes, \( P_U \) is the price of unskilled labor excluding taxes and \( P_{FL} \) is the price of logs excluding taxes. The prices of labor and capital do not include taxes since the logging sector is assumed to operate informally. Since property rights are undefined, the opportunity value of forest conservation is not included in the cost function.
The logging companies own part of the forests and take the opportunity value of the forests into account when property rights are well defined. The opportunity value is represented by a function $H(d)$. The opportunity value per unit of forest, $\varphi$, is assumed constant and is exogenous to the static model:

$$H(d) = \varphi \ d$$

In the case of well-defined property rights (i.e., $\mu = 1$ in the terminology of chapter 2) the logging sector's demand for unskilled labor and capital, respectively, are

$$l^{\log} = \left( P_U^U + \frac{\partial H(d) / (1 + r^{dom})}{\partial(l^{\log})} \right) \beta P_{F L}(l^{\log})^\alpha$$

$$k^{\log} = \left( P_K^U + \frac{\partial H(d) / (1 + r^{dom})}{\partial(k^{\log})} \alpha P_{F L}(l^{\log})^\beta$$

where $r^{dom}$ is the domestic interest rate (exogenously set equal to world market interest rate). Superscript $U$ on the prices of unskilled labor and capital indicates that the prices now include taxes since property rights are well defined, and deforestation now takes place within the formal sector of the economy.

**Squatters**

In terms of the implications of property rights, the approach taken for the squatters is parallel to the approach for the logging sector.

It is assumed that squatters have a monotonically decreasing production function for cleared land ($a^q$) with unskilled labor as the only factor of production:
where $l^q$ is the unskilled labor used in the clearing of land, and $\gamma$ in the elasticity of output with respect to unskilled labor.

The squatters' total revenue from clearing the land ($l^q(d^q)$) is the price paid for the cleared land times the amount of land cleared:

\[
l^w(d^w) = P_{DL} d^w
\]

where $P_{DL}$ is the supply price of cleared land.

The squatters' total private cost -- not including the opportunity value of forest conservation -- for the clearing of the land ($C^q(d^q)$) will, when property rights are undefined, depend only on the amount of labor needed to clear the land:

\[
C^q(d^w) = P_U d^w l^w
\]

where $P_U$ is the price of unskilled labor excluding taxes.

For the sector as a whole, land will be cleared until marginal cost equals marginal revenue. From the profit function, we have that the squatters demand for unskilled labor when property rights are undefined is

\[
l^q = \left( \frac{P_U}{\gamma P_{DL}} \right)^{\gamma-1}
\]

When property rights are well-defined squatters own a share of the forest. The squatters take the future value of the forests into account, and they can choose to clear forested land or to preserve the forests. The total private profit from clearing the forested land ($g^q(d^q)$) is:
\[ g^{eq}(d^{eq}) = P_{dL}^{eq}d^{eq} - C^{eq}(d^{eq}) - \frac{H(d^{eq})}{1 + r_{dom}} \]  

E 5.2-9

The price of unskilled labor now includes taxes since property rights are well defined. Deforestation will occur until marginal cost equals marginal revenue, and from the profit function we have that labor will be allocated to squatting until

\[ I^{eq} = \left( \frac{P_{D}^{eq} + \frac{\partial (H((l^{eq})^{n} / (1 + r_{dom})))}{\partial l^{eq}}}{\gamma / P_{DL}} \right)^{\frac{1}{\gamma - 1}} \]  

E 5.2-10

This result is the same as is obtained from the solution to the equivalent social planner's problem.

5.2.1.2 The general CGE model structure

The representative consumer in the model is assumed to have a monotonically transformed Cobb-Douglas utility function, and maximizes utility subject to a budget constraint:

\[
\text{Max } V = \ln \left( \prod_i D_i^{b_i} \right); \quad i = T, N \\
\text{s.t } I - \sum_i P_i^{D} D_i = 0
\]  

E 5.2-10

where \( V \) represents utility, \( D_i \) represents consumption of good \( i \), \( b_i \) is the expenditure share for good \( i \), \( P_i^{D} \) is the consumer price of good \( i \) and \( I \) is the disposable income. The disposable income is implicitly determined from the external current account

\[ ^{35} \text{More precisely the utility function is the logarithm of the traditional Cobb-Douglas function.} \]
since the model is static. Explicitly, it is defined as the sum of factor incomes, taxes, profits and the external current account.

All primary production factors have been aggregated into a composite input, \( Y \), using CES functions, in a technology specified to exhibit constant returns to scale. The relation between inputs and output is given by sectoral Leontief production functions of the following type:

\[
X_j = \min \left[ \frac{Y_j}{A_j}, \frac{X_y}{a_{ij}} \right] \quad i, j \in T, N
\]

where \( X_j \) is the gross output in sector \( j \), \( Y_j \) is a composite input of production factors in sector \( j \), \( X_y \) is input of output from sector \( i \) in sector \( j \) and \( A_j \) and \( a_{ij} \) are Leontief input-output coefficients. Since the technology exhibits constant returns to scale, the marginal cost and the average cost of production in sector \( j \) can be written as

\[
C_j = P_{ij}^y A_j + \sum_i P_i^D a_{ij} + \tau_j \quad i, j \in T, N
\]

where \( C_j \) is the marginal and average cost in sector \( j \), \( P_{ij}^y \) is the producer price of the composite input of production factors in sector \( i \), \( P_i^D \) is the domestic price of sector \( i \) output, \( A_j \) is the use of production factors per unit of sector \( j \) output, \( a_{ij} \) is the use of sector \( i \) input per sector \( j \) output, and \( \tau_j \) is indirect tax per unit of sector \( j \) output.

Producers are assumed to maximize profits. The producer output prices, \( P_i^o \) in the tradables producing sectors are given by the world market prices. Assuming perfect competition, this implies that pure profits are non-positive, output is non-negative and positive only if pure profits are equal to zero:
\[ P_i - C_i \leq 0; \quad i \in T \]
\[ (P_i - C_i)X_i = 0; \quad i \in T \]
\[ X_i \geq 0; \quad i \in T \]

E 5.2-13

In the non-tradables producing sectors, the sector-specific capital is endogenously adjusted so that price equals marginal cost:

\[ P_i = C_i; \quad i \in N \]

E 5.2-14

For goods produced in the tradables producing sectors, the domestic producer price is equal to the world market price of identical goods. In the non-tradables producing sectors the domestic user prices are equal to the producer prices times the tax rates:

\[ P_i^D = (1 + \sigma_i)P_i^w; \quad i \in T, \]

E 5.2-15

\[ P_i^D = (1 + \sigma_i)P_i; \quad i \in N \]

E 5.2-16

where \( P_i^D \) is the domestic user price of goods produced in sector \( i \), \( P_i^w \) is the world market price of good \( i \), \( P_i \) is the producer price of good \( i \), \( e \) is the exchange rate and \( \sigma_i \) is the ad valorem tax rate on good \( i \).

The intermediate demand for good \( i \) is given by the technology assumptions. Domestic final demand is given by

\[ D_i = \frac{b_i I}{P_i^D}; \quad i \in T, N \]

E 5.2-17

where \( D_i \) is domestic demand for good \( i \), \( b_i \) is the expenditure share for good \( i \), \( P_i^D \) is the consumer price of good \( i \), and \( I \) is the disposable income.

The combination of production factors in the producing sectors can be influenced by taxes and subsidies. The user price, \( P_j^U \), will exceed the supply price, \( P_j \), by a percentage
tax, $T_j$:

\[
P_j^U = P_j(l + T_j); \quad j = DL, UL, SL, K
\]

\[
P_{FL}^U = P_{FL}^{WM}(1 + T_{FL})
\]

In the case of logs, the supply price is determined by the world market price. We assume that logs can be traded on the world market and that Costa Rican logs and logs from other countries are homogenous.

5.2.1.3 Market clearing in the static Costa Rica model

Net exports of tradable goods are determined as the difference between domestic supply and demand in a standard Heckscher-Ohlin fashion. The market equilibrium conditions then become

\[
X_i = \sum_{j \in T, N} a_y X_j + D_i + Z_i; \quad i \in T
\]

\[
X_i = \sum_{j \in T, N} a_y X_j + D_i; \quad i \in N
\]

where $Z_i$ is net export.

The supplies of labor and capital are assumed to be exogenously given. Using Shephard's lemma\textsuperscript{36}, the market equilibrium conditions for capital and unskilled labor, respectively, can be written as

\[
K = \sum_{j \in T, K} \frac{\partial C_j}{\partial P_j^U} X_j + k^{log}
\]

\textsuperscript{36} Shephard's lemma states that the demand for a production factor in a sector is the partial derivative of the cost function with respect to the price of that production factor.
\[ U = \sum_{j \in T, N} \frac{\partial C_j}{\partial P_U^{j_0}} X_j + l^{eq} + l^{log} \]  

where \( P_k^{U} \) is the user price of capital, \( k^{log} \) is the capital used in deforestation by loggers, \( P_U^{U} \) is the user price of unskilled labor, \( l^{eq} \) and \( l^{log} \) are the unskilled labor used in deforestation by squatters and loggers, respectively. There is no demand for skilled labor from squatters or loggers, so the market equilibrium condition for this factor becomes

\[ L = \sum_{j \in T, N} \frac{\partial C_L}{\partial P_U^{j_0}} X_j \]  

where \( P_L^{U} \) is the user price of skilled labor. Equations 5.2.21 to 5.2.23 say that the supplies of labor and capital must equal the demands from the producing sectors plus the amount used for deforestation by squatters and loggers.

It is assumed that there is a world market for logs on which Costa Rican loggers can trade, since although logs cannot officially be traded, smuggling is likely to take place if world market prices are sufficiently high. The market equilibrium condition for logs can then be written as

\[ h d^{log} = \frac{\partial C_{FOREST}}{\partial P_{FL}^{U}} - f^{exp} \]  

where \( d^{log} \) is deforestation from the logging sector, \( P_{FL}^{U} \) is the user price of logs, \( f^{exp} \) is the net export of logs, and \( h \) is a fixed coefficient reflecting the amount of timber per unit of deforested land. Here, \( h \) is assumed equal to one.

The supply of cleared land is composed of the stock of cleared land, \( DL^* \), and deforestation by squatters. Demand for cleared land comes entirely from the agriculture sector. The market equilibrium condition can then be written:
Profits (\(\Pi\)) in the squatting and logging sectors are assumed to be positive, and are defined as

\[
\begin{align*}
\Pi_{sq} &= P_{DL}d^{sq} - P_{U}l^{sq} \\
\Pi_{log} &= P_{W}d^{log} - P_{L}l^{log} - P_{K}k^{log}
\end{align*}
\] E 5.2-26.

When property rights are well defined, the prices paid for labor and capital are the user prices rather than the supply prices.

The closure rule for the model is that the current account is assumed to be constant. This implies that

\[
\sum_{i,T,N} P_{i}Z_{i} = S \quad \text{E 5.2-27}
\]

where \(S\) is the current account surplus. From Walras' law, equation 5.2-27 indirectly determines the disposable income.

Finally, the green gross national product is determined as the sum of factor incomes, and a term reflecting the value of deforestation:

\[
GNP = P^{i}kK + P^{i}lL + P^{i}U + P^{i}_{DL}DL^* + \sum_{j,T,N} \sigma_{j}X_{j} + \sum_{j=sq,log} \Pi_{j} - (d^{sq} + d^{log})H(l). \quad \text{E 5.2-28}
\]
5.2.2 Base case data, assumptions and limitations of the model

The data used in this version of the model originate from Briceño (1986) and the Costa Rican National Accounts (Central Bank 1990). However, the sectors of production are not consistent between the two studies and data were therefore adjusted in Raventós (1990). The input-output matrix in Appendix 4, Table 1 has been calculated from the disaggregated data used in Raventós (1990). The remaining differences have been added to the net export column. Land use data are shown in Appendix 4, table 2. The economic rent to timber has been calculated from Solórzano et al. (1991). Deforestation in 1986 was assumed to equal average deforestation between 1973-1989. The value in 1986 prices was calculated using the increase in consumer price index between January 1985 and December 1986. Rent to land was subtracted from the rent to capital in the agricultural sector, and the labor used for land clearing by squatters was subtracted from the labor used in the same sector. The labor and capital used for logging were subtracted from payments to those factors in the 'forest' sector. Lacking exact data on the sources of deforestation, logging is assumed to be responsible for half total deforestation and land clearing by squatters is assumed to be responsible for the other half.

No estimates of substitution elasticities between production factors are available. It is reasonable to assume that they are imperfect substitutes, and all elasticities in the CES functions were therefore assumed to be less than one. The elasticities in all factor aggregates except the substitution elasticities between logs and land, and the factor aggregates in sectors other than forest and agriculture were set to 0.800. Remaining elasticities were set to zero.

38 Defined as η/(η-1), where η is the elasticity of substitution. An elasticity of 0.8 thus implies η=4.
39 Lacking time series data, these elasticities are reasonable given the aggregated sectoral composition and the elasticities used in other models, e.g. Torna and Rutherford (1992), Bergman (1990a and b).
The parameters in the production functions for squatters and loggers are assumptions, although it is reasonable to assume a labor intensive technology for the squatters and a capital intensive technology for loggers. No hard data on the production technologies were available for squatters and loggers, because of the informal nature of production in these sectors. The parameters and initial values are shown in Appendix 4 Table 3.

Because of these adjustments, and the stylized assumptions about technology and trade, the results of the simulations are indicative only and not necessarily accurate quantitative measures.

There is no general agreement among biologists regarding the amount of biodiversity loss resulting from high-grading, which occurs when only certain species are removed from the forest. The coefficient representing the amount of timber extracted per unit of forest was here assumed to equal one. However, if the logging industry engages in high-grading this coefficient may be smaller. But if highgrading causes for example a large biodiversity loss and the value of this loss is included in the opportunity value, it is still possible that the coefficient is close to one. An alternative view is that the biodiversity loss is proportional to the number of trees extracted, and that squatters and loggers each remove half the timber following the process described in Carrière (1991). This model is constructed under the assumption that the latter view is realistic, but can easily be adjusted to fit the former view.

The model developed in this section is, as mentioned, a static model. Therefore, the results are merely comparative statics of different policy experiments. To take the stock and flow effects into account, and to derive valid results for a longer term planning horizon, a dynamic model is developed later in this chapter.

The approach developed here does not allow for all possible causes of deforestation. Migration and population growth are two factors that may be important (Harrison 1991), but they are not investigated in this model. A further limitation of the
model is that it does not allow for reforestation. In addition, erosion effects of deforestation are not included.

5.2.3 Results from policy experiments in the static model

Numerical results from the policy experiments conducted here are shown in Appendix 7.

The situation existing today with undefined property rights was taken as a base case. As a first step, property rights were defined. The opportunity value per unit of the forests (the H-value) is at minimum 28% higher that the value of deforestation according Solórzano et al. (1991), and sensitivity analysis was conducted with respect to this value. The discount rate was set at 10%, as this discount rate is commonly used and data on discount rates was not available. The results are displayed in Appendix 7 Table 1 and initial factor intensities are shown in Appendix 7 Table 2.

Effects of defining property rights on deforestation are shown in Table 5-1. Defining property rights results in a dramatic decline in deforestation, and an increase in the net import of logs. The price of cleared land increases once property rights to forested land are defined, causing the production technology to become less land intensive in agricultural sector. Production in this sector declines because of higher costs of production. The ‘forest’ sector, however, can import logs at the world market price, and in combination with the lower wages of unskilled labor caused by the diminished production in ‘agriculture’ this causes production in the ‘forest’ sector to increase. Resources are also shifted towards other, non-tradables producing, sectors, and Green GDP increases with the definition of property rights.
Table 5-1 Effects of defining property rights

<table>
<thead>
<tr>
<th></th>
<th>Undefined property rights</th>
<th>Defined property rights (i=10%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(10 billion colones)</td>
<td>%</td>
</tr>
<tr>
<td>H-value</td>
<td>0</td>
<td>0.28</td>
</tr>
</tbody>
</table>

Production in Deforestation sectors:

<table>
<thead>
<tr>
<th></th>
<th>Squatters</th>
<th>Loggers</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.002</td>
<td>0.002</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td>-100.00</td>
<td>-90.00</td>
<td>-95.00</td>
</tr>
</tbody>
</table>

Production in sectors using logs and land:

<table>
<thead>
<tr>
<th></th>
<th>Forest</th>
<th>Agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.0552</td>
<td>1.3984</td>
</tr>
<tr>
<td></td>
<td>28.80</td>
<td>-0.77</td>
</tr>
</tbody>
</table>

Sensitivity analyses with respect to the opportunity value of forests show that a relatively small opportunity value will decrease deforestation dramatically, once property rights are defined. However, for deforestation to cease completely, a very high value is required (see Table 5-2).

Table 5-2, Effects of higher opportunity costs of deforestation (H-values)

<table>
<thead>
<tr>
<th></th>
<th>Undefined pr. rights</th>
<th>Defined property rights (i=10%), sensitivity analysis with respect to different future values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(10 billion colones)</td>
<td>%</td>
</tr>
<tr>
<td>H-value</td>
<td>0</td>
<td>0.48 0.38 0.28 0.18 0.08</td>
</tr>
<tr>
<td>Production in Deforestation sectors:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Squatters</td>
<td>0.002</td>
<td>-100.00 -100.00 -100.00 -100.00 -100.00</td>
</tr>
<tr>
<td>Loggers</td>
<td>0.002</td>
<td>-100.00 -95.00 -90.00 -80.00 -50.00</td>
</tr>
<tr>
<td>Total</td>
<td>0.004</td>
<td>-100.00 -97.50 -95.00 -90.00 -72.50</td>
</tr>
</tbody>
</table>
Recalling that the present value of forest conservation was modeled as $H(d)/(1+r)$, an increase in the opportunity value ($H(d)$) is equivalent to a decrease in the interest rate ($r$) by definition. From the results of an increased opportunity value discussed here, we can therefore infer also that high interest rates promote deforestation, while low interest rates diminish deforestation.

Next, the effects of taxes on logs, land, unskilled labor and capital were investigated. The results are displayed in Appendix 7 Table 3. A 10% tax increase on logs generated the expected results, with no deforestation from loggers (i.e., a 100% decline) and no production in the ‘forest’ sector. Resources were shifted into the agricultural sector, with an increase in deforestation for land and an increase in total deforestation as a consequence. The increase in total deforestation can be explained by lowered prices of unskilled labor, resulting from the discontinued production in the ‘forest’ sector, and a significant increase in the demand for land in the agricultural sector. The tax increase actually results in an elevated utility level, as consumption increases. ‘Green’ GDP also increases, as the increase in production outweighs the loss of forests.

Table 5-3 Effects on production and deforestation from changing taxation on production factors

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>Tax Logs</th>
<th>Subsidy Logs</th>
<th>Tax Land</th>
<th>Subsidy Land</th>
<th>Tax Unskilled labor</th>
<th>Tax Capital</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(10 billion colones)</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Production in deforestation Sectors:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Squatters</td>
<td>0.002</td>
<td>120.00</td>
<td>-80.00</td>
<td>-100.00</td>
<td>1175.00</td>
<td>950.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Loggers</td>
<td>0.002</td>
<td>-100.00</td>
<td>-10.00</td>
<td>0.00</td>
<td>-5.00</td>
<td>45.00</td>
<td>80.00</td>
</tr>
<tr>
<td>Total</td>
<td>0.004</td>
<td>10.00</td>
<td>-42.50</td>
<td>-50.00</td>
<td>582.50</td>
<td>497.50</td>
<td>40.00</td>
</tr>
<tr>
<td>Production in traditional sectors:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forest</td>
<td>0.0552</td>
<td>-100.00</td>
<td>182.97</td>
<td>21.74</td>
<td>-100.00</td>
<td>-100.00</td>
<td>-6.70</td>
</tr>
<tr>
<td>Agri</td>
<td>1.3984</td>
<td>1.57</td>
<td>-1.69</td>
<td>-0.77</td>
<td>8.14</td>
<td>6.71</td>
<td>0.02</td>
</tr>
<tr>
<td>Ind</td>
<td>1.8477</td>
<td>4.17</td>
<td>-7.90</td>
<td>-0.25</td>
<td>-4.44</td>
<td>-2.87</td>
<td>0.05</td>
</tr>
</tbody>
</table>
However, a 10% tax decrease in the tax on logs generates somewhat surprising results, as total deforestation, as well as deforestation from both squatters and loggers decrease. The lowered price of logs increase the demands for other production factors in the 'forest' sector, and the prices of unskilled labor and capital are therefore elevated. This reduces domestic deforestation, but logs are imported and the tax reform encourages use of logs, which are now relatively cheaper than any other production factor. Production in the 'forest' sector therefore increases. The increase in production in this sector is offset by reduced production in the agricultural and 'industry' sectors, caused by the relatively more expensive production factors. The reduction in the size of the agricultural sector reduces deforestation by squatters. Utility, spending and 'green' GDP are all reduced.

Taxes and subsidies on land generate expected results, with a corresponding change in deforestation by squatters and roughly constant deforestation by loggers. Both the tax and the subsidy are distortionary, and reduce utility and income and GDP.

A 10% tax increase on unskilled labor adversely affects the 'forest' sector, but logging continues and logs are exported at the world market. The price of unskilled labor in the deforestation sectors becomes relatively lower, since those sectors are considered 'informal' in the sense that their activities are to a large extent illegal and remain unaffected by government tax policies. Resources are shifted to the agricultural sector, with a large increase in land clearing by squatters as a result. The agricultural sector gains a relative advantage over the industrial sector because of relatively cheaper land, and industrial production is reduced. A 10% tax reduction generates largely the opposite results, with a decrease in deforestation, an increase in 'forest' production and reduced production in the agricultural sector.

A tax increase on capital shifts the production technologies in all sectors towards less capital intensive technologies. In the 'forest' sector -- which is the most capital intensive sector -- production declines when the capital tax is elevated, lowering the price of unskilled labor, which in turn benefits the logging, agricultural and industrial sectors.
Deforestation for land remains unchanged, but deforestation for logs increases significantly, causing 'green' GNP to decline.

Substitution effects prove to be important when policy experiments regarding tax changes on goods produced in tradables sectors are conducted. The numerical results from these taxation experiments are displayed in Appendix 7 Table 4.

Tax changes on goods from the 'forest' sector generate small economywide effects since this sector is small compared to the others. The industrial sector, which uses 'forest' products relatively intensely as an intermediate input, gains from the tax reduction and grows, while production in the 'forest' sector itself suffers. The effects are reversed for a doubling of the tax on 'forest' products. Deforestation remains largely unaffected in both cases, as logs can be imported on the world market.

When the tax on agricultural products is reduced by a half, the agricultural output is actually diminished. This is because the industrial sector benefits because of its extensive use of agricultural products as intermediate inputs, and resources are shifted towards this sector instead. Production in the 'forest' sector is reduced for the same reasons.

Table 5-4 Effects of changing taxation of final goods

<table>
<thead>
<tr>
<th></th>
<th>Base Case (10 billion colones)</th>
<th>Half tax</th>
<th>Double tax</th>
<th>Half tax</th>
<th>Double tax</th>
<th>Half tax</th>
<th>Double tax</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(10 billion colones)</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Squatters</td>
<td>0.002</td>
<td>0.00</td>
<td>0.00</td>
<td>-5.00</td>
<td>10.00</td>
<td>-10.00</td>
<td>25.00</td>
</tr>
<tr>
<td>Loggers</td>
<td>0.002</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Total</td>
<td>0.004</td>
<td>0.00</td>
<td>0.00</td>
<td>-2.50</td>
<td>5.00</td>
<td>-5.00</td>
<td>12.50</td>
</tr>
<tr>
<td>Forest</td>
<td>0.0552</td>
<td>-4.35</td>
<td>10.33</td>
<td>-26.63</td>
<td>63.41</td>
<td>-71.01</td>
<td>146.92</td>
</tr>
<tr>
<td>Agri</td>
<td>1.3984</td>
<td>0.00</td>
<td>0.01</td>
<td>-5.19</td>
<td>12.31</td>
<td>-0.14</td>
<td>0.33</td>
</tr>
<tr>
<td>Ind</td>
<td>1.8477</td>
<td>0.14</td>
<td>-0.32</td>
<td>4.15</td>
<td>-9.82</td>
<td>-1.13</td>
<td>2.34</td>
</tr>
</tbody>
</table>
A reduced tax on products from the industrial sector, which is the largest of the tradables producing sectors, drives up the prices of labor. Resources are then shifted towards the nontradables producing sectors, and production in all of the tradables producing sectors decline. Deforestation by squatters decline, as land demand is diminished in the agricultural sector. Logging, however, remains constant, and logs are exported on the world market. Total production declines, as does total consumer spending and utility. Deforestation for logs remains constant.

5.2.4 Conclusions

Undefined property rights to forests in Costa Rica have important implications for deforestation. A correction of this market failure would result in diminished deforestation. If property rights are well defined and the interest rate is exogenous, the value deforesters assign to preserving the forests is crucial. To stop deforestation, the benefits from preserving the forests must be significantly higher than the value of the logs and the cleared land.

Tax policies may generate unexpected side effects, and substitution effects between inputs in the producing sectors may be important. Therefore, when possible impacts of macroeconomic policies are investigated, a general equilibrium approach may generate different results than a partial equilibrium approach.

5.3 The dynamic CGE model of deforestation in Costa Rica

Next, a two-period dynamic CGE model with endogenous savings and investment is considered, in order to take the dynamic aspects of forest management into account. In terms of taking the value of forest conservation (the exogenous H-value in the static model) into account, the main difference vis-à-vis the static model presented in section 5.2 is that this value is now internalized through the intertemporal allocation decision made by the sectors engaged in deforestation.
In this model, when property rights to the forests are undefined, deforestation is limited only by the size of the land area covered with forests. Forests are assumed to be homogeneous and thus equally suited for land clearing and logging. A government commitment to forest conservation -- for example national parks -- is assumed, but this commitment can be enforced only when property rights are well defined.

When property rights are undefined deforesters do not have the choice of allocating forest clearing between periods. The incentive structure is such that if forests are saved by one agent for the next period, other agents may still clear the land in the current period. Thus, there is no incentive for forest conservation. Therefore, in the case of undefined property rights the deforesting sectors maximize profits in each period.

When property rights are well defined the deforester faces an intertemporal maximization problem and can make an allocation decision regarding deforestation and forest conservation. Furthermore, the size of the forests available for clearing is assumed to be smaller since the government is then assumed to be able to enforce forest conservation in for example national parks.

Producers of traditional goods are assumed to maximize profits in each period, which (since the production factors are perfectly mobile and the market for capital goods is assumed to be perfect) does not affect the intertemporal solution. The representative consumer makes intertemporal consumption and savings decisions. He or she faces an intertemporal utility maximization problem subject to an intertemporal budget constraint, where the income in period 1 depends on all prices and the savings decision in period 0. The consumers' savings and consumption decisions depend on all prices, the rate of time preference, and on the domestic and world market interest rates. There is no explicit government sector in the model; all taxes are assumed to be transfers to the consumers.

The world market interest rate and the rate of time preference are exogenous to the model. The domestic interest rate equals the world market interest rate since capital flows are allowed and foreign investment will occur until they are equal. The discounted sum of
the current accounts are assumed to be zero, and this determines the level of savings. Foreign capital and domestic capital are assumed to be perfect substitutes and there are no adjustment costs of investment in the model. In equilibrium, total savings must equal aggregate investments. The model is solved maximizing intertemporal utility. Forest investments are not included in this model, to obtain results comparable to the results from the static model. As in the static model, most of the experiments conducted in this model concern the case of undefined property rights.

5.3.1 Formal description of the model

Appendix 3 provides a complete list of all variables and parameters in the dynamic CGE model of deforestation in Costa Rica. As before, we begin with a description of the deforestation sectors, and then move on to a description of the standard CGE model.

5.3.1.1 Deforestation sectors

Deforestation takes place to clear land for agriculture and for logs. These activities are represented by 'squatters' (sq) and 'loggers' (log), respectively. There is a limited amount of land available for deforestation when property rights are well defined, whereas when property rights are undefined each logger or squatter perceives the amount of forests that can be cleared to be infinite.

For each deforestation sector, we will first examine the case of undefined property rights and then go on to the case of well-defined property rights.

Squatters -- Undefined property rights

The squatters' production function for land clearing is a log-linear production function with decreasing returns to scale and unskilled labor as the only input:
where $d^{sq}_t$ is deforestation by squatters and $l^{sq}_t$ is the input of unskilled labor into squatting, and $\gamma$ is the elasticity of output with respect to unskilled labor. For the squatting sector the profit maximization condition is that marginal revenue equals marginal cost.

Squatters are assumed to maximize profits in each period when property rights are undefined. The squatters' private profit from land clearing is

$$\pi_{sq} = P_{DL,t} d^{sq}_t - P_{U,t} l^{sq}_t; \quad t = 0,1$$

and from the profit maximization we have that the demand for unskilled labor for squatting is

$$l^{sq}_t = \left(\frac{P_{U,t}}{P_{DL,t}^\gamma}\right)^{\frac{1}{\gamma}} \quad t = 0,1$$

**Squatters – Well-defined property rights**

When property rights are well defined, the squatters face an intertemporal maximization problem:

$$\text{Max} \quad P_{DL,0} d^{sq}_0 - P_{U,0} l^{sq}_0 + \frac{1}{1 + r_{dom}} \left(P_{DL,1} d^{sq}_1 - P_{U,1} l^{sq}_1\right)$$

s.t.  
$$d^{sq}_t = \left(\frac{l^{sq}_t}{l^{sq}_0}\right)^\gamma \quad t = 0,1$$

$$d^{sq}_0 \leq A - d^{log}_0$$

$$d^{sq}_0 + d^{sq}_1 \leq A - d^{log}_0 - d^{log}_1$$

where $A$ is the total amount of land available for deforestation, $d^{sq}_t$ is deforestation by squatters in period $t$, and $d^{log}_t$ denotes deforestation by the logging sector. The squatters
take the amount of logging as exogenous, and the amount of deforestation available to the squatters is therefore $A_{sq}$. From the profit maximization, we have the arbitrage condition that the discounted values of marginal squatting ($\lambda_{sq}$) are equal between periods, unless all forests are exhausted already in the first period:

$$P_{DL0} - \frac{1}{\gamma} P_{U,0} \left( d_{sq}^{sq} \right)^{\frac{1}{\gamma}-1} = \lambda_{sq}^{0} \quad \text{if } d_{sq}^{0} = A, \text{ otherwise}$$

$$\left( \frac{1}{1 + r_{dom}} \right)^{t} \left( P_{DL,t} - \frac{1}{\gamma} P_{U,t} \left( d_{sq}^{sq} \right)^{\frac{1}{\gamma}-1} \right) = \lambda_{sq, t} \quad t = 0, 1 \quad \lambda_{sq} \geq 0,$$

From the Kuhn-Tucker theorem, if the second constraint in E 5.3-4 is binding, $\lambda_{sq}$ is greater than zero. If this constraint is not binding, $\lambda_{sq}$ is equal to zero, and the solution will be the same in both the case of undefined property rights and the case of well-defined property rights.

From the profit function we have that, when property rights are well defined, demand for unskilled labor from squatting is

$$l_{sq}^{t} = \left( \frac{P_{U,t}}{P_{DL,t} - (1 + r_{dom})^t \lambda_{sq}^{t}} \right)^{1 + t} ; \quad t = 0, 1$$

**Loggers — Undefined property rights**

The same approach is used for deforestation by loggers. The logging sector also has a decreasing returns to scale log-linear production function, although both capital and unskilled labor are used as factors of production:

$$d_{log}^{t} = \left( k_{log}^{t} \right)^{\alpha} \left( l_{log}^{t} \right)^{\beta} \quad t = 0, 1, \quad \alpha, \beta > 1, \quad \alpha + \beta < 1$$

where $d_{log}^{t}$ is deforestation by loggers in period $t$, $k_{log}^{t}$ is capital input into logging in period $t$, $l_{log}^{t}$ is unskilled labor input into logging in period $t$, and $\alpha$ and $\beta$ are the
elasticities of output with respect to capital and unskilled labor, respectively.

When property rights are undefined profits are maximized in each period. The loggers' profit function in each period is

$$\pi_{\text{log},t} = P_{\text{FL},t}d_{t}^{\text{log}} - P_{U,t}l_{t}^{\text{log}} - P_{K,t}k_{t}^{\text{log}}; \quad t = 0,1$$ \hspace{1cm} \text{E 5.3-8}

From profit maximization when property rights are undefined in both periods we have that the demands for capital and unskilled labor respectively are

$$k_{t}^{\text{log}} = \left( \frac{P_{K,t}}{P_{\text{FL},t} \alpha \left( l_{t}^{\text{log}} \right)^{\mu}} \right)^{\frac{1}{\alpha - 1}}; \quad t = 0,1$$ \hspace{1cm} \text{E 5.3-9}

$$l_{t}^{\text{log}} = \left( \frac{P_{U,t}}{P_{\text{FL},t} \beta \left( k_{t}^{\text{log}} \right)^{\mu}} \right)^{\frac{1}{\beta - 1}}; \quad t = 0,1$$ \hspace{1cm} \text{E 5.3-10}

Loggers -- Well-defined property rights

When property rights are defined, the intertemporal profit maximization problem for the logger is:

Max $$P_{\text{FL},0}d_{0}^{\text{log}} - P_{K,0}k_{0}^{\text{log}} - P_{U,0}l_{0}^{\text{log}} +$$ $$\frac{1}{1 + r^{\text{dom}}} \left( P_{\text{FL},0}d_{0}^{\text{log}} - P_{K,0}k_{0}^{\text{log}} - P_{U,0}l_{0}^{\text{log}} \right)$$

s.t. $$d_{t}^{\text{log}} = \left( k_{t}^{\text{log}} \right)^{\mu} \left( l_{t}^{\text{log}} \right)^{\beta}; \quad t = 0,1$$ \hspace{1cm} \text{E 5.3-11}

$$d_{0}^{\text{log}} \leq A - d_{0}^{sq}$$

$$d_{0}^{\text{log}} + d_{t}^{\text{log}} \leq A_{\text{log}} = A - d_{0}^{sq} - d_{t}^{sq}$$

The amount of deforestation by squatters is exogenous to the loggers, and the
maximum amount of logging is restricted to $A_{\text{log}}$. From the solution to the profit maximization problem we obtain the arbitrage condition that

$$P_{FL,t} - P_{UL,t} \frac{\partial l_{t}^{\text{log}}}{\partial d_{t}^{\text{log}}} - P_{K,t} \frac{\partial k_{t}^{\text{log}}}{\partial d_{t}^{\text{log}}} = \lambda_{\text{log}}^0 \quad \text{if } A = d_{t}^{\text{eq}} + d_{t}^{\text{log}}, \text{ otherwise}$$

$$\left(\frac{l}{1 + r_{\text{dom}}}\right)^t \left(P_{FL,t} - P_{UL,t} \frac{\partial l_{t}^{\text{log}}}{\partial d_{t}^{\text{log}}} - P_{K,t} \frac{\partial k_{t}^{\text{log}}}{\partial d_{t}^{\text{log}}}\right) = \lambda_{\text{log}}^0; \quad t = 0, 1$$

i.e. the discounted values of the marginal profits of logging are equal in both periods. The demands for capital and unskilled labor, respectively, become

$$k_{t}^{\text{log}} = \left(\frac{P_{K,t}}{(P_{FL,t} - (1 + r_{\text{dom}})^t \lambda_{\text{log}}^0)^\alpha (l_{t}^{\text{log}})^\beta}\right)^{\frac{1}{\alpha-1}}; \quad t = 0, 1 \quad \text{E 5.3-13}$$

$$l_{t}^{\text{log}} = \left(\frac{P_{UL,t}}{(P_{FL,t} - (1 + r_{\text{dom}})^t \lambda_{\text{log}}^0)^\beta (k_{t}^{\text{log}})^\gamma}\right)^{\frac{1}{\beta-1}}; \quad t = 0, 1 \quad \text{E 5.3-14}$$

Logs are assumed to be tradable on the world market, and logging therefore takes place until the domestic producer price of logs $P_{FL,t}$ is equal to the world market price $P_{W,FL,t}$. If the domestic price is higher than the world market price no domestic logging takes place:

$$P_{FL,t} - P_{W,FL,t} \leq 0; \quad t = 0, 1$$

$$d_{t}^{\text{log}} (P_{W,FL,t} - P_{FL,t}) = 0$$

$$d_{t}^{\text{log}} \geq 0$$

$$E 5.3-15$$

The stock of cleared land in each period $(D_{t})$ is the previously existing stock of land plus squatting in the same period:
\[ DL_0 = DL^* + d_0^{sq} \]
\[ DL_t = DL_0 + d_1^{sq} \]

where \( DL^* \) is the initial stock of land.

Total deforestation (\( def \)) in each period is

\[ def_t = d_t^{sq} + d_t^{logs}; \quad t = 0,1 \]

5.3.1.2 The general dynamic CGE model

The utility function in each period is a monotone transformation of a Cobb-Douglas utility function, and it is the same utility function that was used in the static model:

\[ V = \sum_T b_T \log(D_{T,i}) + \sum_N b_N \log(D_{N,i}), \quad \sum b = 1, \quad t = 0,1 \]

where \( V \) is the single period utility function, \( b_i \) is the marginal expenditure share on good \( i \), and \( D_i \) is demand for good \( i \).

The disposable income in each period \( t (t = 0 \text{ and } 1) \) is determined as

\[ I_t = P_{K,t} K_t + P_{L,t} SL_t + P_{U,t} UL_t + P_{DL,t} DL_t + \sum_{i,t} X_{iu} + \Pi_{j,t}; \quad t = 0,1 \]

\[ i = T, N, j = \text{squatters, loggers}, \quad t = 0,1 \]

i.e. the sum of the incomes including taxes from capital (\( K_i \)), skilled labor, (\( SL_i \)), unskilled labor (\( UL_i \)), and the stock of cleared land (\( DL_i \)) that existed in the beginning of the period, profits from deforestation (\( \Pi_{j,t} \)) and indirect taxes (\( t_i \)).

The representative consumer is assumed to maximize the present value of utility subject to an intertemporal budget constraint:
Max \( W = V(D_{1,0}, \ldots, D_{5,0}) + \frac{1}{1 + \rho} V(D_{1,3}, \ldots, D_{5,3}) \) \( 1, 2, 3 \in T, 4, 5 \in N \)

s.t. \( I_0(P) - P_0^D D_0 + \frac{1}{1 + r^{dom}} \left( I_1(P, Inv_0) - P_1^D D_1 \right) = 0 \)

where \( \rho \) is the rate of time preference, \( I_i \) is the income in period \( t \), \( P \) is a vector of factor prices in both periods, \( Inv_0 \) is investments in period 0, \( P^D_t \) and \( D_t \) are vectors of good prices and consumption in period \( t \), and \( r^{dom} \) is the domestic interest rate.

Utility maximization subject to the intertemporal budget constraint generates the following consumption demand functions in the two periods:

\[
D_{i,0} = \frac{b_i (I_0(P) - s_0)}{P_{i,0}^D}; \quad i \in T, N
\]

\[
D_{i,3} = \frac{b_i (I_1(P, Inv_0) + s_0)}{P_{i,3}^D} \frac{1 + r^{dom}}{1 + \rho}
\]  

E 5.3-21

Savings \( (s_0) \) are determined from the intertemporal resource allocation problem (equation 5.3.34).

Producers are assumed to maximize profits in each period. Demands for the production factors are given by Shephard's lemma as:

\[
M_{j,t} = \frac{\partial C_{t}^{u}}{\partial P_{j,t}^{u}} X_{i,t}; \quad t = 0, 1 \quad i \in T, N \quad j = L, U, K, DL, FL
\]  

E 5.3-22

where \( M_{j,t} \) is the demand for factor \( j \) in sector \( i \), \( C_{i,t}^{u} \) is the marginal (which equals average) cost in sector \( i \) and \( X_{i,t} \) is output in sector \( j \) in period \( t \). In equilibrium, we have that \( C_{i,t}^{u} = P_{i,t} \). The production function consists of nested CES functions to obtain a factor aggregate \( Y \) for the inputs of skilled labor, unskilled labor, capital, land and logs. It has a Leontief technology in other intermediate inputs and between other intermediate inputs and the factor aggregate \( Y \).

Like in the static model, the user prices of the primary production factors, \( P_{j,t}^{u} \), as
well as logs and land are defined as the producer price, \( P_{j,t} \), plus a tax, \( t_{j,t} \):

\[
P_{FL,t}^j = P_{FL,t}^M (1 + t_{FL,t})
\]

\[
P_{j,t}^L = P_{j,t} (1 + t_{j,t}); \quad t = 0, 1, \quad j = SL, U, K, DL
\]

The marginal cost and average cost (\( C_{i,t} \)) function in each period is

\[
C_{i,t} = A_i P_{Y,i,t} + \sum_j P_{j,t} a_{ij} + t_{i,t}; \quad t = 0, 1, \quad i, j \in T, N
\]

where \( t_{i,t} \) is the indirect tax rate and \( P_{Y,i,t} \) is the price of the composite factor input \( Y \).

\[
P_{i,t}^L = P_{i,t}^M; \quad t = 0, 1 \quad i \in T
\]

The output price in the tradable sectors is equal to the world market price \( P_{i,t}^WM \) in domestic currency.

In the tradable producing sectors, profit maximization assuming perfect competition yields that profits are non-positive, output is non-negative and positive only if pure profits are equal to zero:

\[
P^n_{i,t} - C_{i,t} \leq 0
\]

\[
X_{i,t}(P_{i,t}^WM - C_{i,t}) = 0; \quad t = 0, 1, \quad i \in T
\]

\[
X_{i,t} \geq 0
\]

In the non-tradable producing sectors the capital stock is endogenously adjusted until price equals marginal cost:

\[
P_{i,t} - C_{i,t} = 0; \quad t = 0, 1, \quad i \in N
\]

Foreign capital and domestic capital are assumed to be perfect substitutes, and
investment costs are assumed to be zero. The value of total investments is defined as

\[ E = 5.3-28 \]

where \( P_{t} \) is the price of composite investments in period \( t \), \( Inv \) is the volume of investments, \( s_i \) is domestic savings and \( S_i \) represents the current account balance in period \( t \). The level of investment is determined by the arbitrage condition that

\[ P_{K,0} = \frac{1}{1+r} P_{K,1} \]  

E 5.3-29

The price of composite investments is defined as

\[ P_{t} = \frac{\sum inv_{i,t} P_{t,i}}{Inv_{t}}; \quad t = 0,1, \ i \in T,N \]  

E 5.3-30

where \( inv_{i} \) is investment by sector of origin and is defined as

\[ inv_{i,t} = \frac{i_i Inv_{t}}{P_{t}}; \quad t = 0, \ i \in T,N \]  

E 5.3-31

where \( i_i \) is the share of aggregate investments from sector \( i \).

The capital stock in period \( t (K_t) \) is defined as

\[ K_t = (1 - \delta) K_{t-1} + Inv_t; \quad t \neq 0 \]  

E 5.3-32

where the rate of depletion of capital (\( \delta \)) and the initial capital stock (\( K_0 \)) are exogenously given. Since capital is assumed to be perfectly mobile between sectors, capital is allocated between sectors until the value of the marginal product of capital is the same in all sectors.
The current account ($S$) in periods 0 and 1 is the sum of net exports of traditional goods ($Z$), and logs ($f^{exp}$):

$$\sum_i P_{it}^{WM} Z_{it} + P_{FL,t}^{WM} f^{exp}_t = S_t; \quad i \in T, t = 0,1$$

E 5.3-33

5.3.1.3 Market clearing

Since the debt must be repaid the sum of the discounted current accounts equals 0:

$$S_0 = \frac{1}{1 + r^{WM}} S_t$$

E 5.3-34

where $r^{WM}$ is the world market interest rate. This condition in turn determines savings by consumers.

A negative current account represents net borrowing from the rest of the world. If the domestic interest rate is higher than the world market rate, we will have a net inflow of capital until the domestic interest rate equals the world market interest rate, and vice versa. In equilibrium, we will therefore have that

$$\rho = r^{dom} = r^{WM}$$

E 5.3-35

This result is dependent upon the assumption that foreign capital and domestic capital are perfect substitutes.

The markets for traditional goods clear when supply equals demand for each good. For tradable producing sectors the supply equals the sum of intermediate demands for the goods plus net exports, domestic consumption demand, and investment demand. For the nontradable producing sectors supply equals intermediate demand plus domestic consumption demand and investment demand:
\[ X_{i,j} = \sum_j a_{ij} X_{j,t} + Z_{i,t} + D_{i,t} + \text{inv}_{i,t}; \quad i = T, j = T, N, \quad t = 0,1 \]
\[ X_{i,j} = \sum_j a_{ij} X_{j,t} + D_{i,t} + \text{inv}_{i,t}; \quad i = N, j = T, N, \quad t = 0,1 \]  
E 5.3-36

The supplies of unskilled and skilled labor are assumed to grow proportionally to the population growth (\text{popgr}):

\[ U_{t+1} = (1 + \text{popgr}) U_t; \quad t = 0,1 \]
\[ L_{t+1} = (1 + \text{popgr}) L_t \]  
E 5.3-37

where the rate of population growth and the initial stocks are exogenously given.

The markets for logs, land, skilled labor, unskilled labor and capital clear when the supply equals total demand in each market:

\[ F_{L,t} = M_{i,F,L,t} + f_{\text{exp}}; \quad t = 0,1, \quad i \in T, N \]
\[ D_{L,t} = M_{i,D,L,t} \]
\[ L_t = \sum_i M_{i,L,t} \]  
E 5.3-38

\[ U_t = \sum_i M_{i,U,t} + l_{\text{unq},t} + l_{\text{log},t} \]
\[ K_t = \sum_i M_{i,K,t} + k_{\text{log},t} \]

where \( M_{i,j,t} \) is demand for production factor \( j \) from sector \( i \) in period \( t \).

And, finally, GNP is defined as the sum of all incomes and taxes:

\[ \text{GNP}_t = P_{K,t}^i K_t + P_{L,t}^i L_t + P_{U,t}^i U_t + P_{D,t}^i D_{L,t} + \sum_i t_{i,u} X_{i,u} + \sum_j \Pi_j; \quad t = 0,1, \quad i \in T, N, \quad j = \text{squatters, loggers} \]  
E 5.3-39
5.3.2 Base Case Data

The base data is the same as in the one period model. Additional data on gross investments and investments by sector of origin was obtained from Raventós (1990) and Briceño. The Social Accounting Matrix (SAM) for 1986 used in this model is displayed in Appendix 5.

Population growth was assumed to be 2.4% per year (World Bank 1992). Net inflow of capital was obtained from the Costa Rica National Accounts (Central Bank 1990). The change in the trade balance between 1986 and 1987 was assumed to be zero. Because all prices are normalized to 1 in the SAM above, the world market interest rate and the rate of time preference were both set to 1. The rate of depletion of the capital stock, 5.4%, was also obtained from the national accounts (Central Bank 1990).

5.3.3 Results from policy experiments in the dynamic model

Three types of policy experiments were considered in the dynamic model. First, the economic effects of enforced limits on deforestation on the economy and the effects of higher interest rates were considered. Second, the effects of taxes on the production factors in the CES aggregate were analyzed, and third the effects of taxes on tradable goods were considered. Unless otherwise mentioned, the case of unlimited deforestation and the tax structure of 1986 was used as a base case. The relative factor intensities in the base data set were shown in Appendix 7 Table 2.

5.3.3.1 Limits on deforestation and the effects of interest rates

A decline in the volume of forests available for deforestation to a level below the initial deforestation level obviously reduces total deforestation (see Table 5-5). As less
forests are available for deforestation in the second period, investments in capital increase in period 0 in order to increase production capacity in the second period.

Table 5-5 Effects of enforceable limits on deforestation. Deforestation is limits are set below the actual levels of deforestation in the base case

<table>
<thead>
<tr>
<th>Deforestation</th>
<th>Unlimited</th>
<th>-8.65%</th>
<th>-15.57%</th>
<th>-22.49%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(10 billion colones)</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Production in deforesting sectors:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Squatters</td>
<td>0.0265</td>
<td>-0.75</td>
<td>-7.92</td>
<td>-15.47</td>
</tr>
<tr>
<td>Loggers</td>
<td>0.0024</td>
<td>-95.83</td>
<td>-100.00</td>
<td>-100.00</td>
</tr>
<tr>
<td>Total</td>
<td>0.0289</td>
<td>-8.65</td>
<td>-15.57</td>
<td>-22.49</td>
</tr>
<tr>
<td>Stock of land</td>
<td>0.2302</td>
<td>-0.09</td>
<td>-0.87</td>
<td>-1.74</td>
</tr>
<tr>
<td>Production in sectors using logs or land:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forest</td>
<td>0.0666</td>
<td>10.66</td>
<td>67.42</td>
<td>128.23</td>
</tr>
</tbody>
</table>

Production, spending and therefore utility are all reduced in the first period, allowing for higher savings. As forests become more scarce, deforestation both for land and for logs decline. Logging declines more rapidly than squatting, as logs can be imported on the world market whereas land is a non-traded resource. All factor prices except for the price of skilled labor increases. This gives the ‘forest’ sector a relative advantage in production as the world market price of logs remains constant. The size of the ‘forest’ sector increases dramatically, whereas production in the ‘agriculture’ sector declines, but relatively slowly as this sector uses the unique production factor land. In addition to that there is an initial stock of land available to the ‘agriculture’ sector, the price of land increases relatively little as compared to the other factor prices. Production in other sectors decline, and GNP declines in the first period.

Higher interest rates discourage spending (at a given rate of time preference) and investments. Deforestation for land by squatters increases, as the net present value of conserving the forests for deforestation in the final period declines. With higher interest
rates, the returns to capital in the first period increase slowly. The returns to land also increase, but very slowly whereas the returns to skilled labor, mainly used in the non-tradable producing sectors, decline. As the skilled labor intensities in production increase in the non-tradables producing sectors, other resources are shifted towards the 'forest' and 'agriculture' sectors. Production in the agricultural sector in the first period increases, as does production in the 'forest' sector. Changes in taxes on production factors

The results of experiments with taxation of capital are shown in Appendix 7 Table 6. A tax of capital in period 0 reduces the prices of land, capital and unskilled labor in this period, while the price of skilled labor increases. Squatting experiences a boom in period 0 as the decline in the price of land is relatively smaller than the decline of the price of unskilled labor. The size of the logging sector declines, as the price of logs is determined by the world market price and remains constant (see Table 5-6).

The prices of other production factors except skilled labor decline, benefiting sectors intensive in the use of these factors but not intensive in the use of logs (because the price of logs is constant and determined on the world market). As a result, the size of the 'forest' sector declines, whereas production and demand for land in the agricultural sector increases. Utility in period 0, welfare (defined as intertemporal utility\textsuperscript{40}), and spending in period 0 also increase. Investment increases, because the rents to capital in period 1 increase relative to the returns to capital in period 0. A subsidy in period 0 generates the opposite effects.

A tax on capital in period 1 generates a decline in investment in period 0, because of the resulting lower present value of returns to capital in that period. Intertemporal welfare declines, as does utility, spending and GNP in period 0. The returns to capital in the first period increase, as do the prices of capital, unskilled labor and cleared land. The price of cleared land declines more than the price of unskilled labor, as a result of which

\textsuperscript{40} See equation 5.3-20.
squatting declines. Because of the factor price increases and the diminished land clearing, production in the 'agriculture' sector declines, shifting resources towards the 'forest' sector.

Table 5-6 Changes in capital taxation

<table>
<thead>
<tr>
<th>Base Solution</th>
<th>1% subsidy Period 0</th>
<th>1% tax Period 0</th>
<th>1% subsidy Period 1</th>
<th>1% tax Period 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 billion colones</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
</tbody>
</table>

**Production in deforestation sectors:**
- Squatters: 0.0265, -2.26, 10.57, 1.51, -1.51
- Loggers: 0.0024, 0.00, -79.17, 0.00, 0.00
- Total period 0: 0.0289, -2.08, 3.11, 1.73, -1.38
- Stock of land: 0.2302, -0.26, 1.17, 0.17, -0.17

**Production in sectors using logs or land:**
- Forest: 0.0666, 35.59, -95.20, -30.03, 29.88
- Agri: 1.5360, -0.27, 1.26, 0.19, -0.19

Land is supplied elastically in both periods. Though there is an initial amount of land, additional land can be bought from squatters, and the supply of land from squatters depends on the relative prices of unskilled labor and land. Results from taxation experiments on land are shown in Table 5-7.

A subsidy on land in the first period increases, as expected, land clearing by squatters, and production in the agricultural sector increases. This results in an increase in the price of unskilled labor, and the prices of skilled labor, capital and cleared land decline. However, as the price of logs is determined by the world market price which remains constant, production in the 'forest' sector declines. Logging discontinues, as resources are shifted towards squatting and the agricultural sector instead. Total deforestation in the period still increases, because of the large increase in squatting activities. A tax on land in period 0 has, as expected, the opposite effects.
Table 5-7 Results from changing taxation of land

<table>
<thead>
<tr>
<th></th>
<th>Base</th>
<th>1% subsidy Period 0</th>
<th>1% tax Period 0</th>
<th>1% subsidy Period 1</th>
<th>1% tax Period 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10 billion colones)</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Deforestation:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Squatters</td>
<td>0.0265</td>
<td>14.34</td>
<td>-13.21</td>
<td>11.70</td>
<td>-1.51</td>
</tr>
<tr>
<td>Loggers</td>
<td>0.0024</td>
<td>-100.00</td>
<td>0.00</td>
<td>8.33</td>
<td>0.00</td>
</tr>
<tr>
<td>Total</td>
<td>0.0289</td>
<td>4.84</td>
<td>-11.76</td>
<td>11.42</td>
<td>-1.38</td>
</tr>
<tr>
<td>Stock of land</td>
<td>0.2302</td>
<td>1.56</td>
<td>-1.43</td>
<td>1.30</td>
<td>-0.22</td>
</tr>
<tr>
<td>Production in sectors using land and logs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forest</td>
<td>0.0666</td>
<td>-20.72</td>
<td>19.37</td>
<td>-100.00</td>
<td>20.57</td>
</tr>
<tr>
<td>Agri</td>
<td>1.5360</td>
<td>1.39</td>
<td>-1.26</td>
<td>1.40</td>
<td>-0.20</td>
</tr>
</tbody>
</table>

A foreseen subsidy of land in the second period creates increased demand for land in that period, and squatting increases. This also increases the returns to capital in the second period, thus increasing investment in period 0. The prices of unskilled labor, capital and cleared land all decline, benefiting production in the agricultural sector. The price of logs remains constant, resulting in a relative disadvantage in the ‘forest’ sector which causes production to cease in this sector. However, as the price of logs is constant but the prices of the inputs into logging decline, logging increases and the export of logs is increased. Total deforestation therefore increases. Utility, GNP and spending all increase in period 0.

Results from the experiments with taxation on logs are shown in Table 5-8. Logs are traded on the world market, and the entire subsidy on logs is therefore benefiting the ‘forest’ sector, which uses logs, as the user price declines with the full amount of the subsidy. The producer price of logs remains constant compared to the base case.
Table 5-8. Effects of taxation of logs

<table>
<thead>
<tr>
<th></th>
<th>Base</th>
<th>1% subsidy</th>
<th>1% tax</th>
<th>1% subsidy</th>
<th>1% tax</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10 billion colones</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Deforestation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Squatters</td>
<td>0.0265</td>
<td>-3.02</td>
<td>3.02</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Loggers</td>
<td>0.0024</td>
<td>-0.37</td>
<td>0.37</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Total</td>
<td>0.0289</td>
<td>-2.42</td>
<td>2.77</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Stock of land</td>
<td>0.2302</td>
<td>-0.35</td>
<td>0.30</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Production</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forest</td>
<td>0.0666</td>
<td>9.30</td>
<td>-9.30</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Agri</td>
<td>1.5360</td>
<td>-0.37</td>
<td>0.37</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

With a subsidy of logs in period 0, production in the ‘forest’ sector expands as expected. In addition to demanding more logs, the demands for other production factors from the ‘forest’ sector increase. This results in an increased price of capital, as the ‘forest’ sector is relatively capital intensive. In turn, this causes production in the agricultural sector to decline, resulting in lowered prices of unskilled labor and cleared land. As the price declines relatively more for cleared land than for unskilled labor, less land is cleared for agricultural purposes in the first period. Further, the increased price of capital outweighs the decline in the price of unskilled labor, causing the logging sector to contract. The result of a subsidy on logs, therefore, is -- rather surprisingly -- a decline in deforestation for both agricultural purposes and for logs, thus reducing total deforestation in the period. GNP increases, as does utility in the first period, and the intertemporal welfare measure. As the rents to capital in the first period increase compared to the second period, investment declines. A tax on logs in period 0 generates the opposite result. Because the base solution generates no production in the ‘forest’ sector in the second period, a change in the taxation of logs (which are used exclusively in the ‘forest’ sector or are exported) in the second periods does not affect the domestic production and consumption decisions in the first period.
5.3.3.2 Changes in taxes on final products

Results from the experiments with changing taxes on ‘forest’ products are shown in Table 5-9. A subsidy on the production of ‘forest’ products in period 0 generates, as expected, increased production in this sector. This results (as in the case of taxation of logs, which are used as inputs only in the ‘forest’ sector) in an increased price of capital, and declining prices of unskilled labor and land. Production in the ‘agriculture’ sector also declines, as does deforestation of land (squatting). Squatting declines because the price fall on land is higher than the price fall for unskilled labor. Logging remains unchanged, logs are imported, and total deforestation declines. Investment in period 0 also declines, because of the relatively lower returns to capital in the second period compared to the returns to capital in the first period, whereas spending and GNP both increase.

