Environmental Effects of Economywide Policies:

Case Studies of Costa Rica and Sri Lanka

by

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A Dissertation for the
Doctor's Degree in Economics

Department of Economics
Stockholm School of Economics
1997

STOCKHOLM SCHOOL
OF ECONOMICS
THE ECONOMIC RESEARCH INSTITUTE

ISBN 91-7258-452-1

Stockholm 1997

To my parents, Margit and Edgar Persson

ACKNOWLEDGMENTS

It is with mixed feelings that I print out this final version of my dissertation, as the journey towards the completion has been difficult as well as fun and rewarding. I am very grateful to my advisors, Karl-Göran Mäler and Lars Bergman, who have been instrumental in the writing and completion of this dissertation. I could not have wished for better advisors. Though I have spent most of the time writing it on the other side of the Atlantic, they have always been helpful and supportive by email, over the phone, and in person. Dale Jorgenson was a wonderful advisor during my two years at Harvard, and I am very grateful for his support as well as his helpful comments. Mohan Munasinghe gave me the privilege of completing much of this work at the World Bank, and his guidance was instrumental in the completion of this dissertation. Pirjo Furtenbach, Kerstin Niklasson, Britt-Marie Eisler, Christina Leijonhufvud and Astrid Auraldsson were extremely helpful in sorting out all kinds of long-distance communication and administration problems, and I am very thankful for all their help.

I am grateful for comments, questions and support from many people. Without Mun Ho, any discussion about interest rates would have been incomprehensible for all practical purposes. Shanta Devarajan, Wilfrido Cruz, Theo Panyotou, Charles Perrings, Jeff Lewis, Billy Pizer, Tohmas Karlsson, Tim Buehrer, Michael Kreimer, Christina Hartler, Pedro Alba, Lena Unemo, and participants at seminars and conferences at the Stockholm School of Economics, the Beijer Institute, the World Bank, IIASA and in Costa Rica and Sri Lanka, have all provided many helpful comments. I am especially grateful to Dr. Pedro Raventós, Dr. Alvaro Umaña, Dr. Karunaratne, Mr. Nimal Siripala and Dr. Anuara Ekanayake for all their help in collecting the data, as well as for their comments and suggestions, and to SIDA, the Royal Swedish Academy of Sciences, and the World Bank for funding this research and my studies abroad.

Many thanks to Nina and Sören Olausson, who have been the most hospitable friends anyone could wish for. Their door has always been open during my frequent visits to Stockholm, and I hope that they will soon give me the opportunity to return their hospitality. Special thanks are due to Bo Andersson and Torbjörn Becker for making studying much more fun that it would have otherwise been, and Helena Kardell and Kristina Gärtze have been good friends throughout this journey. Ingrid and Erik Elgebrandt sparked my interest in the environment at an early age, and I am very grateful to them for all the inspiration, direction and time they generously gave me as well as many others.

My warmest thanks to my husband, Vikram Haksar, who has meant more than I can possibly express in words to me and to the completion of this dissertation. Without his support and encouragement, this work would have been much more difficult, and quite possibly never finished. He also spent a lot of time and patience giving me useful comments and correcting my sometimes erratic English, for which I cannot thank him

enough (although some pickled herring might just do it???).

My family means a lot to me, and to the writing of this dissertation. My sister Ingrid Fristedt, her husband Nils-Arne, and their children Filip and Emma have all been very supportive. Nobody could wish for better parents than mine, Margit and Edgar Persson, to whom this dissertation is dedicated. I can only hope that I will some day be as good a parent to my own children as they have been to me. I have always been able to count on my family for support, whether I deserved it or not, and I will always be grateful to them for that and many other things.

Despite the help of all these wonderful people and institutions, they cannot be held accountable for any remaining errors or omissions, which are solely my own responsibility. All views and findings in this dissertation are my own, and they should not be interpreted as the opinions of the World Bank, nor of any of the other aforementioned institutions.

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 it 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.

TABLE OF CONTENTS

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

property[2].

First, there is open access, where rights to the resource are nonexclusive. This regime is the basis for Hardin's "tragedy of the commons"[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[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

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[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).

[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).

[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 poors' 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[5]. 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.

Carriére (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 straight forward. 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 straight forward 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[7]. 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[8] 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)[9] 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 "Prisoners 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 it's 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[10]

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[11], which

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

[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[12]) today will generate revenue of \$p, whereas it will result in a discounted foregone revenue in the next time period of \$q[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 $-\frac{q}{2} < -q + p < 0 < p - \frac{q}{2}$, and that $\left(p - \frac{q}{2}\right) - q < 0$. 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[12] trees were being harvested at the beginning of the game.

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would be the case in an open access situation.

[12] The optimal level is here defined as the level that would be optimal if the firms cooperated, and maximized joint profits

[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:

		Logger 2	
		Harvest tree	Conserve tree
Logger 1	Harvest tree	(p-q, p-q)	(p-q/2, -q/2)
	Conserve tree	(-q/2, p-q/2)	(0, 0)

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[14]. Assume that all individual loggers are identical, that each individual logger harvests an average of λ trees, and that the optimal[12] solution is for a total number of $\lambda n = L$ 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 $(L+1)\left(1+\frac{p-q}{q}\right) < L$ or, equivalently, $-\frac{p-q}{q} > 1/(L+1)$, 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[15]:

Payoff matrix for logger i

		All other loggers	
		Harvest tree	Conserve tree
Logger i	Harvest tree	1+(p-q)(n+L)/q	1+(p-q)(λ+1)/q
	Conserve tree	(p-q)(L-λ)/q	0

Payoff matrix for all other loggers

		All other loggers	
		Harvest tree	Conserve tree
Logger i	Harvest tree	(n-1)(1+(p-q)(n+L)/q)	(p-q)(L-λ)/q
	Conserve tree	(n-1)(1+(p-q)(n-1)(λ+1)/q)	0

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

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[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 $(\lambda+1)\left(1+\frac{p-q}{q}n\right)-\lambda = 1+\frac{p-q}{q}(n+L)$.

$1/((n-1)(\lambda+1)) < -(p-q)/q$. 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 $1/((n-1)(\lambda+1)+1) < -(p-q)/q$ [16]. 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

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[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 posses 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.

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[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[19].

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 μ.

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:

$$x_i^t = f\left(A_i^t\right.$$

where x_i^t 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 (μ=1). Each firm maximizes profits subject to the constraint that the harvest can not exceed the existing forest biomass in any of the periods:

$$\begin{aligned} Max \quad & p_0 f\left(A_i^0\right) - w_0 A_i^0 - q_0 d_i^0 + \frac{1}{1+r}\left(p_1 f\left(A_i^1\right) - w_1 A_i^1\right) \\ s.t. \quad & f\left(A_i^0\right) \le L_i \\ & f\left(A_i^1\right) \le (1+g)L_i - f\left(A_i^0\right) + d_i^0 \end{aligned}$$

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_t 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:

$$A_i^0: \quad p_0 f'(A_i^0) - w_0 - \frac{1}{1+r}\left(p_1 f'(A_i^1) - w_1\right) = \lambda_0 \qquad \lambda_0 \geq 0$$

$$A_i^1: \quad p_1 f'(A_i^1) - w_1 = \lambda_1 \qquad \lambda_1 \geq 0$$

$$d_i^0: \quad -q_0 + \frac{1}{1+r}\left(p_1 f'(A_i^1) - w_1\right) \leq 0 \qquad \text{if } d_i^0 \geq 0$$

$$\lambda_0: \quad f(A_i^0) - L_i \leq 0$$

$$\lambda_1: \quad f(A_i^1) - (1+g)L_i - f(A_i^0) + d_i^0 \leq 0$$

where λ_o and λ_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, λ_o 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 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 λ_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_i^0 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:

$$Max \quad p_0 f\left(A_i^0\right) - w_0 A_i^0 - q_0 d_i^0 + \frac{1}{N_1}\frac{1}{1+r}\left(p_1 f\left(A_{i,}^1\right) - w_1 A_i^1\right) +$$

$$\left(1 - \frac{1}{N_1}\right)\frac{1}{1+r}\left(p_1 f\left(A_i^1\right) - w_1 A_i^1\right), \qquad i \neq j$$

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

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

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

$$A_i^0: \quad p_0 f'\left(A_i^0\right) - w_0 - \frac{1}{N_1}\frac{1}{1+r}\left(p_1 f'\left(A_i^1\right) - w_1\right) = \lambda_0 \quad \lambda_0 \geq 0$$

$$A_i^1: \quad p_1 f'\left(A_i^1\right) - w_1 = \lambda_1 \qquad \lambda_1 \geq 0$$

$$d_i^0: \quad -q_0 + \frac{1}{N_1}\frac{1}{1+r}\left(p_1 f'\left(A_i^1\right) - w_1\right) \leq 0 \qquad if \quad d_i^0 \geq 0$$

$$\lambda_0: \quad f\left(A_i^0\right) - L_i \leq 0$$

$$\lambda_1: \quad f\left(A_i^1\right) - f\left(A_i^0\right) - \left((1+g) + d_i^0\right)L_i^0 \leq 0$$

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 firms 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, $N_1 > N_0$, and the share of land allocated to firm i will decline so that $L_i^1 = L/N_1 < L_i^0$. 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 :

$$m = 1 - \frac{N_1 - N_0}{N_0}$$

The maximization problem is now:

$$\begin{aligned} Max \quad & p_0 f\left(A_i^0\right) - w_0 A_i^0 - q_0 d_i^0 + m\frac{1}{N_1}\frac{1}{1+r}\left(p_1 f\left(A_i^1\right) - w_1 A_i^1\right) + \\ & (1-m)\left(1-\frac{1}{N_1}\right)\frac{1}{1+r}\left(p_1 f\left(A_i^1\right) - w_1 A_i^1\right) \\ s.t. \quad & f\left(A_i^0\right) \leq L_i \\ & f\left(A_i^1\right) \leq \left((1+g) + d_i^0\right) m L_i^0 - f\left(A_i^0\right) \end{aligned}$$

The first order conditions for the profit maximization problem become:

$$A_i^0:\ p_0 f'\left(A_i^0\right) - w_0 - m\frac{1}{N_1}\frac{1}{1+r}\left(p_1 f'\left(A_i^1\right) - w_1\right) = \lambda_0 \quad \lambda_0 \geq 0$$

$$A_i^1:\ p_1 f'\left(A_i^1\right) - w_1 = \lambda_1 \qquad \lambda_1 \geq 0$$

$$d_i^0:\ -q_0 + m\frac{1}{N_1}\frac{1}{1+r}\left(p_1 f'\left(A_i^1\right) - w_1\right) \leq 0 \qquad \text{if } d_i^0 \geq 0$$

$$\lambda_0:\ f\left(A_i^0\right) - L_i \leq 0$$

$$\lambda_1:\ f\left(A_i^1\right) - f\left(A_i^0\right) - \left((1+g) + d_i^0\right) m L_i^0 \leq 0$$

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_1 increases the expected benefit from reforestation to each firm operating in the first period declines. As N_1 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:

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

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

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

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[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[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

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[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.

[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

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[22] See, for example, Hyde and Newman (1991), Munasinghe and Cruz (1995) and Gandhi (1996).

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[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[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.

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[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 Førsund (1985).

[24] See, for example, Hyde and Newman (1991).

3.1 SOME GENERAL EQUILIBRIUM MODELS PREVIOUSLY APPLIED TO ENVIRONMENTAL AND NATURAL RESOURCE ISSUES[25]

A useful theoretical framework for the incorporation of environmental issues into a general equilibrium framework is provided by Mäler (1974)[26]. 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[27], 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[28].

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.

[28] Bandara and Coxhead (1995) apply this model to Sri Lanka.

survey of models in this area is provided by Bergman (1988)[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

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[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 km^2 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[30]

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"[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

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[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[32]) 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

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

$$\frac{f'(k_0)}{P_0^k} + \frac{P_1^k(1-\delta)}{P_0^k} = 1 + r^{WM}$$

where the price of output in the first period is exogenous and normalized to 1, P^k_t 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^{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):

$$1 + \frac{P_1^K(1-\delta)}{P_0^K} = 1 + r = 1 + r^{WM}.$$

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 μ 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:

$$1+\frac{P_1^k(1-\delta)}{P_0^k}=1+r\ >1+\frac{\mu P_1^D(1-\gamma)}{P_0^D}=1+r^d\ .$$

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 modes 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[34] 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

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[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[34]. 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 mode 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:

$$d^{\log} = (k^{\log})^{\alpha}(l^{\log})^{\beta}, \quad \alpha + \beta < 1 \qquad \text{E 5.2-1}$$

where d^{log} is deforestation by loggers, and k^{log} and l^{log} are the inputs of capital and unskilled labor in logging, and α and β 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., μ=0 in the model developed in chapter 2) are

$$(k^{\log}) = \left[\frac{P_K}{\alpha P_{FL}(l^{\log})^{\beta}}\right]^{\frac{1}{(\alpha-1)}}$$
$$(l^{\log}) = \left[\frac{P_U}{\beta P_{FL}(l^{\log})^{\alpha}}\right]^{\frac{1}{(\beta-1)}} \qquad \text{E 5.2-2}$$

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, φ, is assumed constant and is exogenous to the static model:

$$H(d) = \varphi\, d \qquad 5.2\text{-}3$$

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

$$(l^{\log}) = \left(\frac{P_U^U + \dfrac{\partial H(d)/(1+r^{dom})}{\partial(l^{\log})}}{\beta\, P_{FL}(k^{\log})^{\alpha}} \right)^{\frac{1}{\beta-1}}$$

$$5.2\text{-}4$$

$$(k^{\log}) = \left(\frac{P_K^U + \dfrac{\partial H(d)/(1+r^{dom})}{\partial(k^{\log})}}{\alpha\, P_{FL}(l^{\log})^{\beta}} \right)^{\frac{1}{\alpha-1}}$$

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 (d^{sq}) with unskilled labor as the only factor of production:

$$d^{sq} = d(l^{sq}) = (l^{sq})^{\gamma} \quad \gamma < 1. \qquad \text{E 5.2-5}$$

where l^{sq} is the unskilled labor used in the clearing of land, and γ in the elasticity of output with respect to unskilled labor.

The squatters' total revenue from clearing the land $(I^{sq}(d^{sq}))$ is the price paid for the cleared land times the amount of land cleared:

$$I^{sq}(d^{sq}) = P_{DL} d^{sq} \qquad \text{E 5.2-6}$$

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 $(C^{sq}(d^{sq}))$ will, when property rights are undefined, depend only on the amount of labor needed to clear the land:

$$C^{sq}(d^{sq}) = P_U d^{-1}(d^{sq}) \qquad \text{E 5.2-7}$$

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

$$l^{sq} = \left(\frac{P_U}{\gamma\, P_{DL}}\right)^{\frac{1}{\gamma - 1}} \qquad \text{E 5.2-8}$$

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 $(g^{sq}(d^{sq}))$ is:

$$g^{sq}(d^{sq}) = P^{sq}_{DL} d^{sq} - C^{sq}(d^{sq}) - \frac{H(d^{sq})}{1 + r^{dom}} \qquad \text{E 5.2-9}$$

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

$$l^{sq} = \left(\frac{P^U_U + \dfrac{\partial(H((l^{sq})^{\gamma}) / (1 + r^{dom}))}{\partial l^{sq}}}{\gamma \, P_{DL}} \right)^{\frac{1}{\gamma - 1}} \qquad \text{E 5.2-10}$$

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[35], and maximizes utility subject to a budget constraint:

$$\text{Max } V = \ln \left(\prod_i D_i^{b_i}\right); \qquad i = T, N$$
$$s.t \; I - \sum_i P_i^D D_i = 0 \qquad \text{E 5.2-10}$$

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

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[35] 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:

$$X_j = \min\left[\frac{Y_j}{A_j}, \frac{X_{ij}}{a_{ij}}\right] \quad i,j \in T,N \qquad \text{E 5.2-11}$$

where X_j is the gross output in sector j, Y_j is a composite input of production factors in sector j, X_{ij} 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

$$C_j = P^U_{Yj} A_j + \sum_i P^D_i a_{ij} + t_j; \quad i,j \in T,N \qquad \text{E 5.2-12}$$

where C_j is the marginal and average cost in sector j, P_{Yj}^U 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 t_j is indirect tax per unit of sector j output.

Producers are assumed to maximize profits. The producer output prices, P_i, 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:

$$P_i - C_i \leq 0; \qquad i \in T$$
$$(P_i - C_i) X_i = 0; \qquad i \in T \qquad \text{E 5.2-13}$$
$$X_i \geq 0; \qquad i \in T$$

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

$$P_i = C_i; \qquad i \in N \qquad \text{E 5.2-14}$$

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:

$$P_i^D = (1 + \sigma_i) P_i^W e = (1 + \sigma_i) P_i; \qquad i \in T, \qquad \text{E 5.2-15}$$

$$P_i^D = (1 + \sigma_i) P_i; \qquad i \in N \qquad \text{E 5.2-16}$$

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 σ_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

$$D_i = \frac{b_i I}{P_i^D} \qquad i \in T, N \qquad \text{E 5.2-17}$$

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:

$$P_j^U = P_j(1+T_j); \qquad j = DL, UL, SL, K$$
$$P_{FL}^U = P_{FL}^{WM}(1+T_{FL}) \qquad \text{E 5.2-18}$$

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

$$X_i = \sum_{j \in T,N} a_{ij} X_j + D_i + Z_i; \quad i \in T \qquad \text{E 5.2-19}$$

$$X_i = \sum_{j \in T,N} a_{ij} X_j + D_i; \quad i \in N \qquad \text{E 5.2-20}$$

where Z_i is net export.

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

$$K = \sum_{j \in T,N} \frac{\partial C_j}{\partial P_K^U} X_j + k^{\log} \qquad \text{E 5.2-21}$$

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[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.

$$U = \sum_{j \in T,N} \frac{\partial C_j}{\partial P_U^U} X_j + l^{sq} + l^{\log} \qquad \text{E 5.2-22}$$

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^{sq} 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

$$L = \sum_{j \in T,N} \frac{\partial C_j}{\partial P_L^U} X_j \qquad \text{E 5.2-23}$$

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

$$h d^{\log} = \frac{\partial C_{FOREST}}{\partial P_{FL}^U} - f^{nexp} \qquad \text{E 5.2-24}$$

where d^{log} is deforestation from the logging sector, P_{FL}^U is the user price of logs, f^{nexp} 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:

$$\frac{\partial C_{Agriculture}}{\partial P_{DL}^{U}} = DL^{*} + d^{sq} \qquad \text{E 5.2-25}$$

Profits (Π) in the squatting and logging sectors are assumed to be positive, and are defines as

$$\begin{aligned} \Pi_{sq} &= P_{DL} d^{sq} - P_{U} l^{sq} \\ \Pi_{\log} &= P_{FL}^{WM} d^{\log} - P_{L} l^{\log} - P_{K} k^{\log} \end{aligned} \qquad \text{E 5.2-26.}$$

When peoperty 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

$$\sum_{i \varepsilon T,N} P_i Z_i = S \qquad \text{E 5.2-27}$$

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:

$$GNP = P_{K}^{U} K + P_{L}^{U} L + P_{U}^{U} U + P_{DL}^{U} DL^{*} + \sum_{j \varepsilon T,N} \sigma_j X_j + \sum_{j=sq,\log} \Pi_j - (d^{sq} + d^{\log}) H(l). \qquad \text{E 5.2-28}$$

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)[37] 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)[37] . 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[37]. 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[38] 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[39]. Remaining elasticities were set to zero.

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[37] Unpublished, and full reference not available. Source: Pedro Raventos, INCAE, Costa Rica.

[38] Defined as $\eta/(\eta-1)$, where η is the elasticity of substitution. An elasticity of 0.8 thus implies $\eta=4$.