Table 5-9 Effects of taxation of forest products

<table>
<thead>
<tr>
<th></th>
<th>Base</th>
<th>1% subsidy Period 0</th>
<th>1% tax Period 0</th>
<th>1% subsidy Period 1</th>
<th>1% tax Period 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deforestation</td>
<td>10 billion colones</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Squatters</td>
<td>0.0265</td>
<td>-3.40</td>
<td>3.40</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Loggers</td>
<td>0.0024</td>
<td>0.00</td>
<td>4.17</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Total</td>
<td>0.0289</td>
<td>-3.11</td>
<td>3.46</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Land</td>
<td>0.2302</td>
<td>-0.39</td>
<td>0.35</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Production in sectors using land and logs:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forest</td>
<td>0.0666</td>
<td>11.86</td>
<td>-11.71</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>Agri</td>
<td>1.5360</td>
<td>-0.44</td>
<td>0.44</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

A tax on ‘forest’ products in period 0 has the opposite effects. As there is no production of ‘forest’ products in the base case solution for the second period, a tax on ‘forest’ products in the second period does not affect the production and consumption decisions in the first period.
The results of changing taxes on agricultural products are displayed in Table 5-10. A subsidy on agricultural products in period 0 increases production in the ‘agriculture’ sector in this period (as expected), increasing the prices of cleared land and unskilled labor, while the prices of skilled labor and capital decline. Demand for land from the agricultural sector increases, causing squatting and total deforestation to increase. Investment increases because of the relatively higher returns to capital in the second period, causing spending and utility to decline in the first period. Resources are shifted from the ‘forest’ sector to the agricultural sector, causing production in the ‘forest’ sector to decline. A tax in period 0 has the opposite effects.

Table 5-10 Changes in taxes on agricultural products

<table>
<thead>
<tr>
<th></th>
<th>Base</th>
<th>1% subsidy</th>
<th>1% tax</th>
<th>1% subsidy</th>
<th>1% tax</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Period 0</td>
<td>%</td>
<td>%</td>
<td>Period 0</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>10 billion colones</td>
<td>%</td>
<td>%</td>
<td>1% subsidy</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>1% tax</td>
<td>%</td>
<td>%</td>
<td>1% tax</td>
<td>%</td>
</tr>
<tr>
<td>Deforestation:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Squatters</td>
<td>0.0265</td>
<td>4.53%</td>
<td>-4.15%</td>
<td>-0.38%</td>
<td>0.38%</td>
</tr>
<tr>
<td>Loggers</td>
<td>0.0024</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Total</td>
<td>0.0289</td>
<td>4.50%</td>
<td>-3.81%</td>
<td>0.00%</td>
<td>0.35%</td>
</tr>
<tr>
<td>Stock of land</td>
<td>0.2302</td>
<td>0.48%</td>
<td>-0.48%</td>
<td>-0.04%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Production in sectors using land and logs:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forest</td>
<td>0.0666</td>
<td>-12.46%</td>
<td>9.91%</td>
<td>0.15%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Agri</td>
<td>1.5360</td>
<td>0.59%</td>
<td>-0.54%</td>
<td>-0.03%</td>
<td>0.03%</td>
</tr>
</tbody>
</table>

A subsidy to agricultural production in period 1 generates increased returns to capital in the same period, and thus investment levels increase in period 0. The effects on factor prices in period 0 are very small, generating only small effects on production in this period. The price of unskilled labor increases marginally while the price of skilled labor declines. As the ‘forest’ sector is relatively less intensive in its use of unskilled labor, production increases slightly in this sector while production declines marginally in the agricultural sector. The decline in the agricultural sector causes a decline in the
demand for cleared land from this sector, and thus squatting declines marginally, resulting in an overall small decline in deforestation in this period.

5.3.4 Conclusions

From the dynamic general equilibrium model we can draw several interesting conclusions though, as mentioned, the quantitative changes may not be reliable because of the poor quality of data. Qualitative changes, however, should be reliable.

The results indicate that we can get strong unintended effects on deforestation from macro policies in the presence of a market failure. For example, when a temporary tax on capital is imposed in period 0 deforestation increases dramatically in this period because of relative price changes.

Taxation of land also generates interesting results. The expected result would be an increase in deforestation in the period a subsidy is imposed. A temporary land subsidy in period 0 actually decreases deforestation in this period. Again, relative price changes that spill over to the rest of the economy and affect the investment behavior play an important role.

Thus, in a second best situation, partial models may generate quantitatively unreliable results. To correctly foresee the consequences of macro policies, the spillover effects to the rest of the economy must be considered. By using an approach that allows for substitution effects, the government can identify areas where unwanted side effects such as deforestation are likely to occur, and prevent, for example, environmental degradation with appropriate counter measures.

Taking the lessons learnt so far into consideration, we now move on to the problem of land degradation in Sri Lanka. Chapter 6 gives a background to the Sri Lankan economy and the problem of land degradation in this country. In chapter 7 we construct a dynamic general equilibrium model which includes soil erosion.
6. SRI LANKA

In Sri Lanka, agriculture constitutes nearly 25% of GDP, and it employs nearly half of the labor force (World Bank 1995a). A decade ago, tea, rubber and coconut provided almost half of Sri Lanka’s export earnings and almost 25% of the nation's total revenue. Since then, the share of revenue has declined to 5%, and the share of exports has declined to a quarter of total earnings. Declining productivity is one of the main reasons behind the decline of the tree crops sector in Sri Lanka (World Bank 1994). Soil erosion is a principal reason for land degradation and declining productivity, according to the National Environmental Action Plan for Sri Lanka (Ministry of Environment and Parliamentary Affairs 1994).

Sri Lanka is aiming towards joining the ranks of newly industrialized countries (NICs) by the year 2000. The economy has been growing rapidly, and real GDP growth averaged 5.5% per annum during 1990-95, and 2.2% per annum during the three preceding years (World Bank 1996). This strong growth performance followed significant trade liberalizations in the early 1990's, and reforms in this area are continuing (Central Bank 1995). Most exchange rate controls are now discontinued, and the tariff structure is being liberalized. The budget deficit after transfers was 11.6% of GDP in 1991, but it was reduced in 1992 to 7.3% of GDP (Central Bank, 1993 and 1995). It is now widening again, and there is concern about high current expenditure relative to capital expenditures (World Bank 1996).

Foreign exchange earnings from exports of light manufacturers, remittances from expatriate workers, and tourism are increasing. Unemployment has declined from 24% ten years ago to 14% in 1993 (World Bank 1995a), and has averaged 12% between 1990 and 1995 (World Bank 1996). Exports have been growing fast, but not as fast as imports. Most inward investment has gone to the textile sector, and it is argued that Sri Lanka is now excessively dependent on one industrial sector. In addition, because of the cheap labor the country is used merely as an 'assembly point' by many industries -- resulting in minimal
value added. For example, most cloth for the textile sector is imported.

The growth of the labor force in Sri Lanka is presently higher than population growth, due to higher population growth in the past and increased labor market participation by women. Almost all of the increase of employment (2.2% per year between 1981 and 1992) was in the private sector, whereas the employment in the public sector is steady (mainly because of privatizations of public enterprises).

There are three distinct segments of the labor market in Sri Lanka. Twenty-five percent of the labor force work in the "protected" segment, which consists of the civil service, state-owned companies, and medium and large sized enterprises, whereas 68% are in the "unprotected" segment. The remainder is employed in the estate sector.

Employees in the "protected" segment receive many wage and non-wage benefits, which are regulated by the government. The termination of workers for non-disciplinary reasons without their agreement, or written approval of the Commissioner of Labor, is prohibited. This covers lay-offs motivated by down-sizing or closing, and also on the grounds of incompetence and prolonged illness (World Bank 1995a).

The "unprotected" segment includes workers in agriculture, small-scale manufacturing, the service sector, the informal sector, and some larger enterprises operating under the Board of Investments (World Bank 1995a). The wages in this sector are generally market wages, and there are few regulations and restrictions for labor in this segment of the labor market.

The third segment is the labor force in the state-owned plantations. In this sector, wages are set by public policy. Trade unions are strong in the plantation sector, resulting in low mobility of labor and sticky wages in the sector.

6.1 THE AGRICULTURAL SECTOR

The management of plantations in the tree crops sector is currently undergoing
reform. State-owned plantations are since 1992 being managed by private management companies on five year contracts, with the option of renewing their contracts depending on the profitability of the plantation during the past period. At present, further reforms are being undertaken as pilot projects where the equity of the plantations is being sold on the stock market. The land management is further discussed in the treecrops sector section below.

The agricultural sector is declining in relative importance, while manufacturing is growing. In 1994, production in the tea sector grew by 4%, due to favorable weather conditions and improved financial management of the plantations, because of privatization of management in 1992. The export price of tea at the Colombo auction declined by 5% between 1993 and 1994, and the average cost of production declined because of less resource allocation to field maintenance. Production increased only marginally in the rubber sector in 1994, despite an increase in the average price of rubber exports by 17% and an estimated increase in costs by 8%. Domestic rubber processing is increasing steadily, and now accounts for 34% of raw rubber production. In 1994, coconut production was at the highest level since 1986, with an estimated production of 2,610 million nuts (an increase of 21%), because of the effects of favorable weather conditions in 1993 (Central Bank 1995).

Paddy production increased by 4.4% in 1994, reaching its highest recorded level of production. The production of most minor export crops remained steady, whereas coffee, cardamom, and sugar production increased significantly (Central Bank 1995).

### 6.2 Other sectors

In 1994, the growth of the industrial sector slowed to 9%, compared to 14% in 1993. This can be explained by the application of quotas for imports of garments to the US, general uncertainty because of the elections, and frequent strikes during the latter part of the year. These factors also contributed to relatively low growth in the textile and garment sector, where production grew by 6% in 1994, compared to 17% the previous year (Central Bank 1995).
Finally, the energy sector is critical to the growth of the economy. Reforms in the
directions of marginal cost pricing and more efficient energy production and plant
management are being proposed and in some cases undertaken.

6.3 A MORE DETAILED DISCUSSION OF THE TREECROPS SECTORS

Of Sri Lanka's total land area of about 6.5 million hectares, about 2.2 million are
under permanent cultivation and 1.1 million hectares are under shifting cultivation. In the
wet zone (with an average rainfall of over 100 inches per year) nearly two thirds of the
total land area, or 800,000 hectares, is under permanent crops, mainly in tea, rubber and
coconut (World Bank 1993).

6.3.1 Environmental problems

In general, critical environmental problems in the treecrop sectors include soil
erosion, loss of soil nutrients, and moisture retention. In the wet zone, where soils are
shallow and lateritic, deforestation rapidly leads to erosion and land slides. Erodable
brown loams occur on most land with a gradient of 30-40%, and on some slopes with a
gradient in excess of 45%. There is also soil erosion in clearings in the montane zone
where plantation crops, as well as vegetables and other cash crops, are grown (IIED

The main environmental problems in the tea sector include soil erosion, and
acidification of soils. Rainfall patterns are critical to the level of erosion, and it should be
noted that between 45% and 60% of the plantations are located in erosive areas in areas
with high rainfall.

Tea is grown on high elevation mountain slopes as well as in mid-country and
gently undulating low-country. Environmental degradation accelerated in the 1940's and
1950's, as the plantations grew older and became more vulnerable to environmental
problems. The rate of replacement of plants did not keep pace with the aging, and left open
patches in the plantations. All weeds were removed, leaving the soil completely uncovered.

These environmental problems could have been arrested through contour planting (which provides good drainage -- "lock and spill"), increased ground cover, and the use of shade trees. Uprooting of old plants should have been timed to the dry period, and grass should have been planted with the beginning of the wet season.

In the rubber sector, the main environmental problems include soil erosion and loss of nutrients. Erosion has been estimated to as much as 10 cm in 25 years, and is visible at the roots of older rubber trees.

Rubber is grown in the low country wet zone (below an altitude of 800m), as leaf diseases occur on higher elevations. However, the rate of growth is the same at all elevations. Most estates are located on undulating land, with very few estates on flat land. The gradient is not very important, and rubber is grown on slopes with a gradient of up to 45%. It is not grown on steeper slopes, for reasons of soil conservation and concerns for the labor force -- it is difficult to walk at higher gradients.

Legumes are used for cover crops in the rubber sector, and mulching and drainage are other important conservation measures as well as terracing. Drainage is at present not being done systematically. It lasts 5-6 years, and is not properly maintained for financial reasons. On steep slopes, if proper drainage is not provided, runoff tends to enhance erosion (Samurappuli 1984).

Coconut is grown on flat or gently undulating land, on gradients up to 25%. It is grown in flat, maritime regions, and much coconut land is now being converted to non-agricultural uses. The light conditions are important, as is the level of moisture in the soils. The lifespan of a coconut tree is 50 to 60 years, and coconut is intercropped by a number of different crops, as well as livestock (Liyanage et al. 1984). The main environmental problems of the coconut sector concern water infiltration, water pollution and the organic soil content.
6.3.2 Land Management

Until 1972, treecrop plantations in Sri Lanka were privately owned, although a discussion about nationalization of the estates had been continuing since the late 1950's. Even before nationalization there was little incentive for the private owners to undertake long term investments in for example soil conservation measures because of these nationalization rumors.

Nationalization of the estates did take place in 1972 and 1975. After nationalization the sensitivity to markets and profitability was weak (Fernando 1978), and inexperienced public officials were often put in charge of the plantations, resulting in continued low investments.

Following reforms in 1992, the plantations have been under privatized management. Privatized management was seen as a remedy for the decline in market sensitivity. The two large nationalized plantation corporations were broken up into 22 government owned plantation companies in 1992, and the management was contracted to private management companies (Central Bank 1995). However, the assets of the plantations are still public property. The management contracts cover a period of five years, with an option of renewal depending on profitability.

Because of the short time horizon in the present management contracts, investments in soil conservation as well as other long term investments are being neglected in the treecrop sector. For example, there is some evidence of smaller investments in field maintenance (Central Bank 1995). There seems to be a general agreement that the optimal length of time for a plantation management contract should be much longer, at the very least between 20 and 30 years. In the private sector, investments in such measures are low because of financial constraints, possibly stemming from low world market prices and restricted access to credit markets.

At present, these reforms are carried further. Pilot projects privatizing 50 year
leases of the land and capital of some of the plantation companies on the Colombo stock market are underway.

The market for agricultural land is inefficient, and sometimes virtually nonexistent (Jegasothy et al., undated). Private land transactions seem to take place mainly within villages, and the market is largely informal. Foreign ownership of land is severely restricted, and public policy includes cropping and land use restrictions.

In 1973, a system involving land use rights in the form of Land Development Ordinance (LDO) permits for former British crown lands (about 60% of the agricultural land) were instituted. LDO permits give the "owner" a right to use the land, but the right is not transferable between individuals or institutions. Private agricultural land ownership is restricted to 50 acres per person since 1973. This land reform resulted in land actually being taken away from major land holders.

Private smallholdings (less than 10 acres) are generally not located in the most environmentally sensitive areas. On high elevations, only government estates are operating. In mid-elevation, smallholdings on abandoned estates are common, and in low elevation lands are opened for tree crops.

6.3.3 Allocation of land between estates and smallholders in the tree crops sectors

Government plantations own most of the tea lands in Sri Lanka, and these lands are now by and large being managed by private companies. An expansion in production by smallholders was caused by booming world market prices in 1984. The total land area in tea has declined by 40,000 hectares, and now totals 205,000 hectares. Smallholdings have expanded mainly on abandoned rubber plantations but there has also been a marginal land gain from deforestation in the southern part of the country.

About 30% of the land used in rubber cultivation is government plantations, and about 40% is private plantations between 10 and 50 acres. The rest of the land is in
smallholdings.

75% of the land area in coconuts belong to smallholders, while the remaining 25% is in government plantations. However, smallholders generate only 55% of the total output, with 45% coming from the government owned plantations.

6.3.4 Production incentives in the tree crops sectors

There are at present no fertilizer subsidies in the tea sector, but tea receives the highest input of fertilizer of any crop in Sri Lanka. On government plantations, the fertilization decisions are left to the management companies, but non-conventional decisions with respect to reduced fertilization have to be cleared through the government.

About 215,000 kg of tea are produced per year. Of the total, 49% is produced in the private sector, up from 32% ten years ago, mainly because of booming world market prices in 1984. All export taxes on tea have now been removed.

Productivity of tea land is stagnant in the higher elevations, and declining on mid-elevations. Smallholdings on old rubber lands, etc., are most productive. Government plantations tend to be located on high elevation land, while smallholdings are located in the lower elevations. Output in the estate sector declined by 1.2% per year between 1981 and 1991, while the private sector increased by 12.6% annually.

At present, the low world market price for tea has resulted in financial constraints, affecting fertilizer use and conservation measures. Labor is essentially a fixed cost in the sector, due to strong trade unions and fixed wages.

The average yield of rubber is between 300 - 400 kg of rubber per acre for the first one or two years after maturity. After the first two years, the average yield per acre is about 700 kg for private plantations and 900 kg for government owned plantations.

The world market price for rubber had been low for several years -- about $0.50 per
kg -- but has now increased to $1.10 per kg. This low world market price resulted in financial constraints for the private rubber smallholdings (Samarappuli 1993) (because of the non-transferability of land), and therefore in low investments, both in conservation measures and other areas, in this part of the sector. Production has -- probably due to better access to credit in the estate sector -- increased more in the estate sector than in the private sector.

Rubber cultivation is subsidized by the way of subsidizing the cultivation until the trees are ready for tapping, which takes 7-8 years (1500 rupees per acre), and by full fertilizer subsidies according to government recommendations.

Rubber needs less fertilizer than tea, because rubber recycles nutrients. The total fertilizer need for tea is 40-50 kg per hectare for rubber. Tea needs about four times as much. Some rubber land in higher elevations has been converted to tea, but tea land is difficult to convert to rubber because of the magnesium deficiency in soils used for tea production.

The share of coconut production that is exported is only 20%, with the domestic market absorbing the remaining 80%. All parts of the coconut (meat, fibers, etc.) are used for consumption and export. The price of coconuts remains stable throughout the year, with few seasonal variations. The world market price of coconuts remains low -- about 32 rupees per kilo, which is approximately the break even point.
7. A DYNAMIC CGE MODEL OF LAND DEGRADATION AND INCENTIVES FOR LAND CONSERVATION IN SRI LANKA

7.1 OVERVIEW

This model is a fairly standard dynamic CGE model, which is solved for twenty years in five year intervals. It differs from a standard model by the inclusion of soil conservation and soil degradation in the modeling of the behavior of firms in the treecrops sectors. The model is calibrated according to base data for 1991, and growth in the stocks of different kinds of labor are exogenous to the model. The aggregation of producing sectors is shown in Appendix 2.

There are four types of producing sectors in the model. "Treecrops" sectors include tea, rubber and coconut cultivation. All urban industrial production has been aggregated into the "Colombo" sector. "Energy" sectors include electricity and petroleum, and the remaining sectors are labeled as "Other" sectors. All sectors, except for the energy producing sectors, are assumed to maximize profits subject to their respective production technologies and the prices of production factors. The energy sectors (electricity and petroleum) are not profit maximizing sectors: their output prices are exogenously set by government policy, and production is then increased in order to meet demand at the relevant prices.

The primary production factors in this model are three kinds of labor (estate, rural, and urban labor, which are divided according to residence, not according to occupation), capital, and imports. There are also three kinds of consumers, classified according to the
labor types above. The division of labor is done in order to reflect the highly regulated labor markets in the estate and urban sectors (World Bank 1995a, see also chapter 6⁴²). Labor can be allocated between industrial production and the service sectors, as well as agricultural production.

The allocation of labor and capital to each sector takes place until the value marginal product of labor is equal between sectors for each kind of labor. The producing sectors demand functions for labor, capital and imports are derived from cost minimization. Investments are determined from the consumers' intertemporal utility maximization problem.

The market for land is not functioning properly in Sri Lanka, and therefore there is no relevant land price. However, a land quality index is taken into account in the technology for the treecrops sectors, and other prices in the economy determine the incentives for investments in land conservation. From a sectoral point of view, the incentives for land conservation differ between smallholders and larger estates. Different land conservation functions taking the different time horizons into account are therefore developed for these two types of ownership.

All sectors have a constant returns to scale technology, except for the energy sectors. Labor, capital, electricity and imports are aggregated using nested constant elasticity of scale (CES) function, into a composite factor aggregate in all sectors excluding the energy sectors. This factor aggregate is then combined with intermediate goods using the fixed coefficient technology. The production levels are determined from the profit maximizing condition that price equals marginal cost.

In the energy sectors, the level of production is determined by the level of demand, and the profit maximizing condition that price must equal marginal cost is not imposed. However, the energy producing sectors can change their technology depending

⁴² "Sri Lanka", p. 87
on the prices of inputs: they are assumed to be cost minimizers given a certain level of production.

Produced goods are either domestically consumed or exported. The relative share of exports to domestic consumption in each other sector is determined according to a constant elasticity of transformation (CET) function, following Powell (1968). The allocation of production to domestic consumption vs. exports is thus determined depending on domestic prices relative to export prices (f.o.b.), and the elasticity of transformation of the produced good. A low elasticity of transformation implies that the good is less tradable. The price of exports is a function of the world market price, export duties, and the exchange rate. In the energy sectors, the price of domestic outputs are determined by government policy and thus they are exogenous to the model. In all other sectors, the prices of domestically produced goods are determined by the costs of production.

The consumption demand functions are derived from the base data set, from the solution of a standard consumer's problem. The utility functions are assumed to be monotonically transformed Cobb Douglas utility functions, and consumers maximize intertemporal utility over the entire span of the model. The resulting demand functions are thus functions of income (which is a function of wages and returns to capital) as well as prices. The expenditure shares are exogenous to the model, and calculated from the base data set.

The prices of imported goods are determined by the world market price (c.i.f.) of the good produced in each sector, import duties, and the exchange rate. The current account balance is determined as the sum of net exports; GDP is determined as the sum of factor incomes and all taxes and duties; disposable income is defined as the sum of factor incomes and all taxes and duties, less the current account balance.
7.2 Mathematical Description of the Model

All variables and parameters in the model are listed in Appendix 3. We begin with a detailed description of the modeling of the treecrops sectors, and then move on to the description of the rest of the model, which is a fairly standard model.

7.2.1 The treecrops sectors, soil conservation and soil degradation

Producers in the treecrops sectors maximize profits subject to the production technology. The production technology in all treecrops sectors aggregates three kinds of labor (urban, rural and estate labor), capital, energy, and imports into a composite factor aggregate using nested CES functions, thus allowing for substitution between these factors depending on relative prices. This factor aggregate is then combined with intermediate domestically produced goods using Leontief functions. In the treecrops sectors, production also depends on a soil quality index, which is a function of land degradation (which is exogenous but varies between crops), and soil conservation. Soil conservation is produced using a CES technology, with rural labor and capital as the only inputs, and in each sector soil conservation takes place until the expected marginal value of future benefits of soil conservation equals the marginal cost. The decision problem for the treecrops producers can be written as:

\[
\text{Max } \frac{1}{1+r} \left( \sum_{i=0}^{T} P_{x,i,t} x_{i,t} - \sum_{N} P_{N,i,t} N_{i,t} - \sum_{j} P_{j,i,t} x_{j,i,t} \right) \quad \text{N = A, R, U, E, M}
\]

s.t. \( x_{i,t} = f_{i}(A_{i,t}, R_{i,t}, U_{i,t}, K_{i,t}, E_{i,t}, M_{i,t}, x_{j,i,t}, Q_{i,t}) \) \( i \in \text{Treecrops} \)

\( Q_{i,0} = 1 \)

\( Q_{i,t+1} = Q_{i}(1-g_{i}) + d_{i,t} \)

\( d_{i,t} = \phi_{i}(k_{i}^{x}, r_{i}^{x}) \)

where index \( i \) denotes inputs into sector \( i \), \( r \) is the interest rate, \( P_{x,i,t} \) is the producer price of output in sector \( i \), \( x_{i} \) is the level of production in sector \( i \), \( P_{N,i,t} \) is the price of production factor \( N \) in period \( t \), \( A \) is estate labor, \( R \) is rural labor, \( U \) is urban labor, \( K \) is
capital, $E$ is electricity, $M$ is imports, $P_{C,i,t}$ is the consumption price of sector $i$ output in period $t$, $x_{jt,t}$ is sector $j$ input per unit of sector $i$ output in period $t$, $Q_{i,t}$ is a land quality index variable for land used in sector $i$ in period $t$, $g_i$ is land degradation on land used for production in sector $i$, $d_i$ is soil conservation on land used in sector $i$ undertaken in period $t$, $k^{sc}_i$ is capital input into soil conservation in sector $i$, and $r^{sc}_i$ is labor input into soil conservation in sector $i$. The production technology in all sectors is assumed to have constant returns to scale in all types of labor, capital, imports, electricity, and other intermediary inputs, and the amount of land available for cultivation of each crop is assumed to be fixed. For the rest of this chapter we will drop the time subscript ($t$) for convenience, unless it is explicitly needed in the calculations.

The marginal cost ($mc$) of production in each time period in the tree crops sectors is defined as

$$mc_i = \frac{1}{Q_i} \left( \Phi_i P_{Y,i} + \sum_j \left( P_{c,j} x_{j,i} \right) + t_i - s_i \right), \quad i \in \text{tree crops}$$  \hspace{1cm} (E 7.2-2)

where $\Phi_i$ is the share of factor aggregate $Y$ (labor, capital, imports, and electricity combined using CES functions) in total inputs in sector $i$, $P_{Y,i}$ is the price of the factor aggregate $Y$ in sector $i$, $t_i$ is the indirect tax rate and $s_i$ is the subsidy rate.

From profit maximization, output is determined by the price equals marginal cost condition:

$$P_{X,i} = mc_i, \quad i \in \text{tree crops}$$  \hspace{1cm} (E 7.2-3)

Soil conservation will take place until the marginal benefit of conservation equals the marginal costs of the production factors:
where subscripts $K$ and $R$ denote capital and rural labor, $r^{SC}$ is labor input in soil conservation in sector $i$, $k^{SC}$ is capital input in soil conservation in sector $i$, and where the level of soil conservation $(d_i)$ is determined by a CES function:

$$
(d_i)^\kappa = (r^{SC})^\kappa + (k^{SC})^\kappa
$$

where $\kappa$ is the elasticity of substitution. If the marginal cost of soil conservation is greater than the marginal benefit, no investments in soil conservation will take place.

The time horizons will vary for estates and smallholder (that is, $T$ varies), and total soil conservation in land used for crop $i$ is determined by the contributions from smallholders and estates. The time horizon for estates is the length of the contract, 5 years, whereas the time horizon for smallholders is the full remaining “life” of the model.

### 7.2.2 The standard CGE model

Producers (except for energy sectors) maximize profits subject to the production technology. The production technology in all the producing sectors aggregates the three kinds of labor (urban, rural and estate labor), capital, energy, and imports into a composite factor aggregate using nested CES functions, thus allowing for substitution between these factors depending on relative prices. This factor aggregate is then combined with intermediate domestically produced goods using Leontief functions. In the energy sector, costs are minimized subject to demand given exogenous energy prices. The decision problems for producers not in the treecrops sectors can then be written as:
Max \( \frac{1}{1+r} \left( P_{x,t}^D x_{i,t} - \sum_{j} P_{N,i} N_{i,j} - \sum_{j} P_{c,i,j} x_{j,i} x_{i,j} \right) \)  
\[ \text{N = A, R, U, E, M} \]

s.t.  
\( x_{i,t} = f_i(A_{i,t}, R_{i,t}, U_{i,t}, K_{i,t}, E_{i,t}, M_{i,t}, x_{j,i}) \)  
\[ i \in \text{Colombo, Other sectors} \]

Min \( \frac{1}{1+r} \left( \sum_{j} P_{N,i} N_{i,j} - \sum_{j} P_{c,i,j} x_{j,i} x_{i,j} \right) \)  
\[ i \in \text{Energy} \]

s.t.  
\( x_{i,t} = f_i(A_{i,t}, R_{i,t}, U_{i,t}, K_{i,t}, E_{i,t}, M_{i,t}, x_{j,i}) \)  
\( x_{i,t} = D_{i,t} \)  
\[ i \in \text{Energy} \]

E 7.2-6

where \( D_i \) is total demand for good \( i \). The production technology in all sectors is assumed to have constant returns to scale in all types of labor, capital, imports, electricity, and other intermediary inputs.

Since the production factors are perfectly mobile, factor demand in each period is, according to Shephard’s lemma, derived as:

\[ N_i = \frac{\partial P_{x,i}}{\partial P_N} x_i, \forall i \]  
E 7.2-7

where \( N_i \) is demand for the production factor in sector \( i \).

The marginal cost of production in each time period is defined as

\[ mc_i = \Phi_i P_{x,i} + \sum_{j} \left( P_{c,j} x_{j,i} \right) + t_i - s_i, \ i \notin \text{treerops} \]  
E 7.2-8

From profit maximization, output is determined by the price equals marginal cost condition, except for in the energy sectors where output is determined as the level of demand at exogenous energy prices:

\[ P_{x,i}^D = mc_i, \ i \notin \text{energy} \]

\[ x_i = D_i, \ i \in \text{energy} \]  
E 7.2-9

Final consumption demand for goods results from maximization of the representative consumer’s Cobb-Douglas utility function subject to the consumer’s
budget constraint:

\[ D_{i,B} = \frac{\alpha_{i,B}(I_B - \text{sav}_B) + (1 + r)\text{sav}_{B,t-1} (1 + r)}{(1 + \rho)} \quad \forall i, B = A, R, L \]  

E 7.2-10

where index B is the household type (urban, estate or rural household), \( D_B \) is consumption demand for good \( i \) by household type \( B \), \( I_B \) is income for household type \( B \), \( \text{sav}_B \) is savings by household type \( B \), \( P_{C,i} \) is the consumer price of good \( i \), \( r \) is the interest rate and \( \rho \) is the rate of time preference. In equilibrium, the domestic interest rate will equal the rate of time preference, which in turn equals the world market interest rate assuming that domestic and foreign capital are perfect substitutes. A further assumption is that the scrap value of all resources at the end of period \( T \) is zero. This is done for simplicity, and the implication is that the model results for the final time period \( T \) will not be relevant; the results for all other periods will still be relevant since there are positive scrap values in these periods.

All borrowed money has to be repaid before the end of the time horizon of the model:

\[ \sum_{t=1}^{T} \left( \frac{1}{1 + r_t} \right)^{t-1} \text{sav}_{B,t} = 0, \quad B = A, R, L \]  

E 7.2-11

We have a small country assumption, and assume that domestic goods and export goods are imperfect substitutes. The domestic price of exports (\( P_{i,E} \)) in local currency in each time period is defined as:

\[ P_{i,E} = P_{WM,i}(1 + t_i^E)G, \quad i \notin \text{energy} \]  

E 7.2-12

where \( P_{WM,i} \) is the world market price of good \( i \), \( t_i^E \) is export duty rate for good \( i \), and \( G \) is the exchange rate. Goods are allocated between domestic consumption and exports in each time period using constant elasticity of transformation (CET) functions:
where $D_{ij}'$ is intermediate consumption of good $j$, $E_j$ is exports of good $j$, and $\eta_i$ is the elasticity of transformation between domestic consumption and exports. We find a ratio of exports to domestic consumption so that, in each time period, the price ratio equals the marginal rate of transformation to the rest of the world\textsuperscript{43,44}:

$$\frac{E_j}{D_i + D_{ij}'} = \left(\frac{e_i}{1 - e_i}\right)^\mu_i \left(\frac{P_i^E}{P_{cj}}\right)^\mu_i, \quad i \notin \text{energy}$$

where $D_i$ is total domestic final consumption, and $e_i$ is the initial share of exports in total consumption.

Composite consumption of good $i$ $(C_i)$ consists of final domestic demand, intermediate demand and exports. The price of composite consumption is defined as:

$$p^D_{x,j} = \frac{p_{cj}' (D_i + D_{ij}') + P_i^E E_i}{C_i}, \quad i \notin \text{energy}$$

The composition of investment depends on the prices of investment goods, according to a Cobb-Douglas function:

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\textsuperscript{43} Given that the produced good is exportable. Exports are not defined for sectors in which exports are 0 in the 1991 IOTable.

\textsuperscript{44} $\mu_i = \eta_i / (\eta_i - 1)$
\[ inv_i = \prod_i^{i'} \beta_i \]
\[ i_{i,t} = \frac{\beta_i inv_i}{P_{i,t}} \]
\[ p_{i,t} = \frac{\sum_{j} P_{c_{j,t}} i_{i,j}}{inv_i} \]

where inv is total investment, \( \beta_i \) is the value share of investment from sector \( i \), \( i \) is investment from sector \( i \), and \( P_i \) is the price of investment.

Investment must equal domestic savings plus foreign borrowing in each time period. All loans, domestic and foreign, have to be repaid at the end of the twenty year time period.

The size of the capital stock in the current period is determined by the level of investment in the previous period:

\[ K_{t+1} = K_t (1 - \lambda) + inv_i \]

where \( \lambda \) is the rate of capital depletion (exogenous). The capital stock in the first period is derived from the 1991 base data set, and is exogenous to the model.

### 7.2.3 Market clearing

The factor markets clear when the stock of the factor equals the demand from the producing sectors.

\[ A_t = \sum_i A_{i,t} \]
\[ R_t = \sum_i R_{i,t} + r_{i,t}^{sc} \]
\[ L_t = \sum_i L_{i,t} \]
\[ K_t = \sum_i K_{i,t} + k_{i,t}^{sc} \]

where \( A, R, L \) are the three labor types, and \( K \) is capital. The prices of the production factors are determined from the market equilibrium conditions.
The product markets are in equilibrium when total supply equals total demand, and the market equilibrium condition becomes:

\[ x_i = C_i, \quad \text{(7.2-19)} \]

Total spending and domestics savings (I) in each time period is defined as:

\[ I = \sum N P^U_i + \sum_j (t_j - s_j) x_j + \sum t^M_i M_i + t^E_i E_i + P_{WM,i} M_i R - P^E_i E_i \quad \forall f, N \]

\[ \text{(7.2-20)} \]

and is allocated to the three different household types according to the capital shares in the base data IO table.

Gross domestic product in each time period is defined as:

\[ GDP = \sum N P^U_i + \sum (t_i - s_i) x_i, \quad \forall i, N \]

\[ \text{(7.2-21)} \]

The current account is defined as:

\[ CA = \sum t^E_i E_i - P_{WM,i} M_i R \]

\[ \text{(7.2-22)} \]

The discounted sum of the current accounts must be 0.

### 7.3 Data Requirements

An input-output table for 1991 was developed for this project by the National Planning Department in Sri Lanka, and is displayed in Appendix 6. This IO table is an update of a 1981 IO table, using data from National Accounts, socio-economic, household expenditure, labor force and industrial surveys, customs data, and the government budgets.

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45 Primarily by Dr. S.A. Karunaratne, Mr. Nimal Siripala, and Mr. Premaratne and their team at the National Planning Department in Colombo, Sri Lanka.
Further data for the treecrops sector was collected from existing publications and research projects in Sri Lanka, by representatives from the Ministry of Environment, the Ministry of Plantation Industries, and relevant research institutes.  

### 7.3.1 Soil Erosion (physical data)

Several estimates of soil erosion in different crops have been obtained during the process of data collection. Estimated rates of soil erosion are displayed in Table 7-1.

Table 7-1 Estimated rates of soil erosion

<table>
<thead>
<tr>
<th>Study</th>
<th>Area Under Cultivation (ha)</th>
<th>Rate of soil erosion (tons/ha/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Bandara et al. (1995)&lt;sup&gt;47&lt;/sup&gt;</td>
</tr>
<tr>
<td>Method</td>
<td>Unknown</td>
<td>USLE</td>
</tr>
<tr>
<td>Tea</td>
<td>157,172</td>
<td>17.5</td>
</tr>
<tr>
<td>Well-mgd seedl tea</td>
<td></td>
<td>42</td>
</tr>
<tr>
<td>Poorly-mgd seedl tea</td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>VP tea&lt;sup&gt;50&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rubber</td>
<td>97,416</td>
<td>10</td>
</tr>
<tr>
<td>Coconut</td>
<td>55,529</td>
<td>10</td>
</tr>
</tbody>
</table>

These estimates are used to cross check the validity of the regressions used later to calculate rates of soil erosion in the Sri Lankan treecrops sectors.

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<sup>46</sup> Primarily by Dr. Anura Ekanayake (MPI), Mr. Sapukotane and Ms. Gunawardene (MEnv), and their team.

<sup>47</sup> From Plantations Statistical Pocket Book

<sup>48</sup> From Bandara et al. (1995).

<sup>49</sup> High-yielding vegetatively propagated tea varieties.

<sup>50</sup> High-yielding vegetatively propagated tea varieties.
7.3.2 The costs of soil degradation and soil conservation

Table 7-2 Costs of soil conservation (case study, Nuwara-Eliya).

<table>
<thead>
<tr>
<th>Crops</th>
<th>Cost per ha (hundreds of rupees/year)</th>
<th>Nutrients</th>
<th>O.M.</th>
<th>R&amp;M</th>
<th>Labor</th>
<th>Soil</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>WM s. tea</td>
<td></td>
<td>3.40</td>
<td>5.92</td>
<td>9.00</td>
<td>1.49</td>
<td>19.80</td>
<td>39.61</td>
</tr>
<tr>
<td>PM s. tea</td>
<td></td>
<td>7.47</td>
<td>12.96</td>
<td>9.00</td>
<td>3.31</td>
<td>70.23</td>
<td>102.98</td>
</tr>
<tr>
<td>VP7 tea</td>
<td></td>
<td>1.59</td>
<td>2.79</td>
<td>8.99</td>
<td>0.70</td>
<td>15.00</td>
<td>29.08</td>
</tr>
<tr>
<td>Rubber</td>
<td></td>
<td>5.95</td>
<td>1.13</td>
<td>0.85</td>
<td>9.07</td>
<td>12.46</td>
<td>29.46</td>
</tr>
<tr>
<td>Coconut</td>
<td></td>
<td>2.31</td>
<td>4.63</td>
<td>8.80</td>
<td>0.93</td>
<td>25.00</td>
<td>41.67</td>
</tr>
</tbody>
</table>

Source: Calculated from Abeygunawardena and Samarakoon (undated)

Bandara et al. (1995) estimated the cost of soil erosion (based on nutrient replacement costs)\(^{51}\) at 1187.20 Rs/ha/year for tea, 678.40 Rs/ha/year for rubber, and 678.40 Rs/ha/year for coconut. Abeygunawardena and Samarakoon (undated) calculate the costs for conservation measures and nutrient replacement costs for Nuwara-Eliya as displayed in Table 7-2. These costs are used to calculate the parameters in the cost function for soil conservation.

Benefits of soil conservation are more difficult to obtain data for, since no studies are available at the present time. Ideally, to fit the modeling approach, the benefits of soil conservation should be estimated from changes in production due to soil erosion or land degradation.

As described in Chapter 6\(^{52}\), the most important environmental problem in the tea and rubber sectors is soil erosion. Soil erosion is a cumulative process, and in an attempt to capture this variable time series analysis of yields per hectare has been conducted. In the tea sector, we attempted to explain yields per hectare as a function of the time trend (proxy for land degradation), average annual rainfall, and fertilizer input, using annual

\(^{51}\) Based on Clark (1994)

\(^{52}\) "Environmental problems", page 90
data obtained from the Sri Lankan meteorological service. In order to correct for third-order autocorrelation\textsuperscript{53}, the maximum likelihood (ML) method was used, resulting in the following equation\textsuperscript{54}:

\[ Y_r = 0.7744 - 0.0066t + 0.0001r + 0.0023p + 5.2618f \]

with an adjusted $R^2$ of 0.74, where $Y$ is yield, $t$ is the trend, $p$ is the price, and $f$ is fertilizer input.

For rubber, yields per hectare were explained by a trend, rainfall data, and the change in world market prices for the past year (which are important because of the extremely low world market prices during much of the time period), and the change in world market prices between $t-2$ and $t-3$ (in order to capture price expectations and improvement in conservation measures resulting from higher world market prices). Correcting for third-order autocorrelation and using ML estimation, we obtained the following coefficients\textsuperscript{55}:

\[ Y_r = 0.6019 - 0.0025t + 0.0001r + 0.0037(p_t - p_{t-1}) + 0.0043(p_{t-2} - p_{t-3}) \]

with an adjusted $R^2$ of 0.63.

In the coconut sector, the most important factor in land conservation is moisture conservation, rather than soil erosion. This is not a cumulative process: as yields decline because of land degradation, full capacity can be restored through increased conservation efforts. Therefore, we would not expect functional forms similar to the above to generate relevant results. Instead, we attempted to explain the change in yields between years with the time trend, the change in prices, and the level of the producer price. The assumptions

\textsuperscript{53} Akaike's information criterion was used to determine the appropriate lag length.

\textsuperscript{54} All coefficients were significant at the 10\% level.

\textsuperscript{55} The intercept and the coefficients for the price changes, were significant at the 10\% level. For the trend and rainfall level, the t-statistics were 0.924 and 1.702, respectively.
behind this regression are that higher rainfall would improve yields even without investments in moisture retention, and that higher prices would encourage more efficient production. The trend variable is used as a proxy for land degradation. Correcting for second-order auto-correlation and using ML estimation, we obtained the following coefficients:

\[
\Delta Y_c = 0.0204 - 0.0032r + 0.00003(\Delta r) + 0.0404p_t - 0.0678(\Delta p)
\]

where \( \Delta \) denotes changed, and an adjusted \( R^2 \) of 0.58. A value similar to the \( t \) in the tea and rubber equations can then be obtained through the original time series data.

Table 7-3 Coefficients for values of conservation efforts in Sri Lanka

<table>
<thead>
<tr>
<th></th>
<th>Tea</th>
<th>Rubber</th>
<th>Coconut</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.0066</td>
<td>0.0025</td>
<td>0.0013</td>
</tr>
</tbody>
</table>

Source: Own calculations

The resulting coefficient values (per year) of conservation per unit of output, measured as the cost of not undertaking these measures, are displayed in Table 7-3. Though by no means perfect, these values are consistent in magnitude to what we would expect, given the information about fertilizer use and conservation measures. In addition, comparing with studies for other countries, the values are reasonable. For example, Solorzano et al. (1991) find that the change in yields to soil erosion in selected areas in Costa Rica would be about 0.13% per year for potatoes grown on 15% slopes. Corn grown on 4% slopes would experience a 1.63% change in yields per annum due to soil erosion. Magrath and Arens (1989) find that annual soil loss in Indonesia causes productivity losses: their estimates vary between 0 and 15% over time, averaging about 7%. At a 10% discount rate, the values obtained here for tea in Sri Lanka would approximately correspond to those estimates. Lal and Okigbo (1980) estimated annual

---

56 The price variable and the change in price are significant at the 10% level. The \( t \)-values for the intercept, trend, and change in rainfall variables are 1.077, 1.439 and 1.313, respectively.
change in production due to soil erosion in south-western Nigeria, and obtains estimates ranging from 0.2% to 3.6% for cowpea, and from 0.3% to 1.7% for corn (Bishop and Allen 1989).

All elasticities in the CET and CES aggregates were set to 0.8, in the absence of sufficient time series data for econometric estimation of these parameters. Sensitivity analysis was undertaken with respect to the elasticities, but the qualitative results remain the same.

7.4 Simulation Results

In the base case solution, soil conservation only takes place on smallholdings in the tea sector. It would have been desirable for analytical purposes to have soil conservation in all sectors, but as this would have involved altering the basic data set we decided to pursue the analysis with soil conservation in one sector only. The numerical simulation results and initial factor intensities are displayed in Appendix 8.

7.4.1 Removal of direct subsidies for treecrops production

A removal of subsidies in any of the three treecrops sectors has qualitatively identical results. Similarly, doubling of the subsidies in the treecrops sector has the opposite qualitative result, and therefore only the results from a removal of subsidies in the tea sector are discussed in detail here. A priori, one would think that a removal of the direct subsidies in the treecrops sectors would discourage production in those sectors. However, the results turn out to be quite the opposite, as the removal of subsidies will change all the relative prices in the economy. A removal of any of the subsidies in the tea, rubber and coconut sectors actually encourages production as factor prices decline, due to more efficient use of resources. This also holds true for soil conservation in the tea sector. As land use becomes more intensive (as there is no land market), all resources have to be used more efficiently, and the incentives for land conservation improve. The user prices for labor are lower than the user price for capital, and labor intensive soil conservation
methods such as terracing are encouraged.

In addition to expanding production in the treecrops sectors, production in other sectors also increases with declining factor prices. Total production increases, as does total income. However, the breakdown of incomes shows that rural labor outside the estate labor sector is hardest hit, implying that the rural smallholder sector is the sector which will be hardest hit by a removal of subsidies, whereas increased transfers to the urban and estate sector offset the decline in wages.

![Graph showing energy demand and GDP](image)

Figure 7-1 Increased energy demand and GDP from elimination of subsidies in the tea sector (compared to base case results for each period)

Produced quantities in the energy sectors increase (as shown in Figure 7-1). Demand from other producing sectors increases, even as other factor prices decline whereas the price of energy is held constant. It is noteworthy that except for in the first period, GDP growth increases at a slower rate than energy production. Most of the increase in energy production comes from increased demand in the household sector, as incomes increase. Energy demand increases in the urban and estate sectors, whereas it declines in the rural sector because of slower income growth in this sector. Further, it should be noted that production in the Colombo urban sector increases, as does demand for transportation and other services. This puts increased pressure on infrastructure in the capital, with possible implications for water pollution, solid waste disposal services, as well as air pollution and congestion.
The immediate as well as the medium term effects on GDP and income growth are positive. The trade balance improves in the short run due to significantly increased exports (resulting from lower domestic production costs), particularly from the tree crops sectors. Foreign borrowing increases in the second period, and thereafter the trade balance becomes positive again.

7.4.2 Increasing the price of electricity

Figure 7-2. Changes in production in selected sectors due to an annual increase in the price of electricity of 1% as compared to base case

Three different experiments were undertaken regarding price increases in the electricity sector, with expected price increases of 1% per year, 2% per year and 3% per year while keeping the price in the base period constant. As would be expected, electricity production increases significantly, while the petroleum sector also expands though not to the same extent as the electricity sector (Figure 7-2). The qualitative results from all three experiments are consistent, and the magnitudes of the changes increase with higher prices.

As electricity becomes more expensive, profit maximizing firms become more efficient in their use of electricity, and the supply of energy increases. Energy intensive
sectors suffer more from the price increase than do less energy intensive sectors. In the second period (which is the period in which the electricity price increase actually has taken effect), the service sectors, the trade and transportation sector, and the treecrops sectors increase their production the most. The price of estate labor is elevated, whereas the prices of the other primary production factors are reduced, which explains the significant increase in the production of services. In the Colombo sector, production expands because of relatively cheaper labor and capital. It is noteworthy that the petroleum sector grows at a slower rate than the electricity sector, implying a shift in energy production away from petroleum based production. Further, the share of intermediate consumption in production actually grows over time, as electricity becomes relatively more expensive for households, whereas industry has limited substitution possibilities away from electricity.

Overall, incomes for rural and estate households increase with the reform, as treecrops production benefits from the shift of production factors away from other sectors. The level of soil conservation is the same, which is explained by the time horizon of twenty years for soil conservation and the marginal changes in factor prices in the 2nd and 3rd periods. Urban households initially suffer the most from the price increase, as industrial production declines. However, in the longer term, effects of price reforms are positive for all three household types.

7.4.3 Removal of subsidies in the transportation sector

The impact of a removal of subsidies in the transportation sector is shown in Figure 7-3. Total production is slightly higher than in the base case scenario, and in both cases there are a significant expansion in the service sector as well as in the electricity producing sector. As subsidies are removed, prices for production factors intensively used in the transportation sector (primarily capital and rural labor) decline, and production in other sectors intensive in those factors, increase. (See Figure 7-4 for selected examples.).
Figure 7-3 Impacts on production of a removal of subsidies in the transportation sector, as compared to the base case

As production in the tea sector expands, land becomes more scarce, the incentives for soil conservation improve, and soil conservation efforts in the tea smallholder sector are intensified. Growth in total income, as well as GDP growth, increase in all periods as a result of the removal of subsidies in the transportation sector. However, income in the rural sector declines, as a result of the relatively largest decline in wages for this sector. Incomes in other sectors actually improve, as a result of increased transfers.

The results of a doubling of transport subsidies are opposite to the results of a removal of the subsidies, wherefore these results are not discussed in detail.

Figure 7-4. Change in production as compared to the base case scenario for selected sectors
7.4.4 A 10% increase of taxes in the Colombo sector

As the tax burden in the Colombo industrial sector is increased by 1/10, the prices of production factors that are intensively used by this sector decline. Other sectors, which are intensive in the use of urban and rural labor and capital increase their production the most, even though production in all sectors increase due to declining factor prices (Figure 7-5). Services and electricity are both intensive in their use of urban and rural labor (rural labor travel to Colombo to work in unskilled labor in industries), and these sectors gain from the tax increase.

![Figure 7-5 Changes in production growth in selected sectors after a 10% increase of the tax on Colombo/industrial goods](image)

As some of the labor in the Colombo sector, which is classified as estate labor (because of the classification of descendants of estate workers as estate labor), is transferred to the estate sector, production also grows significantly in the tea and rubber sectors. As production increases in the tea and rubber sectors, land becomes more scarce and soil conservation in the tea smallholder sector increases. Electricity production increases, and final electricity demand increases primarily from urban households, but also from estate households. Total income increases, but as the production factors become cheaper, the value added per unit produced goods declines, and GDP declines. Increased exports, in particular of tea, rubber and coconut products, cause an improvement in the trade balance.
7.5 CONCLUSIONS

While one would expect to find that soil conservation efforts in the treecrops sectors would increase with higher subsidies, the results of this modeling exercise show quite the opposite. Subsidizing production in these sectors instead means an inefficient use of resources, while a removal of subsidies generates more efficient resource allocation and thus increased levels of soil conservation.

The analysis undertaken here also shows that while the common expectation that higher energy prices would encourage energy production holds true, an increase in the price of electricity actually benefits growth, again through the efficiency argument. Increased energy prices would not only benefit sectors which are not energy intensive, such as the treecrops sectors, but also energy intensive sectors such as the industrial and transport sectors. Soil conservation would also be positively affected, as land resources would be more efficiently utilized. Similar results hold for a removal of transport subsidies, whereas increased taxation in the industrial sector generates a shift towards growth of more traditional sectors.
8. CONCLUSIONS

Comparing some of the results from the three models of deforestation in Costa Rica, we find some interesting differences in results. The partial equilibrium model in chapter two showed us the importance of correcting the underlying market failures associated with deforestation. However, given the market failures, the results were less interesting. From the partial model we can only conclude that by imposing taxes we can discourage production of timber, and thus reduce deforestation, which is the traditional and expected result. The question then arises, is this enough? Why construct a more complicated economywide model if we can draw general conclusions in the simpler partial model? If we compare the results with the results from the general equilibrium models, the advantage of an approach that allows for second best effects is quite clear.

First, by defining property rights, we get the expected result that deforestation declines in all three models. In the general equilibrium models, both kinds of deforestation diminish. We can also conclude that the production results from the static model do not necessarily hold for the dynamic model, once investments are endogenous. The industry sector benefits from increased investments, and production in this sector increases in both periods in the dynamic model while industry production decreases in the static model.

A tax on logs generates decreased production of this good in the partial model. In the static model, this result holds. However, the changes in relative prices encourages deforestation for land, and total deforestation increases. In the dynamic model, logging remains unchanged since because of the investments the optimal production in sectors using logs as an input in zero. This is because of the endogenous investment and savings decisions.
A tax on capital, which in the partial model generates decreased production in the logging sector, actually increases deforestation in both general equilibrium models. Due to relative price changes, logging increases in the general equilibrium models (when the tax is imposed in period 0 in the dynamic model). When the tax is imposed in period 1, land clearing increased in period 0.

From this we can conclude that the partial model assists us in coming to the main -- and expected -- result that by correcting the market failure we can avoid excess deforestation. Further, looking at a tax directly affecting only the logging sector, we can still rely on the partial model in coming to this conclusion. However, in the general equilibrium model total deforestation actually increases because relative price changes create higher demand for land. In imposing the result from the partial model without further measures to counteract the unwanted side effects, the government may actually worsen a situation they are trying to correct -- deforestation is encouraged because of substitution effects.

In increasing the tax on inputs used throughout the economy, the shortcomings of the traditional partial approach are even more obvious. Substitution effects, because of relative price changes, actually increase deforestation from the logging sector in the general equilibrium models. Total deforestation also increases in the static model as well as when the tax is imposed in period 1 in the dynamic model. When the tax is imposed in period 0 only, deforestation in this period increases dramatically, and in the short term we get higher deforestation.

Therefore, we can draw several strong conclusions in terms of economic theory from the three modeling experiments conducted here. First, with the existence of a market failure, the side effects may be of such magnitudes that a partial modeling approach is not reliable. Both qualitative and quantitative results may be wrong. Second, by using a general equilibrium approach that allows for second best effects, we can trace the impacts of the policy and draw (more) correct conclusions. Third, by using a static approach
instead of a dynamic approach, we also overlook the importance of the investment decisions. Relative scarcity of capital will encourage investments, thus impacting the consumption / savings decision as well production decisions in the critical sectors.

In the Sri Lanka model, several of our results reflect interesting spillovers in terms of the effects of policies. Lower subsidies for treecrops encourage production in these sectors, because of the effects of relative price changes brought in place by the lowering of the subsidy. Soil conservation benefits, both because of lower factor prices and because of land becoming an increasingly scarce resource, which has to be more efficiently utilized if production is not subsidized. Increased energy prices have similar results: again, resources are becoming more scarce and they therefore have to be utilized more efficiently. A tax increase in the industrial sector slows relative growth in the industrial sector: production in treecrops sectors grows relatively faster. This, in turn, has positive effects on soil conservation...

In terms of practical applicability of the results here, some caution is recommended, both because several parameters are assumptions, because of the stylized assumptions made for some sectors, and because of the quality of data. However, the qualitative results from the equilibrium models should hold, for example, that heavy taxation of logging may result in increased agricultural production creating a demand for newly cleared land. Countermeasures have to be taken in order to ensure that this does not occur. Taxation of capital may increase the production in less capital intensive sectors, thus encouraging deforestation.
9. BIBLIOGRAPHY


Central Bank (1992), Three years of Sustained Achievement 1989-1991, Colombo


Cruz, Wilfrido and Robert Repetto (1992), The Environmental Effects of Stabilization and Structural Adjustment Programs: The Philippines Case. World Resources Institute.


Hanna, Susan, Carl Folke and Karl-Göran Måler (1995), “Property Right Regimes and Environmental Resources” in Hanna, Susan and Mohan Munasinghe (eds.), *Property*


Hazell, P. and R. Stewart (1993), "Should Costa Rica's grain markets be liberalized?", Food Policy Vol. 18 No. 6, December.


Jegasothy, K., C.R. Shumway and H. Lim (undated),"Production Technology and Input Allocations in Sri Lankan Multicrop Farming”

Johansson, P.O. and Löfgren, K.G. (1985), The Economics of Forestry and Natural


Keogh, R. M. (1984), "Changes in the Forest Cover in Costa Rica through History”, Turrialba


Ministerio de Recursos Naturales, Energia y Minas (1990), Estrategia de Conservacion para el Desarrollo Sostenible de Costa Rica, ECODES, San José.


Ministry of Environment and Parliamentary Affairs (1994), National Environmental


Dordrecht.


APPENDIX 1 THE AGGREGATION OF PRODUCING SECTORS IN THE COSTA RICA MODEL.

<table>
<thead>
<tr>
<th>Model sectors</th>
<th>IO Table sectors</th>
</tr>
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<tbody>
<tr>
<td>Forest</td>
<td>9. Forestry and fishing</td>
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<tr>
<td>Agriculture</td>
<td>1. Bananas</td>
</tr>
<tr>
<td></td>
<td>2. Unprocessed coffee</td>
</tr>
<tr>
<td></td>
<td>3. Sugar cane</td>
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<td></td>
<td>4. Cacao</td>
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<td></td>
<td>5. Basic grains</td>
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<td></td>
<td>6. Cotton</td>
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<tr>
<td></td>
<td>7. Tobacco</td>
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<td></td>
<td>8. Livestock</td>
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<td></td>
<td>10. Other agricultural</td>
</tr>
<tr>
<td></td>
<td>14. Coffee processing</td>
</tr>
<tr>
<td></td>
<td>15. Grains milling</td>
</tr>
<tr>
<td></td>
<td>17. Sugar refining</td>
</tr>
<tr>
<td>Industries</td>
<td>11. Meat and milk</td>
</tr>
<tr>
<td></td>
<td>12. Fish tinning</td>
</tr>
<tr>
<td></td>
<td>13. Edible oils</td>
</tr>
<tr>
<td></td>
<td>16. Bakeries</td>
</tr>
<tr>
<td></td>
<td>18. Other manufactured goods</td>
</tr>
<tr>
<td></td>
<td>19. Drink</td>
</tr>
<tr>
<td></td>
<td>20. Tobacco products</td>
</tr>
<tr>
<td></td>
<td>21. Textiles and clothing</td>
</tr>
<tr>
<td></td>
<td>22. Leather and shoes</td>
</tr>
<tr>
<td></td>
<td>23. Timber and furniture</td>
</tr>
<tr>
<td></td>
<td>24. Paper and printing</td>
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<tr>
<td></td>
<td>25. Chemical products</td>
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<td></td>
<td>26. Oil refining</td>
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<td>27. Tire products</td>
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<tr>
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<td>28. Plastic and rubber</td>
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<tr>
<td></td>
<td>29. Glass and ceramic</td>
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<tr>
<td></td>
<td>30. Construction materials</td>
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<td>31. Metal products</td>
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<tr>
<td></td>
<td>32. Electric products</td>
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<td>33. Transport equipment</td>
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<td></td>
<td>34. Other manufacturing</td>
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<tr>
<td>Infrastructure</td>
<td>35. Construction</td>
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<td></td>
<td>38. Transport</td>
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<td>40. Electricity, gas, water</td>
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<td>Services</td>
<td>36. Banking and finance</td>
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<td>37. Commerce</td>
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<td></td>
<td>39. Services</td>
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<td></td>
<td>41. Ownership of dwellings</td>
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<td></td>
<td>42. General government</td>
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APPENDIX 2 The Aggregation Of Producing Sectors In The Sri Lanka CGE Model

<table>
<thead>
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<th>Model Sectors</th>
<th>IO Table sectors</th>
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<tbody>
<tr>
<td>Tea</td>
<td>Tea</td>
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<tr>
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<td>Rubber</td>
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<tr>
<td>Coconut</td>
<td>Coconut</td>
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<tr>
<td>Paddy</td>
<td>Paddy</td>
</tr>
<tr>
<td>Other Agriculture</td>
<td>Other agriculture</td>
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<tr>
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<td>Mining and quarrying</td>
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<tr>
<td>Colombo</td>
<td>Rice Milling</td>
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<td></td>
<td>Flour Milling</td>
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<td>Textile</td>
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<tr>
<td></td>
<td>Garments</td>
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<tr>
<td></td>
<td>Transportation equipment</td>
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<td>Electrical equipment</td>
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<tr>
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<td>Other machinery</td>
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<td></td>
<td>Food processing</td>
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<td>Chemical and fertilizer</td>
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<td>Structural clay</td>
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<td>Other manufacturing</td>
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<td>Basic metal</td>
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<td>Electricity</td>
<td>Electricity</td>
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<td>Transport</td>
<td>Trade and transport</td>
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<td>Other services</td>
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APPENDIX 3 List Of Variables And Parameters In The Models

List of variables for partial equilibrium model of deforestation in Costa Rica

<table>
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<tr>
<th>Variable</th>
<th>Description</th>
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<tbody>
<tr>
<td>$\mu_t$</td>
<td>Stock of forests in period $t$</td>
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<tr>
<td>$\delta_t$</td>
<td>Capital depletion in period $t$</td>
</tr>
<tr>
<td>$g$</td>
<td>Installation costs for capital investments</td>
</tr>
<tr>
<td>$h$</td>
<td>Installation costs for forest investments</td>
</tr>
<tr>
<td>$i_t$</td>
<td>Capital investments in period $t$</td>
</tr>
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<td>$I_t$</td>
<td>Investment costs for capital</td>
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<tr>
<td>$j_t$</td>
<td>Forest investments in period $t$</td>
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<td>$J_t$</td>
<td>Investment costs for forests</td>
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<td>Normalized capital input in period $t$</td>
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<td>Labor input in period $t$</td>
</tr>
<tr>
<td>$M_t$</td>
<td>Deforestation in period $t$</td>
</tr>
<tr>
<td>$m_t$</td>
<td>Normalized deforestation in period $t$</td>
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<td>Price of output in period $t$</td>
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<td>Price of capital investments in period $t$</td>
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<td>Price of forest investments in period $t$</td>
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<td>Price of capital in period $t$</td>
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<td>$P_{M,t}$</td>
<td>Price of deforestation in period $t$</td>
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<td>$s_t$</td>
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<td>Price of labor in period $t$</td>
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<td>$Y_t$</td>
<td>Output in period $t$</td>
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List of variables and parameters for the CGE models of deforestation in Costa Rica

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
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<tbody>
<tr>
<td>$\phi$</td>
<td>Opportunity value of conservation per unit of forest (exogenous)</td>
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<tr>
<td>$\sigma_j$</td>
<td>Tax rate of good j (exogenous)</td>
</tr>
<tr>
<td>$C_j$</td>
<td>Marginal and average cost of production in sector j</td>
</tr>
<tr>
<td>$C_{sq}$</td>
<td>Cost of land clearing for squatters</td>
</tr>
<tr>
<td>$D_i$</td>
<td>Consumption demand for good i</td>
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<td>$DL$</td>
<td>Initial stock of cleared land (exogenous)</td>
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<tr>
<td>$d_{log}$</td>
<td>Deforestation by loggers</td>
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<tr>
<td>$d_{sq}$</td>
<td>Deforestation by squatters</td>
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<tr>
<td>$e$</td>
<td>Exchange rate (exogenous)</td>
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<td>$f_{exp}$</td>
<td>Net exports of logs</td>
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<tr>
<td>$g_{sq}$</td>
<td>Profit from land clearing for squatters</td>
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<td>Opportunity value of forest conservation</td>
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<td>$Inv$</td>
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<td>Revenue of land clearing for squatters</td>
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<td>Stock of skilled labor (exogenous)</td>
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<td>Labor input in logging</td>
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<td>Labor input in squatting</td>
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<td>$M_j$</td>
<td>Input of production factor M in sector j</td>
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<td>$P_{DL}^{U}$</td>
<td>Price of cleared land</td>
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<tr>
<td>$P_{DL}$</td>
<td>User price of cleared land, including taxes</td>
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<tr>
<td>$P_{FL}^{U}$</td>
<td>Price of logs</td>
</tr>
<tr>
<td>$P_{FL}^{WM}$</td>
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<td>World market price of good j (exogenous)</td>
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<td>Producer price of good j</td>
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<td>$P_{K}^{U}$</td>
<td>Price of capital</td>
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<tr>
<td>$P_{K}^{U}$</td>
<td>User price of capital, including taxes</td>
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<tr>
<td>$P_{L}^{U}$</td>
<td>Price of unskilled labor</td>
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<tr>
<td>$P_{L}^{U}$</td>
<td>User price of unskilled labor, including taxes</td>
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<td>$P_{ij}$</td>
<td>User price (including taxes) of primary factor composite in sector j</td>
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<td>$r$</td>
<td>Interest rate (exogenous)</td>
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<td>Savings</td>
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<td>$S$</td>
<td>Current account (exogenous)</td>
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<tr>
<td>$t_j$</td>
<td>Indirect tax rate in sector j (exogenous)</td>
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<td>$T_j$</td>
<td>Tax rate on production factor j</td>
</tr>
</tbody>
</table>
U  Stock of unskilled labor (exogenous)
V  Utility
X_{ij}  Input of sector i output in sector j
X_j  Output in sector j
Y_j  Input of primary production factors in sector j
Z_i  Net exports of good i

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha )</td>
<td>Elasticity of logging output with respect to capital</td>
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<td>( \beta )</td>
<td>Elasticity of logging output with respect to labor</td>
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<td>( \gamma )</td>
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<td>Share of primary production factors in sector j output</td>
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<tr>
<td>b_i</td>
<td>Expenditure share on good i</td>
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<tr>
<td>h</td>
<td>Amount of timber per unit of forested land</td>
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<td>i_i</td>
<td>Share of value of investments from sector i</td>
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List of variables and parameters in the Sri Lanka CGE model

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<td>Demand for estate labor in sector $i$</td>
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<td>Stock of estate labor (exogenous)</td>
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<tr>
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<tr>
<td>$C_{i,t}$</td>
<td>Composite consumption of sector $i$ goods</td>
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<tr>
<td>$D_{i,B,t}$</td>
<td>Final demand for sector $i$ output by household $B$</td>
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<td>Total demand for sector $i$ output</td>
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<td>Soil conservation in sector $i$</td>
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<tr>
<td>$D_{i,i}$</td>
<td>Intermediate consumption of sector $i$ goods</td>
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<td>Exports of sector $i$ output</td>
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<td>$g_{i}$</td>
<td>Rate of land degradation in sector $i$ (exogenous)</td>
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<td>$K_{i,t}$</td>
<td>Demand for capital in sector $i$</td>
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<td>$P_{U_{R_{i},t}}$</td>
<td>User price of rural labor</td>
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<td>$P_{W_{M_{i},t,t}}$</td>
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<td>Subsidy of production in sector $i$ (exogenous)</td>
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<td>$t_{i,t}$</td>
<td>Indirect tax in sector $i$ (exogenous)</td>
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APPENDIX 4 Base Data For The Costa Rica Static CGE Model

Table A4.1 Base Case Data for the Static Model.

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<th>service</th>
<th>cons</th>
<th>nexp</th>
<th>total</th>
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<td>1,3984</td>
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Source: Calculated from a disaggregated input output table constructed by Edgar Briceño, University of Costa Rica, San Pedro, and Costa Rica National Accounts. The adjustments have been calculated from Solórzano et al. 1991.
Table A4.2 Land use data.

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<td>3,154,280</td>
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<td>61.44%</td>
<td>51.93%</td>
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<td>Secondary Forest</td>
<td>299,011</td>
<td>283,571</td>
<td>292,850</td>
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<tr>
<td></td>
<td>5.82%</td>
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<tr>
<td>Other</td>
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<td>135,593</td>
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<tr>
<td></td>
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<td>2.64%</td>
<td>2.64%</td>
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<td>100.00%</td>
<td>100.00%</td>
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Source: Calculated from Solórzano 1991.

Table A4.3 Deforestation parameters and initial values

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<tr>
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### APPENDIX 5 Base Data For The Dynamic Costa Rica Model

Costa Rica 1986, 10 billion colones

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<th>ind</th>
<th>infr</th>
<th>service</th>
<th>cons</th>
<th>invest</th>
<th>nexp</th>
<th>total</th>
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<td>0.0391</td>
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### APPENDIX 6 Base Data For The Sri Lanka Model

IO Table for Sri Lanka 1991
Rupees 10 billion

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<td>9.796125</td>
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<td>0.024253</td>
<td>0.000565</td>
<td>0.179857</td>
<td>0.110481</td>
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<td></td>
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<tr>
<td>Urban</td>
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<td>0.002850</td>
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<td>0.063540</td>
<td>0.025370</td>
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<td>0.000000</td>
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<td>0.000000</td>
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<td>0.059640</td>
<td>0.071280</td>
<td>3.998100</td>
<td>0.030210</td>
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<td>0.485270</td>
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<td>0.110710</td>
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<td>0.036400</td>
<td>0.010050</td>
<td>0.173000</td>
<td>0.033600</td>
<td>0.092260</td>
<td>0.135320</td>
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<td>0.263730</td>
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<td>0.825800</td>
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<td>4.706400</td>
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<td>0.008060</td>
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<td>0.015689</td>
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<td>0.036310</td>
<td>0.051070</td>
<td>0.021650</td>
<td>0.403180</td>
<td>0.415310</td>
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<td>0.001057</td>
<td>2.062061</td>
<td>0.294353</td>
<td>0.033160</td>
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<td>0.088944</td>
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<tr>
<td>Subsid.</td>
<td>-0.01520</td>
<td>-0.01473</td>
<td>-0.00611</td>
<td>-0.00810</td>
<td>-0.06611</td>
<td>-0.39448</td>
<td>-0.06196</td>
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<td></td>
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</tr>
</tbody>
</table>
APPENDIX 7 Numerical Results from the Costa Rica Models

Table A7. 1  Effects of defining property rights, and different alternative opportunity values of forests in the static model

<table>
<thead>
<tr>
<th>H-value</th>
<th>Undefined pr. rights. (10 billion colones)</th>
<th>Defined property rights (i=10%), sensitivity analysis with respect to different future values (% change)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utility</td>
<td>0.0232</td>
<td>0.00%</td>
</tr>
<tr>
<td>GNP</td>
<td>3.1962</td>
<td>0.03%</td>
</tr>
<tr>
<td>Spending</td>
<td>3.7681</td>
<td>-0.01%</td>
</tr>
<tr>
<td>Prices</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital</td>
<td>1</td>
<td>0.17%</td>
</tr>
<tr>
<td>Skilled Labor</td>
<td>1</td>
<td>-0.06%</td>
</tr>
<tr>
<td>Unskilled Labor</td>
<td>1</td>
<td>-0.21%</td>
</tr>
<tr>
<td>Land</td>
<td>1</td>
<td>0.11%</td>
</tr>
<tr>
<td>Logs</td>
<td>1</td>
<td>0.00%</td>
</tr>
<tr>
<td>Production in Deforestation sectors:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Squatters</td>
<td>0.002</td>
<td>-100.00%</td>
</tr>
<tr>
<td>Loggers</td>
<td>0.002</td>
<td>-100.00%</td>
</tr>
<tr>
<td>Total</td>
<td>0.004</td>
<td>-100.00%</td>
</tr>
<tr>
<td>Production:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forest</td>
<td>0.0552</td>
<td>29.17%</td>
</tr>
<tr>
<td>Agri</td>
<td>1.3984</td>
<td>-0.77%</td>
</tr>
<tr>
<td>Ind</td>
<td>1.8477</td>
<td>-0.33%</td>
</tr>
</tbody>
</table>

Table A7. 2  Initial factor intensities in the Costa Rica IO table

<table>
<thead>
<tr>
<th>.</th>
<th>forest</th>
<th>agri</th>
<th>ind</th>
<th>logging</th>
<th>squatting</th>
</tr>
</thead>
<tbody>
<tr>
<td>land</td>
<td>0%</td>
<td>27%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>logs</td>
<td>6%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>capital</td>
<td>48%</td>
<td>27%</td>
<td>37%</td>
<td>58%</td>
<td>0%</td>
</tr>
<tr>
<td>unskilled labor</td>
<td>39%</td>
<td>36%</td>
<td>26%</td>
<td>42%</td>
<td>100%</td>
</tr>
<tr>
<td>skilled labor</td>
<td>1%</td>
<td>1%</td>
<td>17%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>
Table A7.3  Effects of taxation of production factors in the static model

<table>
<thead>
<tr>
<th></th>
<th>Base Case (10 billion colones)</th>
<th>Tax Logs</th>
<th>Subsidy Logs</th>
<th>Tax Land</th>
<th>Subsidy Land</th>
<th>Tax Unskilled labor</th>
<th>Tax Capital</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utility</td>
<td>0.0232</td>
<td>4.74%</td>
<td>-7.76%</td>
<td>-0.43%</td>
<td>-2.59%</td>
<td>-1.29%</td>
<td>0.00%</td>
</tr>
<tr>
<td>GNP</td>
<td>3.1962</td>
<td>0.17%</td>
<td>-0.36%</td>
<td>-0.01%</td>
<td>-0.64%</td>
<td>-0.52%</td>
<td>-0.06%</td>
</tr>
<tr>
<td>Spending</td>
<td>3.7681</td>
<td>0.18%</td>
<td>-0.32%</td>
<td>-0.01%</td>
<td>-0.24%</td>
<td>-0.16%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Prices:</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>-0.43%</td>
<td>0.73%</td>
<td>0.17%</td>
<td>-1.55%</td>
<td>-1.31%</td>
<td>0.01%</td>
</tr>
<tr>
<td>Skilled Labor</td>
<td></td>
<td>1</td>
<td>1.19%</td>
<td>-2.19%</td>
<td>-0.06%</td>
<td>-1.41%</td>
<td>-0.95%</td>
</tr>
<tr>
<td>Unskilled Labor</td>
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<td>1</td>
<td>-0.40%</td>
<td>0.85%</td>
<td>-0.22%</td>
<td>3.79%</td>
<td>2.97%</td>
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<tr>
<td>Land</td>
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<td>1</td>
<td>0.86%</td>
<td>-1.66%</td>
<td>0.11%</td>
<td>-3.11%</td>
<td>-2.37%</td>
</tr>
<tr>
<td>Logs</td>
<td></td>
<td>1</td>
<td>10.00%</td>
<td>-10.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Income in Deforestation Sectors:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Squatters</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loggers</td>
<td>0.002</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Total</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production:</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forest</td>
<td>0.0552</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Agri</td>
<td>1.3984</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ind</td>
<td>1.8477</td>
<td></td>
<td></td>
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Table A7.4  Effects of taxation of final goods in the static model

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<th>double tax</th>
<th>half tax</th>
<th>double</th>
<th>half tax</th>
<th>double</th>
</tr>
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<tbody>
<tr>
<td>(10 billion colones)</td>
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</tr>
<tr>
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<td>3.45%</td>
<td>-41.81%</td>
<td>97.84%</td>
<td>-72.41%</td>
<td>146.55%</td>
</tr>
<tr>
<td>GNP</td>
<td>3.1962</td>
<td>-0.07%</td>
<td>0.06%</td>
<td>-1.17%</td>
<td>2.67%</td>
<td>-2.00%</td>
<td>4.04%</td>
</tr>
<tr>
<td>Spending</td>
<td>3.7681</td>
<td>-0.03%</td>
<td>0.07%</td>
<td>-0.97%</td>
<td>2.29%</td>
<td>-1.67%</td>
<td>3.46%</td>
</tr>
<tr>
<td>Prices</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital</td>
<td>1</td>
<td>0.00%</td>
<td>0.00%</td>
<td>-0.03%</td>
<td>0.08%</td>
<td>-0.09%</td>
<td>0.19%</td>
</tr>
<tr>
<td>Skilled labor</td>
<td>1</td>
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<td>0.00%</td>
<td>0.01%</td>
<td>-0.03%</td>
<td>0.03%</td>
<td>-0.07%</td>
</tr>
<tr>
<td>Unskilled labor</td>
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<td>0.00%</td>
<td>0.00%</td>
<td>0.04%</td>
<td>-0.10%</td>
<td>0.12%</td>
<td>-0.24%</td>
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<tr>
<td>Land</td>
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<td>0.00%</td>
<td>-0.02%</td>
<td>0.05%</td>
<td>-0.06%</td>
<td>0.12%</td>
</tr>
<tr>
<td>Logs</td>
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<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Income in Deforestation sectors:</td>
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<td>-5.00%</td>
<td>10.00%</td>
<td>-10.00%</td>
<td>25.00%</td>
</tr>
<tr>
<td>Loggers</td>
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<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Total</td>
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<td>0.00%</td>
<td>0.00%</td>
<td>-2.50%</td>
<td>5.00%</td>
<td>-5.00%</td>
<td>12.50%</td>
</tr>
<tr>
<td>Production:</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forest</td>
<td>0.0552</td>
<td>-4.35%</td>
<td>10.33%</td>
<td>-26.63%</td>
<td>63.41%</td>
<td>-71.01%</td>
<td>146.92%</td>
</tr>
<tr>
<td>Agri</td>
<td>1.3984</td>
<td>0.00%</td>
<td>0.01%</td>
<td>-5.19%</td>
<td>12.31%</td>
<td>-0.14%</td>
<td>0.33%</td>
</tr>
<tr>
<td>Ind</td>
<td>1.8477</td>
<td>0.14%</td>
<td>-0.32%</td>
<td>4.15%</td>
<td>-9.82%</td>
<td>-1.13%</td>
<td>2.34%</td>
</tr>
</tbody>
</table>
Table A7.5  Effects of enforceable limits on deforestation in the dynamic model.  Deforestation is limits are set below the actual levels of deforestation in the base case (10 billion colones)

<table>
<thead>
<tr>
<th>Deforestation</th>
<th>Unlimited</th>
<th>-4.84%</th>
<th>-8.65%</th>
<th>-12.11%</th>
<th>-15.57%</th>
<th>-19.03%</th>
<th>-22.49%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welfare</td>
<td>0.187</td>
<td>0.05%</td>
<td>0.05%</td>
<td>0.00%</td>
<td>-0.16%</td>
<td>-0.37%</td>
<td>-0.64%</td>
</tr>
<tr>
<td>Utility</td>
<td>0.1234</td>
<td>0.08%</td>
<td>-1.22%</td>
<td>-7.46%</td>
<td>-13.53%</td>
<td>-20.26%</td>
<td>-27.07%</td>
</tr>
<tr>
<td>GNP</td>
<td>3.1724</td>
<td>0.01%</td>
<td>-0.03%</td>
<td>-0.20%</td>
<td>-0.36%</td>
<td>-0.54%</td>
<td>-0.73%</td>
</tr>
<tr>
<td>Spending</td>
<td>3.1727</td>
<td>0.00%</td>
<td>-0.03%</td>
<td>-0.20%</td>
<td>-0.37%</td>
<td>-0.55%</td>
<td>-0.73%</td>
</tr>
<tr>
<td>Investments</td>
<td>1.0849</td>
<td>0.02%</td>
<td>0.06%</td>
<td>0.29%</td>
<td>0.50%</td>
<td>0.73%</td>
<td>0.97%</td>
</tr>
</tbody>
</table>

*User prices of production factors*

| Capital       | 0.9654    | 0.00%  | 0.00%  | 0.01%   | 0.02%   | 0.03%   | 0.04%   |
| Skilled labor | 1.0668    | 0.02%  | -0.12% | -0.87%  | -1.58%  | -2.37%  | -3.16%  |
| Unskilled labor| 1.0393   | 0.00%  | 0.02%  | 0.09%   | 0.15%   | 0.23%   | 0.31%   |
| Cleared land  | 0.9773    | 0.00%  | 0.00%  | 0.00%   | 0.01%   | 0.01%   | 0.01%   |
| Logs          | 1         | 0.00%  | 0.00%  | 0.00%   | 0.00%   | 0.00%   | 0.00%   |

*Production in deforesting sectors:

| Squatters     | 0.0265    | 0.00%  | -0.75% | -4.53%  | -7.92%  | -11.70% | -15.47% |
| Loggers       | 0.0024    | -58.33%| -95.83%| -95.83% | -100.00%| -100.00%| -100.00%|
| Total         | 0.0289    | -4.84% | -8.65% | -12.11% | -15.57% | -19.03% | -22.49% |
| Allowed       | 100.0001  | -99.97% | -99.97%| -99.97% | -99.98% | -99.98% | -99.98% |
| Stock of land | 0.2302    | -0.04% | -0.09% | -0.52%  | -0.87%  | -1.30%  | -1.74%  |

*Production in sectors using logs or land:

| Forest       | 0.0666    | 3.45%  | 10.66% | 39.79%  | 67.42%  | 97.75%  | 128.23% |
| Agri         | 1.5360    | -0.02% | -0.10% | -0.53%  | -0.94%  | -1.39%  | -1.84%  |
Table A7.6  Effects of higher interest rates in the dynamic model (10 billion colones)

<table>
<thead>
<tr>
<th>Interest rate</th>
<th>Base</th>
<th>+0.02%</th>
<th>+0.04%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welfare</td>
<td>0.187</td>
<td>0.48%</td>
<td>1.02%</td>
</tr>
<tr>
<td>Utility</td>
<td>0.1234</td>
<td>0.32%</td>
<td>1.30%</td>
</tr>
<tr>
<td>GNP</td>
<td>3.1724</td>
<td>-0.02%</td>
<td>-0.02%</td>
</tr>
<tr>
<td>Spending</td>
<td>3.1727</td>
<td>-0.02%</td>
<td>-0.02%</td>
</tr>
<tr>
<td>Investments</td>
<td>1.0849</td>
<td>-0.50%</td>
<td>-1.01%</td>
</tr>
</tbody>
</table>

*User prices of production factors:*

- Capital: 0.9654 0.00% 0.01%
- Skilled labor: 1.0668 -0.08% -0.09%
- Unskilled labor: 1.0393 0.01% 0.00%
- Cleared land: 0.9773 0.00% 0.01%
- Logs: 1.00% 0.00%

*Deforestation:*

- Squatters: 0.0265 0.00% 0.38%
- Loggers: 0.0024 0.00% 0.00%
- Land: 0.2302 0.00% 0.04%

*Production in sectors using land and logs:*

- Forest: 0.0666 3.00% 3.15%
- Agri: 1.5360 0.01% 0.06%
Table A7.7 Changes in capital taxation in the dynamic model (10 billion colones)

<table>
<thead>
<tr>
<th></th>
<th>Base Solution</th>
<th>1% subsidy Period 0</th>
<th>1% tax Period 0</th>
<th>1% subsidy Period 1</th>
<th>1% tax Period 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welfare</td>
<td>0.187</td>
<td>-2.94%</td>
<td>2.73%</td>
<td>2.99%</td>
<td>-2.94%</td>
</tr>
<tr>
<td>Utility</td>
<td>0.1234</td>
<td>-2.84%</td>
<td>16.37%</td>
<td>1.62%</td>
<td>-1.62%</td>
</tr>
<tr>
<td>GNP</td>
<td>3.1724</td>
<td>-0.22%</td>
<td>0.60%</td>
<td>0.18%</td>
<td>-0.18%</td>
</tr>
<tr>
<td>Spending</td>
<td>3.1727</td>
<td>-0.22%</td>
<td>0.60%</td>
<td>0.18%</td>
<td>-0.18%</td>
</tr>
<tr>
<td>Investments</td>
<td>1.0849</td>
<td>-2.34%</td>
<td>1.83%</td>
<td>2.41%</td>
<td>-2.36%</td>
</tr>
</tbody>
</table>

*User prices of production factors:*

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital</td>
<td>0.9654</td>
<td>0.03%</td>
<td>-0.06%</td>
<td>-0.03%</td>
<td>0.03%</td>
</tr>
<tr>
<td>Skilled labor</td>
<td>1.0668</td>
<td>-0.94%</td>
<td>2.60%</td>
<td>0.80%</td>
<td>-0.79%</td>
</tr>
<tr>
<td>Unskilled labor</td>
<td>1.0393</td>
<td>0.07%</td>
<td>-0.20%</td>
<td>-0.04%</td>
<td>0.05%</td>
</tr>
<tr>
<td>Cleared land</td>
<td>0.9773</td>
<td>0.02%</td>
<td>-0.03%</td>
<td>-0.02%</td>
<td>0.02%</td>
</tr>
<tr>
<td>Logs</td>
<td>1</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

*Deforestation:*

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Squatters</td>
<td>0.0265</td>
<td>-2.26%</td>
<td>10.57%</td>
<td>1.51%</td>
<td>-1.51%</td>
</tr>
<tr>
<td>Loggers</td>
<td>0.0024</td>
<td>0.00%</td>
<td>-79.17%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Total period 0</td>
<td>0.0289</td>
<td>-2.08%</td>
<td>3.11%</td>
<td>1.73%</td>
<td>-1.38%</td>
</tr>
<tr>
<td>Allowed</td>
<td>100.001</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Land available</td>
<td>0.2302</td>
<td>-0.26%</td>
<td>1.17%</td>
<td>0.17%</td>
<td>-0.17%</td>
</tr>
</tbody>
</table>

*Production in sectors using land and logs:*

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest</td>
<td>0.0666</td>
<td>35.59%</td>
<td>-95.20%</td>
<td>-30.03%</td>
<td>29.88%</td>
</tr>
<tr>
<td>Agri</td>
<td>1.5360</td>
<td>-0.27%</td>
<td>1.26%</td>
<td>0.19%</td>
<td>-0.19%</td>
</tr>
</tbody>
</table>
Table A7. 8  Changes in land taxation in the dynamic model (10 billion colones)

<table>
<thead>
<tr>
<th></th>
<th>Base</th>
<th>1% subsidy Period 0</th>
<th>1% tax Period 0</th>
<th>1% subsidy Period 1</th>
<th>1% tax Period 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welfare</td>
<td>0.187</td>
<td>-1.07%</td>
<td>1.07%</td>
<td>2.35%</td>
<td>-2.57%</td>
</tr>
<tr>
<td>Utility</td>
<td>0.1234</td>
<td>-0.73%</td>
<td>1.94%</td>
<td>19.12%</td>
<td>-2.35%</td>
</tr>
<tr>
<td>GNP</td>
<td>3.1724</td>
<td>-0.04%</td>
<td>0.08%</td>
<td>0.60%</td>
<td>-0.13%</td>
</tr>
<tr>
<td>Spending</td>
<td>3.1727</td>
<td>-0.05%</td>
<td>0.08%</td>
<td>0.60%</td>
<td>-0.13%</td>
</tr>
<tr>
<td>Investments</td>
<td>1.0849</td>
<td>-0.02%</td>
<td>-0.02%</td>
<td>0.33%</td>
<td>-0.95%</td>
</tr>
<tr>
<td><strong>User prices of production factors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital</td>
<td>0.9654</td>
<td>-0.39%</td>
<td>0.37%</td>
<td>-0.05%</td>
<td>0.01%</td>
</tr>
<tr>
<td>Skilled labor</td>
<td>1.0668</td>
<td>-0.14%</td>
<td>0.30%</td>
<td>2.58%</td>
<td>-0.54%</td>
</tr>
<tr>
<td>Unskilled labor</td>
<td>1.0393</td>
<td>0.53%</td>
<td>-0.51%</td>
<td>-0.21%</td>
<td>0.04%</td>
</tr>
<tr>
<td>Cleared land</td>
<td>0.9773</td>
<td>-0.26%</td>
<td>0.25%</td>
<td>-0.03%</td>
<td>0.01%</td>
</tr>
<tr>
<td>Logs</td>
<td>1</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td><strong>Deforestation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Squatters</td>
<td>0.0265</td>
<td>14.34%</td>
<td>-13.21%</td>
<td>11.70%</td>
<td>-1.51%</td>
</tr>
<tr>
<td>Loggers</td>
<td>0.0024</td>
<td>-100.00%</td>
<td>0.00%</td>
<td>8.33%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Total</td>
<td>0.0289</td>
<td>4.84%</td>
<td>-11.76%</td>
<td>11.42%</td>
<td>-1.38%</td>
</tr>
<tr>
<td>Allowed</td>
<td>100.0001</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Land</td>
<td>0.2302</td>
<td>1.56%</td>
<td>-1.43%</td>
<td>1.30%</td>
<td>-0.22%</td>
</tr>
<tr>
<td><strong>Production</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forest</td>
<td>0.0666</td>
<td>-20.72%</td>
<td>19.37%</td>
<td>-100.00%</td>
<td>20.57%</td>
</tr>
<tr>
<td>Agri</td>
<td>1.5360</td>
<td>1.39%</td>
<td>-1.26%</td>
<td>1.40%</td>
<td>-0.20%</td>
</tr>
</tbody>
</table>
Table A7.9  Changes in logs taxation in the dynamic model (10 billion colones)

<table>
<thead>
<tr>
<th></th>
<th>Base</th>
<th>2% subsidy Period 0</th>
<th>1% subsidy Period 0</th>
<th>1% tax Period 0</th>
<th>1% subsidy Period 1</th>
<th>1% tax Period 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welfare</td>
<td>0.1870</td>
<td>0.11%</td>
<td>0.05%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Utility</td>
<td>0.1234</td>
<td>0.49%</td>
<td>0.24%</td>
<td>-0.24%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>GNP</td>
<td>3.1724</td>
<td>0.07%</td>
<td>0.03%</td>
<td>-0.04%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Spending</td>
<td>3.1727</td>
<td>0.07%</td>
<td>0.03%</td>
<td>-0.04%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Investments</td>
<td>1.0849</td>
<td>-0.36%</td>
<td>-0.18%</td>
<td>0.18%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

*User price of production factors*

<table>
<thead>
<tr>
<th></th>
<th>Capital</th>
<th>0.9654</th>
<th>0.31%</th>
<th>0.16%</th>
<th>-0.16%</th>
<th>0.00%</th>
<th>0.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skilled labor</td>
<td>1.0668</td>
<td>0.05%</td>
<td>0.02%</td>
<td>-0.03%</td>
<td>0.00%</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td>Unskilled labor</td>
<td>1.0393</td>
<td>-0.11%</td>
<td>-0.05%</td>
<td>0.06%</td>
<td>0.00%</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td>Cleared land</td>
<td>0.9773</td>
<td>-0.20%</td>
<td>-0.10%</td>
<td>0.10%</td>
<td>0.00%</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td>Logs</td>
<td>1</td>
<td>-2.00%</td>
<td>-1.00%</td>
<td>1.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td></td>
</tr>
</tbody>
</table>

*Deforestation*

<table>
<thead>
<tr>
<th></th>
<th>Squatters</th>
<th>0.0265</th>
<th>-5.66%</th>
<th>-3.02%</th>
<th>3.02%</th>
<th>0.00%</th>
<th>0.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loggers</td>
<td>0.0024</td>
<td>-1.52%</td>
<td>-0.37%</td>
<td>0.37%</td>
<td>0.00%</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.0289</td>
<td>-5.19%</td>
<td>-2.42%</td>
<td>2.77%</td>
<td>0.00%</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td>Allowed</td>
<td>100.0001</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>0.2302</td>
<td>-0.65%</td>
<td>-0.35%</td>
<td>0.30%</td>
<td>0.00%</td>
<td>0.00%</td>
<td></td>
</tr>
</tbody>
</table>

*Production*

<table>
<thead>
<tr>
<th></th>
<th>Forest</th>
<th>0.0666</th>
<th>18.59%</th>
<th>9.30%</th>
<th>-9.30%</th>
<th>0.00%</th>
<th>0.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agri</td>
<td>1.5360</td>
<td>-0.74%</td>
<td>-0.37%</td>
<td>0.37%</td>
<td>0.00%</td>
<td>0.00%</td>
<td></td>
</tr>
</tbody>
</table>


Table A7.10  Effects of taxation of forest products (10 billion colones)

<table>
<thead>
<tr>
<th></th>
<th>Base Period 0</th>
<th>1% subsidy Period 0</th>
<th>1% tax Period 0</th>
<th>1% subsidy Period 1</th>
<th>1% tax Period 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welfare</td>
<td>0.187</td>
<td>0.05%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Utility</td>
<td>0.1234</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>GNP</td>
<td>3.1724</td>
<td>0.03%</td>
<td>-0.03%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Spending</td>
<td>3.1727</td>
<td>0.03%</td>
<td>-0.03%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Investments</td>
<td>1.0849</td>
<td>-0.19%</td>
<td>0.19%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

*User prices of production factors*

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital</td>
<td>0.9654</td>
<td>0.18%</td>
<td>-0.18%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Skilled labor</td>
<td>1.0668</td>
<td>0.01%</td>
<td>-0.01%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Unskilled labor</td>
<td>1.0393</td>
<td>-0.06%</td>
<td>0.07%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Cleared land</td>
<td>0.9773</td>
<td>-0.12%</td>
<td>0.12%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Logs</td>
<td>1</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

*Deforestation*

|                                |               |                    |                  |                    |
| Squatters                      | 0.0265        | -3.40%             | 3.40%            | 0.00%              | 0.00%            |
| Loggers                        | 0.0024        | 0.00%              | 4.17%            | 0.00%              | 0.00%            |
| Total                          | 0.0289        | -3.11%             | 3.46%            | 0.00%              | 0.00%            |
| Allowed                        | 100.0001      | 0.00%              | 0.00%            | 0.00%              | 0.00%            |
| Land                           | 0.2302        | -0.39%             | 0.35%            | 0.00%              | 0.00%            |

*Production*

|                                |               |                    |                  |                    |
| Forest                         | 0.0666        | 11.86%             | -11.71%          | 0.15%              | 0.15%            |
| Agri                           | 1.5360        | -0.44%             | 0.44%            | 0.00%              | 0.00%            |
Table A7.11 Changes in taxes on agricultural products (10 billion colones)

<table>
<thead>
<tr>
<th></th>
<th>Base</th>
<th>1% subsidy Period 0</th>
<th>1% tax Period 0</th>
<th>1% subsidy Period 1</th>
<th>1% tax Period 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welfare</td>
<td>0.187</td>
<td>-0.27%</td>
<td>0.27%</td>
<td>0.59%</td>
<td>-0.59%</td>
</tr>
<tr>
<td>Utility</td>
<td>0.1234</td>
<td>0.08%</td>
<td>0.57%</td>
<td>-0.49%</td>
<td>0.49%</td>
</tr>
<tr>
<td>GNP</td>
<td>3.1724</td>
<td>-0.01%</td>
<td>0.03%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Spending</td>
<td>3.1727</td>
<td>-0.01%</td>
<td>0.03%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Investments</td>
<td>1.0849</td>
<td>0.05%</td>
<td>-0.06%</td>
<td>0.26%</td>
<td>-0.26%</td>
</tr>
</tbody>
</table>

*User prices of production factors:*

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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<td>Capital</td>
<td>0.9654</td>
<td>-0.15%</td>
<td>0.15%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Skilled labor</td>
<td>1.0668</td>
<td>-0.01%</td>
<td>0.07%</td>
<td>-0.01%</td>
<td>-0.01%</td>
</tr>
<tr>
<td>Unskilled labor</td>
<td>1.0393</td>
<td>0.19%</td>
<td>-0.19%</td>
<td>0.01%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Cleared land</td>
<td>0.9773</td>
<td>0.27%</td>
<td>-0.27%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Logs</td>
<td>1</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
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</tr>
</tbody>
</table>

*Deforestation:*

<p>| | | | | | |</p>
<table>
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<tr>
<th></th>
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<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Squatters</td>
<td>0.0265</td>
<td>4.53%</td>
<td>-4.15%</td>
<td>-0.38%</td>
<td>0.38%</td>
</tr>
<tr>
<td>Loggers</td>
<td>0.0024</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Total</td>
<td>0.0289</td>
<td>4.50%</td>
<td>-3.81%</td>
<td>0.00%</td>
<td>0.35%</td>
</tr>
<tr>
<td>Allowed</td>
<td>100.0001</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Land</td>
<td>0.2302</td>
<td>0.48%</td>
<td>-0.48%</td>
<td>-0.04%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

*Production:*

<p>| | | | | | |</p>
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</tr>
</thead>
<tbody>
<tr>
<td>Forest</td>
<td>0.0666</td>
<td>-12.46%</td>
<td>9.91%</td>
<td>0.15%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Agri</td>
<td>1.5360</td>
<td>0.59%</td>
<td>-0.54%</td>
<td>-0.03%</td>
<td>0.03%</td>
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</tbody>
</table>
APPENDIX 8 Numerical Results from the Sri Lanka Model

Table A8. 1 Initial factor intensities

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</tr>
</thead>
<tbody>
<tr>
<td>Electr.</td>
<td>0.36%</td>
<td>0.39%</td>
<td>4.06%</td>
<td>0.05%</td>
<td>0.35%</td>
<td>0.00%</td>
<td>3.22%</td>
<td>0.38%</td>
<td>0.68%</td>
<td>0.52%</td>
<td></td>
</tr>
<tr>
<td>Imports</td>
<td>14.69%</td>
<td>12.31%</td>
<td>2.37%</td>
<td>45.86%</td>
<td>90.48%</td>
<td>0.83%</td>
<td>7.61%</td>
<td>4.32%</td>
<td>16.91%</td>
<td>3.69%</td>
<td>20.31%</td>
</tr>
<tr>
<td>Urban</td>
<td>0.29%</td>
<td>0.20%</td>
<td>0.31%</td>
<td>5.84%</td>
<td>1.16%</td>
<td>9.92%</td>
<td>0.35%</td>
<td>1.84%</td>
<td>1.30%</td>
<td>8.66%</td>
<td>19.78%</td>
</tr>
<tr>
<td>Rural</td>
<td>17.47%</td>
<td>12.34%</td>
<td>7.70%</td>
<td>27.36%</td>
<td>1.63%</td>
<td>9.65%</td>
<td>31.86%</td>
<td>27.77%</td>
<td>22.63%</td>
<td>20.44%</td>
<td>45.19%</td>
</tr>
<tr>
<td>Estate</td>
<td>11.76%</td>
<td>18.53%</td>
<td>26.59%</td>
<td>0.97%</td>
<td>0.08%</td>
<td>0.57%</td>
<td>0.66%</td>
<td>3.29%</td>
<td>0.69%</td>
<td>0.84%</td>
<td>1.88%</td>
</tr>
<tr>
<td>Capital</td>
<td>53.43%</td>
<td>56.25%</td>
<td>62.64%</td>
<td>15.92%</td>
<td>6.60%</td>
<td>78.69%</td>
<td>59.51%</td>
<td>59.56%</td>
<td>58.10%</td>
<td>65.69%</td>
<td>12.31%</td>
</tr>
</tbody>
</table>
Table A8.2 Base case results (Rupees 10 million)

<table>
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</thead>
<tbody>
<tr>
<td>Soil conservation on smallholdings, tea sector</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.3375</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor input</td>
<td>0.0131</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital input</td>
<td>0.3148</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil quality index</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tea</td>
<td>1.3375</td>
<td>1.3045</td>
<td>1.2715</td>
<td>1.2385</td>
</tr>
<tr>
<td>Rubber</td>
<td>1.0000</td>
<td>0.9875</td>
<td>0.9750</td>
<td>0.9625</td>
</tr>
<tr>
<td>Coco</td>
<td>1.0000</td>
<td>0.9935</td>
<td>0.9870</td>
<td>0.9805</td>
</tr>
<tr>
<td>Prices</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estate labor</td>
<td>0.8568</td>
<td>0.8525</td>
<td>0.8638</td>
<td>0.9748</td>
</tr>
<tr>
<td>Urban labor</td>
<td>1.0198</td>
<td>0.8940</td>
<td>0.7949</td>
<td>0.8581</td>
</tr>
<tr>
<td>Rural labor</td>
<td>0.9927</td>
<td>0.9235</td>
<td>0.8687</td>
<td>0.9342</td>
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<tr>
<td>Capital</td>
<td>0.9546</td>
<td>0.8504</td>
<td>0.7655</td>
<td>0.8111</td>
</tr>
<tr>
<td>Production</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tea</td>
<td>5.4415</td>
<td>5.9428</td>
<td>6.2405</td>
<td>5.1910</td>
</tr>
<tr>
<td>Rubber</td>
<td>0.5281</td>
<td>0.5976</td>
<td>0.6553</td>
<td>0.6127</td>
</tr>
<tr>
<td>Coco</td>
<td>1.1277</td>
<td>1.1925</td>
<td>1.2319</td>
<td>1.2166</td>
</tr>
<tr>
<td>Colombo</td>
<td>28.6766</td>
<td>29.6617</td>
<td>30.1633</td>
<td>31.5960</td>
</tr>
<tr>
<td>Paddy</td>
<td>1.9374</td>
<td>1.9938</td>
<td>2.0182</td>
<td>2.0912</td>
</tr>
<tr>
<td>Other agri</td>
<td>6.8062</td>
<td>7.0302</td>
<td>7.1492</td>
<td>7.1419</td>
</tr>
<tr>
<td>Mining</td>
<td>0.5532</td>
<td>0.5782</td>
<td>0.5927</td>
<td>0.6087</td>
</tr>
<tr>
<td>Trade</td>
<td>10.2934</td>
<td>10.9630</td>
<td>11.5015</td>
<td>13.1343</td>
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<tr>
<td>Petroleum</td>
<td>2.3093</td>
<td>3.5263</td>
<td>4.9933</td>
<td>4.8475</td>
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<tr>
<td>Electricity</td>
<td>1.2112</td>
<td>7.7761</td>
<td>16.0134</td>
<td>14.7389</td>
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<tr>
<td>Disposable income</td>
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</tr>
<tr>
<td>Urban HH</td>
<td>10.6147</td>
<td>10.1879</td>
<td>10.0673</td>
<td>10.0346</td>
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<tr>
<td>Rural HH</td>
<td>22.4250</td>
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<td>23.5366</td>
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<tr>
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<td>1.2296</td>
<td>1.2890</td>
<td>1.3847</td>
<td>1.5988</td>
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<tr>
<td>Total income</td>
<td>34.2693</td>
<td>33.6193</td>
<td>33.8211</td>
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<tr>
<td>Trade balance</td>
<td>0.6500</td>
<td>-0.2018</td>
<td>-1.3490</td>
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<tr>
<td>GDP</td>
<td>61.6972</td>
<td>61.1130</td>
<td>60.6347</td>
<td>65.5678</td>
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</table>
Table A8.3 Results of a removal of subsidies in the tea sector, % change compared to base case (Table A8.1)

<table>
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<tr>
<th>Period</th>
<th>1</th>
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<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil conservation on smallholdings, tea sector</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.0533%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor input</td>
<td>0.0764%</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Capital input</td>
<td>0.0476%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil quality index</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tea</td>
<td>0.0135%</td>
<td>0.0138%</td>
<td>0.0142%</td>
<td>0.0145%</td>
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<tr>
<td>Rubber</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
</tr>
<tr>
<td>Coco</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
</tr>
<tr>
<td>Prices</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estate labor</td>
<td>-0.0373%</td>
<td>-0.0481%</td>
<td>-0.0579%</td>
<td>-0.0328%</td>
</tr>
<tr>
<td>Urban labor</td>
<td>-0.0294%</td>
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<td>-0.0591%</td>
<td>-0.0373%</td>
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<tr>
<td>Rural labor</td>
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<td>-0.0541%</td>
<td>-0.0289%</td>
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<tr>
<td>Capital</td>
<td>-0.0346%</td>
<td>-0.0482%</td>
<td>-0.0614%</td>
<td>-0.0358%</td>
</tr>
<tr>
<td>Production</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tea</td>
<td>0.1009%</td>
<td>0.1237%</td>
<td>0.1391%</td>
<td>0.0963%</td>
</tr>
<tr>
<td>Rubber</td>
<td>0.0663%</td>
<td>0.0904%</td>
<td>0.1083%</td>
<td>0.0424%</td>
</tr>
<tr>
<td>Coco</td>
<td>0.0319%</td>
<td>0.0411%</td>
<td>0.0463%</td>
<td>0.0140%</td>
</tr>
<tr>
<td>Colombo</td>
<td>0.0244%</td>
<td>0.0290%</td>
<td>0.0311%</td>
<td>0.0000%</td>
</tr>
<tr>
<td>Paddy</td>
<td>0.0196%</td>
<td>0.0231%</td>
<td>0.0243%</td>
<td>-0.0005%</td>
</tr>
<tr>
<td>Other agri</td>
<td>0.0176%</td>
<td>0.0220%</td>
<td>0.0229%</td>
<td>0.0119%</td>
</tr>
<tr>
<td>Mining</td>
<td>0.0289%</td>
<td>0.0329%</td>
<td>0.0371%</td>
<td>0.0082%</td>
</tr>
<tr>
<td>Trade</td>
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<td>0.0412%</td>
<td>0.0469%</td>
<td>-0.0171%</td>
</tr>
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<td>Service</td>
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<td>0.0377%</td>
<td>0.0506%</td>
<td>0.0426%</td>
</tr>
<tr>
<td>Petroleum</td>
<td>0.0390%</td>
<td>0.0607%</td>
<td>0.0785%</td>
<td>0.0703%</td>
</tr>
<tr>
<td>Electricity</td>
<td>0.0528%</td>
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<td>0.1038%</td>
<td>0.1189%</td>
</tr>
<tr>
<td>Disposable income</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban HH</td>
<td>0.1185%</td>
<td>0.1319%</td>
<td>0.1415%</td>
<td>0.1215%</td>
</tr>
<tr>
<td>Rural HH</td>
<td>-0.0315%</td>
<td>-0.0398%</td>
<td>-0.0437%</td>
<td>-0.0281%</td>
</tr>
<tr>
<td>Estate HH</td>
<td>0.0211%</td>
<td>0.0140%</td>
<td>0.0065%</td>
<td>0.0106%</td>
</tr>
<tr>
<td>Total income</td>
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<td>0.0135%</td>
<td>0.0163%</td>
</tr>
<tr>
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<td>0.0987%</td>
</tr>
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<td>0.0635%</td>
<td>0.0645%</td>
<td>0.0429%</td>
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</table>
Table A8.4 Results of a removal of subsidies in the rubber sector, % change compared to base case (Table A8.1)

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<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil conservation on smallholdings, tea sector</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.0207%</td>
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</tr>
<tr>
<td>Labor input</td>
<td>0.0764%</td>
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<tr>
<td>Capital input</td>
<td>0.0191%</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Soil quality index</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tea</td>
<td>0.0052%</td>
<td>0.0054%</td>
<td>0.0055%</td>
<td>0.0057%</td>
</tr>
<tr>
<td>Rubber</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
</tr>
<tr>
<td>Coco</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
</tr>
<tr>
<td>Prices</td>
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</tr>
<tr>
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<td>-0.0140%</td>
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<td>-0.0243%</td>
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<tr>
<td>Urban labor</td>
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<td>-0.0264%</td>
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<tr>
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<td>-0.0230%</td>
<td>-0.0139%</td>
</tr>
<tr>
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<td>-0.0136%</td>
<td>-0.0188%</td>
<td>-0.0261%</td>
<td>-0.0173%</td>
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<tr>
<td>Production</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tea</td>
<td>0.0391%</td>
<td>0.0496%</td>
<td>0.0580%</td>
<td>0.0426%</td>
</tr>
<tr>
<td>Rubber</td>
<td>0.0246%</td>
<td>0.0368%</td>
<td>0.0458%</td>
<td>0.0196%</td>
</tr>
<tr>
<td>Coco</td>
<td>0.0124%</td>
<td>0.0168%</td>
<td>0.0195%</td>
<td>0.0066%</td>
</tr>
<tr>
<td>Colombo</td>
<td>0.0095%</td>
<td>0.0116%</td>
<td>0.0129%</td>
<td>0.0000%</td>
</tr>
<tr>
<td>Paddy</td>
<td>0.0077%</td>
<td>0.0090%</td>
<td>0.0099%</td>
<td>0.0000%</td>
</tr>
<tr>
<td>Other agri</td>
<td>0.0068%</td>
<td>0.0088%</td>
<td>0.0095%</td>
<td>0.0053%</td>
</tr>
<tr>
<td>Mining</td>
<td>0.0108%</td>
<td>0.0138%</td>
<td>0.0152%</td>
<td>0.0033%</td>
</tr>
<tr>
<td>Trade</td>
<td>0.0137%</td>
<td>0.0164%</td>
<td>0.0196%</td>
<td>-0.0073%</td>
</tr>
<tr>
<td>Service</td>
<td>0.0093%</td>
<td>0.0156%</td>
<td>0.0221%</td>
<td>0.0206%</td>
</tr>
<tr>
<td>Petroleum</td>
<td>0.0152%</td>
<td>0.0255%</td>
<td>0.0348%</td>
<td>0.0345%</td>
</tr>
<tr>
<td>Electricity</td>
<td>0.0206%</td>
<td>0.0391%</td>
<td>0.0470%</td>
<td>0.0593%</td>
</tr>
<tr>
<td>Disposable income</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Urban HH</td>
<td>0.0460%</td>
<td>0.0528%</td>
<td>0.0591%</td>
<td>0.0561%</td>
</tr>
<tr>
<td>Rural HH</td>
<td>-0.0122%</td>
<td>-0.0162%</td>
<td>-0.0187%</td>
<td>-0.0141%</td>
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<tr>
<td>Estate HH</td>
<td>0.0081%</td>
<td>0.0054%</td>
<td>0.0029%</td>
<td>0.0050%</td>
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<td>Total income</td>
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</tr>
<tr>
<td>Trade balance</td>
<td>0.0585%</td>
<td>-0.0347%</td>
<td>0.0430%</td>
<td>0.0538%</td>
</tr>
<tr>
<td>GDP</td>
<td>0.0231%</td>
<td>0.0253%</td>
<td>0.0267%</td>
<td>0.0200%</td>
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Table A8.5 Results of a removal of subsidies in the coconut sector, % change compared to base case (Table A8.1)

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<td>Soil conservation on smallholdings, tea sector</td>
<td></td>
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</tr>
<tr>
<td>Total</td>
<td>0.0059%</td>
<td></td>
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</tr>
<tr>
<td>Labor input</td>
<td>0.0764%</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Capital input</td>
<td>0.0064%</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Soil quality index</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tea</td>
<td>0.0015%</td>
<td>0.0015%</td>
<td>0.0016%</td>
<td>0.0016%</td>
</tr>
<tr>
<td>Rubber</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
</tr>
<tr>
<td>Coco</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
</tr>
<tr>
<td>Prices</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Estate labor</td>
<td>-0.0058%</td>
<td>-0.0070%</td>
<td>-0.0093%</td>
<td>-0.0062%</td>
</tr>
<tr>
<td>Urban labor</td>
<td>-0.0039%</td>
<td>-0.0067%</td>
<td>-0.0088%</td>
<td>-0.0070%</td>
</tr>
<tr>
<td>Rural labor</td>
<td>-0.0050%</td>
<td>-0.0054%</td>
<td>-0.0081%</td>
<td>-0.0054%</td>
</tr>
<tr>
<td>Capital</td>
<td>-0.0063%</td>
<td>-0.0071%</td>
<td>-0.0091%</td>
<td>-0.0074%</td>
</tr>
<tr>
<td>Production</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tea</td>
<td>0.0162%</td>
<td>0.0192%</td>
<td>0.0213%</td>
<td>0.0177%</td>
</tr>
<tr>
<td>Rubber</td>
<td>0.0095%</td>
<td>0.0134%</td>
<td>0.0168%</td>
<td>0.0082%</td>
</tr>
<tr>
<td>Coco</td>
<td>0.0053%</td>
<td>0.0059%</td>
<td>0.0073%</td>
<td>0.0025%</td>
</tr>
<tr>
<td>Colombo</td>
<td>0.0039%</td>
<td>0.0045%</td>
<td>0.0048%</td>
<td>0.0000%</td>
</tr>
<tr>
<td>Paddy</td>
<td>0.0031%</td>
<td>0.0035%</td>
<td>0.0035%</td>
<td>0.0000%</td>
</tr>
<tr>
<td>Other agri</td>
<td>0.0028%</td>
<td>0.0034%</td>
<td>0.0035%</td>
<td>0.0024%</td>
</tr>
<tr>
<td>Mining</td>
<td>0.0054%</td>
<td>0.0052%</td>
<td>0.0067%</td>
<td>0.0016%</td>
</tr>
<tr>
<td>Trade</td>
<td>0.0056%</td>
<td>0.0065%</td>
<td>0.0072%</td>
<td>-0.0032%</td>
</tr>
<tr>
<td>Service</td>
<td>0.0038%</td>
<td>0.0056%</td>
<td>0.0075%</td>
<td>0.0085%</td>
</tr>
<tr>
<td>Petroleum</td>
<td>0.0065%</td>
<td>0.0091%</td>
<td>0.0116%</td>
<td>0.0140%</td>
</tr>
<tr>
<td>Electricity</td>
<td>0.0091%</td>
<td>0.0129%</td>
<td>0.0149%</td>
<td>0.0244%</td>
</tr>
<tr>
<td>Disposable income</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Urban HH</td>
<td>0.0189%</td>
<td>0.0204%</td>
<td>0.0216%</td>
<td>0.0215%</td>
</tr>
<tr>
<td>Rural HH</td>
<td>-0.0050%</td>
<td>-0.0061%</td>
<td>-0.0066%</td>
<td>-0.0056%</td>
</tr>
<tr>
<td>Estate HH</td>
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<td>0.0007%</td>
<td>0.0019%</td>
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<td>0.0021%</td>
<td>0.0025%</td>
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<td>0.0119%</td>
<td>0.0214%</td>
</tr>
<tr>
<td>GDP</td>
<td>0.0095%</td>
<td>0.0099%</td>
<td>0.0099%</td>
<td>0.0074%</td>
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Table A8.6 Results of a 1% increase in the price of energy, % change compared to base case (Table A8.1)