[39] Lacking time series data, these elasticities are reasonable given the aggregated sectoral composition and the elasticities used in other models, e.g. Torma and Rutherfod (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 Carriére (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 disount 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

	Undefined property rights. (10 billion colones)	Defined property rights (i=10%) %
H-value	0	0.28
Production in Deforestation sectors:		
Squatters	0.002	-100.00
Loggers	0.002	-90.00
Total	0.004	-95.00
Production in sectors using logs and land:		
Forest	0.0552	28.80
Agriculture	1.3984	-0.77

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)

	Undefined pr. rights. (10 billion colones)	Defined property rights (i=10%), sensitivity analysis with respect to different future values				
		%	%	%	%	%
H-value	0	0.48	0.38	0.28	0.18	0.08
Production in Deforestation sectors:						
Squatters	0.002	-100.00	-100.00	-100.00	-100.00	-100.00
Loggers	0.002	-100.00	-95.00	-90.00	-80.00	-50.00
Total	0.004	-100.00	-97.50	-95.00	-90.00	-72.50

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

	Base Case	Tax Logs	Subsidy Logs	Tax Land	Subsidy Land	Tax Unskilled labor	Tax Capital
	(10 billion colones)	%	%	%	%	%	%
Production in deforestation Sectors:							
Squatters	0.002	120.00	-80.00	-100.00	1175.00	950.00	0.00
Loggers	0.002	-100.00	-10.00	0.00	-5.00	45.00	80.00
Total	0.004	10.00	-42.50	-50.00	582.50	497.50	40.00
Production in traditional sectors:							
Forest	0.0552	-100.00	182.97	21.74	-100.00	-100.00	-6.70
Agri	1.3984	1.57	-1.69	-0.77	8.14	6.71	0.02
Ind	1.8477	4.17	-7.90	-0.25	-4.44	-2.87	0.05

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

	Base Case (10 billion colones)	Half tax Forest	Double tax Forest	Half tax Agri	Double tax Agri	Half tax Ind	Double tax Ind
	(10 billion colones)	%	%	%	%	%	%
Production in deforestation sectors:							
Squatters	0.002	0.00	0.00	-5.00	10.00	-10.00	25.00
Loggers	0.002	0.00	0.00	0.00	0.00	0.00	0.00
Total	0.004	0.00	0.00	-2.50	5.00	-5.00	12.50
Production in traditional sectors:							
Forest	0.0552	-4.35	10.33	-26.63	63.41	-71.01	146.92
Agri	1.3984	0.00	0.01	-5.19	12.31	-0.14	0.33
Ind	1.8477	0.14	-0.32	4.15	-9.82	-1.13	2.34

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. reason. 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 -- in 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:

$$d_t^{sq} = \left(l_t^{sq}\right)^{\gamma} \qquad t = 0,1, \ \gamma < 1 \qquad \text{E 5.3-1}$$

where d^{sq}_t is deforestation by squatters and l^{sq}_t is the input of unskilled labor into squatting, and γ 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

$$\pi_{sq,t} = P_{DL,t} d_t^{sq} - P_{U,t} l_t^{sq}; \qquad t = 0,1 \qquad \text{E 5.3-2}$$

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

$$l_t^{sq} = \left(\frac{P_{U,t}}{P_{DL,t}\gamma}\right)^{\frac{1}{\gamma-1}} \qquad t = 0,1 \qquad \text{E 5.3-3}$$

Squatters -- Well-defined property rights

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

$$\begin{aligned} Max \quad & P_{DL,0} d_0^{sq} - P_{U,0} l_0^{sq} + \frac{1}{1+r^{dom}}\left(P_{DL,1} d_1^{sq} - P_{U,1} l_1^{sq}\right) \\ s.t. \quad & d_t^{sq} = \left(l_t^{sq}\right)^{\gamma} \qquad t = 0,1 \\ & d_0^{sq} \le A - d_0^{\log} \\ & d_0^{sq} + d_1^{sq} \le A - d_0^{log} - d_1^{log} \end{aligned} \qquad \text{E 5.3-4}$$

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 (λ_{sq}) are equal between periods, unless all forests are exhausted already in the first period:

$$P_{DL,0} - \frac{1}{\gamma} P_{U,0} \left(d^{sq}\right)^{\frac{1}{\gamma}-1} = \lambda^{0}_{sq} \qquad \text{if } d^{0}_{sq} = A, \text{ otherwise}$$

$$\left(\frac{1}{1+r^{dom}}\right)^{t} \left(P_{DL,t} - \frac{1}{\gamma} P_{U,t} \left(d^{sq}\right)^{\frac{1}{\gamma}-1}\right) = \lambda_{sq}, \qquad t = 0,1 \quad \lambda_{sq} \geq 0, \qquad \text{E 5.3-5}$$

From the Kuhn-Tucker theorem, if the second constraint in E 5.3-4 is binding, λ_{sq} is greater than zero. If this constraint is not binding, λ_{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

$$l^{sq}_{t} = \left(\frac{P_{U,t}}{(P_{DL,t} - (1+r^{dom})^{t} \lambda_{sq})\gamma}\right)^{\frac{1}{\gamma-1}}; \quad t = 0,1 \qquad \text{E 5.3-6}$$

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:

$$d^{log}_{t} = \left(k^{log}_{t}\right)^{\alpha} \left(l^{log}_{t}\right)^{\beta} \quad t = 0,1, \; 0 < [\alpha, \beta] < 1, \; \alpha + \beta < 1 \qquad \text{E 5.3-7}$$

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 α and β 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

$$\pi_{\log,t} = P_{FL,t} d_t^{log} - P_{U,t} l_t^{log} - P_{K,t} k_t^{log}; \quad t = 0,1 \qquad \text{E 5.3-8}$$

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

$$k_t^{log} = \left(\frac{P_{K,0}}{P_{FL,0} \alpha \left(l_t^{log}\right)^{\beta}} \right)^{\frac{1}{\alpha - 1}}; \qquad t = 0,1 \qquad \text{E 5.3-9}$$

$$l_t^{log} = \left(\frac{P_{U,t}}{P_{FL,t} \beta \left(k_t^{log}\right)^{\alpha}} \right)^{\frac{1}{\beta - 1}}; \qquad t = 0,1 \qquad \text{E 5.3-10}$$

Loggers -- Well-defined property rights

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

$$\begin{aligned} \text{Max } & P_{FL,0} d_0^{log} - P_{K,0} k_0^{log} - P_{U,0} l_0^{log} + \\ & \frac{1}{1 + r^{dom}} \left(P_{FL,0} d_0^{log} - P_{K,0} k_0^{log} - P_{U,0} l_0^{log} \right. \\ s.t. \quad & d_t^{log} = \left(k_t^{log}\right)^{\alpha} \left(l_t^{log}\right)^{\beta}; \qquad t = 0,1 \qquad \text{E 5.3-11} \\ & d_0^{log} \leq A - d_0^{sq} \\ & d_0^{log} + d_1^{log} \leq A_{\log} = A - d_0^{sq} - d_1^{sq} \end{aligned}$$

The amount of deforestation by squatters is exogenous to the loggers, and the

maximum amount of logging is restricted to A_{log}. From the solution to the profit maximization problem we obtain the arbitrage condition that

$$P_{FL,t} - P_{U,t}\frac{\partial l_t^{log}}{\partial d_t^{log}} - P_{K,t}\frac{\partial k_t^{log}}{\partial d_t^{log}} = \lambda_{\log}^{0} \qquad \text{if } A = d_0^{sq} + d_0^{\log}, \text{ otherwise}$$

$$\left(\frac{1}{1+r^{dom}}\right)^t \left(P_{FL,t} - P_{U,t}\frac{\partial l_t^{log}}{\partial d_t^{log}} - P_{K,t}\frac{\partial k_t^{log}}{\partial d_t^{log}}\right) = \lambda_{\log}; \quad t = 0,1 \qquad \text{E 5.3-12}$$

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

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

$$l_t^{log} = \left(\frac{P_{U,t}}{(P_{FL,t} - (1+r^{dom})^t \lambda_{\log})\beta\left(k_t^{log}\right)^{\alpha}}\right)^{\frac{1}{\beta-1}}; \quad t = 0,1 \qquad \text{E 5.3-14}$$

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 $P^{WM}_{FL,t}$. If the domestic price is higher than the world market price no domestic logging takes place:

$$\begin{aligned} &P^{WM}_{FL,t} - P_{FL,t} \leq 0; \quad t = 0,1 \\ &d_t^{log}(P^{WM}_{FL,t} - P_{FL,t}) = 0 \\ &d_t^{log} \geq 0 \end{aligned} \qquad \text{E 5.3-15}$$

The stock of cleared land in each period (Dl_t) is the previously existing stock of land plus squatting in the same period:

$$DL_0 = DL^* + d_0^{sq}$$
$$DL_1 = DL_0 + d_1^{sq} \qquad \text{E 5.3-16}$$

where DL^* is the initial stock of land.

Total deforestation (def_t) in each period is

$$def_t = d_t^{sq} + d_t^{log}; \qquad t = 0,1 \qquad \text{E 5.3-17}$$

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:

$$V = \sum_T b_T \log(D_{T,t}) + \sum_N b_N \log(D_{N,t}), \quad \sum b = 1, \quad t = 0,1 \qquad \text{E 5.3-18}$$

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 and 1) is determined as

$$I_t = P_{K,t}^U K_t + P_{L,t}^U SL_t + P_{U,t}^U UL_t + P_{DL,t}^U DL_{t-1} + \sum_i t_{i,t} X_{i,t} + \Pi_{j,t};$$
$$i = T, N, j = squatters, loggers, \quad t = 0,1 \qquad \text{E 5.3-19}$$

i.e. the sum of the incomes including taxes from capital (K_t), skilled labor, (SL_t), unskilled labor (UL_t), and the stock of cleared land (DL_t) that existed in the beginning of the period, profits from deforestation ($\Pi_{i,t}$) and indirect taxes (t_t).

The representative consumer is assumed to maximize the present value of utility subject to an intertemporal budget constraint:

$$\text{Max } W = V(D_{1,0},\ldots,D_{5,0}) + \frac{1}{1+\rho} V(D_{1,1},\ldots,D_{5,1}); \quad 1,2,3 \in T,\ 4,5 \in N$$

$$s.t. \quad I_0(P) - P_0^D D_0 + \frac{1}{1+r^{dom}}\left(I_1(P, Inv_0) - P_1^D D_1\right) = 0 \qquad \text{E 5.3-20}$$

where ρ is the rate of time preference, I_t 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:

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

$$D_{i,1} = \frac{b_i(I_1(P, Inv_0) + s_0)}{P_{i,1}^D}\ \frac{1+r^{dom}}{1+\rho} \qquad \text{E 5.3-21}$$

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:

$$M_{j,t} = \frac{\partial C_{i,t}}{\partial P_{j,t}^U} X_{i,t}; \quad t = 0,1 \quad i \in T, N \quad j = L, U, K, DL, FL \qquad \text{E 5.3-22}$$

where $M_{j,t}$ is the demand for factor j in sector i, $C_{i,t}$ 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 $C_{i,t}=P_{i,t}$. 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, $P^U{}_{j,t,}$ as

well as logs and land are defined as the producer price, $P_{j,t}$, plus a tax, $t_{j,t}$:

$$P^{U}_{FL,t} = P^{WM}_{FL,t}(1 + t_{FL,t})$$
$$P^{U}_{j,t} = P_{j,t}(1 + t_{j,t}); \quad t = 0,1, \; j = SL, U, K, DL \qquad \text{E 5.3-23}$$

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

$$C_{i,t} = A_i P_{Y,i,t} + \sum_i P_{j,t} a_{ij} + t_{i,t}; \quad t = 0,1, \; i,j \in T, N \qquad \text{E 5.3-24}$$

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

$$P_{i,t} = P^{WM}_{i,t}; \quad t = 0,1 \; i \in T \qquad \text{E 5.3-25}$$

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:

$$P^{WM}_{i,t} - C_{i,t} \leq 0$$
$$X_{i,t}(P^{WM}_{i,t} - C_{i,t}) = 0; \quad t = 0,1 \; i \in T \qquad \text{E 5.3-26}$$
$$X_{i,t} \geq 0$$

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

$$P_{i,t} - C_{i,t} = 0; \quad t = 0,1, \; i \in N \qquad \text{E 5.3-27}$$

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

$$P_{I,t} Inv_t = s_t + S_t; \quad t = 0,1 \qquad \text{E 5.3-28}$$

where $P_{I,t}$ is the price of composite investments in period t, Inv_t is the volume of investments, s_t is domestic savings and S_t represents the current account balance in period t. The level of investment is determined by the arbitrage condition that

$$P_{K,0} = \frac{1}{1+r} P_{K,1} \qquad \text{E 5.3-29}$$

The price of composite investments is defined as

$$P_{I,t} = \frac{\sum_i inv_{i,t} P_{i,t}}{Inv_t}; \quad t = 0,1, \quad i \in T,N \qquad \text{E 5.3-30}$$

where inv_i is investment by sector of origin and is defined as

$$inv_{i,t} = \frac{i_i Inv_t}{P_{i,t}}; \quad t = 0, \quad i \in T,N \qquad \text{E 5.3-31}$$

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

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

$$K_t = (1 - \delta) K_t + Inv_t; \quad t \neq 0 \qquad \text{E 5.3-32}$$

where the rate of depletion of capital (δ) 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^{nexp}):

$$\sum_i P_{i,t}^{WM} Z_{i,t} + P_{FL,t}^{WM} f_t^{nexp} = S_t; \quad i \in T, t = 0,1 \qquad \text{E 5.3-33}$$

5.3.1.3 Market clearing

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

$$S_0 = -\frac{1}{1+r^{WM}} S_1 \qquad \text{E 5.3-34}$$

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

$$\rho = r^{dom} = r^{WM} \qquad \text{E 5.3-35}$$

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:

$$X_{i,t} = \sum_j a_{ij} X_{j,t} + Z_{i,t} + D_{i,t} + inv_{i,t}; \quad i = T, j = T, N, \quad t = 0,1$$
$$X_{i,t} = \sum_j a_{ij} X_{j,t} + D_{i,t} + inv_{i,t} \quad i = N, j = T, N, \quad t = 0,1 \qquad \text{E 5.3-36}$$

The supplies of unskilled and skilled labor are assumed to grow proportionally to the population growth (*popgr*):

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

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:

$$FL_t = M_{i,FL,t} + f_t^{nexp}; \quad t = 0,1, \quad i \in T, N$$
$$DL_t = M_{i,DL,t}$$
$$L_t = \sum_i M_{i,L,t} \qquad \text{E 5.3-38}$$
$$U_t = \sum_i M_{i,U,t} + l_{sq,t} + l_{\log,t}$$
$$K_t = \sum_i M_{i,K,t} + k_{\log,t}$$

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:

$$GNP_t = P^U_{K,t} K_t + P^U_{L,t} L_t + P^U_{U,t} U_t + P^U_{DL,t} DL_{t-1} + \sum_i t_{i,t} X_{i,t} + \sum_j \Pi_j; \qquad \text{E 5.3-39}$$
$$t = 0,1, \quad i \in T, N, \quad j = \text{squatters, loggers}$$

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[37]. 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 caapital 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

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

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[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

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[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

	Base Solution	1% subsidy Period 0	1% tax Period 0	1% subsidy Period 1	1% tax Period 1
	10 billion colones	%	%	%	%
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

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

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

	Base	1% subsidy Period 0	1% tax Period 0	1% subsidy Period 1	1% tax Period 1
	10 billion colones	%	%	%	%
Deforestation					
Squatters	0.0265	-3.02	3.02	0.00	0.00
Loggers	0.0024	-0.37	0.37	0.00	0.00
Total	0.0289	-2.42	2.77	0.00	0.00
Stock of land	0.2302	-0.35	0.30	0.00	0.00
Production					
Forest	0.0666	9.30	-9.30	0.00	0.00
Agri	1.5360	-0.37	0.37	0.00	0.00

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

	Base	1% subsidy Period 0	1% tax Period 0	1% subsidy Period 1	1% tax Period 1
	10 billion colones	%	%	%	%
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
Land	0.2302	-0.39	0.35	0.00	0.00
Production in sectors using land and logs					
Forest	0.0666	11.86	-11.71	0.15	0.15
Agri	1.5360	-0.44	0.44	0.00	0.00

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

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

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 nations 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 treecrops 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 work 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 treecrops 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[41]

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 1992).

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 treecrops.

6.3.3 Allocation of land between estates and smallholders in the treecrops 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 treecrops 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 6[42]). 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

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[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 fairy 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:

$$
\begin{array}{lll}
Max & \sum_{t=0}^{T} \frac{1}{1+r}\left(P^{D}_{X,i,t} x_{i,t} - \sum_{N} P_{N,t} N_{i,t} - \sum_{j} P_{C,j,t} x_{ji,t} x_{i} \right) & \text{N = A, R, U, E, M} \\
s.t. & x_{i,t} = f_i(A_{i,t},\ R_{i,t},\ U_{i,t}, K_{i,t}, E_{i,t},\ M_{i,t},\ x_{ji,t}, Q_{i,t}) & i \in \text{Treecrops} \\
 & Q_{i,0} = 1 & i \in \text{Treecrops} \\
 & Q_{ii,t+1} = Q_t(1-g_i) + d_{i,t} & i \in \text{Treecrops} \\
 & d_{i,t} = \varphi_i\left(k_i^{sc}, r_i^{sc}\right) & i \in \text{Treecrops}
\end{array}
\qquad \text{E 7.2-1}
$$

where index i denotes inputs into sector i, r is the interest rate, $P^{D}_{X,i,t}$ is the producer price of output in sector i, x_i is the level of production in sector i, $P_{N,t}$ 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, $x_{ji,t}$ 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 treecrops sectors is defined as

$$mc_i = \frac{1}{Q_i}\left(\Phi_i P_{Y,i} + \sum_j \left(P_{C,j} x_{ji}\right) + t_i - s_i\right), \quad i \in treecrops \qquad \text{E 7.2-2}$$

where ϕ_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 is the indirect tax rate and s is the subsidy rate.

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

$$P^D_{X,i} = mc_i, \quad i \in treecrops \qquad \text{E 7.2-3}$$

Soil conservation will take place until the marginal benefit of conservation equals the marginal costs of the production factors:

$$\sum_{\tau=t}^{T}\left(\frac{1}{1+r}\right)^{\tau-1} P^{D}_{x,i,t}\frac{\partial x_{i,\tau}}{Q_{i,\tau}}\frac{Q_{i,\tau}}{\partial d_{i,\tau}}\frac{\partial d_{i,\tau}}{\partial r^{SC}_{i,t}} - P_{R,t} = 0; \qquad i \in \text{treecrops}$$

$$\sum_{\tau=t}^{T}\left(\frac{1}{1+r}\right)^{\tau-1} P^{D}_{x,i,t}\frac{\partial x_{i,\tau}}{Q_{i,\tau}}\frac{Q_{i,\tau}}{\partial d_{i,\tau}}\frac{\partial d_{i,\tau}}{\partial k^{SC}_{i,t}} - P_{K,t} = 0 \qquad \text{E 7.2-4}$$

where subscripts K and R denote capital and rural labor, $r^{SC}{}_{i}$ is labor input in soil conservation in sector i, $k^{SC}{}_{i}$ is capital input in soil conservation in sector i, and where the level of soil conservation (d_i) is determined by a CES function:

$$\left(d_{i,t}\right)^{\kappa} = \left(r^{SC}_{i,r}\right)^{\kappa} + \left(k^{SC}_{i,t}\right)^{\kappa} \qquad \text{E 7.2-5}$$

where κ 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:

$$
\begin{array}{lll}
Max & \sum_{t=0}^{T}\frac{1}{1+r}\left(P_{X,i,t}^{D}x_{i,t}-\sum_{N}P_{N,t}N_{i,t}-\sum_{j}P_{C,i,t}x_{ji,t}x_{i}\right) & \text{N = A, R, U, E, M} \\
s.t. & x_{i,t}=f_i(A_{i,t},\,R_{i,t},\,U_{i,t},\,K_{i,t},E_{i,t},\,M_{i,t},\,x_{ji,t}) & \text{i} \in \text{Colombo, Other sectors} \\
Min & \sum_{t=0}^{T}\frac{1}{1+r}\left(\sum_{N}P_{N,t}N_{i,t}-\sum_{j}P_{C,i,t}x_{ji,t}x_{i,t}\right) & \text{i} \in \text{Energy} \\
s.t. & x_{i,t}=f_i(A_{i,t},\,R_{i,t},\,U_{i,t},\,K_{i,t}\,E_{i,t},\,M_{i,t},\,x_{ji,t}) & \text{i} \in \text{Energy} \\
 & x_{i,t}=D_{i,t} & \text{i} \in \text{Energy}
\end{array}
$$

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:

$$N_i=\frac{\partial P_{X,i,}^{D}}{\partial P_N}x_i,\quad \forall i, \qquad \text{E 7.2-7}$$

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

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

$$mc_i=\Phi_i P_{Y,i}+\sum_{j}\left(P_{C,j}x_{ji}\right)+t_i-s_i,\quad i\notin treecrops \qquad \text{E 7.2-8}$$

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:

$$
\begin{array}{l}
P_{X,i}^{D}=mc_i,\quad i\notin energy \\
x_i=D_{i,}\quad i\in energy
\end{array}
\qquad \text{E 7.2-9}
$$

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

budget constraint:

$$D_{i,B,t} = \frac{\alpha_{i,B}(I_B - sav_{B,t} + (1+r_t)sav_{B,t-1}}{p_{C,i,t}} \frac{(1+r_t)}{(1+\rho)}, \quad \forall i,\ B = A, R, L \qquad \text{E 7.2-10}$$

where index B is the household type (urban, estate or rural household), $D_{B,i}$ is consumption demand for good i by household type B, I_B is income for household type B, sav_B is savings by household type B, $P_{C,i}$ is the consumer price of good i, r is the interest rate and ρ 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:

$$\sum_{t=1}^{T}\left(\frac{1}{1+r_t}\right)^{t-1} sav_{B,t} = 0, \qquad B = A, R, L \qquad \text{E 7.2-11}$$

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:

$$P_i^E = P_{WM,i}(1+t_i^E)G, \quad i \notin energy \qquad \text{E 7.2-12}$$

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:

$$C_i^{\eta_i} = (\sum_B D_{i,B} + D_i^I)^{\eta_i} + E_i^{\eta_i} \qquad \text{E 7.2-13}$$

where D_j^I is intermediate consumption of good j, E_j is exports of good j, and η_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 word[43,44]:

$$\frac{E_i}{D_i + D_i^I} = \left(\frac{e_i}{1-e_i}\right)^{\mu_i} \left(\frac{P_i^E}{P_{C,i}}\right)^{\mu_i}, \quad i \notin energy \qquad \text{E 7.2-14}$$

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:

$$P_{X,i}^D = \frac{P_{c,i}\left(D_i + D_i^I\right) + P_i^E E_i}{C_i}, \quad i \notin energy \qquad \text{E 7.2-15}$$

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

---

43 Given that the produced good is exportable. Exports are not defined for sectors in which exports are 0 in the 1991 IO-table.

Max $P^D{}_{X,i}(d_i+d^I_i) + P^E{}_i E_i$
s.t. $(d_i + d^I_i)^{\eta i} + E_i^{\eta i} = C_i^{\eta i}$

44 $\mu_i = \eta_i / (\eta_i - 1)$

$$inv_t = \prod_i i_{i,t}^{\beta_i}$$
$$i_{i,t} = \frac{\beta_i inv_t}{P_{c,i,t}} \qquad \text{E 7.2-16}$$
$$P_{i,t} = \frac{\sum_i P_{c,i,t} i_t}{inv_t}$$

where inv is total investment, β_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:

$$K_{t+1} = K_t(1-\lambda) + inv_t \qquad \text{E 7.2-17}$$

where λ 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.

$$A_t = \sum_i A_{i,t},$$
$$R_t = \sum_i R_{i,t} + r_{i,t}^{SC}$$
$$L_t = \sum_i L_{i,t}, \qquad \text{E 7.2-18}$$
$$K_t = \sum_i K_{i,t} + k_{i,t}^{SC},$$

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:

$$x_i = C_i, \qquad \text{E 7.2-19}$$

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

$$I = \sum_N P_N^U N + \sum_j (t_j - s_j) x_j + \sum_i \left(t_i^M M_i + t_i^E E_i + P_{WM,i} M_i R - P_i^E E_i\right) \quad \forall j, N$$

E 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:

$$GDP = \sum_N P_N^U N + \sum_i (t_i - s_i) x_i, \quad \forall i, N \qquad \text{E 7.2-21}$$

The current account is defined as:

$$CA = \sum_i \left(P_i^E E_i - P_{WM,i} M_i\right) R \qquad \text{E 7.2-22}$$

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[45], 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.[46]

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

	Area Under Cultivation (ha)	Rate of soil erosion (tons/ha/year)		
Study	Bandara et al. (1995)[47]	Bandharathilake (1994)[48]	Abeygunawardene and Samarakoon (undated)	
Method		Unknown	USLE	Field observ.
Tea	157,172	17.5		
Well-mgd seedl. tea			13	20
Poorly-mgd seedl tea			42	75
VP tea[50]			10	15
Rubber	97,416	10	11.10	10
Coconut	55,529	10	22.9	20

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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[46] Primarily by Dr. Anura Ekanayake (MPI), Mr. Sapukotane and Ms. Gunawardene (MEnv), and their team.

[47] From Plantations Statistical Pocket Book

[48] From Bandara et al. (1995).

[49] High-yielding vegetatively propagated tea varieties.

[50] 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).