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<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.0000%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor input</td>
<td>0.0000%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital input</td>
<td>0.0000%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil quality index</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tea</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
</tr>
<tr>
<td>Rubber</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
</tr>
<tr>
<td>Coco</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
</tr>
<tr>
<td>Prices</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estate labor</td>
<td>0.0000%</td>
<td>0.7367%</td>
<td>1.2966%</td>
<td>9.9871%</td>
</tr>
<tr>
<td>Urban labor</td>
<td>0.0000%</td>
<td>-2.7908%</td>
<td>-5.0437%</td>
<td>5.2465%</td>
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<td>Rural labor</td>
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<td>-1.6557%</td>
<td>-2.9247%</td>
<td>6.6145%</td>
</tr>
<tr>
<td>Production</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Tea</td>
<td>0.0000%</td>
<td>1.8744%</td>
<td>3.3900%</td>
<td>-10.7754%</td>
</tr>
<tr>
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<td>0.0000%</td>
<td>2.2072%</td>
<td>4.4206%</td>
<td>-4.2010%</td>
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<tr>
<td>Coco</td>
<td>0.0000%</td>
<td>0.8754%</td>
<td>1.7234%</td>
<td>-0.7381%</td>
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<tr>
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<td>0.0000%</td>
<td>0.8630%</td>
<td>1.9215%</td>
<td>4.6700%</td>
</tr>
<tr>
<td>Paddy</td>
<td>0.0000%</td>
<td>0.6941%</td>
<td>1.5434%</td>
<td>3.5679%</td>
</tr>
<tr>
<td>Other agri</td>
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<td>0.7885%</td>
<td>1.7581%</td>
<td>0.7072%</td>
</tr>
<tr>
<td>Mining</td>
<td>0.0000%</td>
<td>0.9253%</td>
<td>1.9707%</td>
<td>2.7454%</td>
</tr>
<tr>
<td>Trade</td>
<td>0.0000%</td>
<td>1.9254%</td>
<td>4.2804%</td>
<td>11.9910%</td>
</tr>
<tr>
<td>Service</td>
<td>0.0000%</td>
<td>5.9604%</td>
<td>12.1629%</td>
<td>4.5138%</td>
</tr>
<tr>
<td>Petroleum</td>
<td>0.0000%</td>
<td>13.2931%</td>
<td>22.6948%</td>
<td>9.2019%</td>
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<tr>
<td>Electricity</td>
<td>0.0000%</td>
<td>33.1667%</td>
<td>39.0729%</td>
<td>13.7327%</td>
</tr>
<tr>
<td>Disposable income</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban HH</td>
<td>0.0000%</td>
<td>-0.1432%</td>
<td>1.1828%</td>
<td>1.5413%</td>
</tr>
<tr>
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<td>0.0176%</td>
<td>0.8329%</td>
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<td>0.8293%</td>
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<td>8.1303%</td>
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<tr>
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<td>0.0000%</td>
<td>0.9810%</td>
<td>3.3255%</td>
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<td>164.4284%</td>
<td>62.1032%</td>
<td>28.2731%</td>
</tr>
<tr>
<td>GDP</td>
<td>0.0000%</td>
<td>-0.1528%</td>
<td>0.0558%</td>
<td>5.6635%</td>
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Table A8.7 Results of a 3% increase in the price of energy, % change compared to base case (Table A8.1)

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<tbody>
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<td>Soil conservation on smallholdings tea sector</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.0000%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor input</td>
<td>0.0000%</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Capital input</td>
<td>0.0000%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil quality index</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tea</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
</tr>
<tr>
<td>Rubber</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
</tr>
<tr>
<td>Coco</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
</tr>
<tr>
<td>Prices</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Estate labor</td>
<td>0.0000%</td>
<td>1.6376%</td>
<td>1.0951%</td>
<td>32.7127%</td>
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<td>-8.4865%</td>
<td>-16.3754%</td>
<td>22.2795%</td>
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<td>0.0000%</td>
<td>-5.2716%</td>
<td>-10.7310%</td>
<td>24.1228%</td>
</tr>
<tr>
<td>Production</td>
<td></td>
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</tr>
<tr>
<td>Tea</td>
<td>0.0000%</td>
<td>6.5479%</td>
<td>15.2788%</td>
<td>-31.5124%</td>
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<td>7.6673%</td>
<td>19.4281%</td>
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<td>24.6900%</td>
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<td>5.8774%</td>
<td>18.7581%</td>
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<td>2.6026%</td>
<td>6.6487%</td>
<td>2.7073%</td>
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<td>61.2397%</td>
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<td>Service</td>
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<td>19.3881%</td>
<td>44.3238%</td>
<td>4.1454%</td>
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<td>Petroleum</td>
<td>0.0000%</td>
<td>43.1695%</td>
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<td>9.8025%</td>
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<tr>
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<td>0.0000%</td>
<td>107.6032%</td>
<td>141.3744%</td>
<td>-1.3795%</td>
</tr>
<tr>
<td>Disposable income</td>
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<td></td>
</tr>
<tr>
<td>Urban HH</td>
<td>0.0000%</td>
<td>-0.2053%</td>
<td>4.9402%</td>
<td>6.8631%</td>
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<td>12.8534%</td>
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<tr>
<td>Estate HH</td>
<td>0.0000%</td>
<td>2.1435%</td>
<td>4.1129%</td>
<td>26.6076%</td>
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<td>0.0000%</td>
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<td>11.7695%</td>
</tr>
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<td>0.0000%</td>
<td>535.240%</td>
<td>226.785%</td>
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<td>GDP</td>
<td>0.0000%</td>
<td>-0.4768%</td>
<td>0.1266%</td>
<td>23.7076%</td>
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Table A8.8 Results of a removal of subsidies in the transportation sector, % change compared to base case (Table A8.1)

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<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Soil conservation on smallholdings tea sector</td>
<td></td>
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</tr>
<tr>
<td>Total</td>
<td>0.3792%</td>
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<tr>
<td>Labor input</td>
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<tr>
<td>Capital input</td>
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</tr>
<tr>
<td>Soil quality index</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Tea</td>
<td>0.0957%</td>
<td>0.0981%</td>
<td>0.1007%</td>
<td>0.1033%</td>
</tr>
<tr>
<td>Rubber</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
</tr>
<tr>
<td>Coco</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
</tr>
<tr>
<td>Prices</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estate labor</td>
<td>-0.2638%</td>
<td>-0.3367%</td>
<td>-0.3994%</td>
<td>-0.3365%</td>
</tr>
<tr>
<td>Urban labor</td>
<td>-0.2089%</td>
<td>-0.3065%</td>
<td>-0.4089%</td>
<td>-0.4230%</td>
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<tr>
<td>Rural labor</td>
<td>-0.2126%</td>
<td>-0.2902%</td>
<td>-0.3695%</td>
<td>-0.3243%</td>
</tr>
<tr>
<td>Capital</td>
<td>-0.2430%</td>
<td>-0.3281%</td>
<td>-0.4154%</td>
<td>-0.3859%</td>
</tr>
<tr>
<td>Production</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tea</td>
<td>0.7165%</td>
<td>0.8599%</td>
<td>0.9706%</td>
<td>0.9062%</td>
</tr>
<tr>
<td>Rubber</td>
<td>0.4753%</td>
<td>0.6191%</td>
<td>0.7477%</td>
<td>0.4619%</td>
</tr>
<tr>
<td>Coco</td>
<td>0.2270%</td>
<td>0.2843%</td>
<td>0.3182%</td>
<td>0.1611%</td>
</tr>
<tr>
<td>Colombo</td>
<td>0.1730%</td>
<td>0.2021%</td>
<td>0.2164%</td>
<td>0.0000%</td>
</tr>
<tr>
<td>Paddy</td>
<td>0.1373%</td>
<td>0.1620%</td>
<td>0.1690%</td>
<td>0.0010%</td>
</tr>
<tr>
<td>Other agri</td>
<td>0.1258%</td>
<td>0.1526%</td>
<td>0.1603%</td>
<td>0.1194%</td>
</tr>
<tr>
<td>Mining</td>
<td>0.1989%</td>
<td>0.2370%</td>
<td>0.2598%</td>
<td>0.0805%</td>
</tr>
<tr>
<td>Trade</td>
<td>0.2494%</td>
<td>0.2869%</td>
<td>0.3243%</td>
<td>-0.1604%</td>
</tr>
<tr>
<td>Service</td>
<td>0.1708%</td>
<td>0.2560%</td>
<td>0.3459%</td>
<td>0.4586%</td>
</tr>
<tr>
<td>Petroleum</td>
<td>0.2767%</td>
<td>0.4092%</td>
<td>0.5345%</td>
<td>0.7717%</td>
</tr>
<tr>
<td>Electricity</td>
<td>0.3715%</td>
<td>0.5851%</td>
<td>0.7009%</td>
<td>1.3542%</td>
</tr>
<tr>
<td>Disposable income</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban HH</td>
<td>0.8389%</td>
<td>0.9137%</td>
<td>0.9783%</td>
<td></td>
</tr>
<tr>
<td>Rural HH</td>
<td>-0.2228%</td>
<td>-0.2721%</td>
<td>-0.3003%</td>
<td></td>
</tr>
<tr>
<td>Estate HH</td>
<td>0.1496%</td>
<td>0.0970%</td>
<td>0.0448%</td>
<td></td>
</tr>
<tr>
<td>Total income</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trade balance</td>
<td>1.0523%</td>
<td>-1.0704%</td>
<td>0.5671%</td>
<td>1.2535%</td>
</tr>
<tr>
<td>GDP</td>
<td>0.4224%</td>
<td>0.4412%</td>
<td>0.4477%</td>
<td>0.3813%</td>
</tr>
</tbody>
</table>
Table A8.9 Results of a 10% increase in taxes in the Colombo Industrial sector, % change compared to base case (Table A8.1)

<table>
<thead>
<tr>
<th>Period</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil conservation on smallholdings tea sector</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.2637%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor input</td>
<td>0.3056%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital input</td>
<td>0.2446%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil quality index</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tea</td>
<td>0.0665%</td>
<td>0.0682%</td>
<td>0.0700%</td>
<td>0.0719%</td>
</tr>
<tr>
<td>Rubber</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
</tr>
<tr>
<td>Coco</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
<td>0.0000%</td>
</tr>
<tr>
<td>Prices</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estate labor</td>
<td>-0.1832%</td>
<td>-0.2252%</td>
<td>-0.2582%</td>
<td>-0.2052%</td>
</tr>
<tr>
<td>Urban labor</td>
<td>-0.1442%</td>
<td>-0.2013%</td>
<td>-0.2567%</td>
<td>-0.2482%</td>
</tr>
<tr>
<td>Rural labor</td>
<td>-0.1471%</td>
<td>-0.1917%</td>
<td>-0.2337%</td>
<td>-0.1916%</td>
</tr>
<tr>
<td>Capital</td>
<td>-0.1687%</td>
<td>-0.2164%</td>
<td>-0.2626%</td>
<td>-0.2293%</td>
</tr>
<tr>
<td>Production</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tea</td>
<td>0.4951%</td>
<td>0.5770%</td>
<td>0.6334%</td>
<td>0.5687%</td>
</tr>
<tr>
<td>Rubber</td>
<td>0.3276%</td>
<td>0.4116%</td>
<td>0.4791%</td>
<td>0.2742%</td>
</tr>
<tr>
<td>Coco</td>
<td>0.1570%</td>
<td>0.1895%</td>
<td>0.2054%</td>
<td>0.0962%</td>
</tr>
<tr>
<td>Colombo</td>
<td>0.1196%</td>
<td>0.1366%</td>
<td>0.1423%</td>
<td>0.0000%</td>
</tr>
<tr>
<td>Paddy</td>
<td>0.0950%</td>
<td>0.1093%</td>
<td>0.1110%</td>
<td>0.0005%</td>
</tr>
<tr>
<td>Other agri</td>
<td>0.0870%</td>
<td>0.1027%</td>
<td>0.1049%</td>
<td>0.0746%</td>
</tr>
<tr>
<td>Mining</td>
<td>0.1374%</td>
<td>0.1591%</td>
<td>0.1704%</td>
<td>0.0493%</td>
</tr>
<tr>
<td>Trade</td>
<td>0.1724%</td>
<td>0.1939%</td>
<td>0.2118%</td>
<td>-0.1031%</td>
</tr>
<tr>
<td>Service</td>
<td>0.1181%</td>
<td>0.1678%</td>
<td>0.2170%</td>
<td>0.2735%</td>
</tr>
<tr>
<td>Petroleum</td>
<td>0.1914%</td>
<td>0.2643%</td>
<td>0.3308%</td>
<td>0.4553%</td>
</tr>
<tr>
<td>Electricity</td>
<td>0.2568%</td>
<td>0.3621%</td>
<td>0.4232%</td>
<td>0.7934%</td>
</tr>
<tr>
<td>Disposable income</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban HH</td>
<td>0.5803%</td>
<td>0.6159%</td>
<td>0.6395%</td>
<td>0.6681%</td>
</tr>
<tr>
<td>Rural HH</td>
<td>-0.1541%</td>
<td>-0.1807%</td>
<td>-0.1923%</td>
<td>-0.1773%</td>
</tr>
<tr>
<td>Estate HH</td>
<td>0.1033%</td>
<td>0.0659%</td>
<td>0.0311%</td>
<td>0.0419%</td>
</tr>
<tr>
<td>Total income</td>
<td>0.0826%</td>
<td>0.0701%</td>
<td>0.0645%</td>
<td>0.0738%</td>
</tr>
<tr>
<td>Trade balance</td>
<td>0.7277%</td>
<td>-0.8821%</td>
<td>0.3084%</td>
<td>0.6993%</td>
</tr>
<tr>
<td>GDP</td>
<td>-0.0160%</td>
<td>-0.0238%</td>
<td>-0.0354%</td>
<td>-0.0906%</td>
</tr>
</tbody>
</table>
**MODEL CODE**

**THE STATIC MODEL OF DEFORESTATION IN COSTA RICA**

---

**General Algebraic Modeling System Compilation**

1 * CRONE - A ONE-PERIOD MODEL OF DEFORESTATION IN COSTA RICA
2 * LAND CLEARING BY SQUATTERS AND LOGGING
3 * ANNNIKA PERSSSON MAY 1993
4
5 OPTION LIMROW=0
6 OPTION LIMCOL=0
7
8 OPTION SOLPRINT=OFF
9
10 OPTION DECIMALS=5
11
12 * ITERLIM=1;
13
14 FILE RES /c:\123\W\CRONE.prn/
15
16 SET T Tradables production sectors
17 /
18  FOREST  FOREST
19  AGRI   AGRICULTURE
20  IND    INDUSTRY /
21
22 ALIAS(T,TT);
23
24 DISPLAY TT;
25
26 SET N Nontradables production sectors
27 /
28  INFRA   INFRASTRUCTURE
29  SERVICE SERVICES /
30
31
32 ALIAS(N,NN);
33
34 DISPLAY NN ;
35
36
37 +++++++++++++++++++++++
38 *++++POLICY VARIABLES+++*
39 +++++++++++++++++++++++
40
41 SCALAR FTAXO Tax on LOGS 0 /0/
42
43 SCALAR DTAXO Tax on DLAND 0 /0.1/
44
45 SCALAR LTAXO Tax on SKILLED LABOR 0 /0/
SCALAR UTAZO Tax on UNSKILLED LABOR 0 /0 /

SCALAR KTAXO Tax on CAPITAL 0 /0 /

PARAMETER TAXO(T) Tax change on tradables 0

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General Algebraic Modeling System Compilation

FOREST 1.000
AGRI 1.000
IND 1.000 /

SCALAR HVALUE Future value per value unit forest today /0.5291631/

*0.2791631/

SCALAR RAU Time preference /1/
SCALAR IRATE /1/

SCALAR PRDEF Definition of property rights SQUATTERS /0/
SCALAR PRDEFF Definition of property rights LOGGING /0/

*+++++++++++++++++++++*
* SUBMODEL FOR CALCULATION OF LOGGING PARAMETERS *
*+++++++++++++++++++++*

SCALAR AVSK INITIAL LOGGING /0.00200/
SCALAR LAB INITIAL LABOR IN LOGGING /0.00093/
SCALAR CAP INITIAL CAPITAL IN LOGGING /0.00126/
SCALAR LSQ INITIAL LABOR IN SQUATTING /0.00180/
SCALAR SQO INITIAL SQUATTING /0.00200/

VARIABLES

BETA LABOR INPUT IN LOGGING
ALPHA CAPITAL INPUT IN LOGGING
fpl RENT PAID TO LOGGERS
fps RENT PAID TO SQUATTERS
GAMMA LABOR INPUT SQUATTING
psq
plog;

EQUATIONS
DELAB
DEFCAP
DEFAVS K
166

96  SQUAT
97  DEFlsq
98  proflog
99  profsq;
100
101  DEFAVSK.. AVSK=E=CAP**ALPHA*LAB**BETA;
102  DEFLAB.. LAB-(1/(BETA*CAP**ALPHA))*(1/(BETA-1))=e=fpl;
103  DEFCAP.. CAP-(1/(ALPHA*LAB**BETA))*(1/(ALPHA-1))=e=fpl;
104  SQUAT.. SQO=e=LSQ**GAMMA;
105  DEFlsq.. GAMMA*LSQ**(GAMMA-1)-1=e=psq;
106  profsq.. sq0-lsq=e=psq;
107  proflog.. avsk-cap-lab=e=plog;

GAMS 2.25.059 386/486 DOS 11/13/96 15:49:44 PAGE 3
General Algebraic Modeling System Compilat
108
109
110  ALPHA.LO=0.00000001;
111  BETA.LO=0.00000001;
112  GAMMA.LO=0.0001;
113
114  ALPHA.L=0.5424;  psq.l=0.0020;
115  BETA.L=0.3878;  plog.l=-0.0019;
116  GAMMA.L=1.0604;  fp1.l=0.00031;
117  fps.l=0.9259;
118
119  MODEL DEF2 /all/;
120
121  SOLVE DEF2 USING NLP MAXIMIZING psq;
122
123  DISPLAY ALPHA.L, BETA.L, GAMMA.L, psq.l, plog.l, fp1.l, fps.l;
124
125  *+++++++++++++++++++++++++++++++++++++++++++++++++++++
126  127  *+++++++++++++++++++++++++++++++++++++++++++++++++++++
128  129  *+++++++++++++++++++++++++++++++++++++++++++++++++++++
130  131  *** BASE DATA +++
132  133  *++++++++++++++++**
134
135  TABLE XTT00(T,TT) Benchmark intermediate inputs of T in T
136
137  FOREST AGRI  IND
138
139  FOREST  0.00027  0.00220  0.03907
140
141  AGRI     0.00035  0.40326  0.24882
142
143  IND      0.01372  0.14052  0.73900
144
145  TABLE XTN00(T,N) Benchmark intermediate inputs of T in N
146
147  INFRA SERVICE
<table>
<thead>
<tr>
<th>Sector</th>
<th>Forest</th>
<th>Agriculture</th>
<th>Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>INFRA</td>
<td>0.00043</td>
<td>0.02934</td>
<td>0.08264</td>
</tr>
<tr>
<td>SERVICE</td>
<td>0.00377</td>
<td>0.06020</td>
<td>0.15460</td>
</tr>
</tbody>
</table>

TABLE XNT00(N,T) Benchmark intermediate inputs of N in T

<table>
<thead>
<tr>
<th>Sector</th>
<th>Forest</th>
<th>Agriculture</th>
<th>Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>INFRA</td>
<td>0.06470</td>
<td>0.06841</td>
<td></td>
</tr>
<tr>
<td>SERVICE</td>
<td>0.14867</td>
<td>0.21596</td>
<td></td>
</tr>
</tbody>
</table>

PARAMETER TTAX00(T) Benchmark tax in T-sectors

<table>
<thead>
<tr>
<th>Sector</th>
<th>Forest</th>
<th>Agriculture</th>
<th>Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>INFRA</td>
<td>0.00251</td>
<td>0.07468</td>
<td></td>
</tr>
<tr>
<td>SERVICE</td>
<td>0.11448</td>
<td>0.00251</td>
<td></td>
</tr>
</tbody>
</table>

PARAMETER NTAX00(N) Benchmark tax in N-sectors

<table>
<thead>
<tr>
<th>Sector</th>
<th>Forest</th>
<th>Agriculture</th>
<th>Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>INFRA</td>
<td>0.05800</td>
<td>0.00251</td>
<td></td>
</tr>
<tr>
<td>SERVICE</td>
<td>0.12763</td>
<td>0.11448</td>
<td></td>
</tr>
</tbody>
</table>

PARAMETER KT00(T) Benchmark allocation of CAPITAL to T-sectors

<table>
<thead>
<tr>
<th>Sector</th>
<th>Forest</th>
<th>Agriculture</th>
<th>Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>INFRA</td>
<td>0.01762</td>
<td>0.20524</td>
<td>0.21675</td>
</tr>
</tbody>
</table>

PARAMETER KN00(N) Benchmark allocation of CAPITAL to N-sectors

<table>
<thead>
<tr>
<th>Sector</th>
<th>Forest</th>
<th>Agriculture</th>
<th>Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>INFRA</td>
<td>0.16330</td>
<td>0.15247</td>
<td>0.15247</td>
</tr>
</tbody>
</table>

PARAMETER UT00(T) Benchmark allocation of UNSKILLED LABOR to T-sectors

<table>
<thead>
<tr>
<th>Sector</th>
<th>Forest</th>
<th>Agriculture</th>
<th>Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>INFRA</td>
<td>0.01414</td>
<td>0.27140</td>
<td>0.15247</td>
</tr>
</tbody>
</table>

PARAMETER UN00(N) Benchmark allocation of UNSKILLED LABOR to N-sectors
PARAMETER LT00(T) Benchmark allocation of SKILLED LABOR to T-sectors

PARAMETER LN00(N) Benchmark allocation of SKILLED LABOR to N-sectors

PARAMETER FLT00(T) Benchmark allocation of LOGS to T-sectors

PARAMETER FLN00(N) Benchmark allocation of LOGS to N-sectors

PARAMETER DLTOO(T) Benchmark allocation of DLAND to T-sectors

PARAMETER DLN00(N) Benchmark allocation of DLAND to N-sectors

PARAMETER XT00(T) Benchmark tradables production level

PARAMETER XN00(N) Benchmark nontradables production level
PARAMETER DT00(T) Benchmark consumption of tradables
/ FOREST 0.01241
AGRI 0.35352
IND 1.44260 /
PARAMETER DN00(N) Benchmark consumption of nontradables
/ INFRA 0.83655
SERVICE 1.12303 /
PARAMETER ZT00(T) Benchmark net export level
/ FOREST 0.00107
AGRI 0.39243
IND -0.96425 /
PARAMETER ANT(N,T) Input of nontradables in tradable sectors;
GAMS 2.25.059 386/486 DOS 11/13/96 15:49:44 PAGE 6
General Algebraic Modeling System Compilation
ANT(N,T)=XNT00(N,T)/XT00(T);
PARAMETER ANN(NN,N) Input of nontradables in nontradables sectors;
ANN(N,NN)=XNN00(N,NN)/XN00(NN);
PARAMETER TTX00(TT) Unit tax in tradable sectors;
TTX00(T)=TTX00(T)/XT00(T)*TAX0(T);
PARAMETER NTX00(NN) Unit tax in nontradable sectors;
NTX00(N)=NTX00(N)/XN00(N);
PARAMETER KKT00(TT) Benchmark input coefficients for CAPITAL;
KKT00(T)=KK00(T)/XT00(T);
PARAMETER KKN00(NN) Benchmark input coefficients for CAPITAL;
KKN00(N)=KN00(N)/XN00(N);
PARAMETER UXT00(TT) Benchmark input coefficients for UNSKILLED LABOR;
UXT00(T)=UT00(T)/XT00(T);
PARAMETER UXNO(NN) Benchmark input coefficients for UNSKILLED LABOR;
UXNO(N) = UNO0(N)/XNO0(N);
PARAMETER LXT0(TT) Benchmark input coefficients for SKILLED LABOR;
LXT0(T) = LTO0(T)/XT00(T);
PARAMETER LXNO(NN) Benchmark input coefficients for SKILLED LABOR;
LXNO(N) = LN00(N)/XNO0(N);
PARAMETER FXNO(NN) Benchmark input coefficients for LOGS;
FXNO(N) = FLNO0(N)/XNO0(N);
PARAMETER FXTO(TT) Benchmark input coefficients for LOGS;
FXTO('FOREST') = FLOT00('FOREST')/XT00('FOREST');
PARAMETER DXNO(NN) Benchmark input coefficients for DLAND;
DXNO(N) = DNO0(N)/XNO0(N);
PARAMETER DXTO(TT) Benchmark input coefficients for DLAND;
DXTO(T) = DTO0(T)/XT00(T);
PARAMETER AT(T) Tradable production function scale parameter;
AT(TT) = 1 - SUM(T, ATT(T, TT)) - SUM(N, ANT(N, TT)) - TTAX0(TT);
DISPLAY AT;
PARAMETER AN(N) Nontradable production function scale parameter;
AN(NN) = 1 - SUM(T, ATN(T, NN)) - SUM(N, ANN(N, NN)) - NTAX0(NN);
DISPLAY AN;
PARAMETER DELKRT(TT) CAPITAL share in tradable KD;
DELKRT(T) = KT00(T)/(KT00(T) + DLT00(T));
PARAMETER DELDRT(TT);
DELDRT(T) = 1 - DELKRT(T);
PARAMETER DELKRN(NN) CAPITAL share in nontradable KD;
DELKRN(N) = KNO0(N)/(KNO0(N) + DLNO0(N));
PARAMETER DELDRN(NN);
DELDRN(N) = 1 - DELKRN(N);
PARAMETER DELFMT(TT) LOGS share in tradable FR;
DELFMT(T) = FLOT00(T)/(FLOT00(T) + DLT00(T) + KT00(T));
PARAMETER DELRMT(TT);
PARAMETER DLRT(T) = 1 - DELFR(T);

PARAMETER DELFM(N) LOGS share in nontradable FR substitution;
   DELFM(N) = FLNOO(N) / (FLNOO(N) + DLNOO(N) + KNOO(N));

PARAMETER DELRM(N);  
   DELRM(N) = 1 - DELFM(N);

PARAMETER DELUVT(T) UNSKILLED LABOR share in tradable UV;
   DELUVT(T) = UT00(T) / (UT00(T) + FLT00(T) + DLT00(T) + KTO0(T));

PARAMETER DELMVT(T);  
   DELMVT(T) = 1 - DELUVT(T);

PARAMETER DELUVN(N) UNSKILLED LABOR share in nontradable UV;
   DELUVN(N) = UNO0(N) / (UNO0(N) + FLNOO(N) + DLNOO(N) + KNOO(N));

PARAMETER DELMVN(N);  
   DELMV(N) = 1 - DELUVN(N);

PARAMETER DELLYT(T) SKILLED LABOR share in tradable LV;
   DELLYT(T) = LT00(T) / (LT00(T) + UT00(T) + FLT00(T) + DLT00(T) + KTO0(T));

PARAMETER DELLYT(T);  
   DELLY(T) = 1 - DELLYT(T);

PARAMETER DELLYN(N) SKILLED LABOR share in nontradable LV;
   DELLYN(N) = LNO0(N) / (LNO0(N) + UNO0(N) + DLNO0(N) + FLNO0(N) + KNO0(N));

PARAMETER BT(T) B-coefficient in U;
   BT(T) = DT00(T) / (SUM(T, DT00(T)) + SUM(N, DN00(N)));

PARAMETER BN(N) B-coefficient in U;
   BN(N) = DN00(N) / (SUM(T, DT00(T)) + SUM(N, DN00(N)));

PARAMETER K0 CAPITAL endowment 0;
   K0 = 1.12980;

PARAMETER U0 UNSKILLED LABOR endowment 0;
   U0 = .76006;

PARAMETER L0 SKILLED LABOR endowment 0;
PARAMETER DSTAR DLAND endowment 0;
  DSTAR=0.20524;

PARAMETER SBARO current account surplus 0;
  SBAR0=-0.57075;

PARAMETER UTILOO ;

UTIL00=LOG(PROD(T, (BT(T)*3.76811)**BT(T)) * PROD(N, (BN(N)*3.76811))

**BN(N));

DISPLAY UTILOO;

*++++++++++++++++++++++++++++++++++
*+++ELASTICITIES OF SUBSTITUTION+++*++++++++++++++++++++++++++++++++++

PARAMETER SIGRT(T) Elasticity of tradable KD substitution

/ FOREST  0
  AGRI  0.500
  IND   0  /

PARAMETER SIGRN(N) Elasticity of nontradable KD substitution

/ INFRA  0
  SERVICE 0  /

PARAMETER SIGMT(T) Elasticity of tradable FR substitution

/ FOREST  0.800
  AGRI  0
  IND   0  /

PARAMETER SIGMN(N) Elasticity of nontradable FR substitution

/ INFRA  0
  SERVICE 0  /

PARAMETER SIGVT(T) Elasticity of tradable UY substitution

/ FOREST  0.800
  AGRI  0.800

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PARAMETER EPSI(N)  Price elasticity of export demand
/ INFRA  0.800
  SERVICE  0.800 /

PARAMETER SIGYN(N)  Elasticity of nontradable LV substitution
/ INFRA  0.800
  SERVICE  0.800 /

PARAMETER SIGYT(T)  Elasticity of tradable LV substitution
/ FOREST  0.800
  AGRI  0.800
  IND  0.800 /

PARAMETER SIGYN(N)  Elasticity of nontradable LV substitution
/ INFRA  0.800
  SERVICE  0.800 /

PARAMETER EPSI(N)  Price elasticity of export demand
/ INFRA  -5.000
  SERVICE  -5.000 /

PARAMETER MY(N)  Price elasticity of import demand
/ INFRA  2.000
  SERVICE  2.000 /

PARAMETER PW(T)  World market price of tradables
/ FOREST  1.0000
  AGRI  1.0000
  IND  1.0000 /

PARAMETER PWE(N)  World market price of nontradables
/ INFRA  1.0000
  SERVICE  1.0000 /

PARAMETER ZNO(N)  Export function constant
/ INFRA  0.02746 /

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**++VARIABLES+++**

**+++++++++++++++**

VARIABLES

UTIL0  UTILITY PERIOD 0

DISP0  DISPOSABLE INCOME PERIOD 0

DOSQ0  DLAND produced by deforestation 0

FOSQ0  LOGS deforested 0

FLOG0  LOGGING 0

LSQ0  UNSKILLED LABOR input in deforestation by SQUATTERS 0

LOGL0  UNSKILLED LABOR input in deforestation by LOGGERS

LGK0  CAPITAL input in deforestation by LOGGERS

FEXP0  Net export of LOGS

F0  Deforestation

D0  Supply of DLAND

PUDLO  User price of DLAND

PFL0  Supply price of LOGS including future value

PUFL0  User price of LOGS including future value and taxes

PUK0  User price of CAPITAL

PUU0  User price of SKILLED LABOR

PUU0  User price of UNSKILLED LABOR

XT0(T)  Output in tradable sectors

XN0(N)  Output in non-tradable sectors

ZT0(T)  Net export of tradables

DT0(T)  Consumption demand for tradables

DN0(N)  Consumption demand for nontradables

KT0(T)  CAPITAL input in tradable sectors
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529 KN0(N) CAPITAL input in nontradable sectors

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531 UT0(T) UNSKILLED LABOR demand in tradable sectors

532 UN0(N) UNSKILLED LABOR demand in non-tradable sectors

533 LLT0(T) SKILLED LABOR demand in tradable sectors

534 LN0(N) SKILLED LABOR demand in non-tradable sectors

535 FLT0(T) LOGS demand in tradable sectors

536 DLT0(T) DLAND demand in tradable sectors

537 MCT0(T) Marginal cost in tradable production

538 MCN0(N) Marginal cost in nontradable production

539 PPNO(N) Producer price of nontradable output

540 FN0(N) User price of composite nontradables

541 FYT0(T) Implicit price of Y(T)

542 FYNO(N) Implicit price of Y(N)

543 FVT0(T) Implicit price of V(T)

544 FVNO(N) Implicit price of V(N)

545 FMTO(T) Implicit price of M(T)

546 FMNO(N) Implicit price of M(N)

547 FRTO(T) Implicit price of R(T)

548 FRNO(N) Implicit price of R(N)

549 PK0 Supply price of CAPITAL services

550 PU0 Supply price of UNSKILLED LABOR services

551 PL0 Supply price of SKILLED LABOR services

552 PDLO Supply price of DLAND services

553 DPXDPUT0(T) Partial of PX wrt PUU(T)

554 DPXDPUN0(N) Partial of PX wrt PUU(N)
DPXDPLTO(T) Partial of PX wrt PUL(T)
DPXDPLNO(N) Partial of PX wrt PUL(N)
DPXDPKTO(T) Partial of PX wrt PUK(T)
DPXDPKNO(N) Partial of PX wrt PUK(N)
DPXDPFTO(T) Partial of PX wrt PUFL(T)
DPXDPFNO(N) Partial of PX wrt PUFL(N)
DPXDPDTO(T) Partial of PX wrt PUDL(T)
DPXDPDNO(N) Partial of PX wrt PUDL(N)
DPYDPVT0(T) Partial of PY wrt PV(T)
DPYDPVN0(N) Partial of PY wrt PV(N)
DPYDPULT0(T) Partial of PY wrt PUL(T)
DPYDPULN0(N) Partial of PY wrt PUL(N)
DPVPDPMTO(T) Partial of PV wrt PM(T)
DPVPDPMNO(N) Partial of PV wrt PM(N)
DPVPDPUT0(T) Partial of PV wrt PUU(T)
DPVPDPUUN0(N) Partial of PV wrt PUU(N)
DPMDPRT0(T) Partial of PM wrt PR(T)
DPMDPRN0(N) Partial of PM wrt PR(N)
DPMDFPT0(T) Partial of PM wrt PUFL(T)
DPMDFPN0(N) Partial of PM wrt PUFL(N)
DPRDPKT0(T) Partial of PR wrt PUK(T)
DPRDPKNO(N) Partial of PR wrt PUK(N)
DPRDPDT0(T) Partial of PR wrt PUDL(T)
DPRDPDNO(N) Partial of PR wrt PUDL(N)
DEFUTILO  Definition of UTILO
DEFDOSQ0  Definition of DOSQ
DEFLSQ0  Definition of LSQ
DEFLOGF0  Definition of FLOG
DEFLOGL0  Definition of LOGL
DEFLGK0  Definition of LGK
PRLF0  Price condition LOGS
COMPLF0  Complementary condition LOGS
DEFF0  Definition of total deforestation
DEFD0  Definition of supply of DLAND
DEFPUDL0  Definition of PUDL
DEFPUFL0  Definition of PUFL
DEFPUK0  Definition of PUK
DEFPUL0  Definition of PUL
DEFPUU0  Definition of PUU
DEFPYT0(T)  Definition of PYT
DEFPYN0(N)  Definition of PYN
DEFPVTO(T)  Definition of PVT
DEFPVNO(N)  Definition of PVN
DEFPMT0(T) Definition of PMT
DEFPMNO(N) Definition of PMN
DEFRPT0(T) Definition of PRT
DEFPRNO(N) Definition of PRN
DDPYDPLT0(T) Definition of DPYDPLT
DDPYDPLN0(N) Definition of DPYDPLN
DDPYDPVTO(T) Definition of DPYDPVT
DDPYDPVN0(N) Definition of DPYDPVN
DDFVDPUT0(T) Definition of DFVDPUT
DDFVDPUN0(N) Definition of DFVDPUN
DDFVDPMT0(T) Definition of DFVDPMT
DDFVDPMN0(N) Definition of DFVDPMN
DDPM_DPRT0(T) Definition of DPM_DPRT
DDPM_DPNO(N) Definition of DPM_DPNO
DDPM_DPFT0(T) Definition of DPM_DPFT
DDPM_DPBN0(N) Definition of DPM_DPBN
DDPRDPKT0(T) Definition of DPRDPKT
DDPRDPKN0(N) Definition of DPRDPKN
DDPRDPDT0(T) Definition of DPRDPDT
DDPRDPDN0(N) Definition of DPRDPDN
DDPXDPDT0(T) Definition of DFXDPDT
DDPXDPDN0(N) Definition of DFXDPDN
DDPXDPFT0(T) Definition of DFXDPFT
DDPXDPFN0(N) Definition of DFXDPFN
DDPXDPKT0(T) Definition of DFXDPKT
DDPXDPKN\( (N) \) Definition of \( DPXDPKN \)

DDPXDPLT\( (T) \) Definition of \( DPXDPLT \)

DDPXDPLN\( (N) \) Definition of \( DPXDPLN \)

DDPXDPUT\( (T) \) Definition of \( DPXDPUT \)

DDPXDPUN\( (N) \) Definition of \( DPXDPUN \)

DEFMCT\( (T) \) Definition of marginal cost in tradables prod

DEFMCN\( (N) \) Definition of marginal cost in nontradables prod

DEFPN\( (N) \) Definition of user price of nontradables

PRLMCT\( (T) \) Producer price marginal cost inequality condition

COMPLO\( (T) \) Complementary condition for tradables

PREMCN0 Producer price marginal cost equality condition

LDEMAND\( (T) \) Tradable demand for SKILLED LABOR

LDEMANDN\( (N) \) Nontradable demand for SKILLED LABOR

UDEMAND\( (T) \) Tradable demand for UNSKILLED LABOR

UDEMANDN\( (N) \) Nontradable demand for UNSKILLED LABOR

FDEMAND\( (T) \) Tradable demand for LOGS

KDEMAND\( (T) \) Tradable demand for CAPITAL

KDEMANDN\( (N) \) Nontradable demand for CAPITAL

DDEMAND\( (T) \) Tradable demand for DLAND

TCONSO\( (T) \) Consumption demand for tradables

NCONSO\( (N) \) Consumption demand for nontradables

TMARKETO\( (T) \) Market clearing for tradables

NMARKETO\( (N) \) Market clearing for nontradables

FMARKETO Market clearing for LOGS
Complementary condition DLAND
Market clearing for DLAND
Market clearing for CAPITAL
Market clearing for SKILLED LABOR
Market clearing for UNSKILLED LABOR
Definition of disposable income;
Definition of GNP

\[
\text{PROD} \left( N, \left( BN(N) \cdot \text{DISPO}/\text{PNO}(N) \right) \right) \cdot BN(N) ;
\]

\[
\text{DEFDOSQO} \cdot \text{DOSQO} = \text{LSQO}^2 \cdot \text{GAMMA} ;
\]

\[
\text{PRDEF} \cdot \text{GAMMA} \cdot \text{HVALUE}/\text{IRATE}
\]

\[
\text{DEFLOGF0} \cdot \text{FLOG0} = \text{LGK0} \cdot \text{ALPHA} \cdot \text{LOGLO} \cdot \text{BETA} ;
\]

\[
\text{DEFLOGLO} \cdot \text{LOGLO} = \left( (\text{PU0} + \text{PRDEFF} \cdot \text{BETA} \cdot \text{LGK0} \cdot \text{ALPHA} \cdot \text{LOGLO} \cdot (\text{BETA} - 1) \right) \cdot \text{LSQ0}^2 \cdot \text{GAMMA} \cdot \text{DLO} \cdot \text{LSQ0}^{2 \cdot \text{GAMMA}} ;
\]

\[
\text{DEFLGKO} \cdot \text{LGK0} = \left( (\text{PKO} + \text{PRDEFF} \cdot \text{ALPHA} \cdot \text{LGK0} \cdot (\text{ALPHA} - 1) \right) \cdot \text{LOGLO} \cdot \text{BETA} ;
\]

\[
\text{**(1/(\text{ALPHA}-1))}
\]

\[
\text{PRLF0} \cdot \text{PWF} - \text{PFL0} = L = 0 ;
\]

\[
\text{COMPLF0} \cdot \text{FLOG0} \cdot (\text{PWF} - \text{PFL0}) = E = 0 ;
\]

\[
\text{DEPPUFL0} \cdot \text{PUFL0} = \text{PWF} \cdot (1 + \text{FTAX0}) ;
\]

\[
\text{DEPPUDLO} \cdot \text{PUDLO} = \text{PDLO} \cdot (1 + \text{DTAX0}) ;
\]
DEFPU0.. PU0=E=PO*(1+KX0);
DEFUL0.. PUL0=E=PL0*(1+LX0);
DEFU0U0.. PUU0=E=PU0*(1+UX0);

DEFPY0(T).. PY0(T)=E=(DELYT(T)*PUL0**) 
           (1-SIGYT(T)) + (1-DELYT(T))*PVT0(T)** 
           (1-SIGYT(T))**(1/(1-SIGYT(T)));

DEFY0N0(N).. PY0(N)=E=(DELNY(N)*PUL0**) 
           (1-SIGNY(N)) + (1-DELNY(N))*PYN0(N)** 
           (1-SIGNY(N))**(1/(1-SIGNY(N)));

DEFPY0(T).. PVT0(T)=E=(DELYT(T)*PUU0***(1-SIGVT(T))+ 
           (1-DELYT(T))*PMT0(T)** 
           (1-SIGVT(T))**(1/(1-SIGVT(T)));

DEFPY0N0(N).. PYN0(N)=E=(DELNY(N)*PUU0***(1-SIGNY(N))+ 
           (1-DELNY(N))*PMN0(N)** 
           (1-SIGNY(N))**(1/(1-SIGNY(N)));

DEFPY0(T).. PMT0(T)=E=(DELFMT(T)*PUU0***(1-SIGMT(T))+ 
           (1-DELFMT(T))*PRM0(T)** 
           (1-SIGMT(T))**(1/(1-SIGMT(T)));

DEFPY0N0(N).. PMN0(N)=E=(DELFMN(N)*PUU0***(1-SIGNMN(N))+ 
           (1-DELFMN(N))*PRN0(N)** 
           (1-SIGNMN(N))**(1/(1-SIGNMN(N)));

DEFPY0(T).. PRM0(T)=E=(DELKRT(T)*PUL0***(1-SIGRT(T))+ 
           (1-DELKRT(T))*PUDLO** 
           (1-SIGRT(T))**(1/(1-SIGRT(T)));
\begin{equation}
\text{DDPRDPDTO(T)} = E = (1 - \text{DELKRT(T)}) \times (\text{PRTO(T)}^{\text{SIGRT(T)}}) \\
\times (\text{PUDLO}^{(-\text{SIGRT(T)})})
\end{equation}

\begin{equation}
\text{DDPRDPMN0(N)} = E = (1 - \text{DELUVN(N)}) \times (\text{PVNO(N)}^{\text{SIGUVN(N)}}) \\
\times (\text{PUDLO}^{(-\text{SIGUVN(N)})})
\end{equation}

\begin{equation}
\text{DDPVDPUTO(T)} = E = \text{DELUV(T)} \times (\text{PTV0(T)}^{\text{SIGUV(T)}}) \\
\times (\text{PUUO}^{(-\text{SIGUV(T)})})
\end{equation}

\begin{equation}
\text{DDPVDPMTO(T)} = E = (1 - \text{DELMT(T)}) \times (\text{PMTO(T)}^{\text{SIGMT(T)}}) \\
\times (\text{PUFLO}^{(-\text{SIGMT(T)})})
\end{equation}

\begin{equation}
\text{DDPRDPKTO(T)} = E = \text{DELKRT(T)} \times (\text{PRTO(T)}^{\text{SIGRT(T)}}) \\
\times (\text{PUK0}^{(-\text{SIGRT(T)})})
\end{equation}

\begin{equation}
\text{DDPRDPDNO(N)} = E = (1 - \text{DELRFN(N)}) \times (\text{PNO(N)}^{\text{SIGRFN(N)}}) \\
\times (\text{PUUO}^{(-\text{SIGRFN(N)})})
\end{equation}

\begin{equation}
\text{DDPVDPMNO(N)} = E = (1 - \text{DELUMN(N)}) \times (\text{PVNO(N)}^{\text{SIGUVN(N)}}) \\
\times (\text{PUFLO}^{(-\text{SIGUVN(N)})})
\end{equation}

\begin{equation}
\text{DDPRDPBT0(T)} = E = \text{AT(T)} \times (\text{DPYDPV0(T)} \times \text{DPVDPMTO(T)} \\
\times \text{DPMDPRTO(T)} \times \text{DPRDPDTO(T)})
\end{equation}

\begin{equation}
\text{DDPRDPN0(N)} = E = \text{AT(N)} \times (\text{DPYDPV0(N)} \times \text{DPVDPMNO(N)} \times \text{DPMDPRNO(N)} \times \text{DPRDPDNO(N)})
\end{equation}

\begin{equation}
\text{DDPVDPMTO0(T)} = E = (1 - \text{DELMT(T)}) \times (\text{PMTO(T)}^{\text{SIGMT(T)}}) \\
\times (\text{PUFLO}^{(-\text{SIGMT(T)})})
\end{equation}

\begin{equation}
\text{DDPRDPKTO(T)} = E = \text{AT(T)} \times (\text{DPYDPV0(T)} \times \text{DPVDPMTO(T)} \times \text{DPMDPRTO(T)} \times \text{DPRDPDTO(T)})
\end{equation}

\begin{equation}
\text{DDPRDPDNO(N)} = E = (1 - \text{DELRFN(N)}) \times (\text{PNO(N)}^{\text{SIGRFN(N)}}) \\
\times (\text{PUFLO}^{(-\text{SIGRFN(N)})})
\end{equation}
\[
\text{DDPXDPKN0}(N) = \text{AN}(N) \cdot \text{DPYDPVNO}(N) \cdot \text{DPVDPMNO}(N) \cdot \text{DPMDPRNO}(N)
\]

\[
\text{DDPXDPFNO}(N) = \text{AN}(N) \cdot \text{DPYDPVNO}(N) \cdot \text{DPVDPMNO}(N) \cdot \text{DPMDPFN0}(N)
\]

\[
\text{DDPXDPFT0}(T) = \text{AT}(T) \cdot \text{DPYDPVTO}(T) \cdot \text{DPVDPMT0}(T) \cdot \text{DPMDPFT0}(T)
\]

\[
\text{DDPXDPUN0}(N) = \text{AN}(N) \cdot \text{DPYDPVNO}(N) \cdot \text{DPVDPUN0}(N) \cdot \text{DPMDPN0}(N)
\]

\[
\text{DDPXDPUNO}(N) = \text{AN}(N) \cdot \text{DPYDPVNO}(N) \cdot \text{DPVDPUN0}(N) \cdot \text{DPMDPFN0}(N)
\]

\[
\text{DDPXDPFT0}(T) = \text{AT}(T) \cdot \text{DPYDPVTO}(T) \cdot \text{DPVDPMT0}(T) \cdot \text{DPMDPFT0}(T)
\]

\[
\text{DDPXDPUN0}(N) = \text{AN}(N) \cdot \text{DPYDPVNO}(N) \cdot \text{DPVDPUN0}(N) \cdot \text{DPMDPN0}(N)
\]

\[
\text{DDPXDPFT0}(T) = \text{AT}(T) \cdot \text{DPYDPVTO}(T) \cdot \text{DPVDPMT0}(T) \cdot \text{DPMDPFT0}(T)
\]

\[
\text{DDPXDPUN0}(N) = \text{AN}(N) \cdot \text{DPYDPVNO}(N) \cdot \text{DPVDPUN0}(N) \cdot \text{DPMDPFN0}(N)
\]

\[
\text{DDPXDPFT0}(T) = \text{AT}(T) \cdot \text{DPYDPVTO}(T) \cdot \text{DPVDPMT0}(T) \cdot \text{DPMDPFT0}(T)
\]

\[
\text{DDPXDPUN0}(N) = \text{AN}(N) \cdot \text{DPYDPVNO}(N) \cdot \text{DPVDPUN0}(N) \cdot \text{DPMDPFN0}(N)
\]

\[
\text{DDPXDPFT0}(T) = \text{AT}(T) \cdot \text{DPYDPVTO}(T) \cdot \text{DPVDPMT0}(T) \cdot \text{DPMDPFT0}(T)
\]

\[
\text{DDPXDPUN0}(N) = \text{AN}(N) \cdot \text{DPYDPVNO}(N) \cdot \text{DPVDPUN0}(N) \cdot \text{DPMDPFN0}(N)
\]
NCONS0 (N) = DN0 (N) = E = BN (N) * DISP0 / PNO (N);

XT0 (T) = E = SUM (T, ATT (T, TT) * XTO (TT) ) + SUM (N, ATN (T, N) * XTO (T)) + SUM (N, ANN (T, N) * XN0 (N)) + DNO (N);

FO = FLOGO + DOSQ0;

UO = SUM (T, UTO (T)) + SUM (N, UNO (N)) + LOGLO + LSQ0;

XNO (N) = SUM (T, ANT (N, T) * XTO (T)) + SUM (N, ANN (N, NN) * XN0 (NN)) + DNO (N);

DO = DSTAR + LSQ0;

SUM (T, PW (T) * ZTO (T)) + PW0 * FEXP0 = SBAR0;

LOGLO + LGKO = SUM (T, FLLO (T)) + PW0 * FEXP0;

SUM (T, DLTO (T)) - DSTAR - LSQ0 = E = 0;

X0 = SUM (T, KTO (T)) + SUM (N, KNO (N)) + LGKO;

LO = SUM (T, LLTO (T)) + SUM (N, LNO (N));

U0 = SUM (T, UTO (T)) + SUM (N, UNO (N)) + LOGLO + LSQ0;

INCOME0 = SUM (T, PW (T) * ZTO (T)) + PW0 * FEXP0 = SBAR0;

PUKO * KO + PULO * LO + PUU0 * UO + PULD0 * DSTAR + SUM (T, TTAXO (T) * XTO (T)) + SUM (N, NTAXO (N) * XN0 (N)) - (DOSQ0 + FLOGO) = YY0;

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\[ PNO.L(N) = 1.000; \]
\[ PYTO.L(T) = 1.000; \]
\[ PVTO.L(T) = 1.000; \]
\[ PMTO.L(T) = 1.000; \]
\[ PRTO.L(T) = 1.000; \]
\[ PLO.L = 1.000; \]
\[ PKO.L = 1.000; \]
\[ PFL0.L = 1.000; \]
\[ PUO.L = 1.000; \]
\[ PDL0.L = 1.000; \]
\[ P0.L = 0.0040; \]
\[ PZTO.L(T) = 3.76811; \]
\[ MCTO.L(T) = 1.000; \]

\[ XTO.L(T) = XT00(T); \]
\[ ZTO.L(T) = ZT00(T); \]
\[ YTO.L = 3.19841; \]
\[ KTO.L(T) = KT00(T); \]
\[ LLTO.L(T) = LT00(T); \]
\[ FLT0.L('FOREST') = 0.00219; \]
\[ UT0.L(T) = UT00(T); \]
\[ DLT0.L('AGRI') = 0.20809; \]
\[ DT0.L(T) = DT00(T); \]
\[ FYNO.L(N) = 1.000; \]

\[ PNO0.L(N) = 1.000; \]
\[ PRNO.L(N) = 1.000; \]
\[ PVNO.L(N) = 1.000; \]
\[ MCNO.L(N) = 1.000; \]
\[ XNO.L(N) = XN00(N); \]

\[ KNO.L(N) = KNO0(N); \]
\[ LNO.L(N) = LN00(N); \]
\[ UNO.L(N) = UN00(N); \]
\[ DNO.L(N) = DN00(N); \]

\[ DPXDPKT0.L(T) = KT00(T); \]
\[ DPXDPKNO.L(N) = KXNO(N); \]
\[ DPXDPFL0.L(T) = LT00(T); \]
\[ DPXDPFLNO.L(N) = LXNO(N); \]
\[ DPXDPUTO.L(T) = UT00(T); \]
\[ DPXDPUN0.L(N) = UXNO(N); \]

\[ DPXDPFT0.L('FOREST') = 0.039655; \]

\[ DPXDPFN0.L(N) = FXNO(N); \]
\[ DPXDPDTO.L('AGRI') = 0.1486931; \]
\[ DPXDPDNO.L(N) = DELYN(N); \]
\[ DPYDPLT0.L(T) = DELYT(T); \]
\[ DPYDPLNO.L(N) = DELYN(N); \]
\[ DPYDPVT0.L(T) = DELVYT(T); \]
\[ DPYDPVNO.L(N) = DELVYN(N); \]
\[ DPVDPUTO.L(T) = DELUVT(T); \]
\[ DPVDPUN0.L(N) = DELUVN(N); \]
1051 \( DPVDPMTO.L(T) = DELMVT(T); \) \( DPVDPMNO.L(N) = DELMVN(N); \)
1052 \( DPMDPFTO.L(T) = DELFMT(T); \) \( DPMDPFNO.L(N) = DELFMN(N); \)
1053 \( DPMDPRT0.L(T) = DELRMT(T); \) \( DPMDPRNO.L(N) = DELRMN(N); \)
1054 \( DPRDPKT0.L(T) = DELKRT(T); \) \( DPRDPPNO.L(N) = DELKRN(N); \)
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General Algebraic Modeling System Compilation

1058 \( DPRDPDT0.L(T) = DELDRT(T); \) \( DPRDPDNO.L(N) = DELDRN(N); \)
1059 \( PPNO.L(N) = 1.000; \)
1060 \( LSQO.L = LSQ; \) \( DOSQO.L = SQO; \) \( D0.L = 0.20809; \)
1061 \( FLOG0.L = AVSK; \) \( LOGL0.L = LAB; \)
1062 \( LGKO.L = CAP; \)
1063 \( UTIL0.L = util00; \)
1064 MODEL CRONE /ALL/;
1065 * CRONE.OPTFILE=1;
1066 SOLVE CRONE USING NLP MAXIMIZING UTIL0;
1067 * SOLVE CRONE USING NLP MAXIMIZING UTIL0;
1068 * SOLVE CRONE USING NLP MAXIMIZING UTIL0;
1069 * SOLVE CRONE USING NLP MAXIMIZING UTIL0;
1070 DISPLAY
1071 util0.l,
1072 XT0.L, ZT0.L, KT0.L, LLT0.L, UT0.L, FLT0.L, DLT0.L,
1073 PK0.L,
1074 FUKO.L,
1075 PUUO.L=1.000;
1076 FULO.L=1.000; PUFL0.L=1.000; PUDL0.L=1.000;
1077 PUL0.L=1.000; PUL0.L=1.000; PUD0.L=1.000;
1078 PULO.L=1.000; PUFLO.L=1.000; PUFLO.L=1.000;
PUT RES;

PUT 'PRDEF SQ ',PRDEF:6 /

PUT 'PRDEF LOG ',PRDEFF:6/;

PUT 'HVALUE ', HVALUE: 6 : 4/

PUT 'IRATE ', IRATE: 6:4//

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General Algebraic Modeling System
Compilation

PUT 'KTAX ', KTAX0: 6/;

PUT 'LTAX ', LTAX0: 6/;

PUT 'UTAX ', UTAX0: 6/;

PUT 'DTAX ', DTAX0: 6/;

PUT 'FTAX ', FTAX0: 6/;

LOOP (T,PUT T.TL;
    PUT TAX0(T):6:4 /);

PUT / 'UTILITY ', UTIL0.L:6:4 /;

PUT 'GNP ', YYYY0.L:6:4 /

PUT 'INCOME ', DISP0.L:6:4 //;