	Cost per ha (hundreds of rupees / year)					
Crops	Nutrients	O.M.	R&M	Labor	Soil	Total
WM s. tea	3.40	5.92	9.00	1.49	19.80	39.61
PM s. tea	7.47	12.96	9.00	3.31	70.23	102.98
VP[7] tea	1.59	2.79	8.99	0.70	15.00	29.08
Rubber	5.95	1.13	0.85	9.07	12.46	29.46
Coconut	2.31	4.63	8.80	0.93	25.00	41.67

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

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[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[53], the maximum likelihood (ML) method was used, resulting in the following equation[54]:

$$Y_T = 0.7744 - 0.0066t + 0.0001r + 0.0023p + 5.2618f$$

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 was 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[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

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[53] Akaike's information criterion was used to determine the appropriate lag length.

[54] All coefficients were significant at the 10% level

[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[56]:

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

where Δ 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

Tea	Rubber	Coconut
0.0066	0.0025	0.0013

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.

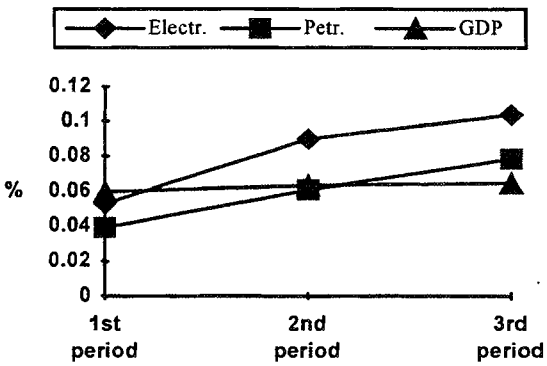


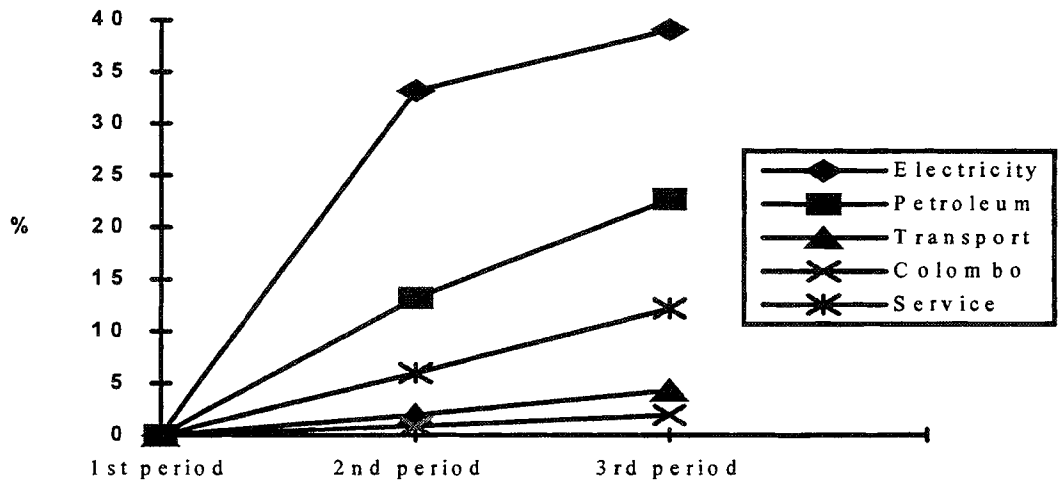
Figure 7-1 Increased energy demand and GDP from elimination of subsidies in the tea sector (compared to base case results for each period)

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 treecrops 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 icreases. Energy intensive

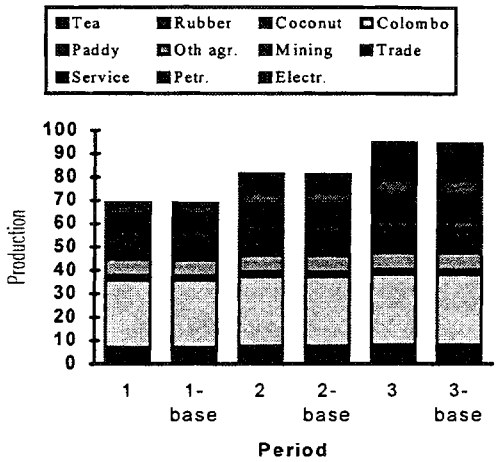
sectors suffer more from the price increase than do less energy intensive sectors. In the second period (which is the period in which the electricity price increase actually has taken effect), the service sectors, the trade and transportation sector, and the treecrops sectors increase their production 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.

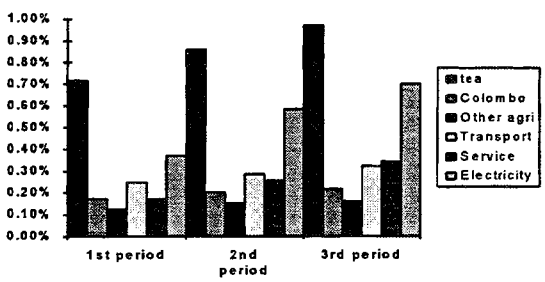


Figure 7-4. Change in production as compared to the base case scenario for selected sectors

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.

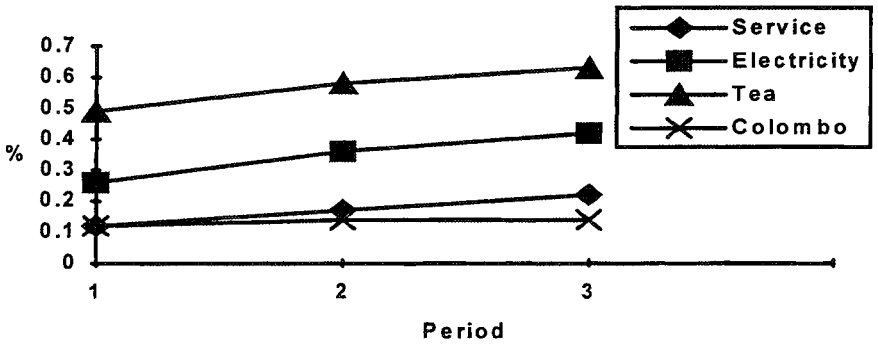


Figure 7-5 Changes in production growth in selected sectors after a 10% increase of the tax on Colombo/industrial goods

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.

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

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

APPENDIX 2 The Aggregation Of Producing Sectors In The Sri Lanka CGE Model

Model Sectors	IO Table sectors
Tea	Tea
Rubber	Rubber
Coconut	Coconut
Paddy	Paddy
Other Agriculture	Other agriculture
Mining and Quarrying	Mining and quarrying
Colombo	Rice Milling
	Flour Milling
	Textile
	Garments
	Transportation equipment
	Electrical equipment
	Other machinery
	Food processing
	Chemical and fertilizer
	Structural clay
	Other manufacturing
	Basic metal
	Construction
Petroleum	Petroleum
Electricity	Electricity
Transport	Trade and transport
Other services	Other services

APPENDIX 3 List Of Variables And Parameters In The Models

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

Variable	Description
μ_t	Stock of forests in period t
δ_t	Capital depletion in period t
g	Installation costs for capital investments
h	Installation costs for forest investments
i_t	Capital investments in period t
I_t	Investment costs for capital
j_t	Forest investments in period t
J_t	Investment costs for forests
K_t	Capital input in period t
k_t	Normalized capital input in period t
L_t	Labor input in period t
M_t	Deforestation in period t
m_t	Normalized deforestation in period t
$p_{f,t}$	Price of output in period t
$p_{i,t}$	Price of capital investments in period t
$p_{j,t}$	Price of forest investments in period t
$p_{k,t}$	Price of capital in period t
$p_{m,t}$	Price of deforestation in period t
q_t	Shadow price of capital in period t
r_t	Interest rate in period t
s_t	Shadow price of deforestation in period t
w_t	Price of labor in period t
Y_t	Output in period t

List of variables and parameters for the CGE models of deforestation in Costa Rica

Variable	Description
ϕ	Opportunity value of conservation per unit of forest (exogenous)
σ_j	Tax rate of good j (exogenous)
Cj	Marginal and average cost of production in sector j
C^{sq}	Cost of land clearing for squatters
D_i	Consumption demand for good i
DL	Initial stock of cleared land (exogenous)
d^{log}	Deforestation by loggers
d^{sq}	Deforestation by squatters
e	Exchange rate (exogenous)
f^{nexp}	Net exports of logs
g^{sq}	Profit from land clearing for squatters
H	Opportunity value of forest conservation
I	Disposable income
Inv	Total investments
inv_i	Investments from sector i
I^{sq}	Revenue of land clearing for squatters
K	Capital stock (exogenous)
k^{log}	Capital input in logging
L	Stock of skilled labor (exogenous)
l^{log}	Labor input in logging
l^{sq}	Labor input in squatting
M_j	Input of production factor M in sector j
P_{DL}	Price of cleared land
P_{DL}^U	User price of cleared land, including taxes
P_{FL}	Price of logs
P_{FL}^U	User price of logs, including taxes
P_{FL}^{WM}	World market price of logs (exogenous)
P_i^D	Domestic user price of good i
P_i^W	World market price of good j (exogenous)
P_j	Producer price of good j
P_K	Price of capital
P_K^U	User price of capital, including taxes
P_U	Price of unskilled labor
P_U^U	User price of unskilled labor, including taxes
P_{Yj}^U	User price (including taxes) of primary factor composite in sector j
r	Interest rate (exogenous)
s	Savings
S	Current account (exogenous)
t_j	Indirect tax rate in sector j (exogenous)
T_j	Tax rate on production factor j

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

Parameter	Description
α	Elasticity of logging output with respect to capital
β	Elasticity of logging output with respect to labor
γ	Elasticity of squatting output with respect to labor
aij	Share of sector j output in sector i production
A_j	Share of primary production factors in sector j output
b_i	Expenditure share on good i
h	Amount of timber per unit of forested land
i_i	Share of value of investments from sector i

List of variables and parameters in the Sri Lanka CGE model

Variable	Description
$A_{i,t}$	Demand for estate labor in sector i
A_t	Stock of estate labor (exogenous)
CA_t	Current account balance
$C_{i,t}$	Composite consumption of sector i goods
$D_{i,B,t}$	Final demand for sector i output by household B
$D_{i,t}$	Total demand for sector i output
$d_{i,t}$	Soil conservation in sector i
$D^I_{i,t}$	Intermediate consumption of sector i goods
$E_{i,t}$	Exports of sector i output
g_i	Rate of land degradation in sector i (exogenous)
$I_{B,t}$	Disposable income for household B
$i_{i,t}$	Investments from sector i
inv_t	Total investments
$K_{i,t}$	Demand for capital in sector i
$k^{SC}_{i,t}$	Capital input in soil conservation in sector i
K_t	Capital stock
$L_{i,t}$	Demand for urban labor in sector i
L_t	Stock of urban labor (exogenous)
$mc_{i,t}$	Marginal cost of production in sector i
$M_{i,t}$	Demand for imports in sector i
$N_{i,t}$	Demand for production factor N in sector i
$P_{C,i,t}$	Price of domestic consumption of good i
$P^D_{x,i,t}$	Price of output in sector i
$P^E_{i,t}$	Price of sector i exports
$P_{i,t}$	Price of investments
$P_{N,t}$	Price of production factor N
$P^U_{K,t}$	User price of capital
$P^U_{R,t}$	User price of rural labor
$P_{WM,i,t}$	World market price of good i (exogenous)
$Q_{i,t}$	Soil quality index in sector i
r	Interest rate
R	Exchange rate (exogenous)
$R_{i,t}$	Demand for rural labor in sector i
$r^{SC}_{i,t}$	Labor input in soil conservation in sector i
R_t	Stock of rural labor (exogenous)
$sav_{B,t}$	Savings for household type B
s_i	Subsidy of production in sector i (exogenous)
$t^E_{i,t}$	Export duty on export from sector i (exogenous)
$t_{i,t}$	Indirect tax in sector i (exogenous)
$x_{i,t}$	Output in sector i
$x_{ji,t}$	Input of sector j output per unit of production in sector i

Parameter	Description
ρ	Rate of time preference
λ	Rate of capital depletion
κ	Elasticity of substitution in soil conservation
Φ_i	Share of primary production factors in sector i output
β_i	Share of investments from sector i
$\alpha_{i,B}$	Expenditure share for good i in household B
e_i	Initial share of exports in total consumption

APPENDIX 4 Base Data For The Costa Rica Static CGE Model

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

Costa Rica 1986, 10 billion colones.

1986	forest	agri	ind	infra	service	cons	nexp	total
forest	0,0003	0,0022	0,0391	0,0002	0,0000	0,0124	0,0011	0,0552
agri	0,0004	0,4033	0,2488	0,0000	0,0000	0,3535	0,3924	1,3984
ind	0,0137	0,1405	0,7390	0,3418	0,1343	1,4426	-0,9643	1,8477
infra	0,0004	0,0293	0,0826	0,0647	0,0684	0,8366		1,0821
service	0,0038	0,0602	0,1546	0,1487	0,2160	1,1230		1,7062
land		0,2070						0,2070
logs	0,0022							0,0022
capital	0,0176	0,2052	0,2168	0,1633	0,5256			1,1285
ulab	0,0141	0,2714	0,1525	0,1754	0,1439			0,7573
slab	0,0002	0,0045	0,0999	0,1299	0,4904			0,7250
indtax	0,0025	0,0747	0,1145	0,0580	0,1276			0,3773
total	0,0552	1,3984	1,8477	1,0821	1,7062	3,7681	-0,5708	9,2870

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.

	1963		1973		1986	
Agriculture	1,544,796	30.09%	2,048,512	39.90%	2,944,616	57.36%
Primary Forest	3,154,280	61.44%	2,666,005	51.93%	1,760,622	34.30%
Secondary Forest	299,011	5.82 %	283,571	5.52%	292,850	5.70%
Other	135,593	2.64 %	135,593	2.64%	135,593	2.64%
Total	5,133,680	100.00%	5,133,681	100.00%	5,133,681	100.00%

Source: Calculated from Solórzano 1991.

Table A4.3 Deforestation parameters and initial values

$l_{sq,0}$	0.00180	γ	0.9833
$k_{log,0}$	0.00126	α	0.5070
$l_{log,0}$	0.00093	β	0.3742

APPENDIX 5 Base Data For The Dynamic Costa Rica Model

Costa Rica 1986, 10 billion colones

1986	forest	agri	ind	infra	service	cons	invest	nexp	total
forest	0.0002	0.0022	0.0391	0.0002	0.0000	0.0124	0.0000	0.0011	0.0552
agri	0.0004	0.4033	0.2488	0.0000	0.0000	0.3503	0.0032	0.3924	1.3984
ind	0.0137	0.1405	0.7390	0.3418	0.1343	1.4133	0.0293	-0.9642	1.8477
infra	0.0004	0.0293	0.0826	0.0647	0.0684	0.7824	0.0542		1.0820
service	0.0038	0.0602	0.1546	0.1487	0.2160	1.1150	0.0080		1.7062
land		0.2070							0.2070
logs	0.0022								0.0022
capital	0.0176	0.2052	0.2167	0.1633	0.5256				1.1285
ulab	0.0141	0.2714	0.1525	0.1754	0.1439				0.7573
slab	0.0002	0.0045	0.0999	0.1299	0.4904				0.7249
indtax	0.0025	0.0747	0.1145	0.0580	0.1276				0.3773
saving						0.0803		0.0144	0.0947
total	0.0552	1.3984	1.8477	1.0821	1.7062	3.7537	0.0947	-0.5564	9.3816

APPENDIX 6 Base Data For The Sri Lanka Model

IO Table for Sri Lanka 1991
Rupees 10 billion

	Tea	Rubber	Coconut	Industry	Petrol.	Electr.	Paddy	Oth.Agri.	Min.& Q.	Transp.Tr	Oth.Serv.	Urban	Rural	Estate	GDCF	Export	Output
Tea											0.003920	0.049520	0.181272	0.017888		1.806154	2.058754
Rubber				0.146519												0.352039	0.498558
Coconut				0.387683							0.005014	0.135261	0.456390	0.043859	0.028610	0.015327	1.072144
Industry	0.323200	0.010161	0.070531	4.077543	0.002768	0.008156	0.249437	0.393864	0.005350	0.929236	1.131084	4.150002	9.802050	0.833175	2.088392	5.168135	29.243084
Paddy				1.470689			0.002196					0.081702	0.342842	0.034428			1.931857
Petr.	0.042948	0.000836	0.005276	0.736365		0.166656	0.007829	0.196363	0.003126	0.391971	0.033476	0.198129	0.130028	0.014031		0.328945	2.255979
Electr.	0.034460	0.001756	0.003636	0.592862	0.000865	0.002223		0.169446	0.001854	0.073771	0.037613	0.121960	0.080137	0.008544			1.129127
Oth.Agri	0.055054	0.002982	0.012328	0.611398		0.001832	0.028881	0.139250			0.341637	1.069719	3.179999	0.302252	0.029730	0.538121	6.313183
Min.& Q				0.185130								0.014101	0.032864	0.001018		0.315810	0.548923
Trsp&Tr	0.065899	0.003007	0.013474	3.573455	0.105544	0.043252	0.025220	0.156960	0.009426	0.238049	0.199378	1.919573	2.508489	0.067484	2.630426	1.104184	12.663820
Oth.Serv	0.129634	0.012709	0.049682	1.434732	0.005543	0.265340	0.087316	0.126425	0.021714	0.443482	0.056628	1.729594	4.210668	0.011928		0.673560	9.258955
Imports	0.208967	0.059379	0.021873	5.919110	1.592480	0.004328	0.111186	0.224857	0.082098	0.222750	1.349097						9.796125
ImpDuty	0.004472	0.000080	0.000087	0.782527	0.086575	0.000964	0.004715	0.002453	0.000665	0.179857	0.110481						1.172876
Urban	0.004160	0.000980	0.002850	0.852860	0.021570	0.063540	0.005370	0.096890	0.006340	0.946100	1.421140	0.000000	0.000000	0.000000	0.000000	0.000000	3.421800
Rural	0.253890	0.059640	0.071280	3.998100	0.030210	0.061820	0.485270	1.460620	0.110710	2.232050	3.247290	0.000000	0.000000	0.000000	0.000000	0.000000	12.010880
Estate	0.170870	0.089520	0.246230	0.141170	0.001500	0.003640	0.010050	0.173000	0.003360	0.092260	0.135320	0.000000	0.000000	0.000000	0.000000	0.000000	1.066920
Capital	0.741520	0.263730	0.575000	1.641365	0.106800	0.297694	0.852800	3.081720	0.262630	6.771610	0.470640						15.065509
Depr.	0.034960	0.008060	0.004950	0.685375	0.015689	0.206366	0.053610	0.051070	0.021650	0.403180	0.413510						1.898420
Ind.Tax	0.003920	0.000448	0.001057	2.006201	0.294535	0.003316	0.007977	0.046875	0.020000	0.088944	0.308917						2.782190
Subsid.	-0.01520	-0.01473	-0.00611		-0.00810			-0.00661		-0.34944	-0.00619						-0.406380
Output	2.058754	0.498558	1.072144	29.24308	2.255979	1.129127	1.931857	6.313183	0.548923	12.66382	9.258955	9.469561	20.92474	1.334607	4.777158	10.30228	

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

H-value	Undefined pr. rights. (10 billion colones)	Defined property rights (i=10%), sensitivity analysis with respect to different future values (% change) 0.48	0.38	0.28	0.18	0.08
Utility	0.0232	0.00%	0.00%	0.00%	0.00%	0.00%
GNP	3.1962	0.03%	0.03%	0.03%	0.03%	0.03%
Spending	3.7681	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%
Prices						
Capital	1	0.17%	0.17%	0.17%	0.17%	0.17%
Skilled. Labor	1	-0.06%	-0.06%	-0.06%	-0.06%	-0.06%
Unskilled Labor	1	-0.21%	-0.21%	-0.21%	-0.22%	-0.21%
Land	1	0.11%	0.11%	0.11%	0.11%	0.11%
Logs	1	0.00%	0.00%	0.00%	0.00%	0.00%
Production in Deforestation sectors:						
Squatters	0.002	-100.00%	-100.00%	-100.00%	-100.00%	-100.00%
Loggers	0.002	-100.00%	-95.00%	-90.00%	-80.00%	-50.00%
Total	0.004	-100.00%	-97.50%	-95.00%	-90.00%	-72.50%
Production:						
Forest	0.0552	29.17%	28.99%	28.80%	27.90%	25.18%
Agri	1.3984	-0.77%	-0.77%	-0.77%	-0.77%	-0.75%
Ind	1.8477	-0.33%	-0.32%	-0.32%	-0.31%	-0.29%

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

.	forest	agri	ind	logging	squatting
land	0%	27%		0%	0%
logs	6%	0%	0%	0%	0%
capital	48%	27%	37%	58%	0%
unskilled labor	39%	36%	26%	42%	100%
skilled labor	1%	1%	17%	0%	0%

Table A7. 3 Effects of taxation of production factors in the static model

	Base Case (10 billion colones)	Tax Logs	Subsidy Logs	Tax Land	Subsidy Land	Tax Unskilled labor	Tax Capital
Utility	0.0232	4.74%	-7.76%	-0.43%	-2.59%	-1.29%	0.00%
GNP	3.1962	0.17%	-0.36%	-0.01%	-0.64%	-0.52%	-0.06%
Spending	3.7681	0.18%	-0.32%	-0.01%	-0.24%	-0.16%	0.00%
Prices:							
Capital	1	-0.43%	0.73%	0.17%	-1.55%	-1.31%	0.01%
Skilled Labor	1	1.19%	-2.19%	-0.06%	-1.41%	-0.95%	0.00%
Unskilled Labor	1	-0.40%	0.85%	-0.22%	3.79%	2.97%	-0.02%
Land	1	0.86%	-1.66%	0.11%	-3.11%	-2.37%	0.01%
Logs	1	10.00%	-10.00%	0.00%	0.00%	0.00%	0.00%
Income in Deforestation Sectors:							
Squatters	0.002	120.00%	-80.00%	-100.00%	1175.00%	950.00%	0.00%
Loggers	0.002	-100.00%	-10.00%	0.00%	-5.00%	45.00%	80.00%
Total	0.004	10.00%	-42.50%	-50.00%	582.50%	497.50%	40.00%
Production:							
Forest	0.0552	-100.00%	182.97%	21.74%	-100.00%	-100.00%	-6.70%
Agri	1.3984	1.57%	-1.69%	-0.77%	8.14%	6.71%	0.02%
Ind	1.8477	4.17%	-7.90%	-0.25%	-4.44%	-2.87%	0.05%

Table A7. 4 Effects of taxation of final goods in the static model

	Base Case (10 billion colones)	half tax Forest	double tax Forest	half tax Agri	double tax Agri	half tax Ind	double tax Ind
Utility	0.0232	-1.29%	3.45%	-41.81%	97.84%	-72.41%	146.55%
GNP	3.1962	-0.07%	0.06%	-1.17%	2.67%	-2.00%	4.04%
Spending	3.7681	-0.03%	0.07%	-0.97%	2.29%	-1.67%	3.46%
Prices							
Capital	1	0.00%	0.00%	-0.03%	0.08%	-0.09%	0.19%
Skilled labor	1	0.00%	0.00%	0.01%	-0.03%	0.03%	-0.07%
Unskilled labor	1	0.00%	0.00%	0.04%	-0.10%	0.12%	-0.24%
Land	1	0.00%	0.00%	-0.02%	0.05%	-0.06%	0.12%
Logs	1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Income in Deforestation sectors:							
Squatters	0.002	0.00%	0.00%	-5.00%	10.00%	-10.00%	25.00%
Loggers	0.002	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total	0.004	0.00%	0.00%	-2.50%	5.00%	-5.00%	12.50%
Production:							
Forest	0.0552	-4.35%	10.33%	-26.63%	63.41%	-71.01%	146.92%
Agri	1.3984	0.00%	0.01%	-5.19%	12.31%	-0.14%	0.33%
Ind	1.8477	0.14%	-0.32%	4.15%	-9.82%	-1.13%	2.34%

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)

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

Interest rate	Base	+0.02%	+0.04%
Welfare	0.187	0.48%	1.02%
Utility	0.1234	0.32%	1.30%
GNP	3.1724	-0.02%	-0.02%
Spending	3.1727	-0.02%	-0.02%
Investments	1.0849	-0.50%	-1.01%
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	0.00%	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)

	Base Solution	1% subsidy Period 0	1% tax Period 0	1% subsidy Period 1	1% tax Period 1
Welfare	0.187	-2.94%	2.73%	2.99%	-2.94%
Utility	0.1234	-2.84%	16.37%	1.62%	-1.62%
GNP	3.1724	-0.22%	0.60%	0.18%	-0.18%
Spending	3.1727	-0.22%	0.60%	0.18%	-0.18%
Investments	1.0849	-2.34%	1.83%	2.41%	-2.36%
User prices of production factors:					
Capital	0.9654	0.03%	-0.06%	-0.03%	0.03%
Skilled labor	1.0668	-0.94%	2.60%	0.80%	-0.79%
Unskilled labor	1.0393	0.07%	-0.20%	-0.04%	0.05%
Cleared land	0.9773	0.02%	-0.03%	-0.02%	0.02%
Logs	1	0.00%	0.00%	0.00%	0.00%
Deforestation:					
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%
Allowed	100.0001	0.00%	0.00%	0.00%	0.00%
Land available	0.2302	-0.26%	1.17%	0.17%	-0.17%
Production in sectors using land and logs:					
Forest	0.0666	35.59%	-95.20%	-30.03%	29.88%
Agri	1.5360	-0.27%	1.26%	0.19%	-0.19%

Table A7. 8 Changes in land taxation in the dynamic model (10 billion colones)

	Base	1% subsidy Period 0	1% tax Period 0	1% subsidy Period 1	1% tax Period 1
Welfare	0.187	-1.07%	1.07%	2.35%	-2.57%
Utility	0.1234	-0.73%	1.94%	19.12%	-2.35%
GNP	3.1724	-0.04%	0.08%	0.60%	-0.13%
Spending	3.1727	-0.05%	0.08%	0.60%	-0.13%
Investments	1.0849	-0.02%	-0.02%	0.33%	-0.95%
User prices of production factors					
Capital	0.9654	-0.39%	0.37%	-0.05%	0.01%
Skilled labor	1.0668	-0.14%	0.30%	2.58%	-0.54%
Unskilled labor	1.0393	0.53%	-0.51%	-0.21%	0.04%
Cleared land	0.9773	-0.26%	0.25%	-0.03%	0.01%
Logs	1	0.00%	0.00%	0.00%	0.00%
Deforestation					
Squatters	0.0265	14.34%	-13.21%	11.70%	-1.51%
Loggers	0.0024	-100.00%	0.00%	8.33%	0.00%
Total	0.0289	4.84%	-11.76%	11.42%	-1.38%
Allowed	100.0001	0.00%	0.00%	0.00%	0.00%
Land	0.2302	1.56%	-1.43%	1.30%	-0.22%
Production					
Forest	0.0666	-20.72%	19.37%	-100.00%	20.57%
Agri	1.5360	1.39%	-1.26%	1.40%	-0.20%

Table A7. 9 Changes in logs taxation in the dynamic model (10 billion colones)

	Base	2% subsidy Period 0	1% subsidy Period 0	1% tax Period 0	1% subsidy Period 1	1% tax Period 1
Welfare	0.1870	0.11%	0.05%	0.00%	0.00%	0.00%
Utility	0.1234	0.49%	0.24%	-0.24%	0.00%	0.00%
GNP	3.1724	0.07%	0.03%	-0.04%	0.00%	0.00%
Spending	3.1727	0.07%	0.03%	-0.04%	0.00%	0.00%
Investments	1.0849	-0.36%	-0.18%	0.18%	0.00%	0.00%
User price of production factors						
Capital	0.9654	0.31%	0.16%	-0.16%	0.00%	0.00%
Skilled labor	1.0668	0.05%	0.02%	-0.03%	0.00%	0.00%
Unskilled labor	1.0393	-0.11%	-0.05%	0.06%	0.00%	0.00%
Cleared land	0.9773	-0.20%	-0.10%	0.10%	0.00%	0.00%
Logs	1	-2.00%	-1.00%	1.00%	0.00%	0.00%
Deforestation						
Squatters	0.0265	-5.66%	-3.02%	3.02%	0.00%	0.00%
Loggers	0.0024	-1.52%	-0.37%	0.37%	0.00%	0.00%
Total	0.0289	-5.19%	-2.42%	2.77%	0.00%	0.00%
Allowed	100.0001	0.00%	0.00%	0.00%	0.00%	0.00%
Land	0.2302	-0.65%	-0.35%	0.30%	0.00%	0.00%
Production						
Forest	0.0666	18.59%	9.30%	-9.30%	0.00%	0.00%
Agri	1.5360	-0.74%	-0.37%	0.37%	0.00%	0.00%

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

	Base	1% subsidy Period 0	1% tax Period 0	1% subsidy Period 1	1% tax Period 1
Welfare	0.187	0.05%	0.00%	0.00%	0.00%
Utility	0.1234	0.00%	0.00%	0.00%	0.00%
GNP	3.1724	0.03%	-0.03%	0.00%	0.00%
Spending	3.1727	0.03%	-0.03%	0.00%	0.00%
Investments	1.0849	-0.19%	0.19%	0.00%	0.00%
User prices of production factors					
Capital	0.9654	0.18%	-0.18%	0.00%	0.00%
Skilled labor	1.0668	0.01%	-0.01%	0.00%	0.00%
Unskilled labor	1.0393	-0.06%	0.07%	0.00%	0.00%
Cleared land	0.9773	-0.12%	0.12%	0.00%	0.00%
Logs	1	0.00%	0.00%	0.00%	0.00%
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)

	Base	1% subsidy Period 0	1% tax Period 0	1% subsidy Period 1	1% tax Period 1
Welfare	0.187	-0.27%	0.27%	0.59%	-0.59%
Utility	0.1234	0.08%	0.57%	-0.49%	0.49%
GNP	3.1724	-0.01%	0.03%	0.00%	0.00%
Spending	3.1727	-0.01%	0.03%	0.00%	0.00%
Investments	1.0849	0.05%	-0.06%	0.26%	-0.26%
User prices of production factors:					
Capital	0.9654	-0.15%	0.15%	0.00%	0.00%
Skilled labor	1.0668	-0.01%	0.07%	-0.01%	-0.01%
Unskilled labor	1.0393	0.19%	-0.19%	0.01%	0.00%
Cleared land	0.9773	0.27%	-0.27%	0.00%	0.00%
Logs	1	0.00%	0.00%	0.00%	0.00%
Deforestation:					
Squatters	0.0265	4.53%	-4.15%	-0.38%	0.38%
Loggers	0.0024	0.00%	0.00%	0.00%	0.00%
Total	0.0289	4.50%	-3.81%	0.00%	0.35%
Allowed	100.0001	0.00%	0.00%	0.00%	0.00%
Land	0.2302	0.48%	-0.48%	-0.04%	0.00%
Production:					
Forest	0.0666	-12.46%	9.91%	0.15%	0.00%
Agri	1.5360	0.59%	-0.54%	-0.03%	0.03%

APPENDIX 8 Numerical Results from the Sri Lanka Model

Table A8. 1 Initial factor intensities

	Tea	Rubber	Coco	Colom.	Petr.	Electr.	Paddy	OthAgr	Mining	Transp.	Service
Electr.		0.36%	0.39%	4.06%	0.05%	0.35%	0.00%	3.22%	0.38%	0.68%	0.52%
Imports	14.69%	12.31%	2.37%	45.86%	90.48%	0.83%	7.61%	4.32%	16.91%	3.69%	20.31%
Urban	0.29%	0.20%	0.31%	5.84%	1.16%	9.92%	0.35%	1.84%	1.30%	8.66%	19.78%
Rural	17.47%	12.34%	7.70%	27.36%	1.63%	9.65%	31.86%	27.77%	22.63%	20.44%	45.19%
Estate	11.76%	18.53%	26.59%	0.97%	0.08%	0.57%	0.66%	3.29%	0.69%	0.84%	1.88%
Capital	53.43%	56.25%	62.64%	15.92%	6.60%	78.69%	59.51%	59.56%	58.10%	65.69%	12.31%

Table A8. 2 Base case results (Rupees 10 million)

Period	1	2	3	4
Soil conservation on smallholdings, tea sector				
Total	0.3375			
Labor input	0.0131			
Capital input	0.3148			
Soil quality index				
Tea	1.3375	1.3045	1.2715	1.2385
Rubber	1.0000	0.9875	0.9750	0.9625
Coco	1.0000	0.9935	0.9870	0.9805
Prices				
Estate labor	0.8568	0.8525	0.8638	0.9748
Urban labor	1.0198	0.8940	0.7949	0.8581
Rural labor	0.9927	0.9235	0.8687	0.9342
Capital	0.9546	0.8504	0.7655	0.8111
Production				
Tea	5.4415	5.9428	6.2405	5.1910
Rubber	0.5281	0.5976	0.6553	0.6127
Coco	1.1277	1.1925	1.2319	1.2166
Colombo	28.6766	29.6617	30.1633	31.5960
Paddy	1.9374	1.9938	2.0182	2.0912
Other agri	6.8062	7.0302	7.1492	7.1419
Mining	0.5532	0.5782	0.5927	0.6087
Trade	10.2934	10.9630	11.5015	13.1343
Service	9.9753	11.8786	14.0042	13.6950
Petroleum	2.3093	3.5263	4.9933	4.8475
Electricity	1.2112	7.7761	16.0134	14.7389
Disposable income				
Urban HH	10.6147	10.1879	10.0673	10.0346
Rural HH	22.4250	22.1424	22.3692	23.5366
Estate HH	1.2296	1.2890	1.3847	1.5988
Total income	34.2693	33.6193	33.8211	35.1701
Trade balance	0.6500	-0.2018	-1.3490	-1.4487
GDP	61.6972	61.1130	60.6347	65.5678

Table A8. 3 Results of a removal of subsidies in the tea sector, % change compared to base case (Table A8.1)

Period	1	2	3	4
Soil conservation on smallholdings, tea sector				
Total	0.0533%			
Labor input	0.0764%			
Capital input	0.0476%			
Soil quality index				
Tea	0.0135%	0.0138%	0.0142%	0.0145%
Rubber	0.0000%	0.0000%	0.0000%	0.0000%
Coco	0.0000%	0.0000%	0.0000%	0.0000%
Prices				
Estate labor	-0.0373%	-0.0481%	-0.0579%	-0.0328%
Urban labor	-0.0294%	-0.0459%	-0.0591%	-0.0373%
Rural labor	-0.0302%	-0.0422%	-0.0541%	-0.0289%
Capital	-0.0346%	-0.0482%	-0.0614%	-0.0358%
Production				
Tea	0.1009%	0.1237%	0.1391%	0.0963%
Rubber	0.0663%	0.0904%	0.1083%	0.0424%
Coco	0.0319%	0.0411%	0.0463%	0.0140%
Colombo	0.0244%	0.0290%	0.0311%	0.0000%
Paddy	0.0196%	0.0231%	0.0243%	-0.0005%
Other agri	0.0176%	0.0220%	0.0229%	0.0119%
Mining	0.0289%	0.0329%	0.0371%	0.0082%
Trade	0.0352%	0.0412%	0.0469%	-0.0171%
Service	0.0241%	0.0377%	0.0506%	0.0426%
Petroleum	0.0390%	0.0607%	0.0785%	0.0703%
Electricity	0.0528%	0.0898%	0.1038%	0.1189%
Disposable income				
Urban HH	0.1185%	0.1319%	0.1415%	0.1215%
Rural HH	-0.0315%	-0.0398%	-0.0437%	-0.0281%
Estate HH	0.0211%	0.0140%	0.0065%	0.0106%
Total income	0.0169%	0.0143%	0.0135%	0.0163%
Trade balance	0.1492%	-0.1288%	0.0867%	0.0987%
GDP	0.0596%	0.0635%	0.0645%	0.0429%

Table A8. 4 Results of a removal of subsidies in the rubber sector, % change compared to base case (Table A8.1)

Period	1	2	3	4
Soil conservation on smallholdings, tea sector				
Total	0.0207%			
Labor input	0.0764%			
Capital input	0.0191%			
Soil quality index				
Tea	0.0052%	0.0054%	0.0055%	0.0057%
Rubber	0.0000%	0.0000%	0.0000%	0.0000%
Coco	0.0000%	0.0000%	0.0000%	0.0000%
Prices				
Estate labor	-0.0140%	-0.0188%	-0.0243%	-0.0154%
Urban labor	-0.0108%	-0.0190%	-0.0264%	-0.0186%
Rural labor	-0.0121%	-0.0173%	-0.0230%	-0.0139%
Capital	-0.0136%	-0.0188%	-0.0261%	-0.0173%
Production				
Tea	0.0391%	0.0496%	0.0580%	0.0426%
Rubber	0.0246%	0.0368%	0.0458%	0.0196%
Coco	0.0124%	0.0168%	0.0195%	0.0066%
Colombo	0.0095%	0.0116%	0.0129%	0.0000%
Paddy	0.0077%	0.0090%	0.0099%	0.0000%
Other agri	0.0068%	0.0088%	0.0095%	0.0053%
Mining	0.0108%	0.0138%	0.0152%	0.0033%
Trade	0.0137%	0.0164%	0.0196%	-0.0073%
Service	0.0093%	0.0156%	0.0221%	0.0206%
Petroleum	0.0152%	0.0255%	0.0348%	0.0345%
Electricity	0.0206%	0.0391%	0.0470%	0.0593%
Disposable income				
Urban HH	0.0460%	0.0528%	0.0591%	0.0561%
Rural HH	-0.0122%	-0.0162%	-0.0187%	-0.0141%
Estate HH	0.0081%	0.0054%	0.0029%	0.0050%
Total income	0.0065%	0.0055%	0.0053%	0.0068%
Trade balance	0.0585%	-0.0347%	0.0430%	0.0538%
GDP	0.0231%	0.0253%	0.0267%	0.0200%

Table A8. 5 Results of a removal of subsidies in the coconut sector, % change compared to base case (Table A8.1)

Period	1	2	3	4
Soil conservation on smallholdings, tea sector				
Total	0.0059%			
Labor input	0.0764%			
Capital input	0.0064%			
Soil quality index				
Tea	0.0015%	0.0015%	0.0016%	0.0016%
Rubber	0.0000%	0.0000%	0.0000%	0.0000%
Coco	0.0000%	0.0000%	0.0000%	0.0000%
Prices				
Estate labor	-0.0058%	-0.0070%	-0.0093%	-0.0062%
Urban labor	-0.0039%	-0.0067%	-0.0088%	-0.0070%
Rural labor	-0.0050%	-0.0054%	-0.0081%	-0.0054%
Capital	-0.0063%	-0.0071%	-0.0091%	-0.0074%
Production				
Tea	0.0162%	0.0192%	0.0213%	0.0177%
Rubber	0.0095%	0.0134%	0.0168%	0.0082%
Coco	0.0053%	0.0059%	0.0073%	0.0025%
Colombo	0.0039%	0.0045%	0.0048%	0.0000%
Paddy	0.0031%	0.0035%	0.0035%	0.0000%
Other agri	0.0028%	0.0034%	0.0035%	0.0024%
Mining	0.0054%	0.0052%	0.0067%	0.0016%
Trade	0.0056%	0.0065%	0.0072%	-0.0032%
Service	0.0038%	0.0056%	0.0075%	0.0085%
Petroleum	0.0065%	0.0091%	0.0116%	0.0140%
Electricity	0.0091%	0.0129%	0.0149%	0.0244%
Disposable income				
Urban HH	0.0189%	0.0204%	0.0216%	0.0215%
Rural HH	-0.0050%	-0.0061%	-0.0066%	-0.0056%
Estate HH	0.0033%	0.0023%	0.0007%	0.0019%
Total income	0.0027%	0.0023%	0.0021%	0.0025%
Trade balance	0.0246%	-0.0248%	0.0119%	0.0214%
GDP	0.0095%	0.0099%	0.0099%	0.0074%

Table A8. 6 Results of a 1% increase in the price of energy, % change compared to base case (Table A8.1)

Period	1	2	3	4
Soil conservation on smallholdings tea sector				
Total	0.0000%			
Labor input	0.0000%			
Capital input	0.0000%			
Soil quality index				
Tea	0.0000%	0.0000%	0.0000%	0.0000%
Rubber	0.0000%	0.0000%	0.0000%	0.0000%
Coco	0.0000%	0.0000%	0.0000%	0.0000%
Prices				
Estate labor	0.0000%	0.7367%	1.2966%	9.9871%
Urban labor	0.0000%	-2.7908%	-5.0437%	5.2465%
Rural labor	0.0000%	-0.9226%	-1.8498%	6.6375%
Capital	0.0000%	-1.6557%	-2.9247%	6.6145%
Production				
Tea	0.0000%	1.8744%	3.3900%	-10.7754%
Rubber	0.0000%	2.2072%	4.4206%	-4.2010%
Coco	0.0000%	0.8754%	1.7234%	-0.7381%
Colombo	0.0000%	0.8630%	1.9215%	4.6700%
Paddy	0.0000%	0.6941%	1.5434%	3.5679%
Other agri	0.0000%	0.7885%	1.7581%	0.7072%
Mining	0.0000%	0.9253%	1.9707%	2.7454%
Trade	0.0000%	1.9254%	4.2804%	11.9910%
Service	0.0000%	5.9604%	12.1629%	4.5138%
Petroleum	0.0000%	13.2931%	22.6948%	9.2019%
Electricity	0.0000%	33.1667%	39.0729%	13.7327%
Disposable income				
Urban HH	0.0000%	-0.1432%	1.1828%	1.5413%
Rural HH	0.0000%	0.0176%	0.8329%	3.7598%
Estate HH	0.0000%	0.8293%	1.9066%	8.1303%
Total income	0.0000%	0.0000%	0.9810%	3.3255%
Trade balance	0.0000%	164.4284%	62.1032%	28.2731%
GDP	0.0000%	-0.1528%	0.0558%	5.6635%

Table A8. 7 Results of a 3% increase in the price of energy, % change compared to base case (Table A8.1)

Period	1	2	3	4
Soil conservation on smallholdings tea sector				
Total	0.0000%			
Labor input	0.0000%			
Capital input	0.0000%			
Soil quality index				
Tea	0.0000%	0.0000%	0.0000%	0.0000%
Rubber	0.0000%	0.0000%	0.0000%	0.0000%
Coco	0.0000%	0.0000%	0.0000%	0.0000%
Prices				
Estate labor	0.0000%	1.6376%	1.0951%	32.7127%
Urban labor	0.0000%	-8.4865%	-16.3754%	22.2795%
Rural labor	0.0000%	-3.2487%	-7.9863%	22.7115%
Capital	0.0000%	-5.2716%	-10.7310%	24.1228%
Production				
Tea	0.0000%	6.5479%	15.2788%	-31.5124%
Rubber	0.0000%	7.6673%	19.4281%	-5.3892%
Coco	0.0000%	3.0104%	7.3270%	3.2147%
Colombo	0.0000%	2.8548%	7.3183%	24.6900%
Paddy	0.0000%	2.2981%	5.8774%	18.7581%
Other agri	0.0000%	2.6026%	6.6487%	2.7073%
Mining	0.0000%	3.0787%	7.6635%	15.9449%
Trade	0.0000%	6.2926%	15.8563%	61.2397%
Service	0.0000%	19.3881%	44.3238%	4.1454%
Petroleum	0.0000%	43.1695%	82.3347%	9.8025%
Electricity	0.0000%	107.6032%	141.3744%	-1.3795%
Disposable income				
Urban HH	0.0000%	-0.2053%	4.9402%	6.8631%
Rural HH	0.0000%	-0.0303%	2.3504%	12.8534%
Estate HH	0.0000%	2.1435%	4.1129%	26.6076%
Total income	0.0000%	0.0000%	3.1935%	11.7695%
Trade balance	0.0000%	535.240%	226.785%	36.3660%
GDP	0.0000%	-0.4768%	0.1266%	23.7076%

Table A8. 8 Results of a removal of subsidies in the transportation sector, % change compared to base case (Table A8.1)

Period	1	2	3	4
Soil conservation on smallholdings tea sector				
Total	0.3792%			
Labor input	0.4584%			
Capital input	0.3558%			
Soil quality index				
Tea	0.0957%	0.0981%	0.1007%	0.1033%
Rubber	0.0000%	0.0000%	0.0000%	0.0000%
Coco	0.0000%	0.0000%	0.0000%	0.0000%
Prices				
Estate labor	-0.2638%	-0.3367%	-0.3994%	-0.3365%
Urban labor	-0.2089%	-0.3065%	-0.4089%	-0.4230%
Rural labor	-0.2126%	-0.2902%	-0.3695%	-0.3243%
Capital	-0.2430%	-0.3281%	-0.4154%	-0.3859%
Production				
Tea	0.7165%	0.8599%	0.9706%	0.9062%
Rubber	0.4753%	0.6191%	0.7477%	0.4619%
Coco	0.2270%	0.2843%	0.3182%	0.1611%
Colombo	0.1730%	0.2021%	0.2164%	0.0000%
Paddy	0.1373%	0.1620%	0.1690%	0.0010%
Other agri	0.1258%	0.1526%	0.1603%	0.1194%
Mining	0.1989%	0.2370%	0.2598%	0.0805%
Trade	0.2494%	0.2869%	0.3243%	-0.1604%
Service	0.1708%	0.2560%	0.3459%	0.4586%
Petroleum	0.2767%	0.4092%	0.5345%	0.7717%
Electricity	0.3715%	0.5851%	0.7009%	1.3542%
Disposable income				
Urban HH	0.8389%	0.9137%	0.9783%	
Rural HH	-0.2228%	-0.2721%	-0.3003%	
Estate HH	0.1496%	0.0970%	0.0448%	
Total income	0.1194%	0.1014%	0.0944%	0.1126%
Trade balance	1.0523%	-1.0704%	0.5671%	1.2535%
GDP	0.4224%	0.4412%	0.4477%	0.3813%