PUT 'PUK ', PU0.L:6:4 /

PUT 'PUU ', PUU0.L:6:4 /

PUT 'PUDL ', PUDLO.L:6:4 /

PUT 'PUFL ', PUFL0.L:6:4 //;

PUT 'DEFORESTATION' /

PUT 'SQUATTERS ', DOSQ0.L:8:5 /

PUT 'LOGGERS ', FLOG0.L:8:5 /

PUT 'TOTAL ', F0.L:8:5 //;

PUT 'STOCK LAND ', D0.L:6:4 //;

PUT 'PRODUCTION' /;

LOOP (T,PUT T.TL;
    PUT X0.L(T):6:4 /));

COMPILATION TIME = 2.640 SECONDS VERID MW2-00-059
**FILE SUMMARY**

<table>
<thead>
<tr>
<th>INPUT</th>
<th>C:\GAMS\DOC\CRONE.GMS</th>
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</thead>
<tbody>
<tr>
<td>OUTPUT</td>
<td>C:\GAMS\DOC\CR1OUT.DOC</td>
</tr>
</tbody>
</table>
MODEL CODE

THE DYNAMIC MODEL OF DEFORESTATION IN COSTA RICA

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General Algebraic Modeling System Compilation

1 * CRTWO - A TWO-PERIOD MODEL OF DEFORESTATION IN COSTA RICA
2 * VERSION 5
3 * LAND CLEARING BY SQUATTERS AND LOGGING
4 * ENDOGENOUS DOMESTIC INTEREST RATE, SAVINGS, INVESTMENTS, AND CAPITAL

FLOWS

5 * ANNIKA PERSSON FEBRUARY 4, 1994
6
7 9 * option domlim=10
8 OPTION LIMROW=O
9 OPTION LIMCOL=O
10 OPTION SOLPRINT=OFF
11 OPTION DECIMALS=4
12
15 PARAMETER low LOWER BOUND VALUE FOR NONLINEAR VARIABLES;
16   LOW=le-5;
17 option ITERLIM=100000;
18 FILE RES /C:\gams\crmod\ftaxo.txt/
19
20 SET T Tradables production sectors
21 / FOREST FOREST
22 AGRI AGRICULTURE
23 IND INDUSTRY /
24 ALIAS(T,TT);
25 DISPLAY TT;
26
27 SET N Nontradables production sectors
28 / INFRA INFRASTRUCTURE
29 SERVICE SERVICES /
30 ALIAS(N,NN);
31 DISPLAY NN ;
32
33 ++++++++++++++++++++++++
34 +++POLICY VARIABLES+++  
35 ++++++++++++++++++++++++  
36
37 SCALAR FTAX0 Tax on LOGS 0 /0/
38 SCALAR FTAX1 1 /0/
39
40 SCALAR DTAX0 Tax on DLAND 0 /0/
41 SCALAR DTAX1 1 /0/
42
43 SCALAR ltax0 Tax on SKILLED LABOR 0 /0/


PARAMETER TAXO(T) Tax change on tradables 0

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General Algebraic Modeling System
Compilation

parameter IRATE World market interest rate;
irate= 1.00;

SCALAR POPGR Annual population growth /0.024/

SCALAR SAVGR Annual Growth of Gross Investments /0/

SCALAR KDEPL Depletion of capital (%) /0.054/
* Source: Costa Rica National Accounts 1980-1988 0.054

PARAMETER TOTDEF Total allowed deforestation;
TOTDEF=100.0001;

INCLUDE C:\GAMS\CRM\SAM.INC

TABLE XTTOO{T,TT} Benchmark intermediate inputs of T in T
FOREST AGRI IND
TABLE XTN00(T,N) Benchmark intermediate inputs of T in N

<table>
<thead>
<tr>
<th>Sector</th>
<th>0.00021</th>
<th>0.00220</th>
<th>0.03907</th>
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<tr>
<td>FOREST</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AGRI</td>
<td>0.00035</td>
<td>0.40326</td>
<td>0.24882</td>
</tr>
<tr>
<td>IND</td>
<td>0.01372</td>
<td>0.14052</td>
<td>0.73900</td>
</tr>
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</table>

TABLE XNT00(N,T) Benchmark intermediate inputs of N in T

<table>
<thead>
<tr>
<th>Sector</th>
<th>0.00022</th>
<th>0.00000</th>
<th>0.34181</th>
<th>0.13432</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOREST</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AGRI</td>
<td>0.00001</td>
<td>0.00003</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IND</td>
<td>0.34181</td>
<td>0.13432</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

PARAMETER TTAX00(T) Benchmark tax in T-sectors

<table>
<thead>
<tr>
<th>Sector</th>
<th>0.00043</th>
<th>0.02934</th>
<th>0.08264</th>
</tr>
</thead>
<tbody>
<tr>
<td>INFRA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SERVICE</td>
<td>0.00377</td>
<td>0.06020</td>
<td>0.15460</td>
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</table>

PARAMETER NTAX00(N) Benchmark tax in N-sectors

<table>
<thead>
<tr>
<th>Sector</th>
<th>0.06470</th>
<th>0.06841</th>
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</thead>
<tbody>
<tr>
<td>INFRA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SERVICE</td>
<td>0.14867</td>
<td>0.21596</td>
</tr>
</tbody>
</table>

PARAMETER KTO00(T) Benchmark allocation of CAPITAL to T-sectors

<table>
<thead>
<tr>
<th>Sector</th>
<th>0.00251</th>
<th>0.07468</th>
<th>0.11448</th>
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<tr>
<td>FOREST</td>
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<td></td>
</tr>
<tr>
<td>AGRI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IND</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

PARAMETER KN00(N) Benchmark allocation of CAPITAL to N-sectors

<table>
<thead>
<tr>
<th>Sector</th>
<th>0.05800</th>
<th>0.12763</th>
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</thead>
<tbody>
<tr>
<td>INFRA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SERVICE</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

PARAMETER UT00(T) Benchmark allocation of UNSKILLED LABOR to T-sectors

<table>
<thead>
<tr>
<th>Sector</th>
<th>0.01762</th>
<th>0.20524</th>
<th>0.21675</th>
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</thead>
<tbody>
<tr>
<td>FOREST</td>
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<td></td>
</tr>
<tr>
<td>AGRI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IND</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sector</th>
<th>0.16330</th>
<th>0.52563</th>
</tr>
</thead>
<tbody>
<tr>
<td>INFRA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SERVICE</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

PARAMETER UTOO(T) Benchmark allocation of UNSKILLED LABOR to T-sectors
PARAMETER UN00(N) Benchmark allocation of UNSKILLED LABOR to N-sectors

PARAMETER LT00(T) Benchmark allocation of SKILLED LABOR to T-sectors

PARAMETER LN00(N) Benchmark allocation of SKILLED LABOR to N-sectors

PARAMETER FLTO0(T) Benchmark allocation of LOGS to T-sectors

PARAMETER FLN00(N) Benchmark allocation of LOGS to N-sectors

PARAMETER DLT00(T) Benchmark allocation of DLAND to T-sectors;

PARAMETER DLN00(N) Benchmark allocation of DLAND to N-sectors

PARAMETER XT00(T) Benchmark tradables production level
PARAMETER XN00(N) Benchmark nontradables production level
/ INFRA 1.08207
SERVICE 1.70623 /

PARAMETER DT00(T) Benchmark consumption of tradables
/ FOREST 0.01241
AGRI 0.35030
IND 1.41334 /

PARAMETER DN00(N) Benchmark consumption of nontradables
/ INFRA 0.78236
SERVICE 1.11504 /

PARAMETER INVSRCT(T)
/ FOREST 0
AGRI 0.00322
IND 0.02926 /

PARAMETER INVSRCN(N)
/ INFRA 0.05419
SERVICE 0.00799 /

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General Algebraic Modeling System Compilation

PARAMETER ZT00(T)
/ FOREST 0.00107
AGRI 0.39243
IND -0.96425 /

SCALAR DISP00 /3.75372/
SCALAR SAV00 /0.08027/
SCALAR ROWSAV00 /0.01439/
SCALAR INV /0.09466/
* Central Bank 0.0460231, 0.09466 SAM
SCALAR GNP00 /3.19624 /
SCALAR AVSK INITIAL LOGGING /0.00200/
SCALAR LAB INITIAL LABOR IN LOGGING /0.00093/
SCALAR CAP INITIAL CAPITAL IN LOGGING /0.00126/
SCALAR LSQ INITIAL LABOR IN SQUATTING /0.00180/
SCALAR SQO INITIAL SQUATTING /0.00200/
INCLUDE C:\GAMS\CRM\BASE.INC
*INITIAL SOLUTION TOTDEF=0.1

PARAMETER DT02(T)
/FOREST 0.0165
AGRI 0.4656
IND 1.8785 /
PARAMETER DN02(N)
/INFRA 1.0399
SERVICE 1.4820 /
PARAMETER XT01(T)
/AGRI 1.4171
IND 2.1250/
PARAMETER DT01(T)
/FOREST 0.0108
AGRI 0.3053
IND 1.2318 /
PARAMETER ZT01(T)
/FOREST -0.0582
AGRI 0.4054
IND -0.6874 /
PARAMETER KT01(T)
/AGRI 0.2102
IND 0.2515/
PARAMETER LLT01(T)
/AGRI 0.0047
GAMS 2.25.059 386/486 DOS 11/13/96 15:26:48 PAGE 6
PARAMETER UT01(T)
/AGRI 0.2683
IND 0.1168/
PARAMETER DLT01(T)
/AGRI 0.2143/
PARAMETER XN01(N)
/INFRA 1.1317
SERVICE 1.6041 /
PARAMETER DN01(N)
/INFRA 0.6815
SERVICE 0.9781 /
PARAMETER KN01(N)
/INFRA 0.1725
SERVICE 0.4944 /

PARAMETER LN01(N)
/INFRA 0.1384
SERVICE 0.4651 /

PARAMETER UN01(N)
/INFRA 0.1794
SERVICE 0.1311 /

PARAMETER DT11(T)
/FOREST 0.0088
AGRI 0.2474
IND 0.9983 /

PARAMETER KT11(T)
/FOREST 0.0445
AGRI 0.2174
IND 0.3913 /

PARAMETER LLT11(T)
/FOREST 0.0005
AGRI 0.0042
IND 0.1564 /

PARAMETER XT11(T)
/FOREST 0.1252
AGRI 1.3398
IND 2.9904 /

PARAMETER YT11(T)
/FOREST 0.0504
AGRI 0.2750
IND -0.1543 /
PARAMETER DLT11(T)
/AGRI 0.2143/
PARAMETER XN11(N)
/INFRA 1.3061 SERVICE 1.5623 /
PARAMETER DN11(N)
/INFRA 0.5464 SERVICE 0.7996 /
PARAMETER KN11(N)
/INFRA 0.2245 SERVICE 0.5270 /
PARAMETER UT11(T)
/FOREST 0.0282 AGRI 0.2281 IND 0.2169 /
PARAMETER LN11(N)
/INFRA 0.1.549 SERVICE 0.4264 /
PARAMETER UN11(N)
/INFRA 0.1900 SERVICE 0.1137 /
SCALAR DOSQ11 /10E-7/
SCALAR FLOG11 /0.0022/
SCALAR LSQ11 /10E-7/
SCALAR LOGL11 /0.0014/
SCALAR LGK11 /0.0023/
SCALAR FEXP11 /-0.0012/
SCALAR D11 /0.2143/
SCALAR F11 /0.0022/
SCALAR YY11 /3.5697/
INCLUDE C:\GAMS\CRNOD\CALC.INC
PARAMETER GAMMA;
GAMMA=LOG(SQ0)/LOG(LSQ);
PARAMETER ATT(T,T,T) Input of tradables in tradable sectors;
ATT(T,T,T)=XTT00(T,T,T)/XT00(TT);
PARAMETER ATN(TT,NN) Input of tradables in nontradable sectors;
   ATN(T,N) = XNTOO(T,N)/XNOO(N);

PARAMETER ANT(NN,TT) Input of nontradables in tradable sectors;
   ANT(N,T) = XNT00(N,T)/XT00(T);

PARAMETER ANN(NN,N) Input of nontradables in nontradables sectors;
   ANN(N,NN) = XNN00(N,NN)/XNO00(NNN);

PARAMETER TTAX0(TT) Unit tax in tradable sectors;
   TTAX0(T) = TTAX00(T)/XT00(T)*TAX0(T);

PARAMETER TTAX1(TT) Unit tax in tradable sectors;
   TTAX1(T) = TTAX00(T)/XT00(T)*TAX1(T);

PARAMETER NTAX0(NN) Unit tax in nontradable sectors;
   NTAX0(N) = NTAX00(N)/XNO00(N);

PARAMETER KXT0(TT) Benchmark input coefficients for CAPITAL;
   KXT0(T) = KTOO(T)/XT00(T);

PARAMETER KXNO(NN) Benchmark input coefficients for CAPITAL;
   KXNO(N) = KNOO(N)/XNO00(N);

PARAMETER UXTO(TT) Benchmark input coefficients for UNSKILLED LABOR;
   UXTO(T) = UTO00(T)/XT00(T);

PARAMETER UXNO(NN) Benchmark input coefficients for UNSKILLED LABOR;
   UXNO(N) = UNO00(N)/XNO00(N);

PARAMETER LXT0(TT) Benchmark input coefficients for SKILLED LABOR;
   LXT0(T) = LT00(T)/XT00(T);

PARAMETER LXNO(NN) Benchmark input coefficients for SKILLED LABOR;
   LXNO(N) = LNO00(N)/XNO00(N);

PARAMETER FXT0(TT) Benchmark input coefficients for LOGS;
   FXT0('FOREST') = FLT00('FOREST')/XT00('FOREST');

PARAMETER FXNO(NN) Benchmark input coefficients for LOGS;
   FXNO(N) = FLNO0(N)/XNO00(N);

PARAMETER DXTO(TT) Benchmark input coefficients for DLAND;
   DXTO(T) = DT00(T)/XT00(T);
PARAMETER DXNO(NN) Benchmark input coefficients for DLAND;

\[ DXNO(N) = DNOO(N) / XNOO(N) \];

PARAMETER AT(T) Tradable production function scale parameter;

\[ AT(T) = 1 - \sum(T, ATT(T,T)) - \sum(N, ANT(N,T)) - TTXO(T) \];

DISPLAY AT;

PARAMETER AN(N) Nontradable production function scale parameter;

\[ AN(N) = 1 - \sum(T, ATN(T,N)) - \sum(N, ANN(N,N)) - NTXO(N) \];

DISPLAY AN;

PARAMETER DELKRT(TT) CAPITAL share in tradable KD;

\[ DELKRT(T) = KTOO(T) / (KTOO(T) + DLTOO(T)) \];

PARAMETER DELDRN(NN) CAPITAL share in nontradable KD;

\[ DELDRN(N) = KNOO(N) / (KNOO(N) + DNLNOO(N)) \];

PARAMETER DELFMT(TT) LOGS share in tradable FR;

\[ DELFMT(T) = FLTOO(T) / (FLTOO(T) + DLTOO(T) + KTOO(T)) \];

PARAMETER DELRMN(NN) LOGS share in nontradable FR substitution;

\[ DELRMN(N) = FLNOO(N) / (FLNOO(N) + DNLNOO(N) + KNOO(N)) \];

PARAMETER DELUVT(TT) UNSKILLED LABOR share in tradable UY;

\[ DELUVT(T) = UTOO(T) / (UTOO(T) + FLTOO(T) + DLTOO(T) + KTOO(T)) \];

PARAMETER DELMVN(NN) UNSKILLED LABOR share in nontradable UY;

\[ DELMVN(N) = UNOO(N) / (UNOO(N) + FLNOO(N) + DNLNOO(N) + KNOO(N)) \];

PARAMETER DELVYT(TT) SKILLED LABOR share in tradable LV;

\[ DELVYT(T) = LTOO(T) / (LTOO(T) + UTOO(T) + FLTOO(T) + DLTOO(T) + KTOO(T)) \];

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PARAMETER DELLYN(NN) SKILLED LABOR share in nontradable LV;

DELLYN(N) = LN00(N)/(LN00(N) + UN00(N) + DLN00(N) + PLN00(N) + KN00(N));

PARAMETER DELVYN(NN);
DELVYN(N) = 1 - DELLYN(N);

PARAMETER BT(TT) B-coefficient in U;
BT(T) = DTOO(T)/(SUM(TT, DTOO(TT)) + SUM(N, DN00(N)));

PARAMETER BN(NN) B-coefficient in u;
BN(N) = DN00(N)/(SUM(T, DTOO(T)) + SUM(NN, DN00(NN)));

DISPLAY BN;

PARAMETER SAVSHR Savings share of disposable income in period 0;
SAVSHR = SAV00/DISP00;

DISPLAY SAVSHR;

PARAMETER INVSHRT(TT);
INVSHRT(T) = INVSRCT(T)/INV;
DISPLAY INVSHRT;

PARAMETER INVSHRN(NN);
INVSHRN(N) = INVSRCN(N)/INV;
DISPLAY INVSHRN;

PARAMETER K0 CAPITAL endowment 0;
K0 = 1.12980;

PARAMETER U0 UNSKILLED LABOR endowment 0;
U0 = .76006;

PARAMETER U1 UNSKILLED LABOR endowment 1;
U1 = U0 * (1 + POPGR);

PARAMETER U2 UNSKILLED LABOR endowment 2;
U2 = U1 * (1 + POPGR);

PARAMETER L0 SKILLED LABOR endowment 0;
L0 = .72496;

PARAMETER L1 SKILLED LABOR endowment 1;
L1 = L0 * (1 + POPGR);

PARAMETER L2 SKILLED LABOR endowment 2;
L2 = L1 * (1 + POPGR);

PARAMETER DSTAR DLAND endowment 0;
DSTAR = 0.20524;
PARAMETER SBAR00 Trade balance surplus 0;
SBAR00=-0.5563;

PARAMETER SBAR1 Trade balance surplus 1;
SBAR1=-0.57075;

PARAMETER UTIL00;
UTIL00=LOG(PROD(T,DT00(T)**BT(T))*PROD(N,DNO0(N)**BN(N)));

DISPLAY UTIL00;

INCLUDE C:\GAMS\CRMOD\EXO.INC

*++++++ELASTICITIES OF SUBSTITUTION+++*

PARAMETER SIGRT(T) Elasticity of tradable KD substitution
/ FOREST 0
AGRI 0.500
IND 0

PARAMETER SIGRN(N) Elasticity of nontradable KD substitution
/ INFRA 0
SERVICE 0

PARAMETER SIGMT(T) Elasticity of tradable FR substitution
/ FOREST 0.800
AGRI 0
IND 0

PARAMETER SIGMN(N) Elasticity of nontradable FR substitution
/ INFRA 0
SERVICE 0

PARAMETER SIGVT(T) Elasticity of tradable UY substitution
/ FOREST 0.800
AGRI 0.800
IND 0.800

PARAMETER SIGVN(N) Elasticity of nontradable UY substitution
/ INFRA 0.800
Elasticity of tradable LV substitution

PARAMETER SIGYT(T)
/ FOREST 0.800
AGRI 0.800
IND 0.800 /

Elasticity of nontradable LV substitution

PARAMETER SIGYN(N)
/ INFRA 0.800
SERVICE 0.800 /

SCALAR MU Elasticity of substitution between foreign and domestic capital

parameter PWFO WM price of logs 0;
pwfo=1.000;

parameter PWFl WM price of logs 1;
pwfl=1.000;

PARAMETER PWO(T) World market price of tradables
/ FOREST 1.0000
AGRI 1.0000
IND 1.0000 /

PARAMETER PW1(t) World market price of tradables
/ FOREST 1.0000
AGRI 1.0000
IND 1.0000 /

*+++++++++++++++++++++++++
+++EXOGENOUS VARIABLES+++*

VARIABLES
* consumers

UTIL0  UTILITY PERIOD 0
UTIL1  UTILITY PERIOD 1

WELF  WELFARE intertemporal sum of utilities

DISP0  Disposable income 0
DISP1  Disposable income 1

DT0(T)  Consumption demand for tradables 0
DT1(T)  Consumption demand for tradables 1

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General Algebraic Modeling System Compilation

DN0(N)  Consumption demand for nontradables 0
DN1(N)  Consumption demand for nontradables 1

* Deforestation sectors

ALPHA  Elasticity of output wrt capital in logging
BETA   Elasticity of output wrt labor in logging
DEF01  Deforestation in both periods

DOSQ0  DLAND produced by deforestation 0
DOSQ1  DLAND produced by deforestation 1

LSQ0   UNSKILLED LABOR input in deforestation by SQUATTERS 0
LSQ1   UNSKILLED LABOR input in deforestation by SQUATTERS 1

PROFSQ0  Profit for SQUATTERS in period 0
PROFSQ1  Profit for SQUATTERS in period 1

FLOG0  LOGGING 0
FLOG1  LOGGING 1

LAMLG0  Shadow price of forested land for loggers 0
LAMLG1  Shadow price of forested land for loggers 1

PFL0   Supply price of LOGS 0
PFL1   Supply price of LOGS including future value 1

LOGL0  UNSKILLED LABOR input in deforestation by LOGGERS 0
LOGL1  UNSKILLED LABOR input in deforestation by LOGGERS 1

LGK0   CAPITAL input in deforestation by LOGGERS 0
LGK1   CAPITAL input in deforestation by LOGGERS 1
Profit for LOGGERS in period 0

Profit for LOGGERS in period 1

Deforestation 0

Deforestation 1

Supply of DLAND 0

Supply of DLAND 1

* Prices

User price of DLAND 0

User price of DLAND 1

User price of LOGS including taxes 0

User price of LOGS including future value and taxes 1

User price of CAPITAL 0

User price of CAPITAL 1

User price of SKILLED LABOR 0

User price of SKILLED LABOR 1

User price of UNSKILLED LABOR 0

User price of UNSKILLED LABOR 1

Implicit price of Y(T) 0

Implicit price of Y(T) 1

Implicit price of Y(N) 0

Implicit price of Y(N) 1

Implicit price of V(T) 0

Implicit price of V(T) 1

Implicit price of V(N) 0

Implicit price of V(N) 1

Implicit price of M(T) 0

Implicit price of M(T) 1

Implicit price of M(N) 0

Implicit price of M(N) 1

Implicit price of R(T) 0

Implicit price of R(T) 1

Implicit price of R(N) 0
PRN1(N)  Implicit price of R(N) 1

* Partial derivatives

DPXDPUT0(T)  Partial of PX wrt PUU(T) 0
DPXDPUT1(T)  Partial of PX wrt PUU(T) 1
DPXDPUN0(N)  Partial of PX wrt PUU(N) 0
DPXDPUN1(N)  Partial of PX wrt PUU(N) 1
DPXDPLO(T)  Partial of PX wrt PUL(T) 0
DPXDPL1(T)  Partial of PX wrt PUL(T) 1
DPXDPNO(N)  Partial of PX wrt PUL(N) 0
DPXDPN1(N)  Partial of PX wrt PUL(N) 1
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General Algebraic Modeling System Compilation

DPXDPFT0(T)  Partial of PX wrt PUFL(T) 0
DPXDPFT1(T)  Partial of PX wrt PUFL(T) 1
DPXDPFN0(N)  Partial of PX wrt PUFL(N) 0
DPXDPFN1(N)  Partial of PX wrt PUFL(N) 1
DPXDPDT0(T)  Partial of PX wrt PULD(T) 0
DPXDPDT1(T)  Partial of PX wrt PULD(T) 1
DPXDPDN0(N)  Partial of PX wrt PULD(N) 0
DPXDPDN1(N)  Partial of PX wrt PULD(N) 1
DPYDPVT0(T)  Partial of PY wrt PV(T) 0
DPYDPVT1(T)  Partial of PY wrt PV(T) 1
DPYDPVN0(N)  Partial of PY wrt PV(N) 0
DPYDPVN1(N)  Partial of PY wrt PV(N) 1
DPYDPLT0(T)  Partial of PY wrt PUL(T) 0
DPYDPLT1(T)  Partial of PY wrt PUL(T) 1
DPYDPLN0(N)  Partial of PY wrt PUL(N) 0
DPYDPLN1(N)  Partial of PY wrt PUL(N) 1
DPVDPMT0(T)  Partial of PV wrt PM(T) 0
DPVDPMT1(T)  Partial of PV wrt PM(T) 1
DPVDPMN0(N) Partial of PV wrt PM(N) 0
DPVDPMN1(N) Partial of PV wrt PM(N) 1

DPVDPUT0(T) Partial of PV wrt PUU(T) 0
DPVDPUT1(T) Partial of PV wrt PUU(T) 1

DPVDPU0(N) Partial of PV wrt PUU(N) 0
DPVDPU1(N) Partial of PV wrt PUU(N) 1

DPMDPRT0(T) Partial of PM wrt PR(T) 0
DPMDPRT1(T) Partial of PM wrt PR(T) 1

DPMDPRN0(N) Partial of PM wrt PR(N) 0
DPMDPRN1(N) Partial of PM wrt PR(N) 1

DPMDPFT0(T) Partial of PM wrt PUFL(T) 0
DPMDPFT1(T) Partial of PM wrt PUFL(T) 1

DPMDPFT0(N) Partial of PM wrt PUFL(N) 0
DPMDPFT1(N) Partial of PM wrt PUFL(N) 1

DPRDPKTO(T) Partial of PR wrt PUK(T) 0
DPRDPKTO(T) Partial of PR wrt PUK(T) 1

DPRDPKNO(N) Partial of PR wrt PUK(N) 0
DPRDPKNO(N) Partial of PR wrt PUK(N) 1

* Producers

MCT0(T) Marginal cost in tradable production 0
MCT1(T) Marginal cost in tradable production 1

MCN0(N) Marginal cost in nontradable production 0
MCN1(N) Marginal cost in nontradable production 1

PNO(N) User price of nontradables 0
PN1(N) User price of nontradables 1

XT0(T) Output in tradable sectors 0
XT1(T) Output in tradable sectors 1

XN0(N) Output in non-tradable sectors 0
XN1(N) Output in non-tradable sectors 1
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819  KT0(T)  CAPITAL input in tradable sectors 0
820  KT1(T)  CAPITAL input in tradable sectors 1
821  KN0(N)  CAPITAL input in nontradable sectors 0
822  KN1(N)  CAPITAL input in nontradable sectors 1
823  UT0(T)  UNSKILLED LABOR demand in tradable sectors 0
824  UT1(T)  UNSKILLED LABOR demand in tradable sectors 1
825  UN0(N)  UNSKILLED LABOR demand in non-tradable sectors 0
826  UN1(N)  UNSKILLED LABOR demand in non-tradable sectors 1
827  LLT0(T)  SKILLED LABOR demand in tradable sectors 0
828  LLT1(T)  SKILLED LABOR demand in tradable sectors 1
829  LN0(N)  SKILLED LABOR demand in non-tradable sectors 0
830  LN1(N)  SKILLED LABOR demand in non-tradable sectors 1
831  FLT0(T)  LOGS demand in tradable sectors 0
832  FLT1(T)  LOGS demand in tradable sectors 1
833  DLT0(T)  DLAND demand in tradable sectors 0
834  DLT1(T)  DLAND demand in tradable sectors 1
835  PI0  Price of composite investments period 0
836  PI1  Price of composite investments period 1
837  INVTO(T)  Investments by sector of origin period 0
838  INVT1(T)  Investments by sector of origin period 1
839  INVNO(N)  Investments by sector of origin period 0
840  INVNI(N)  Investments by sector of origin period 1
841  K1  Capital stock period 1
842  * Rest of world
843  SBAR0  Current Account 0
844  SBAR2  Current Account 2
845  SAV0  Domestic savings 0
846  SAV1  Domestic savings 1
847  * Market clearing
848  ZT0(T)  Net export of tradables 0

General Algebraic Modeling System
Compilation
POSITIVE VARIABLES

LAMLGO, LAMLG1, LAMSQ0, LAMSQ1, XTO, XT1, xn0, xn1, LSQ0, LSQ1, DOSQ0, DOSQ1, FLOG0, FLOG1, 1gk0, 1gk1, log10, log11, PROFSQ0, PROFSQ1, inv0;

* Closing

INVO Aggregate investments period 1

YY0 GNP 0

YY1 GNP 1

** Closing
TCONSO(T) Consumption demand for tradables 0
TCONSI(T) Consumption demand for tradables 1
NCONSO(N) Consumption demand for nontradables 0
NCONSI(N) Consumption demand for nontradables 1

* Deforestation sectors

DEFFALPHA Definition of alpha
DEFBETA Definition of beta
DDEF01 Definition of DEF01
DLAM Total def less than permitted def

DEFLAMSQ0 Definition of lamsq0
DEFLAMSQ1 Definition of lamsq1
DEFDOSQ0 Definition of DOSQ0
DEFDOSQ1 Definition of DOSQ1
COMPLDQ0 Complementary condition DOSQ0
COMPLDQ1 Complementary condition DOSQ1

DEFLSQ0 Definition of LSQ0
DEFLSQ1 Definition of LSQ1
COMPLLQ0 Complementary condition LSQ0
COMPLLQ1 Complementary condition LSQ1

DEFFLOGO Definition of FLOGO
DEFFLOG1 Definition of FLOG1
COMPLF0 Complementary condition FLOG0
COMPLF1 Complementary condition FLOG1

DEFFLOGLO Definition of LOGLO
DEFFLOGL1 Definition of LOGL1
COMPLLFO Complementary condition LOGLO
COMPLLFI Complementary condition LOGL1

DEFLGKO Definition of LGKO
DEFLGKI Definition of LGKI

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General Algebraic Modeling System Compilation

DEFLMLG0 Definition of LMLG0
DEFLMLG1 Definition of LMLG1
DEFLOGL0 Definition of LOGL0
DEFLOGL1 Definition of LOGL1
COMPLF0 Complementary condition LOGL0
COMPLF1 Complementary condition LOGL1

DEFLGK0 Definition of LGK0
DEFLGK1 Definition of LGK1
Complementary condition LGK0
Complementary condition LGK1
Definition of PROFLG0
Definition of PROFLG1
PRLF0  Domestic and world market price equality for logs 0
PRLF1  Domestic and world market price equality for logs 1
Complementary condition LOGS 0  Determines PFL0
Complementary condition LOGS 1  Determines PFL1
Definition of total deforestation 0
Definition of total deforestation 1
Definition of supply of DLAND 0
Definition of supply of DLAND 1
* Prices
Definition of PUDL0
Definition of PUDL1
Definition of PUFL0
Definition of PUFL1
Definition of PUK0
Definition of PUK1
Definition of PUL0
Definition of PUL1
Definition of PUU0
Definition of PUU1
Definition of PYT0
Definition of PYT1
Definition of PYN0
Definition of PYN1
Definition of PVTO
Definition of PVTI
Definition of PVNO
Definition of PVNI
Definition of PYNO
Definition of PVT0
Definition of PVT1
Definition of PVNO
Definition of PVNI
DEFPNVL(N) Definition of PVN1
DEFPMTO(T) Definition of PMTO
DEFPMTL(T) Definition of PMTL
DEFPMNO(N) Definition of PMNO
DEFPN1(N) Definition of PN1
DEFPRTO(T) Definition of PRTO
DEFPRTL(T) Definition of PRTL
DEFPRNO(N) Definition of PRNO
DEFPRN1(N) Definition of PRN1

* Partial derivatives

DDPVDPLTO(T) Definition of DPVDPLTO
DDPVDPLTL(T) Definition of DPVDPLTL
DDPVDPLNO(N) Definition of DPVDPLNO
DDPVDPLN1(N) Definition of DPVDPLN1
DDPVDPVT0(T) Definition of DPVDPVT0
DDPVDPVT1(T) Definition of DPVDPVT1
DDPVDPVN0(N) Definition of DPVDPVN0
DDPVDPVN1(N) Definition of DPVDPVN1
DDPVDPUT0(T) Definition of DPVDPUT0
DDPVDPUT1(T) Definition of DPVDPUT1
DDPVDPUN0(N) Definition of DPVDPUN0
DDPVDPUN1(N) Definition of DPVDPUN1
DDPVDPMTO(T) Definition of DPVDPMTO
DDPVDPMTL(T) Definition of DPVDPMTL
DDPVDPMNO(N) Definition of DPVDPMNO
DDPVDPMN1(N) Definition of DPVDPMN1
DDPMDPRT0(T) Definition of DPMDPRT0
DDPMDPRT1(T) Definition of DPMDPRT1
DDPMDPRN0(N) Definition of DPMDPRN0
DDPMDPRN1(N) Definition of DPMDPRN1
DDPMDPFT0(T) Definition of DPMDPFT0
DDPMDPFT1(T) Definition of DPMDPFT1
1062  DDPMDPFN0 (N)  Definition of DPMDFN0
1063  DDPMDPFN1 (N)  Definition of DPMDFN1
1064
1065  DDPRDPKT0 (T)  Definition of DPRDPKT0
1066  DDPRDPKT1 (T)  Definition of DPRDPKT1
1067
1068  DDPRDPKN0 (N)  Definition of DPRDPKN0
1069  DDPRDPKN1 (N)  Definition of DPRDPKN1
1070
1071  DDPRDPDT0 (T)  Definition of DPRDPDT0
1072  DDPRDPDT1 (T)  Definition of DPRDPDT1
1073
1074  DDPRDPDN0 (N)  Definition of DPRDPDN0
1075  DDPRDPDN1 (N)  Definition of DPRDPDN1
1076
1077  DDPXDPDT0 (T)  Definition of DPXDPDT0
1078  DDPXDPDT1 (T)  Definition of DPXDPDT1
1079
1080  DDPXDPDN0 (N)  Definition of DPXDPDN0
1081  DDPXDPDN1 (N)  Definition of DPXDPDN1
1082
1083  DDPXDPFT0 (T)  Definition of DPXDPFT0
1084  DDPXDPFT1 (T)  Definition of DPXDPFT1
1085
1086  DDPXDPFN0 (N)  Definition of DPXDPFN0
1087  DDPXDPFN1 (N)  Definition of DPXDPFN1
1088
1089  DDPXDPKT0 (T)  Definition of DPXDPKT0
1090  DDPXDPKT1 (T)  Definition of DPXDPKT1
1091
1092  DDPXDPKN0 (N)  Definition of DPXDPKN0
1093  DDPXDPKN1 (N)  Definition of DPXDPKN1
1094
1095  DDPXDPLT0 (T)  Definition of DPXDPLT0
1096  DDPXDPLT1 (T)  Definition of DPXDPLT1
1097
1098  DDPXDPLN0 (N)  Definition of DPXDPLN0
1099  DDPXDPLN1 (N)  Definition of DPXDPLN1
1100
1101  DDPXDPUT0 (T)  Definition of DPXDPUT0
1102  DDPXDPUT1 (T)  Definition of DPXDPUT1
1103
1104  DDPXDPUN0 (N)  Definition of DPXDPUN0
1105  DDPXDPUN1 (N)  Definition of DPXDPUN1
1106
1107  * Producers
1108
1109  DEFMCNO (N)  Definition of MCNO
1110  DEFMCNO1 (T)  Definition of MCNO1
1111
1112  DEFMCNO (N)  Definition of MCNO
1113
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General Algebraic Modeling System Compilation
Definition of MCN1

Definition of user price of nontradables 0

Definition of user price of nontradables 1

Producer price marginal cost inequality

Producer price marginal cost inequality

Complementary condition for tradables 0

Complementary condition for tradables 1

Complementary condition for tradables

Complementary condition for nontradables 0

Complementary condition for nontradables 1

Tradable demand for SKILLED LABOR 0

Tradable demand for SKILLED LABOR 1

Tradable demand for SKILLED LABOR

Nontradable demand for SKILLED LABOR 0

Nontradable demand for SKILLED LABOR 1

Tradable demand for UNSKILLED LABOR 0

Tradable demand for UNSKILLED LABOR 1

Nontradable demand for UNSKILLED LABOR 0

Nontradable demand for UNSKILLED LABOR 1

Tradable demand for LOGS 0

Tradable demand for LOGS 1

Tradable demand for LOGS

Nontradable demand for LOGS 0

Nontradable demand for LOGS 1

Tradable demand for CAPITAL 0

Tradable demand for CAPITAL 1

Nontradable demand for CAPITAL 0

Nontradable demand for CAPITAL 1
* Investments and domestic interest rate

DEFPI0  Definition of PI0

DEFINVT0(T)  Investment demand for tradables period 0

DEFINVN0(N)  Investment demand for nontradables 0

DEFK1  Definition of capital stock period 1

* Rest of world

TRADEBAL0  Trade balance 0  Determines SBAR0

TRADEBAL1  Trade balance 1  Determines SBAR2

DEFinv0  Arbitrage condition SBAR Det SAV0

* Market clearing

TMARKET0(T)  Market clearing for tradables 0  Determines ZT0

TMARKET1(T)  Market clearing for tradables 1  Determines ZT1

NMARKET0(N)  Market clearing for nontradables 0  Determines

PPN0  Determines

NMARKET1(N)  Market clearing for nontradables 1  Determines

PPN1  Determines

FMARKET0  Market clearing for LOGS 0  Determines FEXP0

FMARKET1  Market clearing for LOGS 1  Determines FEXP1

DMARKET0  Market clearing for DLAND 0  Determines PDL0

DMARKET1  Market clearing for DLAND 1  Determines PDL1

CMARKET0  Market clearing for CAPITAL 0  Determines PK0

CMARKET1  Market clearing for CAPITAL 1  Determines PK1

LMARKET0  Market clearing for SKILLED LABOR 0  Determines

PL0  Determines

LMARKET1  Market clearing for SKILLED LABOR 1  Determines

PL1  Determines

UMARKET0  Market clearing for UNSKILLED LABOR 0

Determines PU0

UMARKET1  Market clearing for UNSKILLED LABOR 1
 Determines PU1

1194
1195  * Model closure
1196
1197  DEFGNP0  Definition of GNP 0
1198  DEFGNP1  Definition of GNP 1
1199
1200  definv0  Equality of returns to capital det inv0;
1201
1202
1203  #
1204  #
1205  #
1206  * Slack variable equation
1207
1208  UTIL0=E=LOG(PROD(T,DT0(T)**BT(T))*PROD(N,DN0(N)**BN(N))
1209
1210  WELF=E=UTIL0+1/RAU*UTIL1;
1211
1212  GAMS 2.25.059 386/486 DOS 11/13/96 15:26:48 PAGE 24
General Algebraic Modeling System Compilation

1213  DISPO=E=PUK0*K0+PULO*L0+PUU0*U0+PUDL0*DSTAR+
1214       SUM(T,TTAX0(T)*XT0(T))+SUM(N,NTAX0(N)*XN0(N))

1215  DISP1=E=PUK1*K1+PUL1*L1+PUU1*U1+PUDL1*D0+
1216       SUM(T,TTAX1(T)*XT1(T))+SUM(N,NTAX0(N)*XN1(N))

1217  TCONS0(T) ..  DT0(T)=E=BT(T)*DISP0-SAV0)/PW0(T);
1218  TCONS1(T) ..  DT1(T)=E=BT(T)*DISP1-SAV0)/PW1(T)*IRATE/RAU;
1219
1220  NCONS0(N) ..  DNO(N)=E=BN(N)*(DISP0-SAV0)/FN0(N);
1221  NCONS1(N) ..  DNI(N)=E=BN(N)*(DISP1-SAV0)/FN1(N)*IRATE/RAU;
1222
1223  * Deforestation sectors
1224
1225  * Calculation of parameters
1226
DEFALPHA.. lab=e=(1/(BETA*CAP**ALPHA))**(1/(BETA-1));
DEFBETA.. cap=e=(1/(ALPHA*LAB**BETA))**(1/(ALPHA-1));

* Undefined property rights
* Production functions
* Loggers

DEFFLOG0.. flog0=g=lgk0**alpha.l*log10**beta.l;
DEFFLOG1.. flog1=g=lgk1**alpha.l*log11**beta.l;

COMPLDF0.. (flog0-low)*(flog0-
lgk0**alpha.l*log10**beta.l)=e=0;
COMPLDF1.. (flog1-low)*(flog1-
lgk1**alpha.l*log11**beta.l)=e=0;

DEFLOG0.. log10-(puU0/(PFL0*lgk0**alpha.l))**(1/(beta.l-1))=e=0;
DEFLOG1.. log11-(puU1/(PFL1*lgk1**alpha.l))**(1/(beta.l-1))=e=0;

COMPLF0.. (LOGLO-low)*((LOGLO-
(PUO/(PFL*ALPHA.L*log10**BETA.L))**(1/(ALPHA.L-1)))--
COMPLF1.. (LOG11-low)*((LOG11-
(PU1/(PFL*ALPHA.L*log11**BETA.L))**(1/(ALPHA.L-1)))--

1/IRATE*(1/GK1-
(PUK1/(PFL*ALPHA.L*log11**BETA.L))**(1/(ALPHA.L-1))--

1/IRATE*(1/GK0-
(PUK0/(PFL*ALPHA.L*log10**BETA.L))**

1/IRATE*(1/GK1-
(PUK1/(PFL*ALPHA.L*log11**BETA.L))**

1/IRATE*(1/GK0-
(PUK0/(PFL*ALPHA.L*log10**BETA.L))**)
A.L)**  

(1/(ALPHA.L-l)))=E=LAMLG0;  

LAMLG0*(TOTDEF-F0)=E=0;  

LAMLG1*(TOTDEF-F0-F1)=E=0;  

DPROFLG0..  

PFL0*FLOG0-PUU0*LOGL0-PUK0*LGK0=E=PROFLG0;  

DPROFLG1..  

PFL1*FLOG1-PUU1*LOGL1-PUK1*LGK1=E=PROFLG1;  

* Well defined property rights  

DDEF01..  

DOSQ0+DOSQ1+FLOG0+FLOG1=E=DEF01;  

DLAM..  

DOSQ0+DOSQ1+FLOG0+FLOG1=L=TOTDEF;  

* Squatters  

DEFDOSQ0..  

DOSQ0=g=LSQ0**GAMMA;  

DEFDOSQ1..  

DOSQ1=g=LSQ1**GAMMA;  

COMPLDQ0..  

(DOSQ0-low)*(dosq0-1sq0**gamma)=e=0;  

COMPLDQ1..  

(DOSQ1-low)*(dosq1-1sq1**gamma)=e=0;  

DEFLSQ0..  

pd10*gamma*lsq0**(gamma-1)-puu0-  

1/irate*(pd11*gamma*lsq1**(gamma-1)-puu1)=l=lamsq0;  

DEFLSQ1..  

pd11*gamma*lsq1**(gamma-1)-puu1=l=lamsq1;  

COMPLLQ0..  

(LSQ0-low)*(pd10*gamma*lsq0**(gamma-1)-puu0-  

1/irate*(pd11*gamma*lsq1**(gamma-1)-puu1))=E=lamsq0;  

COMPLLQ1..  

(LSQ1-low)*(pd11*gamma*lsq1**(gamma-1)-  

puu1)=E=lamsq1;  

* Tradable logs equations  

DEFLAMSQ0..  

LAMSQ0*(TOTDEF-f0)=E=0;  

deflamsq1..  

LAMSQ1*(TOTDEF-F0-F1)=E=0;  

DPROFSQ0..  

PDL0*DOSQ0-PUU0*LSQ0=E=PROFSQ0;  

DPROFSQ1..  

PDL1*DOSQ1-PUU1*LSQ1=E=PROFSQ1;  

* Total deforestation  

PRLF0..  

PWF0-PFL0=L=0;  

PRLF1..  

PWF1-PFL1=L=0;  

COMPLF0..  

FLOG0*(PWF0-PFL0)=E=0;  

COMPLF1..  

FLOG1*(PWF1-PFL1)=E=0;  

* Well defined property rights  

DEFDO..  

D0=E=DSTAR+LSQ0;  

DEFD1..  

D1=E=D0+LSQ1;
DEFF0.. F0=E=FLOG0+DOSQ0;

DEFF1.. F1=E=FLOG1+DOSQ1;

* Prices

PUFLO=E=FWF0*(1+FTAXO);
PUFL1=E=FWF1*(1+FTAX1);

PUDLO=E=PDLO*(1+DTAXO);
PUDL1=E=PDL1*(1+DTAX1);

PUK0=E=PKO*(1+KTAX0);
PUK1=E=PK1*(1+KTAX1);

PUL0=E=PL0*(1+LTAX0);
PUL1=E=PL1*(1+LTAX1);

PUU0=E=PUO*(1+UTAXO);
PUU1=E=PU1*(1+UTAX1);

PYT0(T) =E=(DELLYT(T)*PULO**
(1-SIGYT(T))+(1-DELLYT(T))*PVTO(T)**
(1-SIGYT(T)))**(1/(1-SIGYT(T)));

PYT1(T) =E=(DELLYT(T)*PUL1**
(1-SIGYT(T))+(1-DELLYT(T))*PVT1(T)**
(1-SIGYT(T)))**(1/(1-SIGYT(T)));

PYNO(N) =E=(DELLYN(N)*PULO**
(1-SIGYN(N))+(1-DELLYN(N))*PVNO(N)**
(1-SIGYN(N)))**(1/(1-SIGYN(N)));

FVNO(N) =E=(DELUVT(T)*PULO**
(1-DELUV(T)))*PMTO(T)**
(1-DELUV(T)))**(1/(1-SIGVT(T)));

FVVT1(T) =E=(DELUVT(T)*PUL1**
(1-DELUV(T)))*PMT1(T)**
(1-DELUV(T)))**(1/(1-SIGVT(T)));

FVNO(N) =E=(DELUVN(N)*PULO**
(1-DELUVN(N)))*PMNO(N)**
(1-DELUVN(N)))**(1/(1-SIGVN(N)));

DEFF0.. F0=E=FLOG0+DOSQ0;

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General Algebraic Modeling System
Compilation
DEFPVN1(N) ..  PVN1(N) = E = (DELUVN(N) * PUU1**((1-SIGVN(N))) + 
(1-DELUVN(N)) * PMN1(N)**(1/(1-SIGVN(N)));

1364  DEFPMT1(T) ..  PMT1(T) = E = (DELFMT(T) * PUFL1**((1-SIGMT(T))) + 
(1-DELFMT(T)) * PTR1(T)**(1/(1-SIGMT(T)));

1368  DEFPMT0(T) ..  PMT0(T) = E = (DELFMT(T) * PUFL0**((1-SIGMT(T))) + 
(1-DELFMT(T)) * PTR0(T)**(1/(1-SIGMT(T)));

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General Algebraic Modeling System Compilation

1364  DEFPVMN0(N) ..  PMN0(N) = E = (DELFMN(N) * PUFL0**((1-SIGMN(N))) + 
(1-DELFMN(N)) * PRN0(N)**(1/(1-SIGMN(N)));

1369  DEFPFMN1(N) ..  PMN1(N) = E = (DELFMN(N) * PUFL1**((1-SIGMN(N))) + 
(1-DELFMN(N)) * PRN1(N)**(1/(1-SIGMN(N)));

1371  DEFPRT0(T) ..  PRTO(T) = E = (DELKRT(T) * PUK0**((1-SIGRT(T))) + 
+ (1-DELKRT(T)) * PUUL0**((1/(1-SIGRT(T))));

1379  DEFPRT1(T) ..  PR1(T) = E = (DELKRT(T) * PUK1**((1-SIGRT(T))) + 
+ (1-DELKRT(T)) * PUUL1**((1/(1-SIGRT(T))));

1381  DEFPRNO(N) ..  PRNO(N) = E = (DELKRN(N) * PUK0**((1-SIGRN(N))) + 
+ (1-DELKRN(N)) * PUUL0**((1/(1-SIGRN(N))));

1387  DEFPRN1(N) ..  PRN1(N) = E = (DELKRN(N) * PUK1**((1-SIGRN(N))) + 
+ (1-DELKRN(N)) * PUUL1**((1/(1-SIGRN(N))));

1392  * Partial derivatives

1395  DDPYDPLOT0(T) ..  DPYDPLOT0(T) = E = DELLYT(T) * (PYT0(T) 
** SIGYT(T)) * (PU0**(-SIGYT(T)));

1398  DDPYDPLOT1(T) ..  DPYDPLOT1(T) = E = DELLYT(T) * (PYT1(T) 
** SIGYT(T)) * (PU1**(-SIGYT(T)));

1401  DDPYDPLN0(N) ..  DPYDPLN0(N) = E = DELLYN(N) * (PYNO(N) 
** SIGYN(N)) * (PU0**(-SIGYN(N)));

1404  DDPYDPLN1(N) ..  DPYDPLN1(N) = E = DELLYN(N) * (PYN1(N) 
** SIGYN(N)) * (PU1**(-SIGYN(N)));
\begin{align*}
\text{DDPYDPVT0(T)} &\quad \text{DPYDPVT0(T)} = E = (1 - DELLYT(T)) \ast (PYT0(T) \ast \text{SIGYT}(T) \ast (PVT0(T) \ast \text{SIGYT}(T))) \\
\text{DDPYDPVT1(T)} &\quad \text{DPYDPVT1(T)} = E = (1 - DELLYT(T)) \ast (PYT1(T) \ast \text{SIGYT}(T) \ast (PVT1(T) \ast \text{SIGYT}(T))) \\
\text{DDPYDPVNO(N)} &\quad \text{DPYDPVNO(N)} = E = (1 - DELLYN(N)) \ast (PYNO(N) \ast \text{SIGYN}(N) \ast (PVNO(N) \ast \text{SIGYN}(N))) \\
\text{DDPYDPVN1(N)} &\quad \text{DPYDPVN1(N)} = E = (1 - DELLYN(N)) \ast (PYN1(N) \ast \text{SIGYN}(N) \ast (PVN1(N) \ast \text{SIGYN}(N))) \\
\text{DDPVDPMT0(T)} &\quad \text{DPVDPMT0(T)} = E = (1 - DELLUV(T)) \ast (PVT0(T) \ast \text{SIGVT}(T) \ast (PMTO(T) \ast \text{SIGVT}(T))) \\
\text{DDPVDPMT1(T)} &\quad \text{DPVDPMT1(T)} = E = (1 - DELLUV(T)) \ast (PVT1(T) \ast \text{SIGVT}(T) \ast (PMTO(T) \ast \text{SIGVT}(T))) \\
\text{DDPVDPMNO(N)} &\quad \text{DPVDPMNO(N)} = E = (1 - DELLUVN(N)) \ast (PVNO(N) \ast \text{SIGVN}(N) \ast (PMNO(N) \ast \text{SIGVN}(N))) \\
\text{DDPVDPMNO(N)} &\quad \text{DPVDPMNO(N)} = E = (1 - DELLUVN(N)) \ast (PVNO(N) \ast \text{SIGVN}(N) \ast (PMNO(N) \ast \text{SIGVN}(N))) \\
\text{DDPVDPMNO(N)} &\quad \text{DPVDPMNO(N)} = E = (1 - DELLUVN(N)) \ast (PVNO(N) \ast \text{SIGVN}(N) \ast (PMNO(N) \ast \text{SIGVN}(N))) \\
\text{DDPVDPM1(N)} &\quad \text{DPVDPM1(N)} = E = (1 - DELLUVN(N)) \ast (PVN1(N) \ast \text{SIGVN}(N) \ast (PMN1(N) \ast \text{SIGVN}(N))) \\
\text{DDPVDPM1(N)} &\quad \text{DPVDPM1(N)} = E = (1 - DELLUVN(N)) \ast (PVN1(N) \ast \text{SIGVN}(N) \ast (PMN1(N) \ast \text{SIGVN}(N))) \\
\text{DDPVDPM1(N)} &\quad \text{DPVDPM1(N)} = E = (1 - DELLUVN(N)) \ast (PVN1(N) \ast \text{SIGVN}(N) \ast (PMN1(N) \ast \text{SIGVN}(N))) \\
\text{DDPVDPM1(N)} &\quad \text{DPVDPM1(N)} = E = (1 - DELLUVN(N)) \ast (PVN1(N) \ast \text{SIGVN}(N) \ast (PMN1(N) \ast \text{SIGVN}(N))) \\
\text{DDPDMDPRT0(T)} &\quad \text{DPMDPRT0(T)} = E = (1 - DELFMT(T)) \ast (PT0(T) \ast \text{SIGMT}(T) \ast (PRT0(T) \ast \text{SIGMT}(T))) \\
\text{DDPDMDPRT1(T)} &\quad \text{DPMDPRT1(T)} = E = (1 - DELFMT(T)) \ast (PT1(T) \ast \text{SIGMT}(T) \ast (PRT1(T) \ast \text{SIGMT}(T))) \\
\text{DDPDMDPRT0(N)} &\quad \text{DPMDPRT0(N)} = E = (1 - DELFMIN(N)) \ast (PMNO(N) \ast \text{SIGMN}(N) \ast (PRNO(N) \ast \text{SIGMN}(N))) \\
\text{DDPDMDPRT1(N)} &\quad \text{DPMDPRT1(N)} = E = (1 - DELFMIN(N)) \ast (PMNO(N) \ast \text{SIGMN}(N) \ast (PRNO(N) \ast \text{SIGMN}(N))) \\
\text{DDPDMDPRT0(N)} &\quad \text{DPMDPRT0(N)} = E = (1 - DELFMIN(N)) \ast (PMNO(N) \ast \text{SIGMN}(N) \ast (PRNO(N) \ast \text{SIGMN}(N))) \\
\text{DDPDMDPRT1(N)} &\quad \text{DPMDPRT1(N)} = E = (1 - DELFMIN(N)) \ast (PMNO(N) \ast \text{SIGMN}(N) \ast (PRNO(N) \ast \text{SIGMN}(N))) \\
\text{DDPDMDPRT1(N)} &\quad \text{DPMDPRT1(N)} = E = (1 - DELFMIN(N)) \ast (PMNO(N) \ast \text{SIGMN}(N) \ast (PRNO(N) \ast \text{SIGMN}(N))) \\
\text{DDPDMDPRT1(N)} &\quad \text{DPMDPRT1(N)} = E = (1 - DELFMIN(N)) \ast (PMNO(N) \ast \text{SIGMN}(N) \ast (PRNO(N) \ast \text{SIGMN}(N))) \\
\end{align*}
\[
\begin{align*}
DDPMDPFT0(T) &= \text{E} = \text{DELFMT}(T) \cdot (\text{PMT0}(T)^* \text{SIGMT}(T))^* \\
&P(\text{PUFL0}^* (-\text{SIGMT}(T))) ; \\
DDPMDPFT1(T) &= \text{E} = \text{DELFMT}(T) \cdot (\text{PMT1}(T)^* \text{SIGMT}(T))^* \\
&P(\text{PUFL1}^* (-\text{SIGMT}(T))) ; \\
DDPMDPFN0(N) &= \text{E} = \text{DELFMN}(N) \cdot (\text{PRN0}(N)^* \text{SIGMN}(N))^* \\
&P(\text{PUFL0}^* (-\text{SIGMN}(N))) ; \\
DDPMDPFN1(N) &= \text{E} = \text{DELFMN}(N) \cdot (\text{PRN1}(N)^* \text{SIGMN}(N))^* \\
&P(\text{PUFL1}^* (-\text{SIGMN}(N))) ; \\
DDPRDPKT0(T) &= \text{E} = \text{DELRKRT}(T) \cdot (\text{PRTO}(T)^* \text{SIGRT}(T))^* \\
&P(\text{PUKO}^* (-\text{SIGRT}(T))) ; \\
DDPRDPK1(T) &= \text{E} = \text{DELRKRT}(T) \cdot (\text{PR1}(T)^* \text{SIGRT}(T))^* \\
&P(\text{PUK1}^* (-\text{SIGRT}(T))) ; \\
DDPRDPDN0(N) &= \text{E} = (1 - \text{DELRKRN}(N))^* \cdot (\text{PRN0}(N)^* \text{SIGRN}(N))^* \\
&P(\text{PUDL0}^* (-\text{SIGRN}(N))) ; \\
DDPRDPDN1(N) &= \text{E} = (1 - \text{DELRKRN}(N))^* \cdot (\text{PRN1}(N)^* \text{SIGRN}(N))^* \\
&P(\text{PUDL1}^* (-\text{SIGRN}(N))) ; \\
DDPRDPDN0(N) &= \text{E} = \text{AN(N)} \cdot \text{DPYDPVNO}(N) \cdot \text{DPVDPMNO}(N) \cdot \text{DPMDPRNO}(N) \cdot \\
&DPRDPDN0(N) ; \\
DDPRDPDN1(N) &= \text{E} = \text{AN(N)} \cdot \text{DPYDPVN1}(N) \cdot \text{DPVDPM1}(N) \cdot \text{DPMDPRN1}(N) \cdot \\
&DPRDPDN1(N) ; \\
DPXDPDT0(T) &= \text{E} = \text{AT}(T) \cdot \text{DPYDFT0}(T) \cdot \text{DPVDPM0}(T) \\
DPXDPDT1(T) &= \text{E} = \text{AT}(T) \cdot \text{DPYDFT1}(T) \cdot \text{DPVDPM1}(T) \\
\end{align*}
\]
\[ DDPXDPKT0(T) = E = AT(T) \times DPYDPVT0(T) \times DPVDPMT0(T) \times DPMDPRT0(T) \times DPRDPKTO(T); \]

\[ DDPXDPKT1(T) = E = AT(T) \times DPYDPVT1(T) \times DPVDPMT1(T) \times DPMDPRT1(T) \times DPRDPKTO(T); \]

\[ DDPXDPKNO(N) = E = AN(N) \times DPYDPVN0(N) \times DPVDPWN0(N) \times DPMDPRNO(N) \times DPRDPKNO(N); \]

\[ DDPXDPKN1(N) = E = AN(N) \times DPYDPVN1(N) \times DPVDPWN1(N) \times DPMDPRN1(N) \times DPRDPKNO(N); \]

\[ DDPXDPFT0(T) = E = AT(T) \times DPYDPVT0(T) \times DPVDPMT0(T) \times DPMDPFT0(T); \]

\[ DDPXDPFT1(T) = E = AT(T) \times DPYDPVT1(T) \times DPVDPMT1(T) \times DPMDPFT1(T); \]

\[ DEFMCT0(T) = E = AT(T) \times PYT0(T) + SUM(TT, PWO(TT) \times ATT(TT, T)) + SUM(N, PN0(N) \times ANT(N, T)) + TTAX0(T); \]
DEFMCT1(T) ..  
MCT1(T) = E=AT(T) * PYT1(T) + SUM(TT, PWO(TT) * ATN(TT,N))  
ATT(TT,N)) + SUM(NN, PNO(NN) * AN(NN,N)) + TTX0(N) ;