Table A8. 9 Results of a 10% increase in taxes in the Colombo Industrial sector, % change compared to base case (Table A8. 1)

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

MODEL CODE
THE STATIC MODEL OF DEFORESTATION IN COSTA RICA

```
GAMS 2.25.059  386/486 DOS                    11/13/96 15:49:44  PAGE
1
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 * CRONE - A ONE-PERIOD MODEL OF DEFORESTATION IN COSTA RICA
 * LAND CLEARING BY SQUATTERS AND LOGGING
 * ANNIKA PERSSON MAY 1993


  OPTION LIMROW=0
  OPTION LIMCOL=0

  OPTION SOLPRINT=OFF

  OPTION DECIMALS=5

 * ITERLIM=1;

  FILE RES /c:\123W\CRONE.prn/

  SET  T  Tradables production sectors

     / FOREST    FOREST
       AGRI      AGRICULTURE
       IND       INDUSTRY    /

     ALIAS(T,TT);
     DISPLAY TT;

  SET  N  Nontradables production sectors

     / INFRA     INFRASTRUCTURE
       SERVICE   SERVICES        /


       ALIAS(N,NN);

       DISPLAY NN ;


 *++++++++++++++++++++++
 *+++POLICY VARIABLES+++
 *++++++++++++++++++++++

  SCALAR FTAX0  Tax on LOGS 0          /0/

  SCALAR DTAX0  Tax on DLAND 0          /0.1/

  SCALAR LTAX0  Tax on SKILLED LABOR 0  /0/

```

```
  48
  49   SCALAR UTAX0  Tax on UNSKILLED LABOR 0 /0/
  50
  51   SCALAR KTAX0  Tax on CAPITAL  0       /0 /
  52
  53   PARAMETER TAX0(T)   Tax change on tradables  0
  54
GAMS 2.25.059  386/486 DOS                      11/13/96 15:49:44  PAGE
2
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


  55        /  FOREST     1.000
  56           AGRI       1.000
  57           IND        1.000  /
  58
  59
   60      SCALAR  HVALUE  Future  value  per  value  unit  forest  today
/0.5291631/
  61  *0.2791631/
  62
  63   SCALAR RAU   Time preference        /1/
  64
  65   SCALAR IRATE  /1/
  66
  67   SCALAR PRDEF Definition of property rights SQUATTERS / 0/
  68
  69   SCALAR PRDEFF Definition of property rights LOGGING   / 0 /
  70
  71
  72  *++++++++++++++++++++++++++++++++++++++++++++++++++*
  73  *  SUBMODEL FOR CALCULATION OF LOGGING PARAMETERS  *
  74  *++++++++++++++++++++++++++++++++++++++++++++++++++*
  75
  76   SCALAR AVSK          INITIAL LOGGING /0.00200/
  77   SCALAR LAB           INITIAL LABOR IN LOGGING /0.00093/
  78   SCALAR CAP           INITIAL CAPITAL IN LOGGING /0.00126/
  79   SCALAR LSQ           INITIAL LABOR IN SQUATTING /0.00180/
  80   SCALAR SQ0           INITIAL SQUATTING /0.00200/
  81
  82   VARIABLES
  83
  84   BETA                  LABOR INPUT IN LOGGING
  85   ALPHA                 CAPITAL INPUT IN LOGGING
  86   fpl                  RENT PAID TO LOGGERS
  87   fps                  RENT PAID TO SQUATTERS
  88   GAMMA                 LABOR INPUT SQUATTING
  89   psq
  90   plog;
  91
  92   EQUATIONS
  93   DEFLAB
  94   DEFCAP
  95   DEFAVSK
```

```
 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..    SQ0=e=LSQ**GAMMA;
105   DEFlsq..   GAMMA*LSQ**(GAMMA-1)-1=e=fps;
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
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


108
109
110   ALPHA.LO=0.00000001;
111   BETA.LO=0.00000001;
112   GAMMA.LO=0.0001;
113
114
115   ALPHA.L=0.5424;  psq.l=0.0020;
116   BETA.L=0.3878;   plog.l=-0.0019;
117   GAMMA.L=1.0604;  fpl.l=0.00031;
118   fps.l=0.9259;
119
120   MODEL DEF2 /all/;
121
122   SOLVE DEF2 USING NLP MAXIMIZING psq;
123
124   DISPLAY ALPHA.L, BETA.L, GAMMA.L, psq.l, plog.l, fpl.l, fps.l;
125
126  *++++++++++++++++++++++++++++++++++++++++++++++++++
127
128  *++++++++++++++++++++++++++++++++++++++++++++++++++
129
130  *+++++++++++++++**
131  *+++ BASE DATA +++
132  *+++++++++++++++**
133
134   TABLE XTT00(T,TT) Benchmark intermediate inputs of T in T
135
136                   FOREST     AGRI       IND
137
138        FOREST    0.00027    0.00220    0.03907
139        AGRI      0.00035    0.40326    0.24882
140        IND       0.01372    0.14052    0.73900
141
142   TABLE XTN00(T,N) Benchmark intermediate inputs of T in N
143
144                   INFRA      SERVICE
```

```
 145
 146          FOREST   0.00022    0.00000
 147          AGRI     0.00001    0.00003
 148          IND      0.34181    0.13432
 149
 150    TABLE XNT00(N,T) Benchmark intermdiate inputs of N in T
 151
 152                   FOREST     AGRI       IND
 153
 154          INFRA    0.00043    0.02934    0.08264
 155          SERVICE  0.00377    0.06020    0.15460
 156
 157    TABLE XNN00(N,NN) Benchmark intermediate inputs of N in N
 158
 159                   INFRA      SERVICE
 160
GAMS 2.25.059  386/486 DOS                        11/13/96 15:49:44  PAGE
4
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 161          INFRA    0.06470    0.06841
 162          SERVICE  0.14867    0.21596
 163
 164    PARAMETER TTAX00(T) Benchmark tax in T-sectors
 165
 166        / FOREST   0.00251
 167          AGRI     0.07468
 168          IND      0.11448   /
 169
 170    PARAMETER NTAX00(N) Benchmark tax in N-sectors
 171
 172        / INFRA    0.05800
 173          SERVICE  0.12763/
 174
 175    PARAMETER KT00(T)  Benchmark allocation of CAPITAL to T-sectors
 176
 177        / FOREST       0.01762
 178          AGRI         0.20524
 179          IND          0.21675 /
 180
 181    PARAMETER KN00(N)  Benchmark allocation of CAPITAL to N-sectors
 182        / INFRA        0.16330
 183          SERVICE      0.52563  /
 184
 185    PARAMETER UT00(T)  Benchmark allocation of UNSKILLED LABOR to T-
sectors
 186
 187        / FOREST       0.01414
 188          AGRI         0.27140
 189          IND          0.15247  /
 190
 191    PARAMETER UN00(N)  Benchmark allocation of UNSKILLED LABOR to N-
sectors
```

```
 192
 193        / INFRA        0.17544
 194          SERVICE      0.14388   /
 195
 196
 197    PARAMETER LT00(T)  Benchmark allocation of SKILLED LABOR to T-
sectors
 198
 199        / FOREST       0.00024
 200          AGRI         0.00454
 201          IND          0.09989  /
 202
 203    PARAMETER LN00(N)  Benchmark allocation of SKILLED LABOR to N-
sectors
 204
 205        / INFRA        0.12992
 206          SERVICE      0.49037 /
 207
 208   PARAMETER FLT00(T)  Benchmark allocation of LOGS to T-sectors
 209        /  FOREST 0.00219 /
 210   DISPLAY FLT00;
 211
 212
 213   PARAMETER FLN00(N)  Benchmark allocation of LOGS to N-sectors
GAMS 2.25.059  386/486 DOS                        11/13/96 15:49:44  PAGE
5
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 214
 215        / INFRA        0
 216          SERVICE      0          /
 217
 218   PARAMETER DLT00(T)  Benchmark allocation of DLAND to T-sectors;
 219       DLT00('AGRI')=0.20704;
 220   DISPLAY DLT00;
 221
 222   PARAMETER DLN00(N)  Benchmark allocation of DLAND to N-sectors
 223
 224        / INFRA        0
 225          SERVICE      0  /
 226
 227    PARAMETER XT00(T)  Benchmark tradables production level
 228
 229        / FOREST       0.05524
 230          AGRI         1.39842
 231          IND          1.84772 /
 232
 233
 234    PARAMETER  XN00(N) Benchmark nontradables production level
 235
 236        / INFRA        1.08207
 237          SERVICE      1.70623  /
 238
```

```
 239    PARAMETER DT00(T)  Benchmark consumption of tradables
 240
 241       / FOREST       0.01241
 242         AGRI         0.35352
 243         IND          1.44260  /
 244
 245
 246   PARAMETER DN00(N)  Benchmark consumption of nontradables
 247
 248       /  INFRA        0.83655
 249          SERVICE      1.12303 /
 250
 251   PARAMETER ZT00(T)  Benchmark net export level
 252
 253        / FOREST       0.00107
 254          AGRI         0.39243
 255          IND         -0.96425 /
 256
 257  *+++++++++++++++++++++++++++++++++++++++++++++++++**
 258  *+++ CALCULATION OF COEFFICIENTS AND PARAMETERS +++
 259  *+++++++++++++++++++++++++++++++++++++++++++++++++**
 260
 261   PARAMETER ATT(TT,T) Input of tradables in tradable sectors;
 262       ATT(T,TT)=XTT00(T,TT)/XT00(TT);
 263   PARAMETER ATN(TT,NN) Input of tradables in nontradable sectors;
 264       ATN(T,N)=XTN00(T,N)/XN00(N);
 265
 266   PARAMETER ANT(NN,TT)  Input of nontradables in tradable sectors;
GAMS 2.25.059  386/486 DOS                        11/13/96 15:49:44  PAGE
6
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 267       ANT(N,T)=XNT00(N,T)/XT00(T);
 268
 269     PARAMETER  ANN(NN,N)   Input  of  nontradables  in  nontradables
sectors;
 270       ANN(N,NN)=XNN00(N,NN)/XN00(NN);
 271
 272   PARAMETER TTAX0(TT)   Unit tax in tradable sectors;
 273       TTAX0(T)=TTAX00(T)/XT00(T)*TAX0(T);
 274
 275   PARAMETER NTAX0(NN)  Unit tax in nontradable sectors;
 276       NTAX0(N)=NTAX00(N)/XN00(N);
 277
 278   PARAMETER KXT0(TT) Benchmark input coefficients for CAPITAL;
 279       KXT0(T)=KT00(T)/XT00(T);
 280
 281   PARAMETER KXN0(NN) Benchmark input coefficients for CAPITAL;
 282       KXN0(N)=KN00(N)/XN00(N);
 283
 284    PARAMETER  UXT0(TT)  Benchmark  input  coefficients  for  UNSKILLED
LABOR;
 285       UXT0(T)=UT00(T)/XT00(T);
```

```
 286
 287    PARAMETER UXN0(NN) Benchmark input coefficients for UNSKILLED
LABOR;
 288       UXN0(N)=UN00(N)/XN00(N);
 289
 290     PARAMETER LXT0(TT) Benchmark input coefficients for SKILLED
LABOR;
 291       LXT0(T)=LT00(T)/XT00(T);
 292
 293     PARAMETER LXN0(NN) Benchmark input coefficients for SKILLED
LABOR;
 294       LXN0(N)=LN00(N)/XN00(N);
 295
 296   PARAMETER FXT0(TT) Benchmark input coefficients for LOGS;
 297       FXT0('FOREST')=FLT00('FOREST')/XT00('FOREST');
 298
 299   PARAMETER FXN0(NN) Benchmark input coefficients for LOGS;
 300       FXN0(N)=FLN00(N)/XN00(N);
 301
 302   PARAMETER DXT0(TT) Benchmark input coefficients for DLAND;
 303       DXT0(T)=DT00(T)/XT00(T);
 304
 305   PARAMETER DXN0(NN) Benchmark input coefficients for DLAND;
 306       DXN0(N)=DN00(N)/XN00(N);
 307
 308   PARAMETER AT(T)   Tradable production function scale parameter;
 309       AT(TT)=1-SUM(T,ATT(T,TT))-SUM(N,ANT(N,TT))-TTAX0(TT);
 310   DISPLAY AT;
 311
 312   PARAMETER AN(N)  Nontradable production function scale parameter;
 313       AN(NN)=1-SUM(T,ATN(T,NN))-SUM(N,ANN(N,NN))-NTAX0(NN);
 314   DISPLAY AN;
 315
 316   PARAMETER DELKRT(TT)  CAPITAL share in tradable KD;
 317       DELKRT(T)=KT00(T)/(KT00(T)+DLT00(T));
 318
 319   PARAMETER DELDRT(TT);
GAMS 2.25.059  386/486 DOS                      11/13/96 15:49:44  PAGE
7
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 320        DELDRT(T)=1-DELKRT(T);
 321
 322   PARAMETER DELKRN(NN)  CAPITAL share in nontradable KD;
 323        DELKRN(N)=KN00(N)/(KN00(N)+DLN00(N));
 324
 325   PARAMETER DELDRN(NN);
 326       DELDRN(N)=1-DELKRN(N);
 327
 328   PARAMETER DELFMT(TT)  LOGS share in tradable FR;
 329        DELFMT(T)=FLT00(T)/(FLT00(T)+DLT00(T)+KT00(T));
 330
 331   PARAMETER DELRMT(TT);
```

```
 332        DELRMT(T)=1-DELFMT(T);
 333
 334    PARAMETER DELFMN(NN)  LOGS share in nontradable FR substitution;
 335        DELFMN(N)=FLN00(N)/(FLN00(N)+DLN00(N)+KN00(N));
 336
 337    PARAMETER DELRMN(NN);
 338        DELRMN(N)=1-DELFMN(N);
 339
 340    PARAMETER DELUVT(TT)  UNSKILLED LABOR share in tradable UY;
 341        DELUVT(T)=UT00(T)/(UT00(T)+FLT00(T)+DLT00(T)+KT00(T));
 342
 343    PARAMETER DELMVT(TT);
 344        DELMVT(T)=1-DELUVT(T);
 345
 346    PARAMETER DELUVN(NN)  UNSKILLED LABOR share in nontradable UY;
 347        DELUVN(N)=UN00(N)/(UN00(N)+FLN00(N)+DLN00(N)+KN00(N));
 348
 349    PARAMETER DELMVN(NN);
 350        DELMVN(N)=1-DELUVN(N);
 351
 352    PARAMETER DELLYT(TT)  SKILLED LABOR share in tradable LV;
                                                                      353
DELLYT(T)=LT00(T)/(LT00(T)+UT00(T)+FLT00(T)+DLT00(T)+KT00(T));
 354
 355    PARAMETER DELVYT(TT);
 356        DELVYT(T)=1-DELLYT(T);
 357
 358    PARAMETER DELLYN(NN)   SKILLED LABOR share in nontradable LV;
                                                                      359
DELLYN(N)=LN00(N)/(LN00(N)+UN00(N)+DLN00(N)+FLN00(N)+KN00(N));
 360
 361    PARAMETER DELVYN(NN);
 362       DELVYN(N)=1-DELLYN(N);
 363
 364   PARAMETER BT(TT)  B-coefficient in U;
 365       BT(T)=DT00(T)/(SUM(TT,DT00(TT))+SUM(N,DN00(N)));
 366
 367   PARAMETER  BN(NN) B-coefficient in u;
 368       BN(N)=DN00(N)/(SUM(T,DT00(T))+SUM(NN,DN00(NN)));
 369   DISPLAY BN;
 370
 371   PARAMETER K0  CAPITAL endowment 0;
 372       K0=1.12980;
GAMS 2.25.059  386/486 DOS                    11/13/96 15:49:44  PAGE
8
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 373
 374   PARAMETER U0     UNSKILLED LABOR endowment 0;
 375       U0=.76006;
 376
 377
 378   PARAMETER L0     SKILLED LABOR endowment 0;
```

```
 379        L0=.72496;
 380
 381
 382    PARAMETER DSTAR DLAND endowment 0;
 383        DSTAR=0.20524;
 384
 385    PARAMETER SBAR0  current account surplus 0;
 386
 387        SBAR0=-0.57075;
 388
 389    PARAMETER UTIL00 ;
                                                                        390
UTIL00=LOG(PROD(T,(BT(T)*3.76811)**BT(T))*PROD(N,(BN(N)*3.76811)

**BN(N)));
 391    DISPLAY UTIL00;
 392
 393   *++++++++++++++++++++++++++++++++++
 394   *+++ELASTICITIES OF SUBSTITUTION+++
 395   *++++++++++++++++++++++++++++++++++
 396
 397    PARAMETER SIGRT(T)   Elasticity of tradable KD substitution
 398
 399       /  FOREST       0
 400          AGRI         0.500
 401          IND          0     /
 402
 403     PARAMETER SIGRN(N)   Elasticity of nontradable KD substitution
 404
 405        / INFRA        0
 406          SERVICE      0   /
 407
 408
 409
 410     PARAMETER SIGMT(T)   Elasticity of tradable FR substitution
 411
 412        / FOREST       0.800
 413          AGRI         0
 414          IND          0     /
 415
 416     PARAMETER SIGMN(N)   Elasticity of nontradable FR substitution
 417
 418        / INFRA        0
 419          SERVICE      0   /
 420
 421     PARAMETER SIGVT(T)  Elasticity of tradable UY substitution
 422
 423        / FOREST       0.800
 424          AGRI         0.800
GAMS 2.25.059  386/486 DOS                      11/13/96 15:49:44  PAGE
9
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n
```

```
425          IND          0.800 /
426
427    PARAMETER SIGVN(N)  Elasticity of nontradable UY substitution
428
429       / INFRA        0.800
430         SERVICE      0.800  /
431
432    PARAMETER SIGYT(T)   Elasticity of tradable LV substitution
433
434       / FOREST      0.800
435         AGRI        0.800
436         IND         0.800   /
437
438   PARAMETER SIGYN(N)   Elasticity of nontradable LV substitution
439
440      /  INFRA       0.800
441         SERVICE     0.800   /
442
443   PARAMETER EPSI(N)  Price elasticity of export demand
444
445      /  INFRA       -5.000
446         SERVICE     -5.000 /
447
448   PARAMETER MY(N)   Price elasticty of import demand
449
450       / INFRA          2.000
451         SERVICE        2.000  /
452
453
454
455  *+++++++++++++++++++++++++
456  *+++EXOGENOUS VARIABLES+++
457  *+++++++++++++++++++++++++
458   PARAMETER PWF      WM price of logs ;
459       PWF=1.0000;
460
461   PARAMETER PW(T)    World market price of tradables
462
463      / FOREST    1.0000
464        AGRI      1.0000
465        IND       1.0000  /
466
467   PARAMETER PWE(N)   World market price of nontradables
468
469      / INFRA     1.0000
470        SERVICE   1.0000  /
471
472
473   PARAMETER ZN0(N)   Export function constant
474
475     / INFRA       0.02746    /
476
477  *+++++++++++++++
```

General Algebraic Modeling System
Compilation

```
478  *+++VARIABLES+++
479  *+++++++++++++++
480
481   VARIABLES
482
483   UTIL0        UTILITY PERIOD 0
484
485   DISP0        DISPOSABLE INCOME PERIOD 0
486
487   DOSQ0        DLAND produced by deforestation 0
488
489   FOSQ0        LOGS deforested 0
490
491   FLOG0        LOGGING 0
492
493   LSQ0         UNSKILLED LABOR input in deforestation by SQUATTERS 0
494
495   LOGL0        UNSKILLED LABOR input in deforestation by LOGGERS
496
497   LGK0         CAPITAL input in deforestation by LOGGERS
498
499   FEXP0        Net export of LOGS
500
501   F0           Deforestation
502
503   D0           Supply of DLAND
504
505   PUDL0        User price of DLAND
506
507   PFL0         Supply price of LOGS including future value
508
509   PUFL0        User price of LOGS including future value and taxes
510
511   PUK0         User price of CAPITAL
512
513   PUL0         User price of SKILLED LABOR
514
515   PUU0         User price of UNSKILLED LABOR
516
517   XT0(T)        Output in tradable sectors
518
519   XN0(N)        Output in non-tradable sectors
520
521   ZT0(T)        Net export of tradables
522
523   DT0(T)        Consumption demand for tradables
524
525   DN0(N)        Consumption demand for nontradables
526
527   KT0(T)        CAPITAL input in tradable sectors
528
```

```
 529   KN0(N)        CAPITAL input in nontradable sectors
 530
GAMS 2.25.059  386/486 DOS                      11/13/96 15:49:44  PAGE
11
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 531   UT0(T)        UNSKILLED LABOR demand in tradable sectors
 532
 533   UN0(N)        UNSKILLED LABOR demand in non-tradable sectors
 534
 535   LLT0(T)       SKILLED LABOR demand in tradable sectors
 536
 537   LN0(N)        SKILLED LABOR demand in non-tradable sectors
 538
 539   FLT0(T)       LOGS demand in tradable sectors
 540
 541   DLT0(T)       DLAND demand in tradable sectors
 542
 543   MCT0(T)       Marginal cost in tradable production
 544
 545   MCN0(N)       Marginal cost in nontradable production
 546
 547   PPN0(N)       Producer price of nontradable output
 548
 549   PN0(N)        User price of composite nontradables
 550
 551   PYT0(T)       Implicit price of Y(T)
 552
 553   PYN0(N)       Implicit price of Y(N)
 554
 555   PVT0(T)       Implicit price of V(T)
 556
 557   PVN0(N)       Implicit price of V(N)
 558
 559   PMT0(T)       Implicit price of M(T)
 560
 561   PMN0(N)       Implicit price of M(N)
 562
 563   PRT0(T)       Implicit price of R(T)
 564
 565   PRN0(N)       Implicit price of R(N)
 566
 567   PK0           Supply price of CAPITAL services
 568
 569   PU0           Supply price of UNSKILLED LABOR services
 570
 571   PL0           Supply price of SKILLED LABOR services
 572
 573   PDL0          Supply price of DLAND services
 574
 575   DPXDPUT0(T)   Partial of PX wrt PUU(T)
 576
 577   DPXDPUN0(N)   Partial of PX wrt PUU(N)
```

```
 578
 579   DPXDPLT0(T)  Partial of PX wrt PUL(T)
 580
 581   DPXDPLN0(N)  Partial of PX wrt PUL(N)
 582
 583   DPXDPKT0(T)  Partial of PX wrt PUK(T)
GAMS 2.25.059  386/486 DOS                    11/13/96 15:49:44  PAGE
12
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 584
 585   DPXDPKN0(N)  Partial of PX wrt PUK(N)
 586
 587   DPXDPFT0(T)  Partial of PX wrt PUFL(T)
 588
 589   DPXDPFN0(N)  Partial of PX wrt PUFL(N)
 590
 591   DPXDPDT0(T)  Partial of PX wrt PUDL(T)
 592
 593   DPXDPDN0(N)  Partial of PX wrt PUDL(N)
 594
 595   DPYDPVT0(T)  Partial of PY wrt PV(T)
 596
 597   DPYDPVN0(N)  Partial of PY wrt PV(N)
 598
 599   DPYDPLT0(T)  Partial of PY wrt PUL(T)
 600
 601   DPYDPLN0(N)  Partial of PY wrt PUL(N)
 602
 603   DPVDPMT0(T)  Partial of PV wrt PM(T)
 604
 605   DPVDPMN0(N)  Partial of PV wrt PM(N)
 606
 607   DPVDPUT0(T)  Partial of PV wrt PUU(T)
 608
 609   DPVDPUN0(N)  Partial of PV wrt PUU(N)
 610
 611   DPMDPRT0(T)  Partial of PM wrt PR(T)
 612
 613   DPMDPRN0(N)  Partial of PM wrt PR(N)
 614
 615   DPMDPFT0(T)  Partial of PM wrt PUFL(T)
 616
 617   DPMDPFN0(N)  Partial of PM wrt PUFL(N)
 618
 619   DPRDPKT0(T)  Partial of PR wrt PUK(T)
 620
 621   DPRDPKN0(N)  Partial of PR wrt PUK(N)
 622
 623   DPRDPDT0(T)  Partial of PR wrt PUDL(T)
 624
 625   DPRDPDN0(N)  Partial of PR wrt PUDL(N)
 626
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```
 627   YY0          GNP
 628
 629
 630   POSITIVE VARIABLES   XT0, LSQ0,DOSQ0, FLOG0;
 631
 632  *+++++++++++++++
 633  *+++EQUATIONS+++
 634  *+++++++++++++++
 635
 636   EQUATIONS
GAMS 2.25.059  386/486 DOS                      11/13/96 15:49:44  PAGE
13
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 637
 638   DEFUTIL0         Definition of UTIL0
 639
 640   DEFDOSQ0         Definition of DOSQ
 641
 642   DEFLSQ0          Definition of LSQ
 643
 644   DEFLOGF0         Definition of FLOG
 645
 646   DEFLOGL0         Definition of LOGL
 647
 648   DEFLGK0          Definition of LGK
 649
 650   PRLF0            Price condition LOGS
 651
 652   COMPLF0          Complementary condition LOGS
 653
 654   DEFF0            Definition of total deforestation
 655
 656   DEFD0            Definition of supply of DLAND
 657
 658   DEFPUDL0         Definition of PUDL
 659
 660   DEFPUFL0         Definition of PUFL
 661
 662   DEFPUK0          Definition of PUK
 663
 664   DEFPUL0          Definition of PUL
 665
 666   DEFPUU0          Definition of PUU
 667
 668   DEFPYT0(T)       Definition of PYT
 669
 670   DEFPYN0(N)       Definition of PYN
 671
 672   DEFPVT0(T)       Definition of PVT
 673
 674   DEFPVN0(N)       Definition of PVN
 675
```

```
 676   DEFPMT0(T)        Definition of PMT
 677
 678   DEFPMN0(N)        Definition of PMN
 679
 680   DEFPRT0(T)        Definition of PRT
 681
 682   DEFPRN0(N)        Definition of PRN
 683
 684   DDPYDPLT0(T)   Definition of DPYDPLT
 685
 686   DDPYDPLN0(N)   Definition of DPYDPLN
 687
 688   DDPYDPVT0(T)   Definition of DPYDPVT
 689
GAMS 2.25.059  386/486 DOS                      11/13/96 15:49:44  PAGE
14
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 690   DDPYDPVN0(N)   Definition of DPYDPVN
 691
 692   DDPVDPUT0(T)   Definition of DPVDPUT
 693
 694   DDPVDPUN0(N)   Definition of DPVDPUN
 695
 696   DDPVDPMT0(T)   Definition of DPVDPMT
 697
 698   DDPVDPMN0(N)   Definition of DPVDPMN
 699
 700   DDPMDPRT0(T)   Definition of DPMDPRT
 701
 702   DDPMDPRN0(N)   Definition of DPMDPRN
 703
 704   DDPMDPFT0(T)   Definition of DPMDPFT
 705
 706   DDPMDPFN0(N)   Definition of DPMDPFN
 707
 708   DDPRDPKT0(T)   Definition of DPRDPKT
 709
 710   DDPRDPKN0(N)   Definition of DPRDPKN
 711
 712   DDPRDPDT0(T)   Definition of DPRDPDT
 713
 714   DDPRDPDN0(N)   Definition of DPRDPDN
 715
 716   DDPXDPDT0(T)   Definition of DPXDPDT
 717
 718   DDPXDPDN0(N)   Definition of DPXDPDN
 719
 720   DDPXDPFT0(T)   Definition of DPXDPFT
 721
 722   DDPXDPFN0(N)   Definition of DPXDPFN
 723
 724   DDPXDPKT0(T)   Definition of DPXDPKT
```

```
 725
 726   DDPXDPKN0(N)    Definition of DPXDPKN
 727
 728   DDPXDPLT0(T)    Definition of DPXDPLT
 729
 730   DDPXDPLN0(N)    Definition of DPXDPLN
 731
 732   DDPXDPUT0(T)    Definition of DPXDPUT
 733
 734   DDPXDPUN0(N)    Definition of DPXDPUN
 735
 736   DEFMCT0(T)        Definition of marginal cost in tradables prod
 737
 738   DEFMCN0(N)        Definition of marginal cost in nontradables prod
 739
 740   DEFPN0(N)         Definition of user price of nontradables
 741
 742     PRLMCT0(T)            Producer price marginal cost inequality
condition
GAMS 2.25.059  386/486 DOS                      11/13/96 15:49:44  PAGE
15
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 743
 744   COMPL0(T)         Complementary condition for tradables
 745
 746   PREMCN0           Producer price marginal cost equality condition
 747
 748   LDEMANDT0(T)      Tradable demand for SKILLED LABOR
 749
 750   LDEMANDN0(N)      Nontradable demand for SKILLED LABOR
 751
 752   UDEMANDT0(T)      Tradable demand for UNSKILLED LABOR
 753
 754   UDEMANDN0(N)      Nontradable demand for UNSKILLED LABOR
 755
 756   FDEMANDT0(T)      Tradable demand for LOGS
 757
 758   KDEMANDT0(T)      Tradable demand for CAPITAL
 759
 760   KDEMANDN0(N)      Nontradable demand for CAPITAL
 761
 762   DDEMANDT0(T)      Tradable demand for DLAND
 763
 764   TCONS0(T)         Consumption demand for tradables
 765
 766   NCONS0(N)         Consumption demand for nontradables
 767
 768   TMARKET0(T)       Market clearing for tradables
 769
 770   NMARKET0(N)       Market clearing for nontradables
 771
 772   FMARKET0          Market clearing for LOGS
```

```
 773
 774   DMARKET0          Market clearing for DLAND
 775
 776  * DCOMPL0           Complementary condition DLAND
 777
 778   CMARKET0          Market clearing for CAPITAL
 779
 780   LMARKET0          Market clearing for SKILLED LABOR
 781
 782   UMARKET0          Market clearing for UNSKILLED LABOR
 783
 784   DEFGNP0           Definition of GNP
 785
 786   INCOME0           Definition of disposable income;
 787
 788   DEFUTIL0..        UTIL0=E=LOG(PROD(T,(BT(T)*DISP0/PW(T))**BT(T))*
                                                                        789
PROD(N,(BN(N)*DISP0/PN0(N))**BN(N)));
 790
 791   DEFDOSQ0..        DOSQ0=E=LSQ0**GAMMA;
 792
  793       DEFLSQ0..                    GAMMA*PDL0*LSQ0**(GAMMA-1)-PL0-
PRDEF*GAMMA*HVALUE/IRATE
 794                     =e=fps;
 795
GAMS 2.25.059  386/486 DOS                        11/13/96 15:49:44  PAGE
16
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 796   DEFLOGF0..        FLOG0=E=LGK0**ALPHA*LOGL0**BETA;
 797
    798              DEFLOGL0..                                     LOGL0-
((PU0+PRDEFF*BETA*LGK0**ALPHA*LOGL0**(BETA-1)
                                                                        799
*(HVALUE/IRATE))/(BETA*(PFL0)*LGK0**ALPHA))**(1/(BETA-1)

)
 800                    =e=fpl;
 801
  802      DEFLGK0..                LGK0-((PK0+PRDEFF*ALPHA*LGK0**(ALPHA-
1)*LOGL0**BETA
 803                    *(HVALUE/IRATE))/(ALPHA*(PFL0)*LOGL0**BETA))

**(1/(ALPHA-1))
 804                    =e=fpl;
 805
 806   PRLF0..           PWF-PFL0=L=0;
 807
 808   COMPLF0..         FLOG0*(PWF-PFL0)=E=0;
 809
 810   DEFPUFL0..        PUFL0=E=PWF*(1+FTAX0);
 811
 812   DEFPUDL0..        PUDL0=E=PDL0*(1+DTAX0);
```

```
813
814   DEFPUK0..          PUK0=E=PK0*(1+KTAX0);
815
816   DEFPUL0..          PUL0=E=PL0*(1+LTAX0);
817
818   DEFPUU0..          PUU0=E=PU0*(1+UTAX0);
819
820   DEFPYT0(T)..       PYT0(T)=E=(DELLYT(T)*PUL0**
821                     (1-SIGYT(T))+(1-DELLYT(T))*PVT0(T)**
822                     (1-SIGYT(T)))**(1/(1-SIGYT(T)));
823
824   DEFPYN0(N)..       PYN0(N)=E=(DELLYN(N)*PUL0**
825                     (1-SIGYN(N))+(1-DELLYN(N))*PVN0(N)**
826                     (1-SIGYN(N)))**(1/(1-SIGYN(N)));
827
828   DEFPVT0(T)..       PVT0(T)=E=(DELUVT(T)*PUU0**(1-SIGVT(T))+
829                     (1-DELUVT(T))*PMT0(T)**
830                     (1-SIGVT(T)))**(1/(1-SIGVT(T)));
831
832   DEFPVN0(N)..       PVN0(N)=E=(DELUVN(N)*PUU0**(1-SIGVN(N))+
833                     (1-DELUVN(N))*PMN0(N)**
834                     (1-SIGVN(N)))**(1/(1-SIGVN(N)));
835
836   DEFPMT0(T)..       PMT0(T)=E=(DELFMT(T)*PUFL0**(1-SIGMT(T))+
837                     (1-DELFMT(T))*PRT0(T)**
838                     (1-SIGMT(T)))**(1/(1-SIGMT(T)));
839
840   DEFPMN0(N)..       PMN0(N)=E=(DELFMN(N)*PUFL0**(1-SIGMN(N))+
841                     (1-DELFMN(N))*PRN0(N)**
842                     (1-SIGMN(N)))**(1/(1-SIGMN(N)));
843
844   DEFPRT0(T)..       PRT0(T)=E=(DELKRT(T)*PUK0**(1-SIGRT(T))
845                    +(1-DELKRT(T))*PUDL0**
846                    (1-SIGRT(T)))**(1/(1-SIGRT(T)));
```



```
847
848   DEFPRN0(N)..       PRN0(N)=E=(DELKRN(N)*PUK0**(1-SIGRN(N))
849                    +(1-DELKRN(N))*PUDL0**
850                    (1-SIGRN(N)))**(1/(1-SIGRN(N)));
851
852   DDPYDPLT0(T).. DPYDPLT0(T)=E=DELLYT(T)*(PYT0(T)
853                    **SIGYT(T))*(PUL0**(-SIGYT(T)));
854
855   DDPYDPLN0(N).. DPYDPLN0(N)=E=DELLYN(N)*(PYN0(N)
856                    **SIGYN(N))*(PUL0**(-SIGYN(N)));
857
858   DDPYDPVT0(T).. DPYDPVT0(T)=E=(1-DELLYT(T))*(PYT0(T)
859                  **SIGYT(T))*(PVT0(T)**(-SIGYT(T)));
860
861   DDPYDPVN0(N).. DPYDPVN0(N)=E=(1-DELLYN(N))*(PYN0(N)
```

```
 862                  **SIGYN(N))*(PVN0(N)**(-SIGYN(N)));
 863
 864   DDPVDPMT0(T).. DPVDPMT0(T)=E=(1-DELUVT(T))*(PVT0(T)**
 865                   SIGVT(T))*(PMT0(T)**(-SIGVT(T)));
 866
 867   DDPVDPMN0(N).. DPVDPMN0(N)=E=(1-DELUVN(N))*(PVN0(N)**
 868                   SIGVN(N))*(PMN0(N)**(-SIGVN(N)));
 869
 870   DDPVDPUT0(T).. DPVDPUT0(T)=E=DELUVT(T)*(PVT0(T)**SIGVT(T))*
 871                  (PUU0**(-SIGVT(T)));
 872
 873   DDPVDPUN0(N).. DPVDPUN0(N)=E=DELUVN(N)*(PVN0(N)**SIGVN(N))*
 874                  (PUU0**(-SIGVN(N)));
 875
 876   DDPMDPRT0(T).. DPMDPRT0(T)=E=(1-DELFMT(T))*(PMT0(T)**
 877                   SIGMT(T))*(PRT0(T)**(-SIGMT(T)));
 878
 879   DDPMDPRN0(N).. DPMDPRN0(N)=E=(1-DELFMN(N))*(PMN0(N)**
 880                  SIGMN(N))*(PRN0(N)**(-SIGMN(N)));
 881
 882   DDPMDPFT0(T).. DPMDPFT0(T)=E=DELFMT(T)*(PMT0(T)**SIGMT(T))*
 883                   (PUFL0**(-SIGMT(T)));
 884
 885   DDPMDPFN0(N).. DPMDPFN0(N)=E=DELFMN(N)*(PMN0(N)**SIGMN(N))*
 886                   (PUFL0**(-SIGMN(N)));
 887
 888   DDPRDPKT0(T).. DPRDPKT0(T)=E=DELKRT(T)*(PRT0(T)**SIGRT(T))*
 889                  (PUK0**(-SIGRT(T)));
 890
 891   DDPRDPKN0(N).. DPRDPKN0(N)=E=DELKRN(N)*(PRN0(N)**SIGRN(N))*
 892                  (PUK0**(-SIGRN(N)));
 893
 894   DDPRDPDT0(T).. DPRDPDT0(T)=E=(1-DELKRT(T))*(PRT0(T)**SIGRT(T))
 895                  *(PUDL0**(-SIGRT(T)));
 896
 897   DDPRDPDN0(N).. DPRDPDN0(N)=E=(1-DELKRN(N))*(PRN0(N)**SIGRN(N))*
 898                   (PUDL0**(-SIGRN(N)));
 899
GAMS 2.25.059  386/486 DOS                        11/13/96 15:49:44  PAGE
18
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 900   DDPXDPDT0(T)..  DPXDPDT0(T)=E=AT(T)*DPYDPVT0(T)*DPVDPMT0(T)
 901                   *DPMDPRT0(T)*DPRDPDT0(T);
 902
             903                                          DDPXDPDN0(N)..
DPXDPDN0(N)=E=AN(N)*DPYDPVN0(N)*DPVDPMN0(N)*DPMDPRN0(N)*
 904                    DPRDPDN0(N);
 905
             906                                          DDPXDPKT0(T)..
DPXDPKT0(T)=E=AT(T)*DPYDPVT0(T)*DPVDPMT0(T)*DPMDPRT0(T)*
 907                    DPRDPKT0(T);
 908
```

```
                909                                                DDPXDPKN0(N)..
DPXDPKN0(N)=E=AN(N)*DPYDPVN0(N)*DPVDPMN0(N)*DPMDPRN0(N)*
 910                        DPRDPKN0(N);
 911
                912                                                DDPXDPFT0(T)..
DPXDPFT0(T)=E=AT(T)*DPYDPVT0(T)*DPVDPMT0(T)*DPMDPFT0(T);
 913
                914                                                DDPXDPFN0(N)..
DPXDPFN0(N)=E=AN(N)*DPYDPVN0(N)*DPVDPMN0(N)*DPMDPFN0(N);
 915
 916    DDPXDPUT0(T).. DPXDPUT0(T)=E=AT(T)*DPYDPVT0(T)*DPVDPUT0(T);
 917
 918    DDPXDPUN0(N).. DPXDPUN0(N)=E=AN(N)*DPYDPVN0(N)*DPVDPUN0(N);
 919
 920    DDPXDPLT0(T).. DPXDPLT0(T)=E=AT(T)*DPYDPLT0(T);
 921
 922    DDPXDPLN0(N).. DPXDPLN0(N)=E=AN(N)*DPYDPLN0(N);
 923
 924    DEFMCT0(T)..       MCT0(T)=E=AT(T)*PYT0(T)+SUM(TT,PW(TT)*
 925                       ATT(TT,T))+SUM(N,PN0(N)*ANT(N,T))+TTAX0(T);
 926
 927    DEFMCN0(N)..       MCN0(N)=E=AN(N)*PYN0(N)+SUM(TT,PW(TT)*
 928                       ATN(TT,N))+SUM(NN,PN0(NN)*ANN(NN,N))+NTAX0(N);
 929
 930    DEFPN0(N)..        PN0(N)=E=PPN0(N);
 931
 932    PRLMCT0(T)..       PW(T)-MCT0(T)=L=0;
 933
 934    COMPL0(T)..        XT0(T)*(PW(T)-MCT0(T))=E=0;
 935
 936    PREMCN0(N)..       PPN0(N)-MCN0(N)=E=0;
 937
 938    LDEMANDT0(T)..     LLT0(T)=E=DPXDPLT0(T)*XT0(T);
 939
 940    LDEMANDN0(N)..     LN0(N)=E=DPXDPLN0(N)*XN0(N);
 941
 942    UDEMANDT0(T)..     UT0(T)=E=DPXDPUT0(T)*XT0(T);
 943
 944    UDEMANDN0(N)..     UN0(N)=E=DPXDPUN0(N)*XN0(N);
 945
 946    FDEMANDT0(T)..     FLT0(T)=E=DPXDPFT0(T)*XT0(T);
 947
 948    DDEMANDT0(T)..     DLT0(T)=E=DPXDPDT0(T)*XT0(T);
 949
 950    KDEMANDT0(T)..     KT0(T)=E=DPXDPKT0(T)*XT0(T);
 951
 952    KDEMANDN0(N)..     KN0(N)=E=DPXDPKN0(N)*XN0(N);
GAMS 2.25.059  386/486 DOS                        11/13/96 15:49:44  PAGE
19
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 953
 954    TCONS0(T)..        DT0(T)=E=BT(T)*DISP0/PW(T);
```

```
 955
 956   NCONS0(N)..        DN0(N)=E=BN(N)*DISP0/PN0(N);
 957
              958                                                TMARKET0(T)..
XT0(T)=E=SUM(TT,ATT(T,TT)*XT0(TT))+SUM(N,ATN(T,N)*
 959                     XN0(N))+ZT0(T)+DT0(T);
 960
 961   NMARKET0(N)..     XN0(N)=E=SUM(T,ANT(N,T)
 962                    *XT0(T))+SUM(NN,ANN(N,NN)*XN0(NN))+DN0(N);
 963
 964   DEFD0..           D0=E=DSTAR+LSQ0;
 965
 966   DEFF0..           F0=E=FLOG0+DOSQ0;
 967
 968
 969   FMARKET0..        LOGL0+LGK0=E=SUM(T,FLT0(T))+PWF*FEXP0;
 970
 971   DMARKET0..        SUM(T,DLT0(T))-DSTAR-LSQ0=E=0;
 972
 973   CMARKET0..        K0=E=SUM(T,KT0(T))+SUM(N,KN0(N))+LGK0;
 974
 975   LMARKET0..        L0=E=SUM(T,LLT0(T))+SUM(N,LN0(N));
 976
 977   UMARKET0..        U0=E=SUM(T,UT0(T))+SUM(N,UN0(N))+LOGL0+LSQ0;
 978
 979   INCOME0..         SUM(T,PW(T)*ZT0(T))+PWF*FEXP0=E=SBAR0;
 980
               981                                                DEFGNP0..
PUK0*K0+PUL0*L0+PUU0*U0+PUDL0*DSTAR+SUM(T,TTAX0(T)*
 982                    XT0(T))+SUM(N,NTAX0(N)*XN0(N))-(DOSQ0+FLOG0)

*HVALUE=E=YY0;
 983
 984
 985  * LOWER BOUNDS
 986
 987                    PN0.LO(N)=0.10; PYT0.LO(T)=0.10; PVT0.LO(T)=0.10;
 988
 989                    PMT0.LO(T)=0.10; PRT0.LO(T)=0.10;
 990
 991                    PK0.LO=0.10; PU0.LO=0.10;PL0.LO=0.10;
 992
 993                    PDL0.LO=0.50; PFL0.LO=0.10;
 994
 995                    PYN0.LO(N)=0.10; PVN0.LO(N)=0.10; PMN0.LO(N)=0.10;
 996
 997                    PPN0.LO(N)=0.10; PRN0.LO(N)=0.10;
 998
 999                    PUDL0.LO=0.10; PUFL0.LO=0.10;
1000
1001                    PUL0.LO=0.10; PUK0.LO=0.10; PUU0.LO=0.10;
1002
1003
1004  *INITIAL VALUES
GAMS 2.25.059  386/486 DOS                        11/13/96 15:49:44  PAGE
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20
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1005
1006
1007                    PN0.L(N)=1.000; PYT0.L(T)=1.000; PVT0.L(T)=1.000;
1008
1009                    PMT0.L(T)=1.000; PRT0.L(T)=1.000; PL0.L=1.000;
1010
1011                    PK0.L=1.000;  PFL0.L=1.000; PU0.L=1.000;
1012
1013                    PDL0.L=1.000; F0.L=0.0040;
1014
1015                                   DISP0.L=3.76811;  MCT0.L(T)=1.000;
XT0.L(T)=XT00(T);
1016
1017                    ZT0.L(T)=ZT00(T); YY0.L=3.19841;
1018
1019                    KT0.L(T)=KT00(T); LLT0.L(T)=LT00(T);
1020
1021                    FLT0.L('FOREST')=0.00219; UT0.L(T)=UT00(T);
1022
1023                    DLT0.L('AGRI')=0.20809;
1024
1025                                  DT0.L(T)=DT00(T);  PYN0.L(N)=1.000;
PMN0.L(N)=1.000;
1026
1027                    PRN0.L(N)=1.000; PVN0.L(N)=1.000;
1028
1029                                  MCN0.L(N)=1.000;  XN0.L(N)=XN00(N);
KN0.L(N)=KN00(N);
1030
1031                    LN0.L(N)=LN00(N); UN0.L(N)=UN00(N);
1032
1033                    DN0.L(N)=DN00(N);
1034
1035                    DPXDPKT0.L(T)=KXT0(T); DPXDPKN0.L(N)=KXN0(N);
1036
1037                    DPXDPLT0.L(T)=LXT0(T); DPXDPLN0.L(N)=LXN0(N);
1038
1039                    DPXDPUT0.L(T)=UXT0(T); DPXDPUN0.L(N)=UXN0(N);
1040
1041                                       DPXDPFT0.L('FOREST')=0.039655;
DPXDPFN0.L(N)=FXN0(N);
1042
1043                    DPXDPDT0.L('AGRI')=0.1486931; DPXDPDN0.L(N)=0 ;
1044
1045                    DPYDPLT0.L(T)=DELLYT(T); DPYDPLN0.L(N)=DELLYN(N);
1046
1047                    DPYDPVT0.L(T)=DELVYT(T); DPYDPVN0.L(N)=DELVYN(N);
1048
1049                    DPVDPUT0.L(T)=DELUVT(T); DPVDPUN0.L(N)=DELUVN(N);
1050
```

```
1051                    DPVDPMT0.L(T)=DELMVT(T); DPVDPMN0.L(N)=DELMVN(N);
1052
1053                    DPMDPFT0.L(T)=DELFMT(T); DPMDPFN0.L(N)=DELFMN(N);
1054
1055                    DPMDPRT0.L(T)=DELRMT(T); DPMDPRN0.L(N)=DELRMN(N);
1056
1057                    DPRDPKT0.L(T)=DELKRT(T); DPRDPKN0.L(N)=DELKRN(N);
GAMS 2.25.059  386/486 DOS                        11/13/96 15:49:44  PAGE
21
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1058
1059                    DPRDPDT0.L(T)=DELDRT(T); DPRDPDN0.L(N)=DELDRN(N);
1060
1061                    PPN0.L(N)=1.000;
1062
1063                              LSQ0.L=LSQ;  DOSQ0.L=SQ0;  D0.L=0.20809;
PUK0.L=1.000;
1064
1065                         PUL0.L=1.000;  PUFL0.L=1.000;  PUDL0.L=1.000;
PUU0.L=1.000;
1066
1067                    FLOG0.L=AVSK; LOGL0.L=LAB;
1068
1069                    LGK0.L=CAP;
1070
1071                    UTIL0.L=util00;
1072
1073
1074
1075   MODEL CRONE     /ALL/;
1076
1077  * CRONE.OPTFILE=1;
1078
1079    SOLVE CRONE USING NLP MAXIMIZING UTIL0;
1080
1081  * SOLVE CRONE USING NLP MAXiMIZING UTIL0;
1082  * SOLVE CRONE USING NLP MAXIMIZING UTIL0;
1083  * SOLVE CRONE USING NLP MAXIMIZING UTIL0;
1084
1085   DISPLAY
1086
1087
1088                  util0.l,
1089
1090                  XT0.L, ZT0.L, KT0.L, LLT0.L, UT0.L, FLT0.L, DLT0.L,
PK0.L,

PUK0.L,
1091
1092                     PL0.L, PUL0.L, PU0.L, PUU0.L, PFL0.L, PUFL0.L,
PDL0.L,
```

```
PUDL0.L,
1093
1094                    LTAX0, UTAX0, KTAX0, DTAX0, FTAX0, XN0.L,
1095
1096                    KN0.L, LN0.L,  YY0.L,
1097
1098                    MCT0.L, MCN0.L, DOSQ0.L, FLOG0.L, LSQ0.L, LOGL0.L,
1099
1100                    LGK0.L, D0.L, F0.L, PRDEF, PRDEFF, HVALUE;
1101
1102
1103
1104      PUT RES;
1105      PUT 'PRDEF SQ     ',PRDEF:6 /;
1106      PUT 'PRDEF LOG    ',PRDEFF:6/;
1107      PUT 'HVALUE       ',HVALUE:6:4/;
1108      PUT 'IRATE        ',IRATE:6:4//;
GAMS 2.25.059  386/486 DOS                        11/13/96 15:49:44  PAGE
22
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1109      PUT 'KTAX         ',KTAX0:6/;
1110      PUT 'LTAX         ',LTAX0:6/;
1111      PUT 'UTAX         ',UTAX0:6/;
1112      PUT 'DTAX         ',DTAX0:6/;
1113      PUT 'FTAX         ',FTAX0:6/;
1114      LOOP(T,PUT T.TL;
1115              PUT TAX0(T):6:4 /;);
1116      PUT / 'UTILITY     ',UTIL0.L:6:4 /;
1117      PUT 'GNP          ', YY0.L:6:4 /;
1118      PUT 'INCOME       ',DISP0.L:6:4 //;
1119      PUT 'PUK          ',PUK0.L:6:4 /;
1120      PUT 'PUL          ',PUL0.L:6:4 /;
1121      PUT 'PUU          ',PUU0.L:6:4 /;
1122      PUT 'PUDL         ',PUDL0.L:6:4 /;
1123      PUT 'PUFL         ',PUFL0.L:6:4 //;
1124      PUT 'DEFORESTATION'/
1125      PUT 'SQUATTERS    ',DOSQ0.L:8:5 /;
1126      PUT 'LOGGERS      ',FLOG0.L:8:5 /;
1127      PUT 'TOTAL        ',F0.L:8:5 //;
1128      PUT 'STOCK LAND   ',D0.L:6:4 //;
1129      PUT 'PRODUCTION'/;
1130      LOOP(T,PUT T.TL ;
1131             PUT XT0.L(T):6:4 /;);
1132
1133
1134
1135
1136
1137


COMPILATION TIME     =        2.640 SECONDS        VERID MW2-00-059
```

```
USER: The World Bank - for internal use only          G960611:1335CR-MW2
      For Modeling Support - J. Kreuser x32796

**** FILE SUMMARY

INPUT      C:\GAMS\DOC\CRONE.GMS
OUTPUT                                          C:\GAMS\DOC\CR1OUT.DOC
```