DEFMCN0(N) ..  
MCN0(N) = E=AN(N) * PYN0(N) + SUM(TT, PW0(TT) * ATN(TT,N))  
ATN(TT,N)) + SUM(NN, PNO(NN) * AN(NN,N)) + NTX0(N) ;

DEFMCN1(N) ..  
MCN1(N) = E=AN(N) * PYN1(N) + SUM(TT, PW1(TT) * ATN(TT,N))  
ATN(TT,N)) + SUM(NN, PNO(NN) * AN(NN,N)) + NTX0(N) ;

DEFPNO(N) ..  
PNO(N) = E=PPNO(N) ;

DEFPN1(N) ..  
PN1(N) = E=PPN1(N) ;

PRLMCT0(T) ..  
PWO(T) - MCTO(T) = L=0 ;

PRLMCT1(T) ..  
PW1(T) - MCT1(T) = L=0 ;

COMPL0(T) ..  
XT0(T) * (PWO(T) - MCT0(T)) = E=0 ;

COMPL1(T) ..  
XT1(T) * (PW1(T) - MCT1(T)) = E=0 ;

PREMCN0(N) ..  
PPN0(N) - MCN0(N) = e=0 ;

PREMCN1(N) ..  
PPN1(N) - MCN1(N) = e=0 ;

comp1n0(n) ..  
x0(n) * (PPN0(N) - MCN0(N)) = e=0 ;

comp1n1(n) ..  
x1(n) * (PPN1(N) - MCN1(N)) = e=0 ;

LDEMAND0(T) ..  
LLT0(T) = E=DPXDPLO(T) * XT0(T) ;

LDEMAND1(T) ..  
LLT1(T) = E=DPXDPLO1(T) * XT1(T) ;

LDEMANDN0(N) ..  
LN0(N) = E=DPXDPNO(N) * XNO(N) ;

LDEMANDN1(N) ..  
LN1(N) = E=DPXDPNO1(N) * XN1(N) ;

UDEMAND0(T) ..  
UTO(T) = E=DPXDPUT0(T) * XT0(T) ;

UDEMAND1(T) ..  
UT1(T) = E=DPXDPUT1(T) * XT1(T) ;

UDEMANDN0(N) ..  
UN0(N) = E=DPXPUN0(N) * XNO(N) ;

UDEMANDN1(N) ..  
UN1(N) = E=DPXPUN1(N) * XN1(N) ;

FDEMAND0(T) ..  
FLT0(T) = E=DPXDPFT0(T) * XT0(T) ;

FDEMAND1(T) ..  
FLT1(T) = E=DPXDPFT1(T) * XT1(T) ;

KDEMAND0(T) ..  
KTO(T) = E=DPXDPK0(T) * XT0(T) ;

KDEMAND1(T) ..  
KT1(T) = E=DPXDPK1(T) * XT1(T) ;

KDEMANDN0(N) ..  
KNO(N) = E=DPXPKN0(N) * XNO(N) ;

KDEMANDN1(N) ..  
KN1(N) = E=DPXPKN1(N) * XN1(N) ;

DDEMAND0(T) ..  
DLT0(T) = E=DPXDPD0(T) * XT0(T) ;

DDEMAND1(T) ..  
DLT1(T) = E=DPXDPD1(T) * XT1(T) ;

General Algebraic Modeling System
Compilation
* Investments and interest

1595  DEFPI0..  PI0*INV0=E=SUM(T, INVTO(T)*PWO(T)) + SUM(N, INVNO(N))

*PN0(N));

1597  DEFINVT0(T)..  INVT0(T)=E=INVSHRT(T) * INV0/PWO(T);
1598  DEFINVNO(N)..  INVNO(N)=E=INVSHRN(N) * INV0/PNO(N);

1600  DEFK1..  K1=e=K0+INV0-KDEPL*K0;

1603  * Rest of world

1605  TRADEBAL0..  SUM(T, PWO(T) * ZTO(T)) + PWF0 * FEXP0 = E = SBAR0;
1606  TRADEBAL1..  SUM(T, PW1(T) * ZT1(T)) + PWF1 * FEXP1 = - IRATE * SBAR1;

1608  definvo..  pk0=e=1/irate*pk1;

1610  * Market clearing

1612  TMARKETO(T)..

XT0(T)=E=SUM(TT, ATT(T, TT) * XT0(TT)) + SUM(N, ATN(T, N) *
1613  XNO(N)) + ZT0(T) + DT0(T) + INVTO(T);

1614  TMARKET1(T)..

XT1(T)=E=SUM(TT, ATT(T, TT) * XT1(TT)) + SUM(N, ATN(T, N) *
1616  XN1(N)) + ZT1(T) + DT1(T) + INVTO(T);

1617  NMARKETO(N)..  XNO(N)=E=SUM(T, ATN(T, N)) * XT0(T)) + SUM(NN, ANN(N, NN) *
1619  XNO(NN)) + DNO(N) + INVNO(N);

1620  NMARKET1(N)..  XN1(N)=E=SUM(T, ATN(T, N)) * XT1(T)) + SUM(NN, ANN(N, NN) *
1622  XN1(NN)) + DN1(N) + INVN1(N);

1623  FMARKETO..  flog0=E=SUM(T, PWF0*FLT0(T)) + PWF0*FEXP0;
1625  FMARKET1..  flog1+LGK1=E=SUM(T, PWF1*FLT1(T)) + PWF1*FEXP1;

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General Algebraic Modeling System Compile
\[ L_1 = E(\sum T, L_{T1}(T)) + \sum N, L_{N1}(N) \]

\[ U_0 = E(\sum T, U_{T0}(T)) + \sum N, U_{N0}(N) + \log L_0 + \log S_0 \]

\[ U_1 = E(\sum T, U_{T1}(T)) + \sum N, U_{N1}(N) + \log L_1 + \log S_1 \]

\[ \alpha_{UP} = 1; \beta_{UP} = 1; \]

\[ \log L_0 = \text{low}; \log S_0 = \text{low}; \]

\[ \log L_1 = \text{low}; \log S_1 = \text{low}; \]

\[ P_{L0}.LO = 0.1; P_{L1}.LO = 0.1; \]

\[ P_{R0}.LO = 0.1; P_{R1}.LO = 0.1; \]

\[ P_{U0}.LO = 0.01; P_{U1}.LO = 0.01; \]

\[ P_{D0}.LO = 0.001; P_{D1}.LO = 0.001; \]

\[ P_{N0}.LO = 0.10; P_{N1}.LO = 0.10; P_{V0}.LO = 0.10; \]

\[ P_{V1}.LO = 0.10; \]

\[ P_{P0}.LO = 0.01; P_{P1}.LO = 0.01; P_{M0}.LO = 0.01; \]

\[ P_{M1}.LO = 0.01; P_{F0}.LO = 0.10; P_{F1}.LO = 0.10; \]

\[ P_{E0}.LO = 0.50; P_{E1}.LO = 0.10; \]

\[ P_{N0}.LO = 0.10; P_{N1}.LO = 0.10; P_{M0}.LO = 0.10; \]
PPN1.LO(N) = 0.10; PRN0.LO(N) = 0.10;
PUFL1.LO = 0.10; PUF1.LO = 0.10;
PU.0.L0 = 0.10; PU.0.L0 = 0.10; PUFU.0.L0 = 0.10;
PN1.LO(N) = 0.10; PYT1.LO(T) = 0.10; PVT1.LO(T) = 0.10;
PMT1.LO(T) = 0.10; PRT1.LO(T) = 0.10;
PK1.LO = 0.10; PU1.LO = 0.10; PL1.LO = 0.10;
PDL1.LO = 0.50; PFL1.LO = 0.10;
PYN1.LO(N) = 0.10; PVN1.LO(N) = 0.10; PMN1.LO(N) = 0.10;
PPN1.LO(N) = 0.10; PRN1.LO(N) = 0.10;
PUDL1.LO = 0.10; PUFL1.LO = 0.10;
PUL1.LO = 0.10; PU1.LO = 0.10; PUU1.LO = 0.10;
DTO.LO(T) = 0.0001; DT1.LO(T) = 0.0001;
DN0.LO(N) = 0.0001; DN1.LO(N) = 0.0001;

* INITIAL VALUES

INCLUDE C:\GAMS\CRMOD\INITIAL.INC

* INITIAL VALUES FROM BASE SOLUTION
P10.L = 0.9582;
* IRATE.L = 1.000;
WELF.L = -0.1995;
UTIL0.L = -0.1366;
UTIL1.L = -0.3465;
SAV0.L = 0;
INV0.L = 0.3382;
SBAR0.L = -0.3382;
YY0.L = yy01;
YY1.L = yy11;
DISP0.L = 3.2017;
DISP1.L = 3.5688;
XT0.L(T) = XT01(T);
XT1.L(T) = XT11(T);

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1786  MCNO.L(N)=1.000;
1787
1788  DPXDPKT0.L(T)=KXT0(T); DPXDPKNO.L(N)=KXNO(N);
1789
1790  DPXDPLO.T(T)=LXT0(T); DPXDPLNO.L(N)=LXNO(N);
1791
1792  DPXDPUT0.L(T)=UXT0(T); DPXDPUNO.L(N)=UXNO(N);
1793
1794  DPXDPFT0.L('FOREST')=0.039655;
1795  DPXDPFN0.L(N)=FXNO(N);
1796
1797  DPXDPD0.L('AGRI')=0.1486931; DPXDPDNO.L(N)=0;
1798
1799  DPDPLTO.L(T)=DELLYT(T); DPDPLNO.L(N)=DELLYN(N);
1800
1801  DPDPVTO.L(T)=DELVYT(T); DPDPVN0.L(N)=DELVYN(N);
1802
1803  DPDVDT0.L(T)=DELUVT(T); DPDVUN0.L(N)=DELUVN(N);
1804
1805  DPDPMTO.L(T)=DELMVT(T); DPDPMN0.L(N)=DELMVN(N);
1806
1807  DPDPMRTO.L(T)=DELRMT(T); DPDPMRNO.L(N)=DELRMN(N);
1808
1809  DPRDPKTO.L(T)=DELRKT(T); DPRDPKNO.L(N)=DELKRN(N);
1810
1811  DPRDPDTO.L(T)=DELDRT(T); DPRDPMNO.L(N)=DELDRN(N);
1812
1813  PPNO.L(N)=1.000;
1814
1815  PUKO.L=PKO.L;
1816
1817  PUKO.L=PUO.L; PUFLO.L=PFL0.L; PUDLO.L=PDLO.L;
1818
1819  PUKO.L=PUO.L;
1820
1821  PNU.L(N)=1.000; PYT1.L(T)=1.000; PVT1.L(T)=1.000;
1822
1823  PMT1.L(T)=1.000; PRT1.L(T)=1.000; PL1.L=1.0455;
1824
1825  PK1.L=0.8750; PFL1.L=1.0000; PUL1.L=1.1786;
1826
1827  PDL1.L=0.9162;
1828
1829  MCT1.L(T)=1.000;
1830
1831  PYN1.L(N)=1.000; PMN1.L(N)=1.000;
1832
1833  PRN1.L(N)=1.000; PVN1.L(N)=1.000;
MCN1.L(N) = 1.000;

DPXDPKT1.L(T) = KXT0(T); DPXDPKN1.L(N) = KXNO(N);

DPXDPFT1.L('FOREST') = 0.039655;

DPXDPF1.L('AGRI') = 0.148693;

DPYDPLT10.L(T) = DELLYT(T); DPYDPLN1.L(N) = DELLYN(N);

DPYDPLT1.L(T) = DELLYT(T); DPYDPLN1.L(N) = DELLYN(N);

DPYDPVT1.L(T) = DELVYT(T); DPYDPVN1.L(N) = DELVYN(N);

DPYDPVT1.L(T) = DELVYT(T); DPYDPVN1.L(N) = DELVYN(N);

DPYDPUT1.L(T) = UXT0(T); DPXDPUN1.L(N) = UXNO(N);

DPYDPVT1.L(T) = DELVYT(T); DPYDPVN1.L(N) = DELVYN(N);

DPVDPMT1.L(T) = DELMV(T); DPVDPMN1.L(N) = DELM(N);

DPVDPFT1.L(T) = DELFMT(T); DPVDPFN1.L(N) = DELFM(N);

PUN1.L(N) = 1.000;

PUK1.L = pk1.l;

PUU1.L = pul.l;

ALPHA.L = 0.5;

BETA.L = 0.4;

K1.L = KO + 0.3;

model defpar / defalpha, defbeta/

solve defpar using nlp maximizing alpha;
MODEL CRTWO  /ALL/;
CRTWO.OPTFILE=1;
SOLVE CRTWO USING NLP MAXIMIZING WELF;
crtwo.optfile=0;
SOLVE CRTWO USING NLP MAXIMIZING WELF;
* crttwo.optfile=0;
SOLVE CRTWO USING NLP MAXIMIZING WELF;
* SOLVE CRTWO USING NLP MAXIMIZING WELF;
SOLVE CRTWO USING NLP MAXIMIZING WELF;
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* DISPLAY
INCLUDE C:\GAMS\CRMOD\DISPL.INC
DISPLAY mct0.l, pw0, mcno.l, pno.l,
lamsq0.l, lamsq1.l, LAMLG0.L, LAMSQL1.L,
profsq0.l, profsq1.l, profslg0.l, profslg1.l,
welf.l, utilo.l, util1.l, DISPO.L, DISPL.L,
SAVO.L, INV0.L, sbaro.l,
XT0.L, DT0.L, ZT0.L, PK0.L, PKU0.L,
PLO.L, PUL0.L, PVO.L, PUU0.L, PFO.L, PUF0.L,
PFD0.L,

LTA0.L, UTAX0, KTA0, DTAX0, FTA0, XNO.L, DNO.L,
YY0.L,
DOSQ0.L, FLOG0.L, LSQ0.L, LOGLO.L,
LGK0.L, FEXPO.L, D0.L, F0.L,
XT1.L, DT1.L, ZT1.L, PK1.L, PKU1.L,
PDL1.L,

LTA1.L, UTAX1, KTA1, DTAX1, FTA1, XN1.L, DN1.L,
YY1.L,
DOSQ1.L, FLOG1.L, LSQ1.L, LOG1.L,
LG1.L, FEXP1.L, D1.L, Fl.L;

* OUTPUT FILE

PUT RES;
PUT 'KTAX',KTax0:7:4, K Tax1:7:4 /;
PUT 'LTAX',LTax0:7:4, L Tax1:7:4 /;
PUT 'UTAX',UTax0:7:4, UTax1:7:4 /;
PUT 'DTAX',DTax0:7:4, DTax1:7:4 /;
PUT 'PTAX',PTax0:7:4, P Tax1:7:4 /;
LOOP(T,PUT T.TL);
PUT TAX0(T):7:4, TAX1(T):7:4 /;

PUT 'WELFARE', WELFA.L:7:4 /;
PUT 'UTILITY', UTIL0.L:7:4, UTIL1.L:7:4 /;
PUT 'GNP', YY0.L:7:4, YY1.L:7:4 /;

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General Algebraic Modeling System

Include File Summary

GLOBAL TYPE LOCAL FILE NAME
0 INPUT 0 C:\GAMS\CRMOD\CRTWO.GMS
82 INCLUDE 82 C:\GAMS\CRMOD\SAM.INC
235 INCLUDE 83 C:\GAMS\CRMOD\BASE.INC
371 INCLUDE 84 C:\GAMS\CRMOD\CALC.INC
538 INCLUDE 85 C:\GAMS\CRMOD\EXO.INC
1717 INCLUDE 1187 C:\GAMS\CRMOD\INITIAL.INC
1892 INCLUDE 1204 C:\GAMS\CRMOD\DISPL.INC

COMPILATION TIME = 5.660 SECONDS VERID MW2-00-059

USER: The World Bank - for internal use only
For Modeling Support - J. Kreuser x32796

**** FILE SUMMARY

INPUT C:\GAMS\CRMOD\CRTWO.GMS
OUTPUT C:\GAMS\CRMOD\CR2OUT.DOC
MODEL CODE

THE DYNAMIC MODEL OF SOIL DEGRADATION IN SRI LANKA

GAMS 2.25.059 386/486 DOS 11/13/96 17:16:17 PAGE

1 General Algebraic Modeling System Compilation

1 * SRI LANKA DYNAMIC MODEL
2 *
3 * ANNIKA PERSSON
4 *
5 */OFFSYMLIST OFFSYMREF
6 *
7 * option limrow=0
8 * OPTION LIMCOL=0
9 * option bratio=1
10 *
11 OPTION SOLPRINT=off
12 *
13 OPTION DECIMALS=5
14 * option nlp=npsol
15 scalar low /1e-7/
16 option ITERLIM=1000000;
17 FILE RES /SL5_1.TXT/
18 * Defines the name of the result file -- res is just a file to handle

data
19 * Definition of the sets of producing sectors in the macro model
20 *
21 SET P Treecrop sectors
22 *
23 / TEA Tea Plantations
24 RUBBER Rubber plantations
25 COCO Coconot plantations /
26 *
27 set n Colombo sectors
28 / colombo /
29 *
30 set C Colombo sectors
31 / RICEMI
32 FLRMIL
33 TEXTIL
34 GARMEN
35 TRSPQP
36 ELECPQ
37 OTHMAC
38 LGTENG
39 FOODPR
AGROCH
CLAY
MANUF
METAL
CONSTR /

SET E Energy sectors
PETR
ELEC /

SET E1(E)
ELEC /

SET E2(E)
PETR /

SET O Other sectors
PADDY
OTHAGR
MINING
TRADE
SERVICE /

SET H HOUSEHOLDS
URBAN
RURAL
ESTATE /

* Conversion of the column vectors to row vectors

ALIAS (P,PP);
ALIAS (C,CC);
alias (n,nn);
ALIAS (E,EE);
ALIAS (O,OO);
ALIAS (H,HH);
DISPLAY PP;
DISPLAY CC;
DISPLAY BE;
DISPLAY OO;
DISPLAY HH;

* Policy variables

parameter sshare(p) Share of holdings in smallholdings
/ tea 0.644000
rubber 0.452082
coco 0.750000 /
parameter erosion(p) Rate of soil erosion
   / tea  0.066
   rubber 0.025
   coco 0.013 /

parameter dxdp(p) change in output per unit of soil conservation;
   dxdp(p)=1-erosion(p);

parameter pgamma(p) shares of labor in soil conservation
   / tea  0.0376
   rubber 0.3079
   coco 0.0223 /

set t time periods /1*5/
alias (t,tt);

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General Algebraic Modeling System Compilation

scalar tau years per time period /4/
parameter m last time period;
   m=card(t);

parameter TIME Years forward we want to solve the model for;
   time=m*tau;

SCALAR POPG Annual growth rate of non-plantation labor force /1.016/

SCALAR CAPG Annual growth rate of capital stock /1/

* Both according to wber 1994
SCALAR APOPG Annual growth rate in estate labor stock /1.016/

scalar depl Rate of depletion /0.05/

PARAMETER interest(t) Interest rate;
   Interest(t)=0.0;

parameter Ktax(t) Tax on capital;
   ktax(t)=0.000;

parameter ATAX(t) Tax on ESTATE lab;
   atax(t)=0.000;

parameter LTAX(t) Tax on URBAN lab;
   ltax(t)=0.000;

parameter RTAX(t) Tax on RURAL lab;
   rtax(t)=0.000;

parameter XR(t) Exchange rate;
   xr(t)=1.000;
PARAMETER DPE(E,t) Price of energy products;
dpe('elec',t)=1.0;
dpe('petr',t)=1.0;

PARAMETER XE91(E) Production in energy sectors 1991
/ ELEC 2.255979
PETR 1.129127 /

PARAMETER EXPTP(P,t) Export tax on treecrops;
exptp(p,t)=0;

PARAMETER EXPTN(n,t) Export tax on Colombo;
extn(n,t)=0;

PARAMETER EXPTE(E,t) Export tax on energy;
expte(e,t)=0;

PARAMETER EXPTO(O,t) Export tax on other;
expto(o,t)=0;

* Retrieve 1991 IO table

#include \SIMOD\SIM091.INC

* Benchmark data from REVISED 1991 IO table

TABLE XPCO(P,CC) Benchmark inputs of treecrop goods in Colombo

<table>
<thead>
<tr>
<th></th>
<th>FOODPR</th>
<th>MANUF</th>
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<tbody>
<tr>
<td>TEA</td>
<td>0</td>
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<tr>
<td>RUBBER</td>
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<tr>
<td>COCO</td>
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</table>

TABLE XPO0(P,OO) Benchmark inputs of treecrop goods in Other sectors

<table>
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<tr>
<th></th>
<th>FOODPR</th>
<th>MANUF</th>
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<tr>
<td>RUBBER</td>
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<tr>
<td>COCO</td>
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TABLE XCP0(C,PP) Benchmark inputs of Colombo goods in Treecrop production

<table>
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<tr>
<th></th>
<th>TEA</th>
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<th>COCO</th>
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<tbody>
<tr>
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<td>ELECQP</td>
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TABLE XCCO(C,CC) Benchmark inputs of Colombo goods in Colombo

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<thead>
<tr>
<th>prod</th>
<th>RICEMI</th>
<th>FLRMIL</th>
<th>TEXTIL</th>
<th>GARMEN</th>
<th>TRSPQ</th>
<th>ELECQ</th>
<th>OTHMAC</th>
<th>LGTENG</th>
<th>FOODPR</th>
<th>AGROCH</th>
<th>CLAY</th>
<th>MANUF</th>
<th>METAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONSTR</td>
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GAMS 2.25.059 386/486 DOS 11/13/96 17:16:17 PAGE 5
General Algebraic Modeling System Compilation

201 CLAY 0 0 0 0 0 0 0
0.000088 0.000052 0.000471 0 0 0.000605 0
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### TABLE XCB0(C,EE) Benchmark inputs of Colombo goods in Energy production

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<th>212</th>
<th>PETR</th>
<th>ELEC</th>
</tr>
</thead>
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<tr>
<td>213</td>
<td>TRSPQP</td>
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</tr>
<tr>
<td>214</td>
<td>ELECQP</td>
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<tr>
<td>215</td>
<td>OTHMAC</td>
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<td>216</td>
<td>LGTENG</td>
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### TABLE XCO0(C,OO) Benchmark inputs of Colombo goods in Other production

<table>
<thead>
<tr>
<th>224</th>
<th>PADDY</th>
<th>OTHAGR</th>
<th>MINING</th>
<th>TRADE</th>
<th>SERVICE</th>
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</thead>
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### TABLE XEPO(E,PP) Benchmark inputs of Energy in Treecrop Production

<table>
<thead>
<tr>
<th>241</th>
<th>TEA</th>
<th>RUBBER</th>
<th>COCO</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
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</tbody>
</table>
Benchmark inputs of Energy in Colombo production

<table>
<thead>
<tr>
<th>OTHMAC</th>
<th>RICEMI</th>
<th>FLRMIL</th>
<th>TEXTIL</th>
<th>GARMEN</th>
<th>TRSPQP</th>
<th>ELECPQ</th>
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</thead>
<tbody>
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<td>AGROCH</td>
<td>CLAY</td>
<td>MANUF</td>
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Composition

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</thead>
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<td>PETR</td>
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<td>ELBC</td>
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Production

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<table>
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<th>OTHMAC</th>
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TABLE XEC0(E,CC) Benchmark inputs of Energy in Colombo production

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Production

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### TABLE XOEO(O,EE) Benchmark inputs of Other in Energy production

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### TABLE XOOO(O,OO) Benchmark inputs of Other in Other production

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### PARAMETER IMPPO(P) Benchmark imports in Treecrop sectors

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PARAMETER IMPOO(O) Benchmark import in Other sectors

/ PADDY 0.111186
OTHAGR 0.224857
MINING 0.082098
TRADE 0.222750
SERVICE 1.349097

/ CLAY 0.043122
MANUF 1.232410
METAL 0.321793
CONSTR 0.870210

PARAMETER IMPDCO(C) Benchmark import duty in Colombo sectors

/ RICEMI 0.000468
FLRMIL 0.014262
TEXTIL 0.034754
GARMEN 0.099031
TRSPQP 0.006479
ELECGP 0.011033

/ OTHMAC 0.015547
LGETEN 0.010393
FOODPR 0.176817
AGROCH 0.002511
CLAY 0.003420
MANUF 0.240444
METAL 0.030530
CONSTR 0.136838

PARAMETER IMPDEO(E) Benchmark import duty in Energy sectors

/ PETR 1.592480
ELEC 0.004328

PARAMETER IMPDOO(O) Benchmark import duty in Other sectors

/ PADDY 0.004715
OTHAGR 0.002453
MINING 0.000665
TRADE 0.179857
SERVICE 0.00964 /

PARAMETER LPO(P) Benchmark inputs of URBAN labor in Treecrop sectors

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PARAMETER IMPOO(O) Benchmark import in Other sectors

/ PADDY 0.111186
OTHAGR 0.224857
MINING 0.082098
TRADE 0.222750
SERVICE 1.349097

PARAMETER IMPDOO(O) Benchmark import duty in Other sectors

/ PADDY 0.004715
OTHAGR 0.002453
MINING 0.000665
TRADE 0.179857
SERVICE 0.110481

PARAMETER LPO(P) Benchmark inputs of URBAN labor in Treecrop sectors
<table>
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<th>Sector</th>
<th>Benchmark Input of RURAL Labor in Tree Crops</th>
<th>Benchmark Input of ESTATE Labor in Tree Crops</th>
<th>Benchmark Input of URBAN Labor in Colombo</th>
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407  CLAY     0.171650
408  MANUF    0.357940
409  METAL    0.033250
410  CONSTR   1.243760 /
411
412  PARAMETER AC0(C)  Input of ESTATE labor in Colombo sectors
413  / RICEMI   0.001350
414  FLRMIL    0.000510
415  TEXTIL    0.005710
416  GARMEN    0.010300
417  trspqp    0.000240
418  elecqp    0.000690
419  OTHMAC    0
420  LGTENG    0.001460
421  AGROCH    0.004250
422  CLAY      0.005370
423  MANUF     0.013780
424  METAL     0.001020
425  CONSTR    0.044850 /
426
427  PARAMETER LEO(E)  Benchmark inputs of URBAN labor in Energy sectors
428  / PETR     0.021570
429  ELEC      0.063540 /
430
431  PARAMETER RE0(E)  Benchmark inputs of RURAL labor in Energy sectors
432  / PETR     0.030210
433  ELEC      0.061820 /
434
435  PARAMETER AE0(E)  Benchmark inputs of ESTATE labor in Energy sectors
436  / PETR     0.001500
437  ELEC      0.003640 /
438
439  PARAMETER LO0(O)  Benchmark inputs of URBAN labor in Other sectors
440  / PADDY    0.005370
441  OTHAGR    0.096890
442  MINING    0.006340
443  TRADE     0.946100
444  SERVICE   1.421140 /
445
446  PARAMETER RO0(O)  Benchmark input of RURAL labor in Other sectors
447  / PADDY    0.485270

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Compilation
PARAMETER AO0(O)  
Benchmark input of ESTATE labor in Other sectors

/ PADDY  0.010050
/ OTHAGR  0.173000
/ MINING  0.003360
/ TRADE  0.092260
/ SERVICE  0.135320

PARAMETER KPO(P)  
Benchmark inputs of capital in Treecrop sectors

/ TEA  0.741520
/ RUBBER  0.263730
/ COCO  0.575000

PARAMETER KCO(C)  
Benchmark inputs of capital in Colombo sectors

/ RICEMI  0.010680
/ FLRMIL  0.001585
/ TEXTIL  0.046770
/ GARMEN  0.067650
/ TRSPQP  0.019470
/ ELECQP  0.006350
/ OTHMAC  0.011060
/ LGTENG  0.016030
/ FOODPR  0.442600
/ AGROCH  0.082700
/ CLAY  0.043690
/ MANUF  0.145920
/ METAL  0.010030
/ CONSTR  0.736830

PARAMETER KE0(E)  
Benchmark inputs of capital in Energy sector

/ PETR  0.106800
/ ELEC  0.297694

PARAMETER KO0(O)  
Benchmark inputs of capital in Other sector

/ PADDY  0.852800
/ OTHAGR  3.081720
/ MINING  0.262630
/ TRADE  6.771610
/ SERVICE  0.470640

PARAMETER DEPLP0(P)  
Benchmark depletion of capital in Treecrop sectors

/ TEA  0.034960
/ RUBBER  0.008060
/ COCO  0.004950
PARAMETER DEPLCO(C) Benchmark depletion of capital in Colombo sectors

502 / RICEMI 0.007590
504 / FLRMIL 0.005275
505 / TEXTIL 0.029400
506 / GARMEN 0.051170
507 / TRSPQP 0.010440
508 / ELECQP 0.002700
509 / OTHMAC 0.002410
510 / LSTENG 0.003430
511 / FOODPR 0.219390
512 / AGROCH 0.174830
513 / CLAY 0.027840
514 / MANUF 0.037720
515 / METAL 0.003460
516 / CONSTR 0.109720 /

PARAMETER DEPLE0 Benchmark depletion of capital in Energy sector

519 / PETR 0.015689
521 / ELEC 0.206366 /

PARAMETER DEPL00(C) Benchmark depletion of capital in Other sector

523 / PADDY 0.053610
526 / OTHAGR 0.051070
527 / MINING 0.021650
528 / TRADE 0.403180
529 / SERVICE 0.413510 /

PARAMETER ITAXP0(P) Benchmark indirect taxes in Treecrop sector

531 / TEA 0.003920
533 / RUBBER 0.000448
534 / COCO 0.001057 /

PARAMETER SUBSP0(P) Benchmark subsidy in Treecrop sector

535 / TEA 0.015200
538 / RUBBER 0.014730
539 / COCO 0.006110 /

PARAMETER ITAXCO(C) Benchmark indirect tax in Colombo sector

541 / RICEMI 0.000208
543 / FLRMIL 0.019600
544 / TEXTIL 0.184202
545 / GARMEN 0.039151
546 / TRSPQP 0.010517
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**TABLE PCONSO(P,H)** Benchmark private final consumption of Colombo products per household type

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<th>Type</th>
<th>URBAN</th>
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<td>0.135261</td>
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**TABLE CCONSO(C,H)** Benchmark private final consumption of Colombo products per tree crops

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<tbody>
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### TABLE OCONSO(O,H) Benchmark private final consumption of Other products

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### PARAMETER INVP0(P) Benchmark Tree crops in investment

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### PARAMETER INVCO(C) Benchmark Colombo products in investments

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### PARAMETER INVOO(O) Benchmark Other products in investments

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### PARAMETER PEXPO(P) Benchmark export of tree crops

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### PARAMETER CEXPO(C) Benchmark export of Colombo products

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<tr>
<td></td>
<td>3.272270</td>
</tr>
</tbody>
</table>
PARAMETER EEXPO(E) Benchmark export of Energy products
PETR 0.328945 /
PARAMETER OEXPO(O) Benchmark export of Other products
OTHAGR 0.538121 /
MINING 0.315810
TRADE 1.104184
SERVICE 0.673560 /

* Retrieve elasticities
INCLUDE C:\SLMOD\SLELAA.INC
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General Algebraic Modeling System Compilation

* Elasticities of substitution
PARAMETER SIGAKP(P) Elasticity of substitution between L and K in P
TEA 0.800
RUBBER 0.800
COCO 0.800 /
parameter sigakn(n);
sigakn(n)=0.8;

PARAMETER SIGAKC(C) Elasticity of substitution between L and K in C
RICEMI 0.800
FLRMIL 0.800
TEXTIL 0.800
GARMEN 0.800
TRSPQP 0.800
ELECQP 0.800
OTHMAC 0.800
LGTENG 0.800
FOODPR 0.800
AGROCH 0.800
CLAY 0.800
MANUF 0.800
METAL 0.800
PARAMETER SIGAKE(E) Elasticity of substitution between L and K in E

PARAMETER SIGAKO(O) Elasticity of substitution between L and K in O

PARAMETER SIGR1P(P) Elasticity of substitution between R AND 1 in P

PARAMETER SIGR1C(C) Elasticity of substitution between R AND 1 in C

FLRMIL 0.800
TEXTIL 0.800
GARMEN 0.800
TRSPQP 0.800
ELECQP 0.800
OTHMAC 0.800
LGTENG 0.800
FOODPR 0.800
AGROCH 0.800
CLAY 0.800
MANUF 0.800
METAL 0.800
CONSTR 0.800

PARAMETER SIGR1E(E) Elasticity of substitution between R AND 1 in E

ELEC 0.800
PARAMETER SIGR10(O)  Elasticity of substitution between R AND 1 in O

/  PADDY  0.800  
  OTHAGR  0.800  
  MINING  0.800  
  TRADE  0.800  
  SERVICE  0.800  /

PARAMETER SIGL2P(P)  Elasticity of substitution between L AND 2 in P

/  TEA  0.800  
  RUBBER  0.800  
  COCO  0.800  /

parameter sigl2n(n);
  sigl2n(n)=0.8;

PARAMETER SIGL2C(C)  Elasticity of substitution between L AND 2 in C

/  RICEMI  0.800  
  FLRMIL  0.800  
  TEXTIL  0.800  
  GARMEN  0.800  
  TRSPQP  0.800  
  ELECQP  0.800  
  OTHIAC  0.800  
  LGTENG  0.800  
  FOODPR  0.800  
  AGROCH  0.800  
  CLAY  0.800  
  MANUF  0.800  
  METAL  0.800  
  CONSTR  0.800  /

PARAMETER SIGL2E(E)  Elasticity of substitution between L AND 2 in E

/  ELEC  0.800  
  PETR  0.800  /

PARAMETER SIGL20(O)  Elasticity of substitution between L AND 2 in O
PARAMETER SIGE3P(F) Elasticity of substitution between E AND 3 in P

PARAMETER SIGE3C(C) Elasticity of substitution between E AND 3 in C

PARAMETER SIGE3E(E) Elasticity of substitution between E AND 3 in E

PARAMETER SIGE3O(O) Elasticity of substitution between E AND 3 in O
PARAMETER SIGM4P(P) Elasticity of substitution between M AND 4 in P

/ TEA 0.800
RUBBER 0.800
COCO 0.800 /

parameter sigm4n(n);
sigm4n(n)=0.8;

PARAMETER SIGM4C(C) Elasticity of substitution between M AND 4 in C

/ RICEMI 0.800
FLRMIL 0.800
TEXIL 0.800
GARMEN 0.800
TRSPQP 0.800
ELECQP 0.800
OTHMAC 0.800
LGTENG 0.800
FOODPR 0.800
AGROCH 0.800
CLAY 0.800
MANUF 0.800
METAL 0.800
CONSTR 0.800 /

PARAMETER SIGM4E(E) Elasticity of substitution between M AND 4 in E

/ ELEC 0.800
PETR 0.800 /

PARAMETER SIGM4O(O) Elasticity of substitution between M AND 4 in O

/ PADDY 0.800
OTHAGR 0.800
MINING 0.800
TRADE 0.800
SERVICE 0.800 /

PARAMETER MUP(P) Elasticity of transformation between dom and exports

/ tea 1.00
rubber 1.00
COCO 1.00 /

parameter mun(n);
mu(n) = 1;

parameter mu(c) Elasticity of transformation betw dom and exports

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RICEMI 1.000
FLRMIL 1.000
TEXTIL 1.000
GARMEN 1.000
TRSPQP 1.000
ELECQP 1.000
OTHRAC 1.000
LGTENG 1.000
FOODPR 1.000
AGROCH 1.000
CLAY 1.000
MANUF 1.000
METAL 1.000
CONSTR 1.000 /

parameter mu(o) Elasticity of transformation betw dom and exports

PADDY 1.000
OTHAGR 1.000
MINING 1.000
TRADE 1.000
SERVICE 1.000 /

parameter mu(e) Elasticity of transformation betw dom and exports

PETR 1.0
ELEC 1.0 /

* Retrieve WM prices
*$INCLUDE SLPRICEa.INC

* Calculate parameters
$INCLUDE C:\SIMOD\SLAPRL.INC

* Submodel using simultaneous equations to calculate parameters

VARIABLES

PQP0(P) Initial price of composite output P
IMPSHP(P) Share of imports in QP
IMPPD(P,t) Ad valorem import duty rate P
PQC0(C) Initial price of composite output C
pgn0(n)
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General Algebraic Modeling System
Compilation

EQUATIONS

Definition of PPO
Definition of IMPSHP
Definition of IMPDP
Definition of PQCO
Definition of IMPSHC
Definition of IMPDC
Definition of IMPDO
Definition of QPO
Definition of QCD
Definition of QEO
Definition of QOO
Definition of PXO
Definition of CXO
Definition of EXO

OBJ
Objective function has no meaning all variables are
predetermined;

954
dqm0(n)
955
dqe0(E)
956
dq00(O)
957
dpx0(P)
958
dcx0(C)
959
dx0(n)
960
dexo(E)

Definition of QEO
Definition of QO
Definition of PX0
Definition of CX0
Definition of EX0
961 DOXO(O)  Definition of OXO
962 DOBJ Definition of objective function;
963
964 DPQPO(P) = PQPO(P)=E=1;
965
966 DIMPSHP(P) = IMPSHP(P)=E=(IMPP0(P)+impdp0(p))/(qP0(P)/PQPO(P));
967
968 DIMPDP(P,t) = IMPDP(P,t)=E=IMPD00(P)/(IMPP0(P)+impdp0(p));
969
970 DPQCO(C) = PQCO(C)=E=1;
971
972 dpqn0(n) = pqn0(n)=e=1;
973
974 DIMPSC(C) = IMPSHC(C)=E=(IMPC0(C)+impdc0(c))/(qc0(C)/PQCO(C));
975
976 DIMPDC(C,t) = IMPDC(C,t)=E=IMPD00(C)/(IMPC0(C)+impdc0(c));
977
978 DPQEO(E) = PQEO(E)=E=1;
979
980 DIMPSHE(E) = IMPSHE(E)=E=(IMPE0(E)+impde0(e))/(qE0(E)/PQEO(E));
981
982 DIMPDE(E,t) = IMPDE(E,t)=E=IMPE00(E)/(IMPE0(E)+impde0(e));
983
984 DPQOO(O) = PQOO(O)=E=1;
985
986 DIMPSHO(O) = IMPSHO(O)=E=(IMPOO(O)+IMPDO0(O))/(qc0(O);
987
988 DIMPDO(O,t) = IMPDO(O,t)=E=IMPDO0(O)/(IMPOO(O)+impdo0(o));
989
990 DQPO(P) = QPO(P)=E=(PXO(P)+IMPP0(P)+impdp0(p))/PQPO(P);
991
992 DQCO(C) = QC0(C)=E=(CX0(C)+IMPC0(C)+impdc0(c))/PQCO(C);
993
994 dqn0(n) = qn0(n)=e=sum(c,qc0(c));
995
996 DQE0(E) = QE0(E)=E=(EX0(E)+IMPE0(E)+impde0(e))/PQEO(E);
997
998 DQOO(O) = Q00(O)=E=(CX0(O)+IMPOO(O)+impdo0(o))/PQOO(O);
999
1000 DPXO(P) = PXO(P)=E=SUM(C,XCP0(C,P))+SUM(E,XEP0(E,P)) +
1001 SUM(O,XOP0(C,P))+AP0(P)+rp0(p)+lp0(p)+KP0(P)+
1002 dep1p0(p)+ITAXPO(P)+SUBSPO(P);
1003
1004 CX0(C) = E=SUM(P,XPC0(P,C))+SUM(CC,XCC0(CC,C,C))+SUM(E, XEC0(E,
C)\)+
1005 SUM(O,XOC0(O,C)) + LC0(C) + rc0(c) + ac0(c) + KCO(C) +
1006 depl0(c) + ITAXOX0(C);
1007
1008 dx0(n) = e = sum(c, c0x0(c));
1009
1010 DEX0(E) . .
1011 EX0(E) = E = SUM(C, XE00(C,E)) + SUM(EE, XE00(EE,E)) +
1012 SUM(O, XO00(O,E)) + LE0(E) + re0(e) + ae0(e) + KB0(E) +
1013 deple0(e) + ITAXEO(E) - SUBSEO(E);
1014
1015 DOX0(O) = E = SUM(P, XP00(P, O)) + SUM(C, XCO0(C, O)) + SUM(E, XEO0(E, O)) +
1016 SUM(OO, X000(OO, O)) + L00(0) + ro0(o) + ao0(o) + K00(O) +
1017 depl00(0) + ITAX00(O) - SUBSO0(O);
1018
1019 * Initial values
1020 pqp0.1(p) = 1; pqc0.1(c) = 1; pqe0.1(e) = 1; pqo0.1(0) = 1;
1021 q0.1(p) = 1; q0.1(c) = 1; qe0.1(e) = 1; qo0.1(0) = 1;
1022
1023 MODEL PREL / ALL/;
1024 SOLVE PREL USING NLP MAXIMIZING OBJ;
1025
1026 DISPLAY cx0.1, PQ0.1, IMPSH.1, IMPDP.1, PQC.1,
1027 IMPSC.1, IMPDC.1, PQE.1,
1028 IMPSH.E, IMPDE.E, PQ00.1, IMPSO.1, IMPDO.1;
1029 INCLUDE C:\SIMOD\SLCLCAGG.INC
1030 * Calculation of parameters
1031
1032 * Total production
1033
1034 PARAMETER CP0(PP) Dom PROD plus IMPORTS P;
1035 CP0(P) = PX0.1(L(P) + IMP0(P) + IMPDP0(P));
1036 DISPLAY CP0;
1037
1038 PARAMETER CC0(CC) Dom PROD plus IMPORTS C;
1039 CC0(C) = CX0.1(L(C) + IMPC0(C) + IMPDC0(C));
1040 DISPLAY CC0;
1041
1042 parameter cn0(nn) Dom propd plus import agg c;
1043 cn0(n) = sum(c, cn0(c));
1044
1045 PARAMETER CE0(EE) Dom PROD plus IMPORTS E;
1046 CE0(E) = EX0.1(L(E) + IMPE0(E) + IMPDE0(E));
1047 DISPLAY CE0;
1048
1049 PARAMETER CO0(OO) Dom PROD plus IMPORTS O;
1050 CO0(O) = OX0.1(L(O) + IMPO0(O) + IMPDO0(O));
1051 DISPLAY CO0;
* Input coefficients in treecrop production

PARAMETER ACP(C,PP) Shares of C in P production;
ACP(C,P) = (XCP0(C,P)/PQCP0.L(C))/(CP0(P)/PQP0.L(P));
DISPLAY ACP;

parameter anp(n,pp) Shares of N in P production;
anp(n,p) = sum(c, acp(c,p));

PARAMETER AEP(E,PP) Shares of E in P production;
AEP(E,P) = (XEPO(E,P)/PQEO.L(E))/(CP0(P)/PQP0.L(P));
DISPLAY AEP;

PARAMETER AOP(O,PP) Shares of O in P production;
AOP(O,P) = (XOPO(O,P)/PQO0.L(O))/(CP0(P)/PQP0.L(P));
DISPLAY AOP;

PARAMETER EXSPHP(PP) Exports as share of total consumption;
EXSPHP(P) = (PEXPO(P)/(CP0(P)/PQP0.L(P));
DISPLAY EXSPHP;

PARAMETER AAP(PP) Initial input coeff for labor in P production;
AAP(P) = (AP0(P)/(CP0(P)/PQP0.L(P));
DISPLAY AAP;

PARAMETER ALP(PP) Initial input coeff for urban labor in P production;
alp(P) = (LP0(P)/(CP0(P)/PQP0.L(P));

PARAMETER ARP(pp) Initial input coeff for rural labor in P production;
ARP(p) = (RP0(p)/(CP0(p)/PQP0.L(p));

PARAMETER AKP(PP) Initial input coeff for capital in P production;
AKP(P) = (KP0(P) + DEPLP0(P))/(CP0(P)/PQP0.L(P));
DISPLAY AKP;

PARAMETER ITAXP(PP,tt) Indirect tax rate in P sectors;
ITAXP(P,t) = ITAXPO(P)/(CP0(P)/PQP0.L(P));
DISPLAY ITAXP;

PARAMETER SUBSP(PP,tt) Subsidy rate in P sectors;
SUBSP(P,t) = SUBSPO(P)/(CP0(P)/PQP0.L(P));
DISPLAY SUBSP;
PARAMETER otaxp(PP,tt) Net tax rate on p products;
  OTAXP(P,t)=ITAXP(P,t)-SUBSP(P,t);

parameter deplp(p) Depletion rate of capital in P sectors;
  deplp(p)=deplp0(p)/kp0(p);
  display deplp;

parameter deplc(c) Depletion rate of capital in C sectors;
  deplc(c)=deplc0(c)/kc0(c);
  display deplc;

parameter deplo(o) Depletion rate of capital in O sectors;
  deplo(o)=deplo0(o)/ko0(o);
  display deplo;

* Input coefficients in Colombo production

PARAMETER APC(P,CC) Shares of P in C production;
  APC(PP,C)=(XPC0(PP,C)/PQPO.L(PP))/(CC0(C)/PQCO.L(C));
  DISPLAY APC;

parameter xpn0(p);
  xpn0(p)=sum(c,xpc0(p,c));

parameter xnn0(n);
  xnn0(n)=sum(c,sum(cc,xcc0(c,cc)));

PARAMETER ACC(C,CC) Shares of C in C production;
  ACC(CC,C)=(Xcc0(CC,C)/PQCO.L(C))/(CC0(C)/PQCO.L(C));
  DISPLAY ACC;

parameter apn(p,n);
  apn(p,n)=xpn0(p)/PQP0.L(P)/sum(c,CC0(C)/PQCO.L(C));

PARAMETER AEC(E,CC) Shares of E in C production;
  AEC(E,C)=(XEC0(E,C)/PQE0.L(E))/(CC0(C)/PQCO.L(C));
  DISPLAY AEC;
parameter aen(e,nn);

aen(e,n)=\sum(c, (XEC_0(E,C)/PQE_0.L(E)))/\sum(c, (CC_0(C)/PQC_0.L(C)))

PARAMETER AOC(O,CC) Shares of O in C production;

AOC(O,C)=XOC_0(O,C)/PQO_0.L(O)/(CC_0(C)/PQC_0.L(C));

DISPLAY AOC;

PARAMETER expshn(nn)

expshn(n)=\sum(c, (CEXP_0(C)))/\sum(c, (cc0(C)));

DISPLAY expshn;

PARAMETER AON(o,nn)

aon(o,n)=\sum(c, (XOC_0(O,C)/PQO_0.L(O)))/\sum(c, (CC_0(C)/PQC_0.L(C)))

DISPLAY AOn;

PARAMETER EXPSHC(C) Export share of total consumption;

EXPSHC(C)=CEXP_0(C)/(cc0(C));

DISPLAY EXPSHC;

PARAMETER aln(nn)

aln(n)=\sum(c, (LC_0(C)))/\sum(c, (CC_0(C)));

DISPLAY aln;

PARAMETER arc(cc) Initial input coeff for rural labor in C production;

ARC(c)=rc0(c)/(cc0(c)/pqc0.1(c));

PARAMETER ARN(nn)

arn(n)=\sum(c, (rC_0(c)))/\sum(c, (CC0(c)));

PARAMETER aac(cc) Initial input coeff for estate labor in C production;

AAC(C)=ac0(c)/(cc0(c)/pqc0.1(c));

PARAMETER AKC(CC) Initial input coeff for capital in C production;

AKC(C)=LC_0(C)/CC0(C)
PARAMETER OTAXC(CC,tt) Indirect tax rate in C sectors;
ITAXC(C,t)=ITAXC0(C)/(CC0(C)/PQC0.L(C));
DISPLAY ITAXC;

PARAMETER OTAXn(nn,tt) Net tax rate on C products;
OTAXn(n,t)=ITAXn(n,t);

PARAMETER ALE(EE) Initial input coeff for urban labor in E production;
ALE(EE)=LE0(EE)/(CE0(EE)/PQE0.L(EE));
DISPLAY ALE;

PARAMETER ARE(EE) Initial input coeff for rural labor in E production;
ARE(EE)=RE0(EE)/(CE0(EE)/PQE0.L(EE));

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PARAMETER AAE(EE) Initial input coeff for estate labor in E production;
AAE(E) = ae0(e) / (ce0(e) / pqe0.1(e));

PARAMETER AKE(EE) Initial input coeff for capital in E production;
AKE(E) = (KE0(E) + deple0(e)) / (CE0(E) / PQE0.L(E));

DISPLAY AKE;

PARAMETER ITAXE(EE, tt) Indirect tax rate in E sectors;
ITAXE(E, t) = ITAXE0(E) / (CE0(E) / PQ0.L(E));

DISPLAY ITAXE;

PARAMETER SUBSE(EE, T) Subsidy rate in E sectors;
SUBSE(e, t) = subse0(e) / (ce0(e) / pqe0.1(e));

PARAMETER otaxe(EE, tt) Net tax rate on E products;
OTAXE(E, t) = ITAXE(E, t) - subse(e, t);

* Input coefficients in Other production

PARAMETER APO(P, OO) Shares of P in O production;
APO(P, O) = (XPOO(P, O) / PQP0.L(P)) / (COO(O) / PQOO.L(O));

DISPLAY APO;

PARAMETER ACO(C, OO) Shares of C in O production;
ACO(C, O) = (XCOO(C, O) / PQC0.L(C)) / (COO(O) / PQOO.L(O));

DISPLAY ACO;

parameter ano(n, oo) Shares . . . ;
ano(n, o) = sum(c, (XCOO(C, O) / PQC0.L(C)) / (COO(O) / PQOO.L(O));

PARAMETER AEO(E, OO) Shares of E in O production;
AEO(E, O) = (XEOO(E, O) / PQE0.L(E)) / (COO(O) / PQOO.L(O));

DISPLAY AEO;

PARAMETER AOO(O, OO) Shares of O in O production;
AOO(O, O) = (XO00(O, O) / PQO0.L(O)) / (COO(O) / PQOO.L(O));

DISPLAY AOO;

PARAMETER EXPSHO(OO) Export share of total consumption;
EXPSHO(O) = OEXP0(O) / (COO(O));

DISPLAY EXPSHO;

PARAMETER ALO(OO) Initial input coeff for urban labor in O production;
ALO(O) = LO0(O) / (COO(O) / PQOO.L(O));

DISPLAY ALO;

PARAMETER ARO(OO) Initial input coeff for rural labor in O production;
PARAMETER AAO(OO)  Initial input coeff for estate labor in O production;
AAO(O)=AOO(O)/(COO(O)/PQOO.L(O));

PARAMETER AKO(OO) Initial input coeff for capital in O production;
AKO(O)=(KOO(O)+depoO(O))/(COO(O)/PQOO.L(O));

PARAMETER ITAXO(OO,tt) Indirect tax rate in O sectors;
ITAXO(O,t)=ITAXOO(O)/(COO(O)/PQOO.L(O));

PARAMETER SUBSO(OO,tt) Subsidy rate in O sectors;
SUBSO(O,t)=subsoO(O)/(coO(o)/pqoO.l(o));

PARAMETER OTAXO(OO,tt) net tax rate O products;
OTAXO(O,t)=ITAXO(O,t)-subsoO(t);

PARAMETER PTCONSO(PP) Total consumption of P goods in period O;
PTCONSO(P)=sum(h,PCONSO(P,h))/PQPO.L(P)+INVpO(P)/PQP0.L(P);

PARAMETER CTCONSO(CC) Total consumption of C goods in period O;
CTCONSO(C)=sum(h,CCONSO(C,h))/PQCO.L(C)+INVcO(C)/PQCO.L(C);

PARAMETER ETCONSO(EE) Total consumption of E goods in period O;
ETCONSO(E)=sum(h,ECONSO(E,h))/PQEO.L(E);

PARAMETER OTCONSO(00) Total consumption of O goods in period O;
OTCONSO(O)=(sum(h,OCONSO(O,h)+INVoO(O))/PQOO.L(O);

PARAMETER TOTEXPO Total exports;
TOTEXPO=SUM(P,PEXPO(P))+SUM(C,CEXPO(C))+sum(e,exp0(e))
+SUM(O,EXP0(O));

PARAMETER TOTIMP0 Total imports;
TOTIMPO = SUM(P, IMPP0(P)) + SUM(C, IMPC0(C)) + SUM(E, IMPE0(E)) + SUM(O, IMPO0(O));

PARAMETER TIMPDO Total import duty;

TIMPDO = SUM(P, IMPP0(P)) + SUM(C, IMPC0(C)) + SUM(E, IMPE0(E)) + SUM(O, IMPO0(O));

DISPLAY TIMPDO;

PARAMETER TOTCONSO Total consumption;

TOTCONSO = SUM(P, PTCONSO(P)) + SUM(C, CTCONSO(C)) + SUM(E, ETCONSO(E)) + SUM(O, OTCONSO(O));

DISPLAY TOTCONSO;

PARAMETER TBO Initial trade balance;

TBO = TOTEXPO - TOTIMPO;

DISPLAY TBO;

PARAMETER TOTLO Total urban labor supply;

TOTLO = SUM(P, lp0(P)) + SUM(C, LCO(C)) + SUM(E, LE0(E)) + SUM(O, LO0(O));

DISPLAY TOTLO;

PARAMETER TOTr0 Total rural labor supply;

TOTr0 = SUM(P, rp0(P)) + SUM(C, rC0(C)) + SUM(E, rE0(E)) + SUM(O, rO0(O));

DISPLAY TOTr0;

PARAMETER TOTA0 Total estate labor supply;

TOTA0 = SUM(P, ap0(P)) + SUM(C, aC0(C)) + SUM(E, aE0(E)) + SUM(O, aO0(O));

DISPLAY TOTA0;

PARAMETER TOTK0 Total capital supply;

TOTK0 = SUM(P, kp0(P)) + deplP0(p) + SUM(C, KC0(C)) + deplC0(c)) + SUM(E, KE0(E)) + deple0(e)) + SUM(O, K00(O) + deplo0(o));

DISPLAY TOTK0;

PARAMETER TTAX0 Total benchmark taxes EXCEPT direct taxes;

TTAX0 = SUM(P, (ITAXPO(P) - SUBSP0(P))) + SUM(C, ITAXCO(C)) + SUM(E, ITAXEO(E)) - SUBSE0(E)) + SUM(O, (ITAXOO(O) - SUBSO0(O)));

DISPLAY TTAX0;

PARAMETER TB0 Initial trade balance;

TB0 = TOTEXP0 - TOTIMPO;

DISPLAY TB0;

PARAMETER DISPO(h) Benchmark disposable income for household h;

DISPO(h) = sum(p, pcons0(p,h)) + sum(c, ccons0(c,h)) + sum(e, econs0(e,h)) + sum(o, ccons0(o,h));

DISPLAY DISPO;
PARAMETER TOTINVO Benchmark investment level;

\[
\text{totinv} = \text{sum}(p, \text{invp}(p)) + \text{sum}(c, \text{invc}(c)) + \text{sum}(o, \text{invo}(o));
\]

display totinv0;

parameter tr Total transfers and capital incomes not;

\[
\text{tr} = \text{sum}(h, \text{disp}(h)) - (\text{totl} + \text{totr}_0 + \text{totl10});
\]

display tr;

parameter KH Share of transfers and capital income to HH;

\[
\begin{align*}
n &\text{\text{\text{\text{'urban'}})))/(tb0+totinv0-tr);} \\
\text{kh} &\text{('rural')} = (\text{totr}_0 - \text{disp}('rural'))/(tb0+totinv0-tr); \\
\text{kh} &\text{('estate')} = (\text{tota}_0 - \text{disp}('estate'))/(tb0+totinv0-tr);
\end{align*}
\]

display kh;

parameter test;

\[
\text{test} = \text{sum}(h, \text{disp}(h)) + \text{tb0} + \text{totinv0} - \text{totl10} - \text{totr}_0 - \text{totl0} - \text{tr};
\]

display test;

parameter sav(h);

\[
\begin{align*}
\text{sav}('urban') &\text{= totl10+kh('urban')*(totk0+ttax0+timpd0)} - \\
\text{disp}('urban'); \\
\text{sav}('rural') &\text{= totr0+kh('rural')*(totk0+ttax0+timpd0)} - \\
\text{disp}('rural'); \\
\text{sav}('estate') &\text{= tota0+kh('estate')*(totk0+ttax0+timpd0)} - \\
\text{disp}('estate');
\end{align*}
\]

display sav;

parameter disp01;

\[
\text{disp01} = \text{totl10+kh('urban')*(totk0+ttax0+timpd0)} - \text{totinv0-tb0};
\]

display disp01;

PARAMETER PALPHA(PP, h) Expenditure share on P goods for household h;

\[
\text{PALPHA}(P, h) = \text{PCONSO}(P, h) * \text{PQO.L(P)}/\text{DISPO}(h);
\]

display PALPHA;

PARAMETER CALPHA(CC, h) Expenditure share on C goods;

\[
\text{CALPHA}(C, h) = \text{CCONSO}(C, h) * \text{PQO.L(C)}/\text{DISPO}(h);
\]

display CALPHA;

parameter nalpha(nn, h);

\[
\text{nalpha}(n, h) = \text{sum}(c, \text{calpha}(c, h));
\]

PARAMETER EALPHA(EE, h) Expenditure share on E goods;
EALPHA(E,h)=ECONSO(E,h)\*PQE0\_L(E)/DISP0(h);
DISPLAY EALPHA;

PARAMETER OALPHA(OO,h) Expenditure share on O goods;
OALPHA(O,h)=OCONSO(O,h)\*PQO0\_L(O)/DISP0(h);
DISPLAY OALPHA;

PARAMETER TALPHA(h) Total share check;
TALPHA(h)=SUM(P,PALPHA(P,h))+SUM(C,CALPHA(C,h))+SUM(E,EALPHA(E,h))
+SUM(O,OALPHA(O,h));
DISPLAY TALPHA;

parameter pbeta(p) Investment share of P goods;
pbeta(p)=invp0(p)/totinv0;
display pbeta;

parameter cbeta(c) Investment share of C goods;
cbeta(c)=invc0(c)/totinv0;
display cbeta;

parameter nbeta(n);
nbeta(n)=sum(c,cbeta(c));

parameter obeta(o) Investment share of O goods;
obeta(o)=invo0(o)/totinv0;
display obeta;

PARAMETER AP(PP,t) Production function scale parameter P sectors;
AP(P,t)=1-
(SUM(C,ACP(C,P))+SUM(O,AOP(O,P))+SUM(E,EAP(E2,P)))
-TAXP(P,t);
DISPLAY AP;

PARAMETER AC(CC,t) Production function scale parameter C
AC(C, t) = 1 - (SUM(P, APC(P, C)) + SUM(CC, ACC(CC, C)) + SUM(E2, AEC(E2, C))
+ SUM(O, AOC(O, C))) - OTAXC(C, t);
DISPLAY AC;

parameter an(nn, t);
an(nn, t) = 1 - (SUM(P, APn(P, n)) + Ann(n) + SUM(E2, AEn(E2, n))
+ SUM(O, AOn(O, n))) - OTAXn(n, t);
display an;

PARAMETER AE(EE, t) Production function scale parameter E
sectors;
AE(EE, t) = 1 - (SUM(C, ACE(C, E)) + SUM(E2, AEE(E2, E)) +
SUM(O, AOE(O, E))) - OTAXE(E, t);
DISPLAY AE;

PARAMETER AO(OO, t) Production function scale parameter O
sectors;
AO(O, t) = 1 -
(SUM(P, APO(P, O)) + SUM(C, ACO(C, O)) + SUM(E2, AEO(E2, O)) +
SUM(OO, AOO(OO, O))) - OTAXO(O, t);
DISPLAY AO;

PARAMETER DELA1(PP) Share of estate labor in k+a factors P;
DELA1(P) = APO(P) / (AP0(P) + KP0(P) + dep0P0(P));
DISPLAY DELA1;

PARAMETER delr2(PP) Share of rural labor in k+a+r factors P;
delr2(P) = rPO(P) / (AP0(P) + KP0(P) + dep0P0(p) + rp0(P));
DISPLAY delr2;

PARAMETER delL3(PP) Share of URBAN labor in k+a+r+L factors P;
delL3(P) = LP0(P) / (AP0(P) + KP0(P) + dep0P0(p) + rp0(P) + LP0(P));
DISPLAY delL3;

parameter DELE4(PP) Share of electricity in total k+a+r+1+elec P;

DELE4(p) = xep0('elec', p) / (ap0(p) + kp0(p) + dep0P0(p) + LP0(P) + RP0(P) +
xep0('elec', p));
display dele4;

PARAMETER DELMY(PP) share of imports in total factors P;
DELMY(P) = (IMP0(P) + impdp0(p)) / (ap0(p) + kp0(p) + dep0P0(p) + LP0(P) +
RP0(P) + xep0('elec', p) +
IMP0(P) + impdp0(p));
DISPLAY DELMY;
PARAMETER DELA1C(CC) Share of estate labor in k+a factors C;
DEL A1C(C)=AC0(C)/(AC0(C)+KC0(C)+DEPL00(C)+rCO(C));
DISPLAY DELA1C;

PARAMETER DELa1n(n);
deLa1n(n)=sum(c,AC0(C))/sum(c,(AC0(C)+KC0(C)+DEPL00(C)+rCO(C)));

PARAMETER DELR2C(C) Share of rural labor in k+a+r factors C;
DELR2C(C)=rCO(C)/(AC0(C)+KC0(C)+DEPL00(C)+rCO(C));
DISPLAY DELR2C;

parameter delr2n(n);
delr2n(n)=sum(c,rCO(C))/sum(c,(AC0(C)+KC0(C)+DEPL00(C)+rCO(C)));

PARAMETER DELL3C(CC) Share of URBAN labor in k+a+r+L factors C;
DELL3C(C)=LC0(C)/(AC0(C)+KC0(C)+DEPL00(C)+rCO(C)+LC0(C));
DISPLAY DELL3C;

parameter del13n(n);
del13n(n)=sum(c,LC0(C))/sum(c,(AC0(C)+KC0(C)+DEPL00(C)+rCO(C)));

parameter DELe4C(CC) Share of electricity in K+A+R+L+ELEC factors C;
DELE4C(C)=xeC0('elec',C)/(aC0(C)+KC0(C)+DEPL00(C)+rCO(C)+
+xeC0('ELEC',C));
DISPLAY DELe4C;

parameter dele4n(n);
dele4n(n)=sum(c,xeC0('elec',C))/sum(c,(aC0(C)+KC0(C)+DEPL00(C)+
+LC0(C)+rCO(C)+
+xeC0('ELEC',C)));

PARAMETER DELMYC(CC) share of imports in total factors C;
DELMYC(C)=(IMPC0(C)+impdc0(c))/(aC0(C)+KC0(C)+DEPL00(C)+LC0(C)+
+IMPC0(C)+impdc0(c));
DISPLAY DELMYC;

parameter delmyn(n);
delmyn(n)=sum(c,IMPC0(C)+impdc0(c))/sum(c,(aC0(C)+KC0(C)+DEPL00(C)+
+LC0(C)+rCO(C)+
+IMPC0(C)+impdc0(c));
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1544 \( \text{xEC0('elec',C)+} \)
1545 \( \text{IMPC0(C)+impdc0(c));} \)
1546 \( \text{display delmyn;} \)
1547
1548 \( \text{PARAMETER DELA1E(EE) Share of estate labor in k+a factors E;} \)
1549 \( \text{DELA1E(E)=AE0(E)/(AE0(E)+KE0(E)+DEPLE0(E));} \)
1550 \( \text{DISPLAY DELA1E;} \)
1551
1552 \( \text{PARAMETER delr2E(EE) Share of rural labor in k+a+r factors E;} \)
1553 \( \text{DELr2E(E)=rE0(E)/(AE0(E)+KE0(E)+DEPLE0(E)+rE0(E));} \)
1554 \( \text{DISPLAY DELr2E;} \)
1555
1556 \( \text{PARAMETER dell3E(EE) Share of URBAN labor in k+a+r+L factors E;} \)
1557 \( \text{DELl3E(E)=LE0(E)/(AE0(E)+KE0(E)+DEPLE0(E)+rE0(E)+LE0(E));} \)
1558 \( \text{DISPLAY DELl3E;} \)
1559
1560 \( \text{parameter DELe4E(EE) Share of electricity in k+a+r+L+ELEC factors E;} \)
1561 \( \text{DELe4E(E)=xeE0('elec',E)/(AE0(E)+KE0(E)+DEPLE0(E)+LE0(E)+rE0(E)+} \)
1562 \( \text{XEEO('ELEC',E))} \)
1563 \( \text{display dele4E;} \)
1564
1565 \( \text{PARAMETER DELMYE(EE) share of imports in total factors E;} \)
1566 \( \text{DELMYE(E)=(IMPE0(E)+impde0(e))/(AE0(E)+KE0(E)+DEPLE0(E)+LE0(E)+} \)
1567 \( \text{RE0(E)+xeEO('elec',E)+} \)
1568 \( \text{IMPE0(E)+impde0(e));} \)
1569 \( \text{DISPLAY DELMYE;} \)
1570
1570 \( \text{PARAMETER DELA10(00) Share of estate labor in k+a factors O;} \)
1571 \( \text{DELA10(O)=AO0(O)/(AO0(O)+KO0(O)+DEPLO0(O));} \)
1572 \( \text{DISPLAY DELA10;} \)
1573
1574 \( \text{PARAMETER delr2O(00) Share of rural labor in k+a+r factors O;} \)
1575 \( \text{DELr2O(O)=rO0(O)/(AO0(O)+KO0(O)+DEPLO0(O)+rO0(O));} \)
1576 \( \text{DISPLAY DELr2O;} \)
1577
1578 \( \text{PARAMETER dell3O(00) Share of URBAN labor in k+a+r+L factors O;} \)
1579 \( \text{DELl3O(O)=LO0(O)/(AO0(O)+KO0(O)+DEPLO0(O)+rO0(O)+LO0(O));} \)
1580 \( \text{DISPLAY DELl3O;} \)
1581
1582 \( \text{parameter DELe4O(00) Share of electricity in k+L+A+R+ELEC factors O;} \)
1583 \( \text{DELe4O(O)=xeO0('elec',O)/(AO0(O)+KO0(O)+DEPLO0(O)+LO0(O)+rO0(O)+} \)
1584 \( \text{XEO0('ELEC',O))} \)
1585 \( \text{display dele4O;} \)
1586
1587 \( \text{PARAMETER DELMYO(00) share of imports in total factors O;} \)
DELMYO(O) = (IMPOO(O) + impdoO(o)) / (a00(O) + kco(O) + deploO(o) + LOG(O) + XEOO('elec',O) + IMPOO(O) + impdoO(o))

DISPLAY DELMYO;

* Definition of trade substitution elasticity IMPORTS

The smaller the elasticity the more imperfect substitutes are dom and

* Definition of world market price for exports

parameter wmepp(pp,t);

**1.01**(time*tau);

parameter wmeC(CC,t);

wmeC(C,t) $(EXPSHC(C) GT 0)=1;$
\[
\frac{\text{expsh}(C)}{\left(1 - \text{expsh}(C)\right)^{\mu(C)}}^{\frac{1}{\nu(C)}} \text{i display wmen(n,t)};
\]

\[
\text{wmen}(n,t) = 1;
\]

\[
\text{parameter wmeo}(oo,t);
\]

\[
\text{wmeo}(o,t) \quad (\text{EXP}SH(o) \gt 0) = 1;
\]

\[
\frac{\text{expsh}(O)}{\left(1 - \text{expsh}(O)\right)^{\mu(O)}}^{\frac{1}{\nu(O)}} \text{i display wmeo};
\]

\[
\text{parameter wmeen}(ee,t);
\]

\[
\text{wmeen}(e,t) \quad (\text{EXP}SH(e) \gt 0) = 1;
\]

\[
\frac{\text{expsh}(E)}{\left(1 - \text{expsh}(E)\right)^{\mu(E)}}^{\frac{1}{\nu(E)}} \text{i display wmeen};
\]

\[
\text{parameter RHOP}(PP,t);
\]

\[
\text{RHOP}(P,t) = 1/\text{EPSP}(P,t) - 1;
\]

\[
\text{DISPLAY RHOP};
\]

\[
\text{PARAMETER RHOC(CC,t)};
\]

\[
\text{RHOC}(C,t) = 1/\text{EPSC}(C,t) - 1;
\]

\[
\text{DISPLAY RHOC};
\]

\[
\text{parameter rhon(nn,t)};
\]

\[
\text{rhon}(n,t) = 1/\text{EPSN}(n,t) - 1;
\]

\[
\text{display rhon};
\]

\[
\text{PARAMETER RHOE(EE,t)};
\]

\[
\text{RHOE}(E,t) = 1/\text{EPSN}(E,t) - 1;
\]

\[
\text{DISPLAY RHOE};
\]

\[
\text{PARAMETER RHOO(00,t)};
\]

\[
\text{RHOO}(0,t) = 1/\text{EPSO}(0,t) - 1;
\]

\[
\text{DISPLAY RHOO};
\]
INCLUDE C:\SIMOD\SLPRICEA.INC
1676 * World market prices
1677
1678 PARAMETER WMP(PP,t) World market price for imports to P;
1679 WMP(PP,t)=1/(1+impdp.P(PP,t));
1680 DISPLAY WMP;
1681
1682 PARAMETER WMN(n,t) World market price for imports to C;
1683 WMN(n,t)=1/(1+impdn.1(n,t));
1684 DISPLAY WMN;
1685
1686 PARAMETER WME(EE,t) World market price for imports to E;
1687 WME(EE,t)=1/(1+impde.1(e,t));
1688 DISPLAY WME;
1689
1690 PARAMETER WMO(OO,t) World market price for imports to O;
1691 WMO(OO,t)=1/(1+impdo.1(o,t));
1692 DISPLAY WMO;
1693
1694 * PARAMETER WMEP(P,t) World market price for exports of P
1695
1696 / TEA 1.00
1697 / RUBBER 1.00
1698 / COCO 1.00 /
1699
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1700 * PARAMETER WMEN(n) World market price for exports of C
1701 / MINING 1.000
1702 / MILLIN 1.000
1703 / TEXTIL 1.000
1704 / MACHIN 1.000
1705 / FOOD 1.000
1706 / AGROCH 1.000
1707 / CLAY 1.000
1708 / MANUF 1.000
1709 / METAL 1.000
1710 / TRANSP 1.000 /
1711
1712 * PARAMETER WMEE(E,t) World market price for exports of E;
1713 * wmeE(e,t)=1;
1714
1715 * PARAMETER WMOE(O) World market price for exports of O
1716 / AGRI 1.000
1717 / RURIND 1.000
1718 / CONSTR 1.000
1719 / SERVIC 1.000 /
1720
1721 PARAMETER PCPO(PP);
1722 PCPO(PP)=1;
PARAMETER Pnn0(n);
Pnn0(nn)=1;
PARAMETER PCEO(E);
PCEO(EE)=1;
PARAMETER PCOO(O);
PCOO(OO)=1;

parameter l(tt);
l(t)$(ord(t) eq 1)=totl0;
l(t)$(ord(t) ne 1)=totl0*popg**((ord(t)-1)*tau);
display l;

parameter r(tt);
r(t)$(ord(t) eq 1)=totr0;
r(t)$(ord(t) ne 1)=totr0*popg**((ord(t)-1)*tau);
display r;

parameter a(tt);
a(t)$(ord(t) eq 1)=totao;
a(t)$(ord(t) ne 1)=totao*apopg**((ord(t)-1)*tau);
display a;

* List of variables
INCLUDE C:\SLMOD\SLVARA.INC

* List of variables

VARIABLES

totimp
tottax
* slack
* ks(t)
* as(t)
* ls(t)
* rs(t)

PUA(t) User price of estate labor
PUR(T) USER PRICE OF RURAL LABOR
FUL(t) User price of URBAN labor

FUK(t) User price of capital

P1P(P,t) Price of factor aggregate 1 in P sectors
P2P(P,T) Price of factor aggregate 2 in P sectors
P3P(P,T) Price of factor aggregate 3 in P sectors
P4P(P,T) Price of factor aggregate 4 in P sectors
PYP(P,t) Price of composite input Y in P sectors
P1N(N,t) Price of factor aggregate 1 in C sectors
P2N(N,T) Price of factor aggregate 2 in C sectors
P3N(N,T) Price of factor aggregate 3 in C sectors
P4N(N,T) Price of factor aggregate 4 in C sectors
PYN(N,t) Price of composite input Y in C sectors
PYE(E,t) Price of composite input Y in E sectors
P1E(E,T) Price of factor aggregate 1 in E sectors
P2E(E,T) Price of factor aggregate 2 in E sectors
P3E(E,T) Price of factor aggregate 3 in E sectors
P4E(E,T) Price of factor aggregate 4 in E sectors
P1O(O,t) Price of factor aggregate 1 in O sectors
P2O(O,T) Price of factor aggregate 2 in O sectors
P3O(O,T) Price of factor aggregate 3 in O sectors
P4O(O,T) Price of factor aggregate 4 in O sectors
PYO(O,t) Price of composite input Y in O sectors
DPYDPAP(P,t) Partial derivative of PY wrt PL in P sectors
DPYDPRP(P,T) Partial derivative of PY wrt PR in P sectors
DPYDPLP(P,T) Partial derivative of PY wrt PL in P sectors
DPYDKPK(P,t) Partial derivative of PY wrt PK in P sectors
DPYDPEP(P,t) Partial derivative of PY wrt PE in P sectors
DPYPMP(P,T) Partial derivative of PY wrt PM in P sectors
Partial derivative of PY wrt P4 in P sectors
Partial derivative of P4 wrt P3 in P sectors
Partial derivative of P3 wrt P2 in P sectors
Partial derivative of P2 wrt P1 in P sectors
Partial derivative of P4 wrt PE in P sectors
Partial derivative of P3 wrt PL in P sectors
Partial derivative of P2 wrt PR in P sectors
Partial derivative of P1 wrt PK in P sectors
Partial derivative of P1 wrt PL in P sectors
Partial derivative of PY wrt PL in C sectors
Partial derivative of PY wrt PR in C sectors
Partial derivative of PY wrt PL in C sectors
Partial derivative of PY wrt PK in C sectors
Partial derivative of PY wrt PE in C sectors
Partial derivative of PY wrt PM in C sectors
Partial derivative of PY wrt P4 in C sectors
Partial derivative of P4 wrt P3 in C sectors
Partial derivative of P3 wrt P2 in C sectors
Partial derivative of P2 wrt P1 in C sectors
Partial derivative of P1 wrt PK in C sectors
Partial derivative of P1 wrt PL in C sectors
Partial derivative of P4 wrt PE in C sectors
Partial derivative of P3 wrt PL in C sectors
Partial derivative of P2 wrt PR in C sectors
Partial derivative of PY wrt PA in E sectors
DPYDPRE(E,T) Partial derivative of PY wrt PR in E sectors
DPYDPLE(E,T) Partial derivative of PY wrt PL in E sectors
DPYDPKE(E,t) Partial derivative of PY wrt PK in E sectors
DPYDPEE(E,t) Partial derivative of PY wrt PE in E sectors
DPYDPME(E,T) Partial derivative of PY wrt PM in E sectors
DPYDP4E(E,t) Partial derivative of PY wrt P4 in E sectors
DP4DP3E(E,T) Partial derivative of P4 wrt P3 in E sectors
DP3DP2E(E,T) Partial derivative of P3 wrt P2 in E sectors
DP2DPRE(E,T) Partial derivative of P2 wrt PR in E sectors
DPYDPAO(O,t) Partial derivative of PY wrt PA in O sectors
DPYDPRO(O,T) Partial derivative of PY wrt PR in O sectors
DPYDPLO(O,T) Partial derivative of PY wrt PL in O sectors
DPYDPKO(O,t) Partial derivative of PY wrt PK in O sectors
DPYDPEO(O,t) Partial derivative of PY wrt PE in O sectors
DPYDPMO(O,T) Partial derivative of PY wrt PM in O sectors
DPYDP4O(O,t) Partial derivative of PY wrt P4 in O sectors
DP4DP3O(O,T) Partial derivative of P4 wrt P3 in O sectors
DP3DP2O(O,T) Partial derivative of P3 wrt P2 in O sectors
DP2DP1O(O,T) Partial derivative of P2 wrt P1 in O sectors
DP1DPOK(0,t) Partial derivative of P1 wrt PK in O sectors
DP1DPAP(0,t) Partial derivative of P1 wrt PA in O sectors
DP4DPEO(O,T) Partial derivative of P4 wrt PE in O sectors
DP3DPLO(O,T) Partial derivative of P3 wrt PL in O sectors
DP2DPOK(O,T) Partial derivative of P2 wrt PK in O sectors
DPXDPAP(P,t) Partial derivative of PX wrt PA in P sectors
DPXDPKP(P,t) Partial derivative of PX wrt PK in P sectors
DPXDPAN(N,t) Partial derivative of PX wrt PA in C sectors
DPXDPKN(N,t) Partial derivative of PX wrt PK in C sectors
DPXDPAE(E,t) Partial derivative of PX wrt PA in E sectors
DPXDPEE(E,t) Partial derivative of PX wrt PE in E sectors
DPXDPME(E,T) Partial derivative of PX wrt PM in E sectors
1969
1970
1971 DPXDPAO(O,t) Partial derivative of PX wrt PA in O sectors
1972
1973 DPXDPRO(O,t) Partial derivative of PX wrt PR in O sectors
1974
1975 DPXDPLO(O,t) Partial derivative of PX wrt PL in O sectors
1976
1977 DPXDPKO(O,t) Partial derivative of PX wrt PK in O sectors
1978
1979 DPXDPEO(O,t) Partial derivative of PX wrt PE in O sectors
1980
1981 DPXDPMO(O,T) Partial derivative of PX wrt PM in O sectors
1982
1983
1984 AALP(P,t) Demand for estate labor in P sectors
1985
1986 RP(P,t) Demand for rural labor in P sectors
1987
1988 LP(P,T) Demand for urban labor in P sectors
1989
1990 KP(P,t) Demand for capital in P sectors
1991
1993
1994 IMPP(P,t) Demand for imports in P sectors
1995
1996
1997 AALN(N,t) Demand for estate labor in C sectors
1998
1999 RN(N,t) Demand for rural labor in C sectors
2000
2001 LN(N,T) Demand for urban labor in C sectors
2002
2003 KN(N,t) Demand for capital in C sectors
2004
2005 EN(N,t) Demand for electricity in C sectors
2006
2007 IMPN(N,t) Demand for imports in C sectors
2008
2009
2010 AALE(E,t) Demand for estate labor in E sectors
2011
2012 RE(E,t) Demand for rural labor in E sectors
2013
2014 LE(E,T) Demand for urban labor in E sectors
2015
2016 KE(E,t) Demand for capital in E sectors
2017

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<table>
<thead>
<tr>
<th>Year</th>
<th>Symbol</th>
<th>Description</th>
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<tbody>
<tr>
<td>2018</td>
<td>EDEME(EE,t)</td>
<td>Demand for electricity in E sectors</td>
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<tr>
<td>2019</td>
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<tr>
<td>2020</td>
<td>IMPE(E,t)</td>
<td>Demand for imports in E sectors</td>
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<td>2023</td>
<td>AALO(O,t)</td>
<td>Demand for estate labor in O sectors</td>
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<td>2024</td>
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<td>2025</td>
<td>RO(O,t)</td>
<td>Demand for rural labor in O sectors</td>
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<td>2026</td>
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<td>LO(O,T)</td>
<td>Demand for urban labor in O sectors</td>
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<td>KO(O,t)</td>
<td>Demand for capital in O sectors</td>
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<td>IMPO(O,t)</td>
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<td>XP(P,t)</td>
<td>Production in P sectors</td>
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<td>2036</td>
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</tr>
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<td>2037</td>
<td>XN(N,t)</td>
<td>Production in C sectors</td>
</tr>
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</tr>
<tr>
<td>2039</td>
<td>XB(E,t)</td>
<td>Production in E sectors</td>
</tr>
<tr>
<td>2040</td>
<td></td>
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<tr>
<td>2041</td>
<td>XO(O,t)</td>
<td>Production in O sectors</td>
</tr>
<tr>
<td>2042</td>
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<tr>
<td>2043</td>
<td>MCP(P,t)</td>
<td>Marginal cost in P sectors</td>
</tr>
<tr>
<td>2044</td>
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<tr>
<td>2045</td>
<td>MCN(N,t)</td>
<td>Marginal cost in C sectors</td>
</tr>
<tr>
<td>2046</td>
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<tr>
<td>2047</td>
<td>MCE(E,t)</td>
<td>Marginal cost in E sectors</td>
</tr>
<tr>
<td>2048</td>
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<tr>
<td>2049</td>
<td>MCO(O,t)</td>
<td>Marginal cost in O sectors</td>
</tr>
<tr>
<td>2050</td>
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<tr>
<td>2051</td>
<td>DPP(P,t)</td>
<td>Domestic price of domestically produced P goods</td>
</tr>
<tr>
<td>2052</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2053</td>
<td>DPN(N,t)</td>
<td>Domestic price of domestically produced C goods</td>
</tr>
<tr>
<td>2054</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2055</td>
<td>DPE(E)</td>
<td>Domestic price of domestically produced E goods</td>
</tr>
<tr>
<td>2056</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2057</td>
<td>DPO(O,t)</td>
<td>Domestic price of domestically produced O goods</td>
</tr>
<tr>
<td>2058</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2059</td>
<td>DDP(P,h,t)</td>
<td>Domestic demand for composite P goods per hh type</td>
</tr>
<tr>
<td>2060</td>
<td></td>
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</tr>
<tr>
<td>2061</td>
<td>DDN(N,h,t)</td>
<td>Domestic demand for composite C goods per hh type</td>
</tr>
<tr>
<td>2062</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2063</td>
<td>DDE(E,h,t)</td>
<td>Domestic demand for E goods per hh type</td>
</tr>
<tr>
<td>2064</td>
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<tr>
<td>2065</td>
<td>INTERE(e,t)</td>
<td>Intermediate demand for E products</td>
</tr>
<tr>
<td>2066</td>
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<tr>
<td>2067</td>
<td>INTERF(t)</td>
<td>Intermediate demand for Fuel products</td>
</tr>
<tr>
<td>2068</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2069</td>
<td>DDO(O,h,t)</td>
<td>Domestic demand for composite O goods per hh type</td>
</tr>
</tbody>
</table>
2071 \( P_{MP}(P,t) \) Domestic price of P imports in local currency
2072 \( P_{MN}(N,t) \) Domestic price of C imports in local currency
2073 \( P_{ME}(E,t) \) Domestic price of E imports in local currency
2074 \( P_{MO}(O,t) \) Domestic price of O imports in local currency
2075 \(* \ Q_{P}(P,t) \) Quantity of composite P produced and imported goods
2076 \(* \ Q_{N}(N,t) \) Quantity of composite C produced and imported goods
2077 \(* \ Q_{E}(E) \) Quantity of composite E produced and imported goods
2078 \(* \ Q_{O}(O,t) \) Quantity of composite O produced and imported goods
2079 \(* \ I_{MP}(P,t) \) Import of P goods
2080 \(* \ I_{MPN}(N,t) \) Import of C goods
2081 \(* \ I_{MPE}(E) \) Import of E goods
2082 \(* \ I_{MPO}(O,t) \) Import of O goods
2083 \( P_{EP}(P,t) \) Domestic price of P exports in local currency
2084 \( P_{EN}(N,t) \) Domestic price of C exports in local currency
2085 \( P_{EE}(E,t) \) Domestic price of E exports in local currency
2086 \( P_{EO}(O,t) \) Domestic price of O exports in local currency
2087 \( C_{P}(P,t) \) Total domestic and foreign consumption of P products
2088 \( C_{CN}(N,t) \) Total domestic and foreign consumption of C products
2089 \( C_{CE}(E,t) \) Total domestic and foreign consumption of E products
2090 \( C_{CO}(O,t) \) Total domestic and foreign consumption of O products
2111 \text{EXPP}(P,t) \quad \text{Exports of } P \text{ goods}
2113 \text{EXPN}(N,t) \quad \text{Exports of } C \text{ goods}
2115 \text{EXPE}(E,t) \quad \text{Exports of } E \text{ goods}
2117 \text{EXPO}(O,t) \quad \text{Exports of } O \text{ goods}
2119 \text{PL}(t) \quad \text{Price of labor services}
2121 \text{PR}(T) \quad \text{Price of estate labor services}
2123 \text{PA}(t) \quad \text{Price of estate labor services}
2124 \text{PK}(t) \quad \text{Price of capital services}
2129 * \text{PQP}(P,t) \quad \text{Price of composite output goods } P
2131 * \text{PQN}(N,t) \quad \text{Price of composite output goods } C
2132 * \text{PQE}(E) \quad \text{Price of composite output goods } E
2134 * \text{PQO}(O,t) \quad \text{Price of composite output goods } O
2137 \text{PCP}(P,t) \quad \text{Price of composite consumption good } P
2139 \text{PCN}(N,t) \quad \text{Price of composite consumption good } C
2141 \text{PCE}(E,t) \quad \text{Price of composite consumption good } E
2143 \text{PCO}(O,t) \quad \text{Price of composite consumption good } O
2145 * \text{sav}(t) \quad \text{Total savings}
2147 \text{savh}(h,t) \quad \text{Savings by household type } h
2149 \text{domsav}(t) \quad \text{Domestic savings}
2151 \text{invest}(t) \quad \text{Price of investments in period } t
2155 \text{invp}(p,t)
The following variables are restricted to nonnegative values

**POSITIVE VARIABLES**

- \text{scs}(p,t), \text{scs}(p,t), \text{lscs}(p,t), \text{kscs}(p,t), \text{lscs}(p,t), \text{csce}(p,t), \\
- \text{EXPP}(P,t), \text{EXPN}(N,t), \text{EXPO}(O,t), \text{EXPE}(E,t), \text{IMPP}(P,t), \\
- \text{IMPN}(N,t), \text{k}(t), \\
- \text{IMPO}(O,t), \text{IMPE}(E,t), \text{XP}(P,t), \text{XN}(N,t), \text{XO}(O,t), \text{xe}(e,t), \\
- \text{ddp}(p,h,t), \text{ddn}(n,h,t), \text{dde}(e,h,t), \text{ddo}(o,h,t), \text{invp}(p,t), \\
- \text{invn}(n,t), \\
- \text{invo}(o,t), \text{invest}(t), \text{disph}(h,t), \text{tdisph}(h,t);
Definition of user price of estate labor
Definition of user price of rural labor
Definition of user price of urban labor
Definition of user price of capital
Definition of price of factor aggregate 1 in \( P \) sectors
Definition of price of factor aggregate 2 in \( P \) sectors
Definition of price of factor aggregate 3 in \( P \) sectors
Definition of price of factor aggregate 4 in \( P \) sectors
Definition of price of composite input \( Y \) in \( P \) sectors
Definition of price of factor aggregate 1 in \( C \) sectors
Definition of price of factor aggregate 2 in \( C \) sectors
Definition of price of factor aggregate 3 in \( C \) sectors
Definition of price of factor aggregate 4 in \( C \) sectors
Definition of price of composite input \( Y \) in \( C \) sectors
sectors
2246
DEFP1E(E,t)
Definition of price of factor aggregate 1 in E
sectors
2249
DEFP2E(E,t)
Definition of price of factor aggregate 2 in E
sectors
2251
DEFP3E(E,T)
Definition of price of factor aggregate 3 in E
sectors
2253
DEFP4E(E,T)
Definition of price of factor aggregate 4 in E
sectors
2255
DEFPYE(E,t)
Definition of price of composite input Y in E
sectors
2257
DEFP10(O,t)
Definition of price of factor aggregate 1 in O
sectors
2260
DEFP20(O,t)
Definition of price of factor aggregate 2 in O
sectors
2262
DEFP30(O,T)
Definition of price of factor aggregate 3 in O
sectors
2264
DEFP40(O,T)
Definition of price of factor aggregate 4 in O
sectors
2266
DEFPYO(O,t)
Definition of price of composite input Y in O
sectors
2268
2269
DDPYDPAP(P,t)
Definition of partial derivative of PY wrt PA in P
sectors
2271
DDPYDPRP(P,t)
Definition of partial derivative of PY wrt PR in P
sectors
2273
DDPYDPLP(P,t)
Definition of partial derivative of PY wrt PL in P
sectors
2275
DDPYDPKP(P,t)
Definition of partial derivative of PY wrt PK in P
sectors
2277
sectors
2279
DDPYDPMP(P,T) Definition of partial derivative of PY wrt PM in P
sectors
2280
DDPYDP4P(P,t) Definition of partial derivative of PY wrt P4 in P
sectors
2281
DDP4DP3P(P,t) Definition of partial derivative of P4 wrt P3 in P
sectors
2282
DDP3DP2P(P,t) Definition of partial derivative of P3 wrt P2 in P
sectors
2283
DDP2DP1P(P,t) Definition of partial derivative of P2 wrt P1 in P
sectors
2284
DDP1DPAP(P,t) Definition of partial derivative of P1 wrt PA in P
sectors
2285
DDP1DPKP(P,t) Definition of partial derivative of P1 wrt PK in P
sectors
2286
DDP4DPEP(P,t) Definition of partial derivative of P4 wrt PE in P
sectors
2287
DDP3DPLP(P,t) Definition of partial derivative of P3 wrt PL in P
Definition of partial derivative of $P_2$ wrt $PR$ in $P$ sectors

Definition of partial derivative of $PY$ wrt $PA$ in $C$

Definition of partial derivative of $PY$ wrt $PR$ in $C$

Definition of partial derivative of $PY$ wrt $PL$ in $C$

Definition of partial derivative of $PY$ wrt $PK$ in $C$

Definition of partial derivative of $PY$ wrt $PE$ in $C$

Definition of partial derivative of $PY$ wrt $PM$ in $C$

Definition of partial derivative of $PY$ wrt $P4$ in $C$

Definition of partial derivative of $P4$ wrt $P3$ in $C$

Definition of partial derivative of $P3$ wrt $P2$ in $C$
sectors 2318
2319 DDP2DP1N(N,t) Definition of partial derivative of P2 wrt P1 in C

sectors 2320
2321 DDP1DPAN(N,t) Definition of partial derivative of P1 wrt PA in C

sectors 2322 ddp1dpal(n,t)
2323 DDP1DPKN(N,t) Definition of partial derivative of P1 wrt PK in C

sectors 2324
2325 DDP4DPEN(N,t) Definition of partial derivative of P4 wrt PE in C

sectors 2326
2327 DDP3DPLN(N,t) Definition of partial derivative of P3 wrt PL in C

sectors 2328
2329 DDP2DPRN(N,t) Definition of partial derivative of P2 wrt PR in C

sectors 2330 ddp2dprl(n,t)
2331 DDPYDPARE(E,t) Definition of partial derivative of PY wrt PA in E

sectors 2333
2334 DDPYDPRE(E,t) Definition of partial derivative of PY wrt PR in E

sectors 2335
2336 DDPYDPLE(E,t) Definition of partial derivative of PY wrt PL in E

sectors 2337
2338 DDPYDPKE(E,t) Definition of partial derivative of PY wrt PK in E

sectors 2339
2340 DDPYDPEE(E,T) Definition of partial derivative of PY wrt PE in
sectors
2341
2342 \text{DDFYDPME}(E,T) \quad \text{Definition of partial derivative of } PY \text{ wrt } PM \text{ in } E

sectors
2343
2344 \text{DDFYDP4E}(E,t) \quad \text{Definition of partial derivative of } PY \text{ wrt } P4 \text{ in } E

sectors
2345
2346 \text{DDP4DP3E}(E,t) \quad \text{Definition of partial derivative of } P4 \text{ wrt } P3 \text{ in } E

sectors
2347
2348 \text{DDP3DP2E}(E,t) \quad \text{Definition of partial derivative of } P3 \text{ wrt } P2 \text{ in } E

sectors
2349
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\text{General Algebraic Modeling System}
\text{Compilation}

2350 \text{DDP2DP1E}(E,t) \quad \text{Definition of partial derivative of } P2 \text{ wrt } P1 \text{ in } E

sectors
2351
2352 \text{DDP1DPAE}(E,t) \quad \text{Definition of partial derivative of } P1 \text{ wrt } PA \text{ in } E

sectors
2353
2354 \text{DDP1DPKE}(E,t) \quad \text{Definition of partial derivative of } P1 \text{ wrt } PK \text{ in } E

sectors
2355
2356 \text{DDP4DPEE}(E,t) \quad \text{Definition of partial derivative of } P4 \text{ wrt } PE \text{ in } E

sectors
2357
2358 \text{DDP3DPLE}(E,t) \quad \text{Definition of partial derivative of } P3 \text{ wrt } PL \text{ in } E

sectors
2359
Definition of partial derivative of $P_2$ wrt $P_R$ in $E$

2360  DDP2DPRE(E,t)  Definition of partial derivative of $P_2$ wrt $P_R$ in $E$

sectors
2361
2362
2363  DDPYDPAO(O,t)  Definition of partial derivative of $PY$ wrt $PA$ in $O$

sectors
2364
2365  DDPYDPRO(O,t)  Definition of partial derivative of $PY$ wrt $PR$ in $O$

sectors
2366
2367  DDPYDPLO(O,t)  Definition of partial derivative of $PY$ wrt $PL$ in $O$

sectors
2368
2369  DDPYDPKO(O,t)  Definition of partial derivative of $PY$ wrt $PK$ in $O$

sectors
2370
2371  DDPYDPEO(O,T)  Definition of partial derivative of $PY$ wrt $PE$ in $O$

sectors
2372
2373  DDPYDPMO(O,T)  Definition of partial derivative of $PY$ wrt $PM$ in $O$

sectors
2374
2375  DDPYDP4O(O,t)  Definition of partial derivative of $PY$ wrt $P_4$ in $O$

sectors
2376
2377  DDP4DP3O(O,t)  Definition of partial derivative of $P_4$ wrt $P_3$ in $O$

sectors
2378
2379  DDP3DP2O(O,t)  Definition of partial derivative of $P_3$ wrt $P_2$ in $O$

sectors
2380
2381  DDP2DP1O(O,t)  Definition of partial derivative of $P_2$ wrt $P_1$ in $O$

sectors
Definition of partial derivative of $P_1$ with respect to $P_A$ in sectors

Definition of partial derivative of $P_1$ with respect to $P_K$ in sectors

Definition of partial derivative of $P_4$ with respect to $P_E$ in sectors

Definition of partial derivative of $P_3$ with respect to $P_L$ in sectors

Definition of partial derivative of $P_2$ with respect to $P_R$ in sectors

Definition of partial derivative of $P_X$ with respect to $P_A$ in sectors

Definition of partial derivative of $P_X$ with respect to $P_K$ in sectors

Definition of partial derivative of $P_X$ with respect to $P_P$ in sectors

Definition of partial derivative of $P_X$ with respect to $P_E$ in sectors
sectors
2403
2404 DDPXDPM(P,T) Definition of partial derivative of PX wrt PM in P
sectors
2405
2406
sectors
2407 DDPXDPA(N,t) Definition of partial derivative of PX wrt PA in C
sectors
2408
2409 DDPXDPR(N,t) Definition of partial derivative of PX wrt PR in C
sectors
2410
2411 DDPXDPN(N,t) Definition of partial derivative of PX wrt PL in C
sectors
2412
2413 DDPXDPK(N,t) Definition of partial derivative of PX wrt PK in C
sectors
2414
2415 DDPXDPE(N,T) Definition of partial derivative of PX wrt PE in C
sectors
2416
2417 DDPXDMN(N,T) Definition of partial derivative of PX wrt PM in C
sectors
2418
2419
sectors
2420 DDPXDAE(E,t) Definition of partial derivative of PX wrt PA in E
sectors
2421
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General Algebraic Modeling System Compilation
sectors
2422 DDPXDPR(E,t) Definition of partial derivative of PX wrt PR in E
sectors
Definition of partial derivative of PX wrt PL in E

sectors
Definition of partial derivative of PX wrt PK in E
sectors
Definition of partial derivative of PX wrt PE in E
sectors
Definition of partial derivative of PX wrt PM in E
sectors
Definition of partial derivative of PX wrt PA in O
sectors
Definition of partial derivative of PX wrt PR in O
sectors
Definition of partial derivative of PX wrt PL in O
sectors
Definition of partial derivative of PX wrt PK in O
sectors
Definition of partial derivative of PX wrt PE in O
sectors
Definition of partial derivative of PX wrt PM in O
sectors
Shephard's lemma demand for estate labor in P
Shephard's lemma demand for electricity in P sectors

Shephard's lemma demand for urban labor in P sectors

Shephard's lemma demand for rural labor in P sectors

Shephard's lemma demand for capital in P sectors

Shephard's lemma demand for electricity in P sectors

Shephard's lemma demand for imports in P sectors

Shephard's lemma demand for estate labor in C sectors

Shephard's lemma demand for rural labor in C sectors

Shephard's lemma demand for urban labor in C sectors

Shephard's lemma demand for capital in C sectors

Shephard's lemma demand for electricity in C sectors

Shephard's lemma demand for imports in C sectors

Shephard's lemma demand for estate labor in E sectors

Shephard's lemma demand for rural labor in E sectors

Shephard's lemma demand for urban labor in E sectors

Shephard's lemma demand for capital in E sectors

Shephard's lemma demand for electricity in E sectors

Shephard's lemma demand for imports in E sectors
Shephards lemma demand for estate labor in O sectors
Shephards lemma demand for rural labor in O sectors
Shephards lemma demand for urban labor in O sectors
Shephards lemma demand for capital in O sectors
Shephards lemma demand for electricity in O sectors
Shephards lemma demand for imports in O sectors

Definition of marginal cost in P sectors
Definition of marginal cost in C sectors
Definition of marginal cost in E sectors
Definition of marginal cost in O sectors
Price equals marginal cost in P sectors
determines dom
Price equals marginal cost in C sectors
determines dom
Demand equals supply in E sectors
Price equals marginal cost in O sectors
determines dom
Consumption demand function for P goods
pconsl(p,h,t)  Consumption demand function for C goods
nCONS(n,h,t)  Consumption demand function for E goods
ncons1(n,h,t)
ECONS(E,h,t)  Consumption demand function for O goods
econs1(e,h,t)
EINTERE(t)  INTERMEDIATE DEM FOR ELEC GOODS
EINTERF(t)  INTERMEDIATE DEM FOR FUEL
OCONS(O,h,t)
ocons1(o,h,t)
DEFPMP(P,t)  Definition of domestic price of P imports in local currency
DEFPMN(N,t)  Definition of domestic price of C imports in local currency
DEFPME(E,t)  Definition of domestic price of E imports in local currency
DEFPMO(O,t)  Definition of domestic price of O imports in local currency
DQP(P,t)  Definition of quantity of composite P goods
DQN(N,t)  Definition of quantity of composite C goods
DQE(E)  Definition of quantity of composite E goods
DQO(O,t)  Definition of quantity of composite O goods
PRAT(P,t)  Ratio of import of P goods to dom P goods det IMP
pcompl(p,t)
nRAT(n,t)  Ratio of import of C goods to dom C goods det IMP
ncompl(n,t)
* ERAT(E)  Ratio of import of E goods to dom E goods det IMP

* ORAT(O,t)  Ratio of import of O goods to dom O goods det IMP

* ocompl(o,t)

DPEP(P,t)  Definition of domestic price of P exports in local currency

DPEN(N,t)  Definition of domestic price of C exports in local currency

dpenb(n,t)

DPEE(E,t)  Definition of domestic price of E exports in local currency
dpeeb(e,t)

DPEO(O,t)  Definition of domestic price of O exports in local currency
dpeob(o,t)

DCP(P,t)  Definition of total domestic and foreign consumption of P products

DCN(N,t)  Definition of total domestic and foreign consumption of C products

DCE(E,t)  Definition of total domestic and foreign consumption of E products

DCO(O,t)  Definition of total domestic and foreign consumption of O products
DEXPP(P,t) Ratio of export of P goods to dom P goods det
EXP
DEXPNA(n,t) Ratio of export of C goods to dom C goods det
EXP
DEXPNB(n,t)
DEXPEA(E,t) Ratio of export of E goods to dom E goods det
EXP
DEXPEB(E,t)
DEXPOA(O,t) Ratio of export of O goods to dom O goods det
EXP
DEXPOB(O,t)
kstock(t)
kstock1(t)
*d kstock2(t)
dinvest(t) definition of investments
dinvestm(t) definition of investments in period m
* dinvest1(t)
invlow(t) Lower bound on disinvestments
dlascs(p,t) labor input in soil conservation
dlasc(p,t)
dlabscp(t)
dlasc(p,t)
dlasc(v,p,t)
dlasc(p,t)
dcapcs(p,t) capital input in soil conservation
dcs(p,t)
dcs(p,t)
dcs(p,t)
dcscs(p,t)
dcscs(p,t)
dcscs(p,t)
dmrscs(p,t) definition of marginal revenue of soil conservation
dmrscp(p,t)
soil conservation level smallh
dscs(p,t)
dscs(p,t)
dscs(p,t)
dscs(p,t)
dscs(p,t)
Land quality index
* dq(p,t)

Land quality index when no soil conservation

definition of urban savings

definition of savings for hh H h no urban

definition of domestic savings

Urban labor market equilibrium condition

Rural labor market equilibrium condition

Rural labor market equilibrium condition when no soil conservation

Estate labor market equilibrium condition

Capital market equilibrium condition

Capital market equilibrium condition when no soil conservation

definition of PQP

Definition of PQC

Definition of PQE

Definition of PCO

P product market equilibrium conditions det XP

C product market equilibrium conditions det XC
DPI(T)     Determination of price of investments
DPINV(P,t)  Determination of P goods in investments
dpinv1(p,t)
DnINV(n,t)  Determination of C goods in investments
dninv1(n,t)
DOINV(O,t)  Determination of O goods in investments
doinv1(o,t)
* EMARKETE(t)  Energy product market equilibrium conditions
det NEXPE
* EMARKETF(t)  Fuel product market equilibrium condition det
NEXPE(fuel)
* ECOMPL(t)  Complementary condition for the energy market
* EPOS(t)    Exports of electricity are non-positive
OMARKET(O,t) O product market equilibrium conditions det XO
dtb(t)       definition of trade balance
dtb1(t)
* dtb1(t)
INCOME(t)   Det DISP
incomeu(t)  Income for urban households
incomer(t)  Income for rural households
incomee(t)  Income for estate households
consinc(h,t) Income used for consumption
DEFGDP(t)   Definition of gross domestic product
dttotdisp
2718 2719 * Model equations
2720 2721 * User prices of production factors
2722 * Obs price of estate labor -- the markets are not yet separated
2723 2724 DEFPUA(t) .. PUA(t)=E=PA(t)*(1+ATAX(t));
2725 DEFPUR(T) .. PUR(T)=E=PR(T)*(1+RTAX(T));
2726 DEFPUL(t) .. PUL(t)=E=PL(t)*(1+LTAX(t));
2727 DEFPUK(t) .. PUK(t)=E=PK(t)*(1+KTAX(t));
2728 2729 * Prices of composite input Y in all sectors
2730 2731 DEFPIP(P,t) .. P1P(P,t)=E=(DELA1(P)*PUA(t)**(1-SIGAKP(P»+(1-
2732 * PUK(t)**(1-SIGAKP(P»)**(1/(1-
2733 2734 DEFP2P(P,T) .. P2P(P,T)=E=(DELR2(P)*PUR(T)**(1-SIGRIP(P»+(1-
2735 * PUK(t)**(1-SIGAKP(P»)**(1/(1-
2736 2737 DEFP3P(P,T) .. P3P(P,T)=E=(DELL3(P)*PUL(T)**(1-SIGL2P(P»+(1-
2738 * PUK(t)**(1-SIGAKP(P»)**(1/(1-
2739 2740 DEFP4P(P,T) .. P4P(P,T)=E=(DELE4(P)*PUE('ELEC',T)**(1-
2741 * SIGE3P(P»)**
2742 2743 2744 DEFPYP(P,t) .. PYP(P,t)=E=(DELMY(P)*PMP(P,T)**(1-SIGM4P(P»+
2745 * (1-DELMY(P))*P4P(P,t)**(1-
2746 2747 2748 DEFPI1N(N,t) .. P1N(N,t)=E=(DELA1N(N)*PUA(t)**(1-SIGAKN(N»+(1-
2749 DEL1N(N))*
2750 2751 2752 DEFP2N(N,T) .. P2N(N,T)=E=(DELR2N(N)*PUR(T)**(1-SIGR1N(N»+(1-
2753 DELR2N(N))*
2754 2755
DEFP3N(N,T) = E = (DELL3N(N) * PUL(T) ** (1 - SIGL2N(N)) + (1 - DEFP3N(N,T)) * P2N(N,T) ** (1 - SIGL2N(N))) ** (1/(1 - SIGL2N(N)))

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DEFP4N(N,T) = E = (DELE4N(N) * DPE('ELEC',T) ** (1 - SIGE3N(N)) + (1-DELE4N(N)) * P3N(N,T) ** (1 - SIGE3N(N))) ** (1/(1-SIKE3N(N)))

DEFPYN(N,t) = E = (DELMYN(N) * PMN(N,t) ** (1 - SIGM4N(N)) + (1-DELMYN(N)) * P4N(N,t) ** (1 - SIGM4N(N))) ** (1/(1 - SIGM4N(N)))

DEFP1E(E,t) = E = (DELA1E(E) * PUA(t) ** (1 - SIGAKE(E)) + (1-DELA1E(E)) * P1E(E,t) ** (1 - SIGAKE(E))) ** (1/(1 - SIGAKE(E)))

DEFP2E(E,T) = E = (DLR2E(E) * PUR(T) ** (1 - SIGI1E(E)) + (1-DLR2E(E)) * P2E(E,T) ** (1 - SIGI1E(E))) ** (1/(1 - SIGI1E(E)))

DEFP3E(E,T) = E = (DELL3E(E) * PUL(T) ** (1 - SIGL2E(E)) + (1-DELL3E(E)) * P3E(E,T) ** (1 - SIGL2E(E))) ** (1/(1 - SIGL2E(E)))

DEFP4E(E,T) = E = (DELE4E(E) * DPE('ELEC',T) ** (1 - SIGE3E(E)) + (1-DELE4E(E)) * P4E(E,T) ** (1 - SIGE3E(E))) ** (1/(1 - SIGE3E(E)))

DEFPIO(O,t) = E = (DELAIO(O) * PUA(t) ** (1 - SIGAKO(O)) + (1-DELAIO(O)) * P1O(O,t) ** (1 - SIGAKO(O))) ** (1/(1 - SIGAKO(O)))

DEFP10(O,t) = E = (DELA1O(O) * PUA(t) ** (1 - SIGAKO(O)) + (1-DELA1O(O)) * P1O(O,t) ** (1 - SIGAKO(O))) ** (1/(1 - SIGAKO(O)))

DEFP20(O,T) = E = (DLR2O(O) * PUR(T) ** (1 - SIGI1O(O)) + (1-DLR2O(O)) * P2O(O,T) ** (1 - SIGI1O(O))) ** (1/(1 - SIGI1O(O)))
SYstem (1-DEL30(O»*PUL(T)**(1-SIGL20(O»)**(1/(1-
P20(O,T)**(1-SIGL20(O»))**((1/(1-
Model) *(1/(1/SIGE30(O»))i
P40(O,T)=E=(DELE40(O)*DPE('ELEC',T)**(1-
SIGE30(O»)j
P30(O,T)=E=(DELL30(O)*PUL(T)**(1-SIGL20(O»)+(1-
SIGRI0(O»))*P30(O,T)**((1-
SIGE30(O»))**
(1/(1/(1-SIGE30(O»));

* Partial derivatives of PY wrt PUK and PUA and PUL

PPM(P,t)**(-SIGE3P(P»;

DP2DPEP(P,t) ..
DP4DP3P(P,t)=E=(1-DELE4(P)*P3P(P,t)**SIGE3P(P)*
DPE('ELEC',T)**(-SIGE3P(P»;

DP3DPLP(P,t) .. DP3DPLP(P,t)=E=(1-DELL3(P)*PUL(T)**SIGL2P(P)*
PP2P(P,t)**(-SIGL2P(P»;

DP2DIP(P,t) ..
PUL(T)**(-SIGL2P(P»;

DP2DPIP(P,t) ..
PUL(T)**(-SIGL2P(P»;

DP2DPRP(P,t) .. DP2DPRP(P,t)=E=DELR2(P)*PUR(T)**SIGR1P(P)*
P1P(P,t)**(-SIGR1P(P»;

DP2DP1P(P,t) .. DP2DP1P(P,t)=E=(1-DELR2(P)*P1P(P,t)**SIGR1P(P)*
PUR(T)**(-SIGR1P(P»;

DP1DPAP(P,t) .. DP1DPAP(P,t)=E=DELA1(P)*PUA(T)**SIGAKP(P)*
PUK(t)**(-SIGAKP(P»;
301

2837  DDP1DPKP(P,t)=E=(1-DELA1(P))*PUK(t)**SIGAKP(P)*
2838          PUA(T)**(-SIGAKP(P));
2840  DDPYDPAP(P,t)=E=DPYDP4P(P,t)*DP4DP3P(P,t)*DP3DP2P(P,t)*
2842          DP2DP1P(P,T)*DP1DPAP(P,T);
2843  DDPYDPKP(P,t)=E=DPYDP4P(P,t)*DP4DP3P(P,t)*DP3DP2P(P,t)*
2845          DP2DP1P(P,T)*DP1DPKP(P,T);
2846  DDPYDPRP(P,t)=E=DPYDP4P(P,t)*DP4DP3P(P,t)*DP3DP2P(P,t)*
2848          DP2DPRP(P,T);
2849  DDPYDPLP(P,t)=E=DPYDP4P(P,t)*DP4DP3P(P,t)*DP3DPLP(P,T);
2850  DDPYDPEP(P,t)=E=DPYDP4P(P,t)*DP4DPEP(P,t);
2851  DDPYDP4N(N,t)=E=DELMYN(N)*P4N(N,t)**SIGM4N(N)*
2852          DPE('ELEC',T)**(-SIGE3N(N)} ;
2853  DP4DPEN(N,t)=E=DELE4N(N)*DPE('ELEC',T)**SIGE3N(N)*
2854          P3N(N,t)**(-SIGE3N(N));
2855  DDP3DPLN(N,t) =E=DELL3N(N)*PUL(T)**SIGL2N(N)*
2856          P2N(N,t)**(-SIGL2N(N));
2857  DDP3DP2N(N,t) =E=DELL3N(N)*P2N(N,t)**SIGL2N(N)*
2858          PUL(T)**(-SIGL2N(N));
2859  DDP2DPRN(N,t)=$(delr2n(n) gt 0) ;
2860  DDP2DPRN(N,t)=E=DELR2N(N)*PUR(T)**SIGR1N(N)*
2861          P1N(N,t)**(-SIGR1N(N));
2862  DDP2DPRN(N,t)=E=DELR2N(N)*PUR(T)**SIGR1N(N)*
2863          P1N(N,t)**(-SIGR1N(N));
2864  GAMS 2.25.059 386/486 DOS
2865  11/13/96 17:16:17 PAGE 58
2866  General Algebraic Modeling System
2867  Compilation
2868  dp2dpr1(n,t)$(delr2n(n) eq 0) ; dp2dprn(n,t)=e=0;
DP2DP1N(N,t) = (1 - DEL1N(N)) * PIN(N,t) ** SIG1N(N) * PUR(T) ** (-SIG1N(N));