MODEL CODE
THE DYNAMIC MODEL OF DEFORESTATION IN COSTA RICA

```
GAMS 2.25.059  386/486 DOS                    11/13/96 15:26:48  PAGE
1
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


   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
   8
   9  * option domlim=10
  10   OPTION LIMROW=0
  11   OPTION LIMCOL=0
  12   OPTION SOLPRINT=OFF
  13   OPTION DECIMALS=4
  14
  15   PARAMETER low LOWER BOUND VALUE FOR NONLINEAR VARIABLES;
  16     LOW=1e-5;
  17   option ITERLIM=100000;
  18   FILE RES /C:\gams\crmod\ftax0.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/
```

```
  44   SCALAR LTAX1                        1  /0/
  45
  46   SCALAR UTAX0  Tax on UNSKILLED LABOR 0 /0/
  47   SCALAR UTAX1                          1 /0/
  48
  49   SCALAR KTAX0  Tax on CAPITAL  0       /0 /
  50   SCALAR KTAX1                  1       /0/
  51
  52   PARAMETER TAX0(T)   Tax change on tradables  0
  53
GAMS 2.25.059  386/486 DOS                      11/13/96 15:26:48  PAGE
2
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


  54        /  FOREST     1.000
  55           AGRI       1.000
  56           IND        1.000  /
  57
  58   PARAMETER TAX1(T)   Tax change on tradables 1
  59
  60       /   FOREST     1.000
  61           AGRI       1.000
  62           IND        1.000       /
  63
  64
  65   SCALAR RAU   Time preference        /1.00/
  66
  67   parameter IRATE World market interest rate;
  68     irate= 1.00;
  69
  70   SCALAR POPGR  Annual population growth  /0.024/
  71   * Source: World Developmet Report 1992, popgr 1980-1990 2.4% /
year
  72
  73   SCALAR SAVGR  Annual Growth of Gross Investments  /0/
  74   * Source: World Development Report 1992, invgr 5.2% /year 1980-
1990
  75
  76   SCALAR KDEPL  Depletion of capital  (%)  /0.054/
  77  * Source: Costa Rica National Accounts 1980-1988 0.054
  78
  79   PARAMETER TOTDEF Total allowed deforestation;
  80    TOTDEF=100.0001;
  81
INCLUDE    C:\GAMS\CRMOD\SAM.INC
  83  *+++++++++++++++**
  84  *+++ BASE DATA +++
  85  *+++++++++++++++**
  86
  87   TABLE XTT00(T,TT) Benchmark intermediate inputs of T in T
  88
  89                  FOREST     AGRI       IND
  90
```

```
 91        FOREST    0.00021    0.00220    0.03907
 92        AGRI      0.00035    0.40326    0.24882
 93        IND       0.01372    0.14052    0.73900
 94
 95   TABLE XTN00(T,N) Benchmark intermediate inputs of T in N
 96
 97                  INFRA      SERVICE
 98
 99         FOREST   0.00022    0.00000
100         AGRI     0.00001    0.00003
101         IND      0.34181    0.13432
102
103   TABLE XNT00(N,T) Benchmark intermdiate inputs of N in T
104
105                  FOREST     AGRI       IND
106
GAMS 2.25.059  386/486 DOS                      11/13/96 15:26:48  PAGE
3
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


107         INFRA    0.00043    0.02934    0.08264
108         SERVICE  0.00377    0.06020    0.15460
109
110   TABLE XNN00(N,NN) Benchmark intermediate inputs of N in N
111
112                  INFRA      SERVICE
113
114         INFRA    0.06470    0.06841
115         SERVICE  0.14867    0.21596
116
117   PARAMETER TTAX00(T) Benchmark tax in T-sectors
118
119       / FOREST   0.00251
120         AGRI     0.07468
121         IND      0.11448   /
122
123   PARAMETER NTAX00(N) Benchmark tax in N-sectors
124
125       / INFRA    0.05800
126         SERVICE  0.12763/
127
128   PARAMETER KT00(T)  Benchmark allocation of CAPITAL to T-sectors
129
130       / FOREST       0.01762
131         AGRI         0.20524
132         IND          0.21675 /
133
134   PARAMETER KN00(N)  Benchmark allocation of CAPITAL to N-sectors
135       / INFRA        0.16330
136         SERVICE      0.52563  /
137
138   PARAMETER UT00(T)  Benchmark allocation of UNSKILLED LABOR to T-
sectors
```

```
 139
 140        / FOREST        0.01414
 141          AGRI          0.27140
 142          IND           0.15247  /
 143
 144    PARAMETER UN00(N)  Benchmark allocation of UNSKILLED LABOR to N-
sectors
 145
 146        / INFRA         0.17544
 147          SERVICE       0.14388   /
 148
 149
 150    PARAMETER LT00(T)  Benchmark allocation of SKILLED LABOR to T-
sectors
 151
 152        / FOREST        0.00024
 153          AGRI          0.00454
 154          IND           0.09989  /
 155
 156    PARAMETER LN00(N)  Benchmark allocation of SKILLED LABOR to N-
sectors
 157
 158        / INFRA         0.12992
 159          SERVICE       0.49037 /
GAMS 2.25.059  386/486 DOS                        11/13/96 15:26:48  PAGE
4
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 160
 161    PARAMETER FLT00(T)  Benchmark allocation of LOGS to T-sectors
 162        /  FOREST 0.00219 /
 163    DISPLAY FLT00;
 164
 165
 166    PARAMETER FLN00(N)  Benchmark allocation of LOGS to N-sectors
 167
 168        / INFRA         0
 169          SERVICE       0          /
 170
 171    PARAMETER DLT00(T)  Benchmark allocation of DLAND to T-sectors;
 172        DLT00('AGRI')=0.20704;
 173    DISPLAY DLT00;
 174
 175    PARAMETER DLN00(N)  Benchmark allocation of DLAND to N-sectors
 176
 177        / INFRA         0
 178          SERVICE       0  /
 179
 180    PARAMETER XT00(T)  Benchmark tradables production level
 181
 182        / FOREST        0.05518
 183          AGRI          1.39842
 184          IND           1.84772 /
```

```
 185
 186
 187    PARAMETER  XN00(N) Benchmark nontradables production level
 188
 189       / INFRA        1.08207
 190         SERVICE      1.70623  /
 191
 192    PARAMETER DT00(T)  Benchmark consumption of tradables
 193
 194       / FOREST       0.01241
 195         AGRI         0.35030
 196         IND          1.41334  /
 197
 198
 199   PARAMETER DN00(N)  Benchmark consumption of nontradables
 200
 201       /  INFRA        0.78236
 202          SERVICE      1.11504 /
 203
 204   PARAMETER INVSRCT(T)
 205       /  FOREST       0
 206          AGRI         0.00322
 207          IND          0.02926 /
 208
 209   PARAMETER INVSRCN(N)
 210       /  INFRA        0.05419
 211          SERVICE      0.00799 /
 212
GAMS 2.25.059  386/486 DOS                        11/13/96 15:26:48  PAGE
5
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 213   PARAMETER ZT00(T)
 214
 215       /  FOREST      0.00107
 216          AGRI        0.39243
 217          IND        -0.96425  /
 218
 219   SCALAR DISP00  /3.75372/
 220
 221   SCALAR SAV00   /0.08027/
 222
 223   SCALAR ROWSAV00 /0.01439/
 224
 225   SCALAR INV /0.09466/
 226  * Central Bank 0.0460231, 0.09466 SAM
 227
 228   SCALAR GNP00  /3.19624 /
 229
 230   SCALAR AVSK         INITIAL LOGGING /0.00200/
 231   SCALAR LAB          INITIAL LABOR IN LOGGING /0.00093/
 232   SCALAR CAP          INITIAL CAPITAL IN LOGGING /0.00126/
 233   SCALAR LSQ          INITIAL LABOR IN SQUATTING /0.00180/
```

```
 234   SCALAR SQ0          INITIAL SQUATTING /0.00200/
INCLUDE    C:\GAMS\CRMOD\BASE.INC
 236  *INITIAL SOLUTION TOTDEF=0.1
 237
 238   PARAMETER DT02(T)
 239   /FOREST  0.0165
 240    AGRI    0.4656
 241    IND     1.8785 /
 242   PARAMETER DN02(N)
 243   /INFRA   1.0399
 244    SERVICE 1.4820 /
 245
 246   PARAMETER XT01(T)
 247   /AGRI 1.4171
 248    IND  2.1250/
 249
 250   PARAMETER DT01(T)
 251   /FOREST 0.0108
 252    AGRI   0.3053
 253    IND    1.2318 /
 254
 255   PARAMETER ZT01(T)
 256   /FOREST -0.0582
 257    AGRI    0.4054
 258    IND    -0.6874 /
 259
 260   PARAMETER KT01(T)
 261   /AGRI    0.2102
 262    IND     0.2515/
 263
 264   PARAMETER LLT01(T)
 265   /AGRI    0.0047
GAMS 2.25.059  386/486 DOS                    11/13/96 15:26:48  PAGE
6
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 266    IND     0.1168/
 267
 268   PARAMETER UT01(T)
 269   /AGRI    0.2683
 270    IND     0.1713/
 271
 272   PARAMETER DLT01(T)
 273   /AGRI    0.2143/
 274
 275   PARAMETER XN01(N)
 276   /INFRA   1.1317
 277    SERVICE 1.6041 /
 278
 279   PARAMETER DN01(N)
 280   /INFRA   0.6815
 281    SERVICE 0.9781 /
 282
```

```
 283   PARAMETER KN01(N)
 284   /INFRA   0.1725
 285    SERVICE 0.4944 /
 286
 287   PARAMETER LN01(N)
 288   /INFRA    0.1384
 289    SERVICE  0.4651 /
 290
 291   PARAMETER UN01(N)
 292   /INFRA    0.1794
 293    SERVICE  0.1311 /
 294
 295   SCALAR DOSQ01 /0.0098/
 296   SCALAR FLOG01 /0.0014/
 297   SCALAR LSQ01  /0.0091/
 298   SCALAR LOGL01 /0.0008/
 299   SCALAR LGK01  /0.0012/
 300   SCALAR FEXP01 /0.0020/
 301   SCALAR D01    /0.2132/
 302   SCALAR F01    /0.0116/
 303
 304   SCALAR YY01   /3.1991/
 305
 306
 307   PARAMETER XT11(T)
 308    /FOREST 0.1252
 309     AGRI 1.3398
 310    IND   2.9904/
 311
 312   PARAMETER DT11(T)
 313   /FOREST 0.0088
 314    AGRI   0.2474
 315    IND    0.9983 /
 316
 317   PARAMETER ZT11(T)
 318   /FOREST  0.0504
GAMS 2.25.059  386/486 DOS                        11/13/96 15:26:48  PAGE
7
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 319    AGRI    0.2750
 320    IND    -0.1543 /
 321
 322   PARAMETER KT11(T)
 323   /FOREST  0.0445
 324    AGRI    0.2174
 325    IND     0.3913/
 326
 327   PARAMETER LLT11(T)
 328   /FOREST  0.0005
 329    AGRI    0.0042
 330    IND     0.1564/
 331
```

```
 332   PARAMETER UT11(T)
 333   /FOREST  0.0282
 334    AGRI    0.2281
 335    IND     0.2169 /
 336
 337   PARAMETER DLT11(T)
 338   /AGRI    0.2143/
 339
 340   PARAMETER XN11(N)
 341   /INFRA   1.3061
 342    SERVICE 1.5623 /
 343
 344   PARAMETER DN11(N)
 345   /INFRA   0.5464
 346    SERVICE 0.7996 /
 347
 348   PARAMETER KN11(N)
 349   /INFRA   0.2245
 350    SERVICE 0.5270 /
 351
 352   PARAMETER LN11(N)
 353   /INFRA   0.1549
 354    SERVICE 0.4264 /
 355
 356   PARAMETER UN11(N)
 357   /INFRA   0.1900
 358    SERVICE 0.1137 /
 359
 360   SCALAR DOSQ11 /10E-7/
 361   SCALAR FLOG11 /0.0022/
 362   SCALAR LSQ11  /10E-7/
 363   SCALAR LOGL11 /0.0014/
 364   SCALAR LGK11  /0.0023/
 365   SCALAR FEXP11 /-0.0012/
 366   SCALAR D11    /0.2143/
 367   SCALAR F11    /0.0022/
 368
 369   SCALAR YY11   /3.5697/
 370
INCLUDE    C:\GAMS\CRMOD\CALC.INC
GAMS 2.25.059  386/486 DOS                        11/13/96 15:26:48  PAGE
8
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 372  *+++++++++++++++++++++++++++++++++++++++++++++++**
 373  *+++ CALCULATION OF COEFFICIENTS AND PARAMETERS +++
 374  *+++++++++++++++++++++++++++++++++++++++++++++++**
 375
 376   PARAMETER GAMMA;
 377       GAMMA=LOG(SQ0)/LOG(LSQ);
 378
 379   PARAMETER ATT(TT,T) Input of tradables in tradable sectors;
 380       ATT(T,TT)=XTT00(T,TT)/XT00(TT);
```

```
 381   PARAMETER ATN(TT,NN) Input of tradables in nontradable sectors;
 382       ATN(T,N)=XTN00(T,N)/XN00(N);
 383
 384   PARAMETER ANT(NN,TT)  Input of nontradables in tradable sectors;
 385       ANT(N,T)=XNT00(N,T)/XT00(T);
 386
 387     PARAMETER  ANN(NN,N)   Input  of  nontradables  in  nontradables
sectors;
 388       ANN(N,NN)=XNN00(N,NN)/XN00(NN);
 389
 390   PARAMETER TTAX0(TT)   Unit tax in tradable sectors;
 391       TTAX0(T)=TTAX00(T)/XT00(T)*TAX0(T);
 392
 393   PARAMETER TTAX1(TT)   Unit tax in tradable sectors;
 394       TTAX1(T)=TTAX00(T)/XT00(T)*TAX1(T);
 395
 396   PARAMETER NTAX0(NN)  Unit tax in nontradable sectors;
 397       NTAX0(N)=NTAX00(N)/XN00(N);
 398
 399   PARAMETER KXT0(TT) Benchmark input coefficients for CAPITAL;
 400       KXT0(T)=KT00(T)/XT00(T);
 401
 402   PARAMETER KXN0(NN) Benchmark input coefficients for CAPITAL;
 403       KXN0(N)=KN00(N)/XN00(N);
 404
 405    PARAMETER  UXT0(TT)  Benchmark  input  coefficients  for  UNSKILLED
LABOR;
 406       UXT0(T)=UT00(T)/XT00(T);
 407
 408    PARAMETER  UXN0(NN)  Benchmark  input  coefficients  for  UNSKILLED
LABOR;
 409       UXN0(N)=UN00(N)/XN00(N);
 410
 411     PARAMETER  LXT0(TT)  Benchmark  input  coefficients  for  SKILLED
LABOR;
 412       LXT0(T)=LT00(T)/XT00(T);
 413
 414     PARAMETER  LXN0(NN)  Benchmark  input  coefficients  for  SKILLED
LABOR;
 415       LXN0(N)=LN00(N)/XN00(N);
 416
 417   PARAMETER FXT0(TT) Benchmark input coefficients for LOGS;
 418       FXT0('FOREST')=FLT00('FOREST')/XT00('FOREST');
 419
 420   PARAMETER FXN0(NN) Benchmark input coefficients for LOGS;
 421       FXN0(N)=FLN00(N)/XN00(N);
 422
 423   PARAMETER DXT0(TT) Benchmark input coefficients for DLAND;
 424       DXT0(T)=DT00(T)/XT00(T);
GAMS 2.25.059  386/486 DOS                      11/13/96 15:26:48  PAGE
9
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n
```

```
 425
 426   PARAMETER DXN0(NN) Benchmark input coefficients for DLAND;
 427       DXN0(N)=DN00(N)/XN00(N);
 428
 429   PARAMETER AT(T)   Tradable production function scale parameter;
 430       AT(TT)=1-SUM(T,ATT(T,TT))-SUM(N,ANT(N,TT))-TTAX0(TT);
 431   DISPLAY AT;
 432
 433   PARAMETER AN(N)  Nontradable production function scale parameter;
 434       AN(NN)=1-SUM(T,ATN(T,NN))-SUM(N,ANN(N,NN))-NTAX0(NN);
 435   DISPLAY AN;
 436
 437   PARAMETER DELKRT(TT)  CAPITAL share in tradable KD;
 438       DELKRT(T)=KT00(T)/(KT00(T)+DLT00(T));
 439
 440   PARAMETER DELDRT(TT);
 441        DELDRT(T)=1-DELKRT(T);
 442
 443   PARAMETER DELKRN(NN)  CAPITAL share in nontradable KD;
 444        DELKRN(N)=KN00(N)/(KN00(N)+DLN00(N));
 445
 446   PARAMETER DELDRN(NN);
 447       DELDRN(N)=1-DELKRN(N);
 448
 449   PARAMETER DELFMT(TT)  LOGS share in tradable FR;
 450        DELFMT(T)=FLT00(T)/(FLT00(T)+DLT00(T)+KT00(T));
 451
 452   PARAMETER DELRMT(TT);
 453        DELRMT(T)=1-DELFMT(T);
 454
 455    PARAMETER DELFMN(NN)  LOGS share in nontradable FR substitution;
 456        DELFMN(N)=FLN00(N)/(FLN00(N)+DLN00(N)+KN00(N));
 457
 458    PARAMETER DELRMN(NN);
 459        DELRMN(N)=1-DELFMN(N);
 460
 461    PARAMETER DELUVT(TT)  UNSKILLED LABOR share in tradable UY;
 462        DELUVT(T)=UT00(T)/(UT00(T)+FLT00(T)+DLT00(T)+KT00(T));
 463
 464    PARAMETER DELMVT(TT);
 465        DELMVT(T)=1-DELUVT(T);
 466
 467    PARAMETER DELUVN(NN)  UNSKILLED LABOR share in nontradable UY;
 468        DELUVN(N)=UN00(N)/(UN00(N)+FLN00(N)+DLN00(N)+KN00(N));
 469
 470    PARAMETER DELMVN(NN);
 471        DELMVN(N)=1-DELUVN(N);
 472
 473    PARAMETER DELLYT(TT)  SKILLED LABOR share in tradable LV;
                                                                    474
DELLYT(T)=LT00(T)/(LT00(T)+UT00(T)+FLT00(T)+DLT00(T)+KT00(T));
 475
 476    PARAMETER DELVYT(TT);
 477        DELVYT(T)=1-DELLYT(T);
GAMS 2.25.059  386/486 DOS                    11/13/96 15:26:48  PAGE
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```
 478
 479    PARAMETER DELLYN(NN)    SKILLED LABOR share in nontradable LV;
                                                                        480
DELLYN(N)=LN00(N)/(LN00(N)+UN00(N)+DLN00(N)+FLN00(N)+KN00(N));
 481
 482    PARAMETER DELVYN(NN);
 483       DELVYN(N)=1-DELLYN(N);
 484
 485   PARAMETER BT(TT)  B-coefficient in U;
 486       BT(T)=DT00(T)/(SUM(TT,DT00(TT))+SUM(N,DN00(N)));
 487
 488   PARAMETER  BN(NN) B-coefficient in u;
 489       BN(N)=DN00(N)/(SUM(T,DT00(T))+SUM(NN,DN00(NN)));
 490   DISPLAY BN;
 491
 492   PARAMETER SAVSHR Savings share of disposable income in period 0;
 493       SAVSHR=SAV00/DISP00;
 494   DISPLAY SAVSHR;
 495
 496   PARAMETER  INVSHRT(TT);
 497       INVSHRT(T)=INVSRCT(T)/INV;
 498   DISPLAY INVSHRT;
 499
 500   PARAMETER INVSHRN(NN);
 501       INVSHRN(N)=INVSRCN(N)/INV;
 502   DISPLAY INVSHRN;
 503
 504   PARAMETER K0  CAPITAL endowment 0;
 505       K0=1.12980;
 506
 507   PARAMETER U0     UNSKILLED LABOR endowment 0;
 508       U0=.76006;
 509
 510   PARAMETER U1     UNSKILLED LABOR endowment 1;
 511       U1=U0*(1+POPGR);
 512
 513   PARAMETER U2     UNSKILLED LABOR ensowment 2;
 514       U2=u1*(1+popgr);
 515
 516   PARAMETER L0     SKILLED LABOR endowment 0;
 517       L0=.72496;
 518
 519   PARAMETER L1     SKILLED LABOR endowment 1;
 520       L1=L0*(1+popgr);
 521
 522   PARAMETER L2     SKILLED LABOR endowment 2;
 523       L2=L1*(1+popgr);
 524
 525   PARAMETER DSTAR DLAND endowment 0;
 526       DSTAR=0.20524;
```

```
 527
 528   PARAMETER SBAR00  Trade balance surplus 0;
 529       SBAR00=-0.5563;
 530
GAMS 2.25.059  386/486 DOS                        11/13/96 15:26:48  PAGE
11
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 531  * PARAMETER SBAR1  Trade balance surplus 1;
 532  *     SBAR1=-0.57075;
 533
 534   PARAMETER UTIL00 ;
 535         UTIL00=LOG(PROD(T,DT00(T)**BT(T))*PROD(N,DN00(N)**BN(N)));
 536   DISPLAY UTIL00;
 537
INCLUDE    C:\GAMS\CRMOD\EXO.INC
 539  *++++++++++++++++++++++++++++++++++
 540  *+++ELASTICITIES OF SUBSTITUTION+++
 541  *++++++++++++++++++++++++++++++++++
 542
 543
 544
 545   PARAMETER SIGRT(T)   Elasticity of tradable KD substitution
 546
 547      /  FOREST       0
 548         AGRI         0.500
 549         IND          0     /
 550
 551    PARAMETER SIGRN(N)   Elasticity of nontradable KD substitution
 552
 553       / INFRA        0
 554         SERVICE      0   /
 555
 556    PARAMETER SIGMT(T)   Elasticity of tradable FR substitution
 557
 558       / FOREST       0.800
 559         AGRI         0
 560         IND          0     /
 561
 562    PARAMETER SIGMN(N)   Elasticity of nontradable FR substitution
 563
 564       / INFRA        0
 565         SERVICE      0   /
 566
 567    PARAMETER SIGVT(T)  Elasticity of tradable UY substitution
 568
 569       / FOREST       0.800
 570         AGRI         0.800
 571         IND          0.800 /
 572
 573    PARAMETER SIGVN(N)  Elasticity of nontradable UY substitution
 574
 575       / INFRA        0.800
```

```
 576          SERVICE      0.800  /
 577
 578    PARAMETER SIGYT(T)   Elasticity of tradable LV substitution
 579
 580       / FOREST      0.800
 581         AGRI        0.800
 582         IND         0.800   /
 583
GAMS 2.25.059  386/486 DOS                        11/13/96 15:26:48  PAGE
12
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 584   PARAMETER SIGYN(N)   Elasticity of nontradable LV substitution
 585
 586      /  INFRA       0.800
 587         SERVICE     0.800   /
 588
 589   SCALAR MU Elasticity of substitution between foreign and domestic

capital
 590
 591      / 0.8000 /
 592
 593  *+++++++++++++++++++++++++
 594  *+++EXOGENOUS VARIABLES+++
 595  *+++++++++++++++++++++++++
 596   parameter  PWF0      WM price of logs 0;
 597     pwf0=1.000;
 598
 599   parameter  PWF1      WM price of logs 1;
 600     pwf1=1.000;
 601
 602   PARAMETER PW0(T)    World market price of tradables
 603
 604      / FOREST    1.0000
 605        AGRI      1.0000
 606        IND       1.0000  /
 607
 608   PARAMETER PW1(t)   World market price of tradables
 609
 610      / FOREST     1.0000
 611        AGRI       1.0000
 612        IND        1.0000  /
 613
 614
 615
 616
 617  *+++++++++++++++
 618  *+++VARIABLES+++
 619  *+++++++++++++++
 620
 621   VARIABLES
 622
```

```
 623  * consumers
 624
 625   UTIL0        UTILITY PERIOD 0
 626   UTIL1        UTILITY PERIOD 1
 627
 628   WELF         WELFARE intertemporal sum of utilities
 629
 630   DISP0        Disposable income 0
 631   DISP1        Disposable income 1
 632
 633   DT0(T)       Consumption demand for tradables 0
 634   DT1(T)       Consumption demand for tradables 1
 635
GAMS 2.25.059  386/486 DOS                      11/13/96 15:26:48  PAGE
13
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 636   DN0(N)       Consumption demand for nontradables 0
 637   DN1(N)       Consumption demand for nontradables 1
 638
 639  * Deforestation sectors
 640
 641   ALPHA        Elasticity of output wrt capital in logging
 642   BETA         Elasticity of output wrt labor in logging
 643
 644   DEF01        Deforestation in both periods
 645
 646   DOSQ0        DLAND produced by deforestation 0
 647   DOSQ1        DLAND produced by deforestation 1
 648
 649   LAMSQ0       Shadow price of forested land for squatters 0
 650   lamsq1       Shadow price of forested land for squatters 1
 651
 652   LSQ0         UNSKILLED LABOR input in deforestation by SQUATTERS 0
 653   LSQ1         UNSKILLED LABOR input in deforestation by SUATTERS  1
 654
 655   PROFSQ0      Profit for SQUATTERS in period 0
 656   PROFSQ1      Profit for SQUATTERS in period 1
 657
 658   FLOG0        LOGGING 0
 659   FLOG1        LOGGING 1
 660
 661   LAMLG0       Shadow price of forested land for loggers 0
 662   LAMLG1       Shadow price of forested land for loggers 1
 663
 664   PFL0         Supply price of LOGS 0
 665   PFL1         Supply price of LOGS including future value 1
 666
 667   LOGL0        UNSKILLED LABOR input in deforestation by LOGGERS 0
 668   LOGL1        UNSKILLED LABOR input in deforestation by LOGGERS 1
 669
 670   LGK0         CAPITAL input in deforestation by LOGGERS 0
 671   LGK1         CAPITAL input in deforestation by LOGGERS 1
```