DP1DPN(N,t) = DEL1N(N) * PUA(T) ** SIGAKN(N) * PUK(T) ** (-SIGAKN(N));

ddp1dpn1(n,t) $ (del1n(n) eq 0) .. dp1dpn(n,t) = e = 0;

DDP1DPKN(N,t) .. DP1DPKN(N,t) = (1 - DEL1N(N)) * PUK(T) ** SIGAKN(N) * PUA(T) ** (-SIGAKN(N));

DPYDPN(N,t) = DPYDP4N(N,t) * DP4DP3N(N,t) * DP3DP2N(N,t) * DP2DP1N(N,t) * DP1DPN(N,t);

DDPYDPKN(N,t) .. DPYDPKN(N,t) = DPYDP4N(N,t) * DP4DP3N(N,t) * DP3DP2N(N,t) * DP2DP1N(N,t) * DP1DPKN(N,t);

DDPYDPRN(N,t) .. DPYDPRN(N,t) = DPYDP4N(N,t) * DP4DP3N(N,t) * DP3DP2N(N,t) * DP2DPRN(N,t);

DDPYDP40(O,t) = (1 - DELMY0(O)) * P40(O,t) ** SIG40(O) * PMO(O,T) ** (-SIG40(O));

ddp4dpel(o,t) $ (del4o(o) eq 0) .. dp4dpe(o,t) = e = 0;

GAMS 2.25.059 386/486 DOS 11/13/96 17:16:17 PAGE 59 General Algebraic Modeling System Compilation
$\text{DDP3DPL0}(O,t) = E = \text{DELL30}(O) \ast \text{PUL}(T) \ast \text{SIGL2O}(O) * P20(O,t) \ast (-\text{SIGL2O}(O))$;

$\text{DDP3DP2O}(O,t) = E = (1 - \text{DELL30}(O)) \ast P20(O,t) \ast \text{SIGL2O}(O) * \text{PUL}(T) \ast (-\text{SIGL2O}(O))$;

$\text{DDP2DPRO}(O,t) = E = \text{DELR20}(O) \ast \text{PUR}(T) \ast \text{SIGR10}(O) * P10(O,t) \ast (-\text{SIGR10}(O))$;

$\text{DDP2DP1O}(O,t) = E = (1 - \text{DELR20}(O)) \ast P10(O,t) \ast \text{SIGR10}(O) * \text{PUR}(T) \ast (-\text{SIGR10}(O))$;

$\text{DDP1DPAO}(O,t) = E = \text{DELA10}(O) \ast \text{PUA}(T) \ast \text{SIGAKO}(O) * PUK(t) \ast (-\text{SIGAKO}(O))$;

$\text{DDP1DPKO}(O,t) = E = (1 - \text{DELA10}(O)) \ast \text{PUA}(T) \ast (-\text{SIGAKO}(O)) * \text{PUK(t)} \ast \text{SIGAKO}(O)$;

$\text{DDPYDPAO}(O,t) = E = \text{DPYDP40}(O,t) \ast \text{DP4DP3O}(O,t) \ast \text{DP3DP2O}(O,T) \ast \text{DP2DPRO}(O,T) \ast \text{DPIDPKO}(O,T)$;

$\text{DDPYDPKO}(O,t) = E = \text{DPYDP40}(O,t) \ast \text{DP4DP3O}(O,t) \ast \text{DP3DP2O}(O,T) \ast \text{DP2DP1O}(O,T) \ast \text{DP1DPAO}(O,T)$;

$\text{DDPYDPRO}(O,t) = E = \text{DPYDP40}(O,t) \ast \text{DP4DP3O}(O,t) \ast \text{DP3DP2O}(O,T) \ast \text{DP2DP1O}(O,T) \ast \text{DP1DPKO}(O,T)$;

$\text{DDPYDPLO}(O,t) = E = \text{DPYDP40}(O,t) \ast \text{DP4DP3O}(O,t) \ast \text{DP3DP2O}(O,T) \ast \text{DP2DPRO}(O,T) \ast \text{DP1DPAO}(O,T)$;

$\text{DDPYDPME}(E,t) = E = \text{DELMYE}(E) \ast \text{PME}(E,T) \ast \text{SIGM4E}(E) \ast P4E(E,t) \ast (-\text{SIGM4E}(E))$;

$\text{DDPYDP4E}(E,t) = E = \text{DELMYE}(E) \ast P4E(E,t) \ast \text{SIGM4E}(E) \ast \text{PME}(E,T) \ast (-\text{SIGM4E}(E))$;

$\text{DP4DPEE}(E,t) = E = \text{DELE4E}(E) \ast \text{DPE}('ELEC',T) \ast \text{SIGE3E}(E) \ast \text{P3E}(E,t) \ast (-\text{SIGE3E}(E))$;

$\text{DP4DP3E}(E,t) = E = (1 - \text{DELE4E}(E)) \ast \text{P3E}(E,t) \ast \text{SIGE3E}(E) \ast \text{DPE}('ELEC',T) \ast (-\text{SIGE3E}(E))$;

$\text{DP4DPL0}(E,t) = E = \text{DELL3E}(E) \ast \text{PUL}(T) \ast \text{SIGL2E}(E) * P2E(E,t) \ast (-\text{SIGL2E}(E))$;}
Partial derivatives of \( P_X \) wrt \( P_UK, P_UL \) and \( P_UA \)

\[
\begin{align*}
\text{DDP1DPAE}(E,t) &= E = \text{DDP1DPAE}(E,t) \\
\text{DDP1DPKE}(E,t) &= E = \text{DDP1DPKE}(E,t) \\
\text{DDP2DPAE}(E,t) &= E = \text{DDP2DPAE}(E,t) \\
\text{DDP2DPKE}(E,t) &= E = \text{DDP2DPKE}(E,t) \\
\text{DPYDPAE}(E,t) &= E = \text{DPYDPAE}(E,t) \\
\text{DPYDPKE}(E,t) &= E = \text{DPYDPKE}(E,t) \\
\text{DPYDPRE}(E,t) &= E = \text{DPYDPRE}(E,t) \\
\text{DPYDPLE}(E,t) &= E = \text{DPYDPLE}(E,t) \\
\text{DPYDPEE}(E,t) &= E = \text{DPYDPEE}(E,t) \\
\end{align*}
\]
3021  \text{DDPXDPAN}(N,t) \quad \text{DPXDPAN}(N,t) = E = AN(N,t) \times DPYDPAN(N,t);
3022  \text{DDPXDPKN}(N,t) \quad \text{DPXDPKN}(N,t) = E = AN(N,t) \times DPYDPKN(N,t);
3023  \text{DDPXDPEN}(N,t) \quad \text{DPXDPEN}(N,t) = E = AN(N,t) \times DPYDPEN(N,t);
3024  \text{DDPXDPMLN}(N,T) \quad \text{DPXDPMLN}(N,T) = E = AN(N,T) \times DPYDPMLN(N,T);
3025  \text{DDPXDPEN}(N,T) \quad \text{DPXDPEN}(N,T) = E = AN(N,T) \times DPYDPEN(N,T);
3026  \text{DDPXDPMN}(N,T) \quad \text{DPXDPMN}(N,T) = E = AN(N,T) \times DPYDPMN(N,T);
3027  \text{DDPXDPAR}(O,t) \quad \text{DPXDPAR}(O,t) = E = AO(O,t) \times DPYDPAR(O,t);
3028  \text{DDPXDPKO}(O,t) \quad \text{DPXDPKO}(O,t) = E = AO(O,t) \times DPYDPKO(O,t);
3029  \text{DDPXDPBO}(O,t) \quad \text{DPXDPBO}(O,t) = E = AO(O,t) \times DPYDPBO(O,t);
3030  \text{DDPXDOEO}(O,t) \quad \text{DPXDOEO}(O,t) = E = AO(O,t) \times DPYDOEO(O,t);
3031  \text{DDPXDPOO}(O,T) \quad \text{DPXDOPO}(O,T) = E = AO(O,T) \times DPYDOPO(O,T);
3032  \text{DDPXDOEC}(E,t) \quad \text{DPXDOEC}(E,t) = E = AE(E,t) \times DPYDOEC(E,t);
3033  \text{DDPXDPKE}(E,t) \quad \text{DPXDPKE}(E,t) = E = AE(E,t) \times DPYDPKE(E,t);
3034  \text{DDPXDPER}(E,T) \quad \text{DPXDPER}(E,T) = E = AE(E,T) \times DPYDPER(E,T);
3035  \text{DDPXDPHE}(E,T) \quad \text{DPXDPHE}(E,T) = E = AE(E,T) \times DPYDPHE(E,T);
3036  \text{DDPXDPME}(E,T) \quad \text{DPXDPME}(E,T) = E = AE(E,T) \times DPYDPME(E,T);
3037  \text{ADEMP}(P,t) \quad \text{AALP}(P,t) = E = DPXDPAP(P,t) \times XP(P,t);
3038  \text{RDEMP}(P,T) \quad \text{RP}(P,T) = E = DPXDPRP(P,T) \times XP(P,T);
3039  \text{LDEMPP}(P,T) \quad \text{LP}(P,T) = E = DPXDPDLP(P,T) \times XP(P,T);
3040  \text{KDEMP}(P,t) \quad \text{KP}(P,t) = E = DPXDPKXP(P,t) \times XP(P,t);
3041  \text{EDEMPP}(P,t) \quad \text{EP}(P,t) = E = DPXDPDEP(P,t) \times XP(P,t);
3042  \text{MDEMP}(P,T) \quad \text{IMPP}(P,T) = E = DPXDPMP(P,T) \times XP(P,T);
Definition of marginal and average costs in different sectors

They are equal because we have CRS everywhere in this version

In the tree crops sectors the land quality index plays a role
MCO(O,t) = E(AM(O,t) * FYO(O,t)) + SUM(P, DPP(P,t) * APO(P,O))

SUM(n, DPN(N,t) * ANO(n,O)) + DPF('PETR',t) * AEO('PETR',O) +
SUM(0, DPO(0,t) * AOO(0,0)) + ITAXO(O,t) - SUBSO(O,T);

* Price equals marginal cost
* Determines output price
* In the case of energy price is exogenous and output determined from demand

PRMCP(P,t) .. DPP(P,t) = l = MCP(P,t);
ppcomp(p,t) .. xp(p,t) * (dpp(p,t) - mcp(p,t)) = e = 0;

PRMCN(N,t) .. DPN(N,t) = l = MCN(N,t);
nncomp(n,t) .. xn(n,t) * (dpn(n,t) - mcn(n,t)) = e = 0;

* Domestic consumption demand functions for composite goods

PCONS(P,H,t) $(ord(T) NE 1)..
DDP(P,H,t) = E = PALPHA(P,H) * (DISPh(H,T) + (1 + interest(t)) ** tau * savh(H,T - 1)) / DPP(P,t);

PCONS1(p,H,t) $(ord(t) EQ 1)..
DDP(P,H,t) = E = PALPHA(P,H) * DISPh(H,T) / DPP(P,T);

nCONS(n,H,t) $(ord(T) NE 1)..
DDN(N,H,t) = E = nALPHA(n,H) * (DISPh(H,T) + (1 + INTEREST(t)) ** tau * SAVH(H,T - 1)) / DPN(N,t);

nCONS1(n,H,T) $(ord(T) EQ 1)..
DDN(N,H,T) = E = nALPHA(n,H) * DISPh(H,T) / DPN(N,T);

ECONS(E,H,t) $(ord(T) NE 1)..
DDE(E,H,t) = E = EALPHA(E,H) * (DISPh(H,T) + (1 + INTEREST(t)) ** tau * SAVH(H,T - 1)) / DPE(E,t);

ECONS1(E,H,T) $(ord(T) EQ 1)..
DDE(E,H,T) = E = EALPHA(E,H) * DISPh(H,T) / DPE(E,T);
3149 \text{OCONS}(O,H,t) $(\text{ord}(T) \neq 1)$ ..
3150 \text{DDO}(O,H,t) = \text{E} = \text{OALPHA}(O,H) \times \text{DISPh}(H,t) + (1 + \text{INTEREST}(t))^\tau \times \text{SAVh}(H,T-1) / \text{DPO}(O,t);
3151 \text{OCONS1}(O,H,T) $(\text{ord}(t) = 1)$ ..
3152 \text{DDO}(O,H,T) = \text{E} = \text{OALPHA}(O,H) \times \text{DISPh}(H,T) / \text{DPO}(O,T);
3153
3154 *++++++++++*
3155 * Imports *
3156 *++++++++++*
3157 * Definition of domestic price of imports
3158 * Small country assumption. Can purchase at constant WM prices
3159 * IMPDP is the ad valorem import duty rate
3160
3161 \text{DEFPMP}(P,t) .. \text{PMP}(P,t) = \text{E} = \text{WMP}(P,t) \times (1 + \text{IMPDP}(P,t)) \times \text{XR}(t);
3162 \text{DEFPMN}(N,t) .. \text{PMN}(N,t) = \text{E} = \text{WMN}(N,t) \times (1 + \text{IMPDN}(N,t)) \times \text{XR}(t);
3163 \text{DEFPME}(E,t) .. \text{PME}(E,t) = \text{E} = \text{WME}(E,t) \times (1 + \text{IMPDE}(E,t)) \times \text{XR}(t);
3164 \text{DEFPMO}(O,t) .. \text{PMO}(O,t) = \text{E} = \text{WMO}(O,t) \times (1 + \text{IMPDO}(O,t)) \times \text{XR}(t);
3165
3166 * Armington assumption
3167 *++++++++++*
3168 * EXPORTS *
3169 *++++++++++*
3170 * Assume domestic goods and export goods imperfect substitutes
3171 * Assume small country
3172
3173 * Domestic price of exports in local currency
3174 * Only defined if exports are possible -- $|$ is if statement
3175
3176 \text{GAMS} 2.25.059 386/486 DOS 11/13/96 17:16:17 PAGE 64
3177 General Algebraic Modeling System Compilation
3178
3179 \text{DPEP}(P,t) .. \text{PEP}(P,t) = \text{E} = \text{WMPE}(P,t) \times (1 + \text{EXPTP}(P,t)) \times \text{XR}(t);
3180 \text{DPEN}(N,t) $ \text{PEN}(N,t) = \text{E} = \text{WMEN}(N,t) \times (1 + \text{EXPTN}(N,t)) \times \text{XR}(t);$
3181
3182 \text{dpen}(n,t) $ \text{pen}(n,t) = e = .1;$
3183 \text{dpeeb}(e,t) $ \text{pee}(e,t) = e = .1;$
3184
3185
3186
3187
3188
3189  DPEO(O,t) $ (expsho(o)  gt  0).  
PEO(O,t) = E = WMEO(O,t) * (1 + EXPTO(O,t))

*XRT(t);
3190  dpeob(o,t) $ (expsho(o) eq 0).  
PEO(O,t) = E = 1;

3193  * CET transformation functions between dom cons and exports
3194  * Determine total consumption of domestically produced goods
3195  * expsh is the share of exports in total consumption
3196
3197
3198
3199
3200  DCP(P,t) ..
3201  CP(P,t) = E = SUM(H, DDP(P,H,t)) + INVP(P,t) + EXPP(P,t) +
3202  SUM(n, APn(P,n)*XN(N,t)) +
3203  SUM(O, APO(P,O) * XO(O,t));
3204  DCN(N,t) ..
3205  cCN(N,t) = E = SUM(H, DDN(N,H,t)) + INVN(N,t) + EXPN(N,t) +
3206  SUM(P, AnP(n,P)*XP(P,t))
3207  + SUM(nn, AnN(nn)*XN(Nn,t)) + sum(e, ane(n,e) * xe(e,t)) +
3208  SUM(O, AOn(O,n) * XO(O,t));
3209  DCE(e,t) ..
3210  CB(N,t) = E = SUM(H, DDe(e,h,t)) + intere(e,t) + expe(e,t);
3211  DCO(O,t) ..
3212  CO(O,t) = E = SUM(H, DDO(O,H,t)) + INVO(O,t) + EXPO(O,t) + SUM(P, AOP(O,P) * XP(P,t))
3213  + SUM(n, AOn(O,n)*XN(N,t)) + sum(e, aoe(o,e) * xe(e,t)) +
3214  SUM(OO, AOO(O,OO) * XO(00,t));
3215
3216  * Find a ration of exp to domestic consumption so that the price
3217  ratio
3218  equals
3219  * the MRT for RoW.
3220  * Determine exports if exports possible else exports equal to 0
3221  DEXPP(P,t) ..  EXPP(P,t)/(cp(p,t) - expp(p,t)) = E = (EXPSPH(P) / (1 -
EXPSPH(P)))
3222  **MUP(P)*
3223  (PEP(P,t)/DPP(P,t)) **MUP(P);
3224
3225  DEXPnA(N,t) $(EXPSPH(N) NE 0) ..  EXPN(N,t) / (CCN(N,t) -
expn(n,t)) = E =
3226  (EXPSPH(N) / (1 -
3227  EXPSHN(N))) **MUN(N) * (PEN(N,t)/DPN(N,t)) **MUN(N);
3228  DEXPnB(N,t) $(EXPSPH(N) EQ 0) ..  EXPN(N,t) = E = 0;

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3229
3230  DEXPEA(E,t)$(EXPSHE(E) NE 0) .. EXPE(E,t)/(CE(E,t) -
3231  exp(e,t)) = E = (EXPSHE(E) /
3232  (1 -
3233  EXPSHE(E) )) ** MUE(E) * (PEE(E,t)/DPE(E,t) ) ** MUE(E);
3234  DEXPEB(E,t)$(EXPSHE(E) EQ 0) .. EXPE(E,t) = E = 0;
3235  DEXPAO(O,t)$(EXPSPH(O) NE 0) .. EXPO(O,t)/(CO(O,t) -
3236  cxpo(o,t)) = E =
3237  (EXPSPH(O))/(1 -
3238  EXPSPH(O) ) ** MUO(O) * (PEO(O,t)/DPO(O,t) ) ** MUO(O);
3239  DEXPOS(O,t)$(EXPSPH(O) EQ 0) .. EXPO(O,t) = E = 0;
3240  * Factor market equilibrium
3241  * Determine prices of production factors
3242  * Obs: Kmarket1 and Rmarket1 are used to obtained a base solution
w/o
3243  * conservation
3244  L(t)=E=SUM(P,LP(P,T)) + SUM(n,LN(N,t)) + SUM(e,le(e,t)) +
3245  SUM(O,LO(O,t));
3246  A(t)=E=SUM(P,AALP(P,T)) + SUM(n,AALN(N,T)) + SUM(O,AALO(O,T)) +
3247  SUM(E,AALE(E,T));
3248  RMARKET(T) ..
3249  R(T)=E=SUM(P,RP(P,T) + lscs(p,t) + lsce(p,t)) +
3250  SUM(n,RN(N,t)) + SUM(e,Re(e,t)) +
3251  SUM(O,RO(O,t));
3252  RMARKET1(T) ..
3253  R(T)=E=SUM(P,RP(P,T)) + SUM(n,RN(N,T)) + SUM(O,RO(O,T)) +
3254  SUM(E,RE(E,T));
3255  KMARKET(T) ..
3256  K(t)=E=SUM(P,KP(P,t) + cscs(p,t) + csce(p,t)) +
3257  SUM(n,KN(N,t)) + SUM(e,ke(e,t)) +
3258  SUM(O,KO(O,t));
3259  KMARKET1(T) ..
3260  K(T)=E=SUM(P,KP(P,T)) + SUM(n,KN(N,T)) + SUM(O,KO(O,T)) +
3261  SUM(E,KE(E,T));
3262  *INVESTMENTS
3263  DINV(P,T).. INVP(P,T) = E = PBETA(P) * invest(t) * pi(t) / DPF(P,T);
3264  DINV(O,T) .. INVNO(O,T) = E = OBETA(O) * invest(t) * pi(t) / DPO(O,T);
doinvl(o,t) = invo(o,t) = 0;

invest(t) = E = (SUM(P, INVP(P,T) * DPP(P,T)) + SUM(n, INVN(N,T) * DPN(N,T)) + SUM(o, INVO(O,T) * DPO(O,T))/pi(t);

KSTOCK(T) ..
K(t) =E= (1-depl)*k(t-1) + invest(t-1);
kstock1(t) $ (ord(T) eq 1) ..
K(t) =E= totk0;

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* Soil conservation

* dxddp(p) *

dlabcscs(p,t) .. sum(tt$(ord(tt) gt ord(t)),(tau*dpp(p,tt)

*(lscs(p,t)

** (pgamma(p)-1))*(cscs(p,t)**(l-

pgamma(p)))-

pgamma(p)*scs(p,t)/pur(t)=e=0;

dlscsc(p,t) .. (lscs(p,t)-low)*(sum(tt$(ord(tt) gt

ord(t)),(tau*dpp(p,tt)

dlscsc(p,t) ..

*(lscs(p,t)

** (pgamma(p)-1))*(cscs(p,t)**(l-

pgamma(p)))-

pgamma(p)*scs(p,t)/pur(t)=e=0;

dlscsc(p,t) ..

*(lscs(p,t)

** (pgamma(p)-1))*(cscs(p,t)**(l-

pgamma(p)))-

pgamma(p)*scs(p,t)/pur(t)=e=0;

dlscsc(p,t) ..

*(lscs(p,t)

** (pgamma(p)-1))*(cscs(p,t)**(l-

pgamma(p)))-

pgamma(p)*scs(p,t)/pur(t)=e=0;

dlscsc(p,t) ..

*(lscs(p,t)

** (pgamma(p)-1))*(cscs(p,t)**(l-

pgamma(p)))-

pgamma(p)*scs(p,t)/pur(t)=e=0;

dlscsc(p,t) ..
puk(t))
= e=0;
3302
3303
sccs(p,t)=e=1sccs(p,t)**pgamma(p)*ccss(p,t)**
3304 (1-pgamma(p));
3305
dabsce(p,t).. sum(tt$((ord(tt)-ord(t)-1) eq
0), (tau*dpp(p,tt)

* dxddp(p)
3307 *(1/(1+
3308 interest(tt))**(ord(tt)-ord(t))))
3309 *pgamma(p)*(lsccs(p,t)
3310 **((pgamma(p)-1))*(ccss(p,t)**(1-
3311 pgamma(p)))) -
3312 pgamma(p)*scs(p,t)
3313 /pur(t)=e=0;
3314
dlscsc(p,t).. (lsccs(p,t)-low)*sum(tt$((ord(tt)-ord(t)-
1) eq 0)
3315 ,
3316 (tau*dpp(p,tt)*dxddp(p)*(1/(1+
3317 interest(tt))**(ord(tt)-ord(t))))-
3318 pur(t))=e=0;
3319
dcapsce(p,t).. sum(tt$((ord(tt)-ord(t)-1) eq
0), (tau*dpp(p,tt)*
3320 dxddp(p)*
3321 (1/(1+
3322 interest(tt))**(ord(tt)-
3323 ord(t))))*(lsccs(p,t)
3324 **pgamma(p)*((1-pgamma(p))*ccss(p,t)
3325 **(-
3326 pgamma(p)))) -
3327 GAMS 2.25.059 386/486 DOS 11/13/96 17:16:17 PAGE
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3324 (1-pgamma(p))*
3325 scs(p,t)/puk(t)=e=0;
3326
dcssec(p,t).. (csce(p,t)-low)*sum(tt$((ord(tt)-ord(t)-
1) eq
0),
3327 (tau*dpp(p,tt)*dxddp(p)*
3328 (1/(1+interest(tt))**((ord(tt)-ord(t))))-
3329 puk(t))=e=0;
dsce(p,t) = \text{e} = lsce(p,t)**pgamma(p) * csce(p,t)**(1-pgamma(p));

dq(p,t) = \text{e} = 1 - erosion(p) * tau * (ord(t) - 1) + \sum(tt$(ord(tt)) le ord(t)), sshare(p) * scs(p,t) + (1 - sshare(p)) * sce(p,t);

* Determine the savings by hh type

* Assume rate of time preference equals interest rate

dinvest(t) = pk(t) = \frac{1}{1 + \text{interest}(t)} * pk(t+1);

dsavh(h,t) = disph(h,t) = disph(h,t+1) + (1 + \text{interest}(t))

**tau*

dsavhl(h,t) = \text{e} = disph(h,t) + \sum(tt, tdishph(h,tt) - disph(h,tt)) = e = 0;

* Determine trade balance

dtb(t) = tb(t) = \text{e} = \sum(P, PEP(P,t) * EXPP(P,t) - Pmp(P,t))

* Define prices of composite (dom const plus exports) consumption

DPCP(P,t) = PCP(P,t) = cp(p,t) = E = DPP(P,t) * (CP(P,t) - EXPP(P,t))

DPCN(N,t) = PCN(N,t) = ccn(n,t) = E = DPN(N,t) * (CCN(N,t) - EXPN(N,t))

DPCO(O,t) = PCO(O,t) = co(o,t) = E = DPO(O,t) * (CO(O,t) - EXPO(O,t))

+PEO(O,t)*

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3372 \text{EXPO}(O,t);
3373 \text{DPCE}(E,t)\ldots \text{PCE}(E,t)\ast \text{ce}(e,t) = \text{DPE}(E,t)\ast \text{CE}(E,t) - \text{EXPE}(E,t))
3374 + \text{PCE}(E,t)\ast \text{ce}(e,t) = \text{DPE}(E,t)\ast \text{CE}(E,t) - \text{EXPE}(E,t))
3375 \text{EXPE}(E,t);
3376 \text{EXPE}(E,t);
3377 \text{EXPE}(E,t);
3378 \text{EXPE}(E,t);
3379 \text{EXPE}(E,t);
3380 \text{EXPE}(E,t);
3381 \text{EXPE}(E,t);
3382 \text{EXPE}(E,t);
3383 \text{EXPE}(E,t);
3384 \text{EXPE}(E,t);
3385 \text{EXPE}(E,t);
3386 \text{EXPE}(E,t);
3387 \text{EXPE}(E,t);
3388 \text{EXPE}(E,t);
3389 \text{EXPE}(E,t);
3390 \text{EXPE}(E,t);
3391 \text{EXPE}(E,t);
3392 \text{EXPE}(E,t);
3393 \text{EXPE}(E,t);
3394 \text{EXPE}(E,t);
3395 \text{EXPE}(E,t);
3396 \text{EXPE}(E,t);
3397 \text{EXPE}(E,t);
3398 \text{EXPE}(E,t);
3399 \text{EXPE}(E,t);
3400 \text{EXPE}(E,t);
3401 \text{EXPE}(E,t);
3402 \text{EXPE}(E,t);
3403 \text{EXPE}(E,t);
3404 \text{EXPE}(E,t);
3405 \text{EXPE}(E,t);
3406 \text{EXPE}(E,t);
3407 \text{EXPE}(E,t);
3408 \text{EXPE}(E,t);
3409 \text{EXPE}(E,t);
3410 \text{EXPE}(E,t);
3411 \text{EXPE}(E,t);
3412 \text{EXPE}(E,t);
3413 \text{EXPE}(E,t);
3414 \text{EXPE}(E,t);
3415 \text{EXPE}(E,t);
3416 \( \sum(n, iTAXN(N,t) \cdot XN(N,t)) + \sum(E, iTAXE(E,t) - \text{subse}(e,t) \cdot XE(E,t)) + \)
3417 \( \sum(O, (iTAXO(O,t) - \text{subso}(o,t) \cdot XO(O,t)) - tb(t) - \text{invest}(t)) ; \)
3418
3419 INCOME(T) ..
3420 DISPH('ESTATE',t) = E=PUA(t) \cdot A(T) + K'H('ESTATE') \cdot (PUK(t) \cdot K(T) +
3421 \sum(P, OTAXP(P,t) \cdot XP(P,t)) +
3422 SUM(n, OTAXN(N,t) \cdot XN(N,t)) + \sum(E, OTAXE(E,t) \cdot XE(E,t)) +
3423 SUM(O, OTAXO(O,t) \cdot XO(O,t)) - tb(t) - \text{invest}(t));

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3424 consinc(h,t) ..  tdisph(h,t) - savh(h,t) = e= disph(h,t);
3425
3426 INCOME(T) ..  SUM(H, DISPH(H,T)) = E= DISP(T);
3427
3428 dtotdisp ..  totdisp = e= sum(t, disp(t));
3429
3430 * Gross domestic product
3431 DEFGDP(t) ..  PUA(t) \cdot A(t) + PUK(t) \cdot K(t) + PUL(t) \cdot L(t) + PUR(T) \cdot R(T) +
3432 \sum(P, OTAXP(P,t) \cdot XP(P,t))
3433 + \sum(n, OTAXN(N,t) + XN(N,t)) + \sum(E, OTAXE(E,t) \cdot XE(E,t)) +
3434 \sum(O, OTAXO(O,t) \cdot XO(O,t))
3435 = e= GDP(T);
3436
3437 * Set lower bounds for variables
3438 INCLUDE C:\SLMOD\SLOWA.INC
3439 * Lower bounds for PRICES
3440 q.lo(p,t)=0.001;
3441 pur.lo(t)=0.001;
3442
3443 PUA.LO(T)=0.001;  PUL.LO(T)=0.001;  PUK.LO(T)=0.001;
3444 pur.lo(t)=0.001;
3445
3446 plp.lo(p,t)=0.001;  pln.lo(n,t)=0.001;  ple.lo(e,t)=0.001;
3447 p2p.lo(p,t)=0.001;  p2n.lo(n,t)=0.001;  p2e.lo(e,t)=0.001;
3448 pyo.lo(o,t)
3449 =0.001;
3450
3451
3452 plo.lo(o,t)
3453 =0.001;
3454
3455 p2lo(lo(o,t)
=0.001;
3455
3456 \( p_{3p} \cdot \text{lo}(p,t) = 0.001; \quad p_{3n} \cdot \text{lo}(n,t) = 0.001; \quad p_{3e} \cdot \text{lo}(e,t) = 0.001; \quad p_{3o} \cdot \text{lo}(o,t) \)
3457
3458 \( p_{4p} \cdot \text{lo}(p,t) = 0.001; \quad p_{4n} \cdot \text{lo}(n,t) = 0.001; \quad p_{4e} \cdot \text{lo}(e,t) = 0.001; \quad p_{4o} \cdot \text{lo}(o,t) \)
3459
3460
3461 \( \text{MCP} \cdot \text{LO}(P,T) = 0.001; \quad \text{MCN} \cdot \text{LO}(N,T) = 0.001; \quad \text{MCE} \cdot \text{LO}(E,T) = 0.001; \quad \text{MCO} \cdot \text{LO}(O,T) \)
3462
3463 \( \text{DPP} \cdot \text{LO}(P,T) = 0.001; \quad \text{DPN} \cdot \text{LO}(N,T) = 0.001; \)
3464
3465 \( \ast \text{DPE} \cdot \text{LO}(E,T) = 0.001; \)
3466
3467 \( \text{DPO} \cdot \text{LO}(O,T) = 0.001; \)
3468
3469 \( \text{PMP} \cdot \text{LO}(P,T) = 0.2; \quad \text{PMN} \cdot \text{LO}(N,T) = 0.2; \quad \text{PMO} \cdot \text{LO}(O,T) = 0.2; \quad p_{me} \cdot \text{lo}(e,t) = 0.2; \)
3470
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3471 \( \text{PEP} \cdot \text{LO}(P,T) = 0.001; \quad \text{PEN} \cdot \text{LO}(N,T) = 0.001; \quad \text{pee} \cdot \text{lo}(e,t) = 0.001; \quad \text{PEO} \cdot \text{LO}(O,T) \)
3472
3473 \( \text{PL} \cdot \text{LO}(T) = 0.001; \quad \text{PK} \cdot \text{LO}(T) = 0.001; \quad \text{PA} \cdot \text{LO}(T) = 0.001; \quad p_{r} \cdot \text{lo}(t) = 0.001; \)
3474
3475 \( \ast \text{PQP} \cdot \text{LO}(P,T) = 0.2; \quad \text{PQN} \cdot \text{LO}(N,T) = 0.2; \quad \text{PQO} \cdot \text{LO}(O,T) = 0.2; \)
3476
3477 \( \text{PCP} \cdot \text{LO}(P,T) = 0.001; \quad \text{PCN} \cdot \text{LO}(N,T) = 0.001; \quad \text{pce} \cdot \text{lo}(e,t) = 0.001; \quad \text{PCO} \cdot \text{LO}(O,T) \)
3478
3479 \( \text{cscs} \cdot \text{lo}(p,t) = \text{low}; \quad \text{lscs} \cdot \text{lo}(p,t) = \text{low}; \quad \text{csce} \cdot \text{lo}(p,t) = \text{low}; \)
3480
3481 \( \text{lscs} \cdot \text{lo}(p,t) = \text{low}; \)
3482
3483 \( \text{scs} \cdot \text{lo}(p,t) = \text{low}; \quad \text{sce} \cdot \text{lo}(p,t) = \text{low}; \)
3484
3485 \( \text{dpydpmp} \cdot \text{lo}(p,t) = 0.000001; \quad \text{dpydpmn} \cdot \text{lo}(n,t) = 0.000001; \quad \text{dpydpme} \cdot \text{lo}(e,t) \)
0.000001;
3486  dpydp4n.lo(n,t) = 0.000001; dpydp4p.lo(p,t) = 0.000001;

0.000001;
3487  dpydp4e.lo(e,t) = 0.000001; dpydp4o.lo(o,t) = 0;
dp4dpep.lo(p,t) = 0.000001;
3488  dp4dpen.lo(n,t) = 0.000001; dp4dpee.lo(e,t) = 0.000001;
dp4dpeo.lo(o,t)

0.000001;
3489  dp4dp3p.lo(p,t) = 0.000001; dp4dp3n.lo(n,t) = 0.000001;

0.000001;
3490  dp4dp3lo(e,t) = 0.000001; dp3dplp.lo(p,t) = 0.000001;
dp3dplo.lo(o,t)

0.000001;
3491  dp3dpel.lo(e,t) = 0.000001; dp3dplo.lo(o,t) = 0.000001;
dp3dp2p.lo(p,t)

0.000001;
3492  dp3dp2n.lo(n,t) = 0.000001; dp3dp2e.lo(e,t) = 0.000001;

0.000001;
3493  dp2dprp.lo(p,t) = 0.000001; dp2dprn.lo(n,t) = 0;
3494  dp2dpre.lo(e,t) = 0.000001;
3495  dp2dpro.lo(o,t) = 0.000001; dp2dplo.lo(p,t) = 0.000001;
dp2dp1n.lo(n,t)

0.000001;
3496  dp2dpep.lo(e,t) = 0.000001; dp2dplo.lo(o,t) = 0.000001;
dp1dpkp.lo(p,t)

0.000001;
3497  dp1dpkn.lo(n,t) = 0.000001; dp1dpke.lo(e,t) = 0.000001;
dp1dpko.lo(o,t)

0.000001;
3498  dp1dpap.lo(p,t) = 0.000001; dp1dpan.lo(n,t) = 0;
3499  dp1dpaelo(e,t) = 0.000001;
3500  dp1dpae.lo(e,t) = 0.000001;
3501  dp1dpao.lo(o,t) = 0.000001;
3502  dp1dpb.lo(b,t) = 0.000001;
3503  dp1dpc.lo(c,t) = 0.000001;
3504  dp1dpd.lo(d,t) = 0.000001;
3505  dp1dpel.lo(e,t) = 0.000001;
3506  dp1dpf.lo(f,t) = 0.000001;
3507  dp1dp1.lo(p,t) = 0.000001;
3508  dp1dpnlo(n,t) = 0.000001;
3509  dp1dpel.lo(e,t) = 0.000001;
3510  dp1dpdlo(d,t) = 0.000001;
3511 * Set initial values for variables
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INCLUDE C:\SLMON\SLININ.INC
3513 * Initial values for variables
3514 totax.l(t)=ttax0; totimp.l(t)=timpd0;
3515 savh.l(h,t)=0; k.l(t)=totk0;
3516 domsav.l(t)=0;
3517 * MUP.L(P,T)=1; MUN.L(N,T)=1; MUO.L(O,T)=1; MUE.L(E,T)=1;
3518 NEXPE.L(E,T)=NEXPE0(E);
3519 pi.l(t)=1;
3520 PUA.L(T)=1; PUR.L(T)=1; PUL.L(T)=1; PUK.L(T)=1;
3521 * MUP.L(P,T)=1; MUN.L(N,T)=1; MUO.L(O,T)=1; MUE.L(E,T)=1;
3522 dpydpap.l(P,T)=DELAl(P)*(1-DELr2(P))*(1-del13(P))*(1-dele4(P))
3523 *(1-
delmy(P));
3524 dpydpkp.l(p,t)=(1-del1(p))*(1-DELr2(P))*(1-del13(p))*(1-
dele4(p))
3525 *(1-
delmy(p));
3526 dpydprp.l(p,t)=DELr2(P)*(1-del13(p))*(1-dele4(p))*(1-delmy(p));
3527 dpydpdp.l(p,t)=del13(p)*(1-dele4(p))*(1-delmy(p));
3528 dpydpep.l(p,t)=dele4(p)*(1-delmy(p));
3529 dpydpmp.l(p,t)=delmy(p);
3530 DPYDPAN.L(N,T)=DELA1n(n)*(1-DELr2N(N))*(1-del13n(n))*(1-
dele4n(n))
3531 *(1-delmy(n));
3532 dpydpkn.l(n,t)=(1-del1n(n))*(1-DELr2N(N))*(1-del13n(n))*(1-
dele4n(n))
3533 *(1-delmy(n));
3534 dpydprn.l(n,t)=DELr2N(N)*(1-del13n(n))*(1-dele4n(n))*(1-delmy(n));
3535 dpydpmn.l(n,t)=del13n(n)*(1-delmy(n));
3536 dpydpen.l(n,t)=dele4n(n)*(1-delmy(n));
3537 dpydpnn.l(n,t)=delmy(n);
3538 DPYDPAP.L(E,T)=DELA1e(e)*(1-DELr2E(E))*(1-del13e(e))*(1-
dele4e(e))
3539 *(1-delmye(e));
3551 \[ \text{dpydpke}.l(e,t) = (1 - \text{dela}e(e)) \times (1 - \text{DELr}2E(e)) \times (1 - \text{dell}3e(e)) \times (1 - \text{dele}4e(e)) \times \]
3552 \[ (1 - \text{delmy}e(e)); \]
3553 \[ \text{dpydpre}.l(e,t) = \text{DELr}2E(e) \times (1 - \text{dell}3e(e)) \times (1 - \text{dele}4e(e)) \times (1 - \text{delmy}e(e)); \]
3554 \[ \text{dpydpde}.l(e,t) = \text{dell}3e(e) \times (1 - \text{dele}4e(e)) \times (1 - \text{delmy}e(e)); \]
3555 \[ \text{dpydpmpe}.l(e,t) = \text{dele}4e(e) \times (1 - \text{delmy}e(e)); \]
3556 \[ \text{dpydpmre}.l(e,t) = \text{delmy}e(e); \]
3557 \[ \text{dpydppke}.l(e,t) = (1 - \text{dela}el(e)) \times (1 - \text{DELr}2E(e)) \times (1 - \text{dell}3e(e)) \times (1 - \text{dele}4e(e)) \times (1 - \text{delmy}e(e)); \]
3558 \[ \text{DPYDP}.O.L(o,t) = \text{DEL}a0(o) \times (1 - \text{DELr}2O(o)) \times (1 - \text{dell}3o(o)) \times (1 - \text{dele}4o(o)); \]
3559 \[ (1 - \text{delmy}o(o)); \]
3560 \[ \text{dpydpko}.1(o,t) = (1 - \text{dela}lo(o)) \times (1 - \text{DELr}2O(o)) \times (1 - \text{dell}3o(o)) \times (1 - \text{dele}4o(o)) \times (1 - \text{delmy}o(o)); \]
3561 \[ \text{DAMS 2.25.059 386/486 DOS 11/13/96 17:16:17 PAGE 72} \]
3562 \[ \text{General Algebraic Modeling System} \]
3563 \[ \text{Compilation} \]
3564 \[ \text{dpydpho}.1(o,t) = \text{dell}3o(o) \times (1 - \text{dele}4o(o)) \times (1 - \text{delmy}o(o)); \]
3565 \[ \text{dpydphe}.1(o,t) = \text{dele}4o(o) \times (1 - \text{delmy}o(o)); \]
3566 \[ \text{dpydphmo}.1(o,t) = \text{delmy}o(o); \]
3567 \[ \text{dpydp4p}.1(p,t) = (1 - \text{delmy}(p)); \]
3568 \[ \text{dpydp3p}.1(p,t) = (1 - \text{dele}4(p)); \]
3569 \[ \text{dpydp2p}.1(p,t) = (1 - \text{dell}3(p)); \]
3570 \[ \text{dpydp1p}.1(p,t) = (1 - \text{delr}2(p)); \]
3571 \[ \text{dpldpap}.1(p,t) = \text{dela}1(p); \]
3572 \[ \text{dpldpkp}.1(p,t) = (1 - \text{dela}1(p)); \]
3573 \[ \text{dpydp4n}.1(n,t) = (1 - \text{delmy}(n)); \]
3574 \[ \text{dpydp3n}.1(n,t) = (1 - \text{dele}4(n)); \]
3575 \[ \text{dpydp2n}.1(n,t) = (1 - \text{dell}3(n)); \]
3576 \[ \text{dpydp1n}.1(n,t) = (1 - \text{delr}2(n)); \]
3577 \[ \text{dpldpan}.1(n,t) = \text{dela}1(n); \]
3578 \[ \text{dpldkn}.1(n,t) = (1 - \text{dela}1(n)); \]
3579 \[ \text{dpydp4e}.1(e,t) = (1 - \text{delmy}(e)); \]
3580 \[ \text{dpydp3e}.1(e,t) = (1 - \text{dele}4(e)); \]
3581 \[ \text{dpydp2e}.1(e,t) = (1 - \text{dell}3(e)); \]
3582 \[ \text{dpydp1e}.1(e,t) = (1 - \text{delr}2(e)); \]
3583 \[ \text{dpydpe}.1(e,t) = \text{dele}4(e); \]
3584 \[ \text{dpydpe}.1(e,t) = \text{dele}4(e); \]
3585 \[ \text{dpydpe}.1(e,t) = \text{dele}4(e); \]
3586 \[ \text{dpydpe}.1(e,t) = \text{dele}4(e); \]
3587 \[ \text{dpydpe}.1(e,t) = \text{dele}4(e); \]
3588 \[ \text{dpydpe}.1(e,t) = \text{dele}4(e); \]
3589 \[ \text{dpydpe}.1(e,t) = \text{dele}4(e); \]
3590 \[ \text{dpydpe}.1(e,t) = \text{dele}4(e); \]
\[ \text{dplpao} .(o,t) = \text{dpola} .(o,t) \]  
\[ \text{dp1dpko} .(o,t) = (1 - \text{delao} .(o)) \]  

* \[ \text{dpdydpdrp} .(p,t) \]  
\[ \text{dpxdplp} .(p,t) = \text{ap} .(p,t) * \text{dpydplp} .(p,t) \]  

* \[ \text{dpdydpkp} .(p,t) \]  
\[ \text{dpxdpmp} .(p,t) = \text{ap} .(p,t) * \text{dpydpmp} .(p,t) \]  

* \[ \text{dpdydpkn} .(n,t) \]  
\[ \text{dpxdprn} .(n,t) = \text{ap} .(n,t) * \text{dpydprn} .(n,t) \]  

* \[ \text{dpdydpep} .(e,t) \]  
\[ \text{dpxdpme} .(e,t) = \text{ae} .(e,t) * \text{dpydpme} .(e,t) \]  

* \[ \text{dpdydpao} .(o,t) \]  
\[ \text{dpxdpmo} .(o,t) = \text{ao} .(o,t) * \text{dpydplo} .(o,t) \]  

* \[ \text{AALP} .(P,T) = \text{AP} .P \]  
\[ \text{rp} .(p,t) = \text{rp0} .(p) \]  
\[ \text{lp} .(p,t) = \text{lp0} .(p) \]  
\[ \text{EP} .(P,T) = \text{XEP0} .('\text{ELEC'},P) \]  
\[ \text{impp} .(p,t) \]
\begin{verbatim}
=impp0(p) +
3608  impdp0(p);
3609  
3610  AALN.L(N,T)=sum(c,AC0(C));  ln.l(n,t)=sum(c,rc0(c));
1c0(c));
3611  KN.L(N,T)=sum(c,Kc0(c)+deplc0(c));
EN.L(N,T)=sum(c,XEC0('ELEC',c));
3612  impn.l(n,t)=sum(c,imp0(c)+
3613  impdc0(c));
3614  
3615  AALE.L(E,T)=AE0(E);  re.l(e,t)=re0(e);  le.l(e,t)=le0(e);
3616  KE.L(E,T)=KE0(E)+deple0(e);  EdemE.L(E,T)=XEO0('ELEC',e);
3617  impe.l(e,t)=impe0(e)+impde0(e);
3618  
3619  AAAL.O(O,T)=AO0(O);  ro.l(o,t)=ro0(o);  lo.l(o,t)=lo0(o);
3620  KO.L(O,T)=KO0(O)+depol0(o);  EO.L(O,T)=XEO0('ELEC',o);  impo.l(o,t)
3621  =impo0(o) +
3622  impdo0(o);
3623  
3624  XP.L(P,T)=cp0(P);  XN.L(N,T)=sum(c,Cc0(c));
3625  
3626  XE.L(E,T)=ce0(E);
3627  
3628  XO.L(O,T)=co0(O);
3629  
3630  INTERE.L(e,t)=sum(p,xep0(e,p))+sum(c,xec0(e,c))+sum(ee,xee0(e,ee)) +
3631  sum(o,xeo0(e,o));
3632  
3633  MCP.L(P,T)=1;  MCN.L(N,T)=1;  MCE.L(E,T)=1;  MCO.L(O,T)=1;
3634  
3635  DPP.L(P,T)=1;  DPN.L(N,T)=1;
3636  
3637  * domsav.l(t)=-tb0;
3638  
3639  * DPE.L(E,T)=1;
3640  
3641  DPO.L(O,T)=1;
3642  
3643  DDP.L(P,h,T)=PCONS0(P,h);  DDN.L(N,h,T)=sum(c,cCONS0(c,h));
3644  
3645  DDE.L(E,h,T)=ECONS0(E,h);  DDO.L(O,h,T)=OCONS0(O,h);
3646  
3647  PMP.L(P,T)=1;  PMN.L(N,T)=1;
3648  PMO.L(O,T)=1;  pme.l(e,t)=1;
3649  
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General Algebraic Modeling System
Compilation
\end{verbatim}
PEP.L(P,T) = wmeP(p,t); PEN.L(N,T) = wmen(n,t); PEE.L(E,T) = wmeE(e,t);
PEO.L(O,T) = wme0(o,t);
CP.L(P,T) = QPO.L(P); CCN.L(N,t) = QnO.L(n); ce.L(e,t) = ce0(e);
CO.L(O,T) = Q00.L(O);

EXPP.L(P,T) = PEXP0(P); EXPN.L(N,T) = sum(c, cEXP0(c));

EXP0.L(O,T) = OEXP0(O); expe.L(e,t) = exexp0(e);
PL.L(T) = 1; PR.L(T) = 1; PK.L(T) = 1; PA.L(T) = 1;
PCP.L(P,T) = 1; PCN.L(N,T) = 1; PCE.L(e,t) = 1; PCO.L(O,T) = 1;
invest.L(t) = 0; q.L(p,t) = 1;
cscs.L(p,t) = 0.04; csce.L(p,t) = 0.01;
lscs.L(p,t) = 0.03; lsce.L(p,t) = 0.01;
scs.L(p,t) = 0.07; sce.L(p,t) = 0.02;
invo.L(p,t) = invp0(p);
invo.L(n,t) = sum(c, invc0(c));
invo.L(o,t) = invo0(o);

; DISPh.L(h,T) = disp0(h);
tdisph.L(h,t) = disp0(h) + sav0(h);
disp.L(t) = sum(h, disp0(h));
totdisp.L = m*sum(h, disp0(h)); tb.L(t) = tb0 - tImpd0;
GDP.L(T) = sum(h, disp0(h)) - tb0;
k.L(t) = totk0; q.L(p,t) = 1

#include C:\SIMOD\MOD.INC
model mod1/
dtottax,
dtottax,
deppua,
deppur,
General Algebraic Modeling System
Compilation

DEFPUL,
DEFPUK,
DEFP1P,
DEFP2P,
DEFP3P,
DEFP4P,
DEFPYP,
DEFP1N,
DEFP2N,
DEFP3N,
DEFP4N,
DEFPYN,
DEFP1E,
DEFP2E,
DEFP3E,
DEFP4E,
DEFPYE,
DEFP1O,
DEFP2O,
DEFP3O,
DEFP4O,
DEFPYO,
DDPYDPAP,
DDPYDPRP,
DDPYDLP,
DDPYDPKP,
DDPYDPEP,
DDPYDMP,
DDPYDPMP,
DDPYDP4P,
DDP4DP3P,
DDP3DP2P,
DDP2DP1P,
DDP1DPAP,
DDP1DPKP,
DDP4DPEP,
DDP3DLP,
DDP2DPEP,
DDP2DPAP,
DDP2DPKN,
DDP1DPKN,
DDP1DPEN,
DDP4DP4N,
DDP3DP2N,
DDP2DP1N,
DDP1DPAN,
ddpldpal,
General Algebraic Modeling System
Compilation

3754  DDPYDPLE,
3755  DDPYDPKE,
3756  DDPYDPEE,
3757  DDPYDPMZ,
3758  DDPYDPEZ,
3759  DDP4DP3E,
3760  DDP3DP2E,
3761  DDP2DP1E,
3762  DDP1DPAE,
3763  DDP1DPKE,
3764  DDP4DPEE,
3765  DDP3DPLE,
3766  DDP2DPRE,
3767  DDPYDPAO,
3768  DDPYDPRO,
3769  DDPYDPLO,
3770  DDPYDPKO,
3771  DDPYDPEO,
3772  DDPYDPMO,
3773  DDPYDPO,
3774  DDP4DP3O,
3775  DDP3DP2O,
3776  DDP2DP1O,
3777  DDP1DPAO,
3778  DDP1DPKO,
3779  DDP4DPEO,
3780  dp4dpe1,
3781  DDP3DPLO,
3782  DDP2DPRO,
3783  DDPXDPAP,
3784  DDPXDPRP,
3785  DDPXDLP,
3786  DDPXDPKP,
3787  DDPXDSEP,
3788  DDPXDMP,
3789  DDPXDPAN,
3790  DDPXDPRN,
3791  DDPXDPLN,
3792  DDPXDPKN,
3793  DDPXDPEN,
3794  DDPXDPMN,
3795  DDPXDPAE,
3796  DDPXDPRE,
3797  DDPXDPLE,
3798  DDPXDPKE,
3799  DDPXDPKE,
3800  DDPXDPME,
3801  DDPXDPAO,
3802  DDPXDPRO,
3803  DDPXDPRO,
3804  DDPXDPRO,
3805  DDPXDPRO,
3806  DDPXDPMO,
3807  ADEMP,
3808  RDEMP,
3809  LDEMP,
3810  KDEMP,
3811  EDEMP,
3812  MDEMP,
3813  ADEMN,
3814  RDEMN,
3815  LDEMN,
3816  KDEMN,
3817  EDEMN,
3818  MDEMN,
3819  ADEME,
3820  RDEME,
3821  LDEME,
3822  KDEME,
3823  DEDEME,
3824  MDEME,
3825  ADEMO,
3826  RDEMO,
3827  LDEMO,
3828  KDEMO,
3829  EDEMO,
3830  MDEMO,
3831  DEDEME,
3832  DEFMCP,
3833  DEPMCN,
3834  DEFMCE,
3835  DEFMCO,
3836  PRMCP,
3837  pcomp,
3838  PRMCN,
3839  nncomp,
3840  *PRMCE,
3841  PRMCO,
3842  ocomp,
3843  PCONS,
3844  pcons1,
General Algebraic Modeling System
Compilation

DPEE, dpeeb,
DPEO, dpeob,
DCP,
DCN,
DCE,
DCO,
DEXPP,
DEXPnA,
DEXPnB,
DEXPEA,
DEXPEB,
DEXPOA,
DEXPOB,
kstock,
kstock1
dinvest,
* dinvestm,
* dinvestl,
* invlow,
dlabcscs,
dlscscs,
dlabcse,
dlscsec,
dcapscs,
dscscs,
dcapsce,
dscsec,
* dmrscs,
* dmrsce,
dscs,
* dscsc,
dsce,
* dscec, dq,
* dq1, *dsav, *dsav1, dsavh, *dsavhl, ddomsav,
LMARKET, RMARKET, *rmarket1, AMARKET, KMARKET,
* kmarket1, *DPQP, *DPQN, *DPQE, *DPQO, DPCP,
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General Algebraic Modeling System Compilation

DPCN, DPCE, DPCO, P MARKET, nMARKET, emarket,
DPI, DPINV, dpinv1, DnINV, dnv1, DOINV, doinv1, OMARKET,
dtb, INCOME, incomeu, incomer, incomee, consinc, DEFGDP,
dtotdisp /;
modl.optfile=1;
SOLVE modl USING nlp MAXIMIZING totDISP;
mod1.optfile=0;
* solve s11 using nlp maximizing totdisp;
* solve s11 using nlp maximizing totdisp;
* solve s11 using nlp maximizing totdisp;
* Display variables
INCLUDE C:\SLMOD\SLDISA.INC

Display variables

k.l,

scs.l, sce.l, lscs.l, lsce.l, cscs.l, csce.l, q.l,

savh.l, Xe.L, wmee, invest.l,

interc.l,

* MUP.L, MUN.L, MUE.L, MUO.L,

PUL.L, PUK.L, pur.l,

pa.l, pl.l, pk.l, pr.l,

* PYP.L, PYN.L, PYE.L, PYO.L,

* plp.l, pln.l, ple.l, plo.l,

* p2p.l, p2n.l, p2e.l, p2o.l,

* p3p.l, p3n.l, p3e.l, p3o.l,

* p4p.l, p4n.l, p4e.l, p4o.l,

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General Algebraic Modeling System
Compilation

AALP.L, rp.l, lp.l,KP.L, EP.L,

* aain.l, rn.l, LN.L, KN.L, EN.L,

aaLE.L, re.l, le.l, KE.L, EDEME.L,

aaLO.L, ro.l, lo.l, KO.L, EO.L,

XP.L, XN.L,

XO.L, xe.l,

DPP.L, DPN.L, DPE, DPO.L,

DDP.L, DDN.L,

DDE.L, DDO.L,

* FMP.L, PMN.L, PMO.L,

* CP.L, CCN.L, CO.L,
GLOBAL TYPE LOCAL FILE NAME

0 INPUT 0 C:\SLMOD\SL7FIN.GMS
159 INCLUDE 159 .C:\SLMOD\SLIO91.INC
657 INCLUDE 162 .C:\SLMOD\SLELAA.INC
904 INCLUDE 169 .C:\SLMOD\SLAPRL.INC
1029 INCLUDE 170 .C:\SLMOD\SLCLCAGG.INC
1675 INCLUDE 171 .C:\SLMOD\SLPRICEA.INC
1750 INCLUDE 189 .C:\SLMOD\SLVARA.INC
2209 INCLUDE 192 .C:\SLMOD\SLEQUA.INC
3441 INCLUDE 916 .C:\SLMOD\SLLOWA.INC
3512 INCLUDE 919 .C:\SLMOD\SLINIA.INC
3692 INCLUDE 922 .C:\SLMOD\SLMOD.INC
3943 INCLUDE 931 .C:\SLMOD\SLDISA.INC

COMPILATION TIME = 15.370 SECONDS

USER: The World Bank - for internal use only
For Modeling Support - J. Kreuser x32796

**** FILE SUMMARY

INPUT C:\SLMOD\SL7FIN.GMS
OUTPUT C:\SLMOD\SL7OUT.DOC