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 672
 673   PROFLG0     Profit for LOGGERS in period 0
 674   PROFLG1     Profit for LOGGERS in period 1
 675
 676   F0          Deforestation 0
 677   F1          Deforestation 1
 678
 679   D0          Supply of DLAND 0
 680   D1          Supply of DLAND 1
 681
 682  * Prices
 683
 684   PUDL0       User price of DLAND 0
 685   PUDL1       User price of DLAND 1
 686
 687   PUFL0       User price of LOGS including taxes 0
 688   PUFL1       User price of LOGS including future value and taxes 1
GAMS 2.25.059  386/486 DOS                      11/13/96 15:26:48  PAGE
14
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 689
 690   PUK0        User price of CAPITAL 0
 691   PUK1        User price of CAPITAL 1
 692
 693   PUL0        User price of SKILLED LABOR 0
 694   PUL1        User price of SKILLED LABOR 1
 695
 696   PUU0        User price of UNSKILLED LABOR 0
 697   PUU1        User price of UNSKILLED LABOR 1
 698
 699   PYT0(T)     Implicit price of Y(T) 0
 700   PYT1(T)     Implicit price of Y(T) 1
 701
 702   PYN0(N)     Implicit price of Y(N) 0
 703   PYN1(N)     Implicit price of Y(N) 1
 704
 705   PVT0(T)     Implicit price of V(T) 0
 706   PVT1(T)     Implicit price of V(T) 1
 707
 708   PVN0(N)     Implicit price of V(N) 0
 709   PVN1(N)     Implicit price of V(N) 1
 710
 711   PMT0(T)     Implicit price of M(T) 0
 712   PMT1(t)     Implicit price of M(T) 1
 713
 714   PMN0(N)     Implicit price of M(N) 0
 715   PMN1(N)     Implicit price of M(N) 1
 716
 717   PRT0(T)     Implicit price of R(T) 0
 718   PRT1(T)     Implicit price of R(T) 1
 719
 720   PRN0(N)     Implicit price of R(N) 0
```

```
 721   PRN1(N)      Implicit price of R(N) 1
 722
 723  * Partial derivatives
 724
 725   DPXDPUT0(T)  Partial of PX wrt PUU(T) 0
 726   DPXDPUT1(T)  Partial of PX wrt PUU(T) 1
 727
 728   DPXDPUN0(N)  Partial of PX wrt PUU(N) 0
 729   DPXDPUN1(N)  Partial of PX wrt PUU(N) 1
 730
 731   DPXDPLT0(T)  Partial of PX wrt PUL(T) 0
 732   DPXDPLT1(T)  Partial of PX wrt PUL(T) 1
 733
 734   DPXDPLN0(N)  Partial of PX wrt PUL(N) 0
 735   DPXDPLN1(N)  Partial of PX wrt PUL(N) 1
 736
 737   DPXDPKT0(T)  Partial of PX wrt PUK(T) 0
 738   DPXDPKT1(T)  Partial of PX wrt PUK(T) 1
 739
 740   DPXDPKN0(N)  Partial of PX wrt PUK(N) 0
 741   DPXDPKN1(N)  Partial of PX wrt PUK(N) 1
GAMS 2.25.059  386/486 DOS                      11/13/96 15:26:48  PAGE
15
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 742
 743   DPXDPFT0(T)  Partial of PX wrt PUFL(T) 0
 744   DPXDPFT1(T)  Partial of PX wrt PUFL(T) 1
 745
 746   DPXDPFN0(N)  Partial of PX wrt PUFL(N) 0
 747   DPXDPFN1(N)  Partial of PX wrt PUFL(N) 1
 748
 749   DPXDPDT0(T)  Partial of PX wrt PUDL(T) 0
 750   DPXDPDT1(T)  Partial of PX wrt PUDL(T) 1
 751
 752   DPXDPDN0(N)  Partial of PX wrt PUDL(N) 0
 753   DPXDPDN1(N)  Partial of PX wrt PUDL(N) 1
 754
 755   DPYDPVT0(T)  Partial of PY wrt PV(T) 0
 756   DPYDPVT1(T)  Partial of PY wrt PV(T) 1
 757
 758   DPYDPVN0(N)  Partial of PY wrt PV(N) 0
 759   DPYDPVN1(N)  Partial of PY wrt PV(N) 1
 760
 761   DPYDPLT0(T)  Partial of PY wrt PUL(T) 0
 762   DPYDPLT1(T)  Partial of PY wrt PUL(T) 1
 763
 764   DPYDPLN0(N)  Partial of PY wrt PUL(N) 0
 765   DPYDPLN1(N)  Partial of PY wrt PUL(N) 1
 766
 767   DPVDPMT0(T)  Partial of PV wrt PM(T) 0
 768   DPVDPMT1(T)  Partial of PV wrt PM(T) 1
 769
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 770   DPVDPMN0(N)   Partial of PV wrt PM(N) 0
 771   DPVDPMN1(N)   Partial of PV wrt PM(N) 1
 772
 773   DPVDPUT0(T)   Partial of PV wrt PUU(T) 0
 774   DPVDPUT1(T)   Partial of PV wrt PUU(T) 1
 775
 776   DPVDPUN0(N)   Partial of PV wrt PUU(N) 0
 777   DPVDPUN1(N)   Partial of PV wrt PUU(N) 1
 778
 779   DPMDPRT0(T)   Partial of PM wrt PR(T) 0
 780   DPMDPRT1(T)   Partial of PM wrt PR(T) 1
 781
 782   DPMDPRN0(N)   Partial of PM wrt PR(N) 0
 783   DPMDPRN1(N)   Partial of PM wrt PR(N) 1
 784
 785   DPMDPFT0(T)   Partial of PM wrt PUFL(T) 0
 786   DPMDPFT1(T)   Partial of PM wrt PUFL(T) 1
 787
 788   DPMDPFN0(N)   Partial of PM wrt PUFL(N) 0
 789   DPMDPFN1(N)   Partial of PM wrt PUFL(N) 1
 790
 791   DPRDPKT0(T)   Partial of PR wrt PUK(T) 0
 792   DPRDPKT1(T)   Partial of PR wrt PUK(T) 1
 793
 794   DPRDPKN0(N)   Partial of PR wrt PUK(N) 0
GAMS 2.25.059  386/486 DOS                      11/13/96 15:26:48  PAGE
16
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 795   DPRDPKN1(N)   Partial of PR wrt PUK(N) 1
 796
 797   DPRDPDT0(T)   Partial of PR wrt PUDL(T) 0
 798   DPRDPDT1(T)   Partial of PR wrt PUDL(T) 1
 799
 800   DPRDPDN0(N)   Partial of PR wrt PUDL(N) 0
 801   DPRDPDN1(N)   Partial of PR wrt PUDL(N) 1
 802
 803  * Producers
 804
 805   MCT0(T)      Marginal cost in tradable production 0
 806   MCT1(T)      Marginal cost in tradable production 1
 807
 808   MCN0(N)      Marginal cost in nontradable production 0
 809   MCN1(N)      Marginal cost in nontradable production 1
 810
 811   PN0(N)       User price of nontradables 0
 812   PN1(N)       User price of nontradables 1
 813
 814   XT0(T)       Output in tradable sectors 0
 815   XT1(T)       Output in tradable sectors 1
 816
 817   XN0(N)       Output in non-tradable sectors 0
 818   XN1(N)       Output in non-tradable sectors 1
```

```
 819
 820   KT0(T)       CAPITAL input in tradable sectors 0
 821   KT1(T)       CAPITAL input in tradable sectors 1
 822
 823   KN0(N)       CAPITAL input in nontradable sectors 0
 824   KN1(N)       CAPITAL input in nontradable sectors 1
 825
 826   UT0(T)       UNSKILLED LABOR demand in tradable sectors 0
 827   UT1(T)       UNSKILLED LABOR demand in tradable sectors 1
 828
 829   UN0(N)       UNSKILLED LABOR demand in non-tradable sectors 0
 830   UN1(N)       UNSKILLED LABOR demand in non-tradable sectors 1
 831
 832   LLT0(T)      SKILLED LABOR demand in tradable sectors 0
 833   LLT1(T)      SKILLED LABOR demand in tradable sectors 1
 834
 835   LN0(N)       SKILLED LABOR demand in non-tradable sectors 0
 836   LN1(N)       SKILLED LABOR demand in non-tradable sectors 1
 837
 838   FLT0(T)      LOGS demand in tradable sectors 0
 839   FLT1(T)      LOGS demand in tradable sectors 1
 840
 841   DLT0(T)      DLAND demand in tradable sectors 0
 842   DLT1(T)      DLAND demand in tradable sectors 1
 843
 844  * Investments and domestic interest rate
 845
 846   PI0          Price of composite investments period 0
 847   PI1          Price of composite investments period 1
GAMS 2.25.059  386/486 DOS                        11/13/96 15:26:48  PAGE
17
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 848
 849   INVT0(T)      Investments by sector of origin period 0
 850   INVT1(T)      Investments by sector of origin period 1
 851
 852   INVN0(N)      Investments by sector of origin period 0
 853   INVN1(N)      Investments by sector of origin period 1
 854
 855   K1           Capital stock period 1
 856
 857  * Rest of world
 858
 859   SBAR0        Current Account 0
 860   SBAR2        Current Account 2
 861
 862   SAV0         Domestic savings 0
 863  *SAV1         Domestic savings 1
 864
 865  * Market clearing
 866
 867   ZT0(T)       Net export of tradables 0
```

```
 868   ZT1(T)       Net export of tradables 1
 869
 870   PPN0(N)      Producer price of nontradable output 0
 871   PPN1(N)      Producer price of nontradable output 1
 872
 873   PK0          Supply price of CAPITAL services 0
 874   PK1          Supply price of CAPITAL services 1
 875
 876   PU0          Supply price of UNSKILLED LABOR services 0
 877   PU1          Supply price of UNSKILLED LABOR services 1
 878
 879   PL0          Supply price of SKILLED LABOR services 0
 880   PL1          Supply price of SKILLED LABOR services 1
 881
 882   PDL0         Supply price of DLAND services 0
 883   PDL1         Supply price of DLAND services 1
 884
 885   FEXP0        Net export of LOGS 0
 886   FEXP1        Net export of LOGS 1
 887
 888  * Closing
 889
 890   INV0          Aggregate investments period 1
 891
 892   YY0           GNP 0
 893   YY1           GNP 1
 894
 895
 896   POSITIVE VARIABLES
 897       LAMLG0, LAMLG1, LAMSQ0, LAMSQ1, XT0, XT1,xn0, xn1, LSQ0,LSQ1,
 898        DOSQ0,DOSQ1,FLOG0,FLOG1,
 899       lgk0, lgk1, logl0, logl1, PROFSQ0, PROFSQ1,inv0;
 900
GAMS 2.25.059  386/486 DOS                        11/13/96 15:26:48  PAGE
18
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 901  *+++++++++++++++
 902  *+++EQUATIONS+++
 903  *+++++++++++++++
 904
 905   EQUATIONS
 906
 907  * Consumers
 908
 909   DEFUTIL0          Definition of UTIL0
 910   DEFUTIL1          Definition of UTIL1
 911
 912   DEFDISP0          Definition of DISP0
 913   DEFDISP1          Definition of DISP1
 914
 915   DEFWELF           Definition of objective function WELF
 916
```

```
 917   TCONS0(T)         Consumption demand for tradables 0
 918   TCONS1(T)         Consumption demand for tradables 1
 919
 920   NCONS0(N)         Consumption demand for nontradables 0
 921   NCONS1(N)         Consumption demand for nontradables 1
 922
 923  * Deforestation sectors
 924
 925   DEFALPHA          Definition of alpha
 926   DEFBETA           Definition of beta
 927
 928   DDEF01            Definition of DEF01
 929   DLAM              Total def less than permitted def
 930
 931   DEFLAMSQ0         Definition of lamsq0
 932   DEFLAMSQ1         Definition of lamsq1
 933
 934   DEFDOSQ0          Definition of DOSQ0
 935   DEFDOSQ1          Definition of DOSQ1
 936
 937   COMPLDQ0          Complementary condition DOSQ0
 938   COMPLDQ1          Complementary condition DOSQ1
 939
 940   DEFLSQ0           Definition of LSQ0
 941   DEFLSQ1           Definition of LSQ1
 942
 943   COMPLLQ0          Complementary condition LSQ0
 944   COMPLLQ1          Complementary condition LSQ1
 945
 946   DPROFSQ0          Definition PROFSQ0
 947   DPROFSQ1          Definition PROFSQ1
 948
 949   DEFFLOG0          Definition of FLOG0
 950   DEFFLOG1          Definition of FLOG1
 951
 952   COMPLDF0          Complementary condition FLOG0
 953   COMPLDF1          Complementary condition FLOG1
GAMS 2.25.059  386/486 DOS                      11/13/96 15:26:48  PAGE
19
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 954
 955   DEFLAMLG0         Definition of LAMLG0
 956   DEFLAMLG1         Definition of LAMLG1
 957
 958   DEFLOGL0          Definition of LOGL0
 959   DEFLOGL1          Definition of LOGL1
 960
 961   COMPLLF0          Complementary condition LOGL0
 962   COMPLLF1          Complementary condition LOGL1
 963
 964   DEFLGK0           Definition of LGK0
 965   DEFLGK1           Definition of LGK1
```

```
 966
 967   COMPLKF0          Complementary condition LGK0
 968   COMPLKF1          Complementary condition LGK1
 969
 970   DPROFLG0          Definition of PROFLG0
 971   DPROFLG1          Definition of PROFLG1
 972
 973    PRLF0               Domestic and world market price equality for
logs 0
 974    PRLF1               Domestic and world market price equality for
logs 1
 975
 976   COMPLF0           Complementary condition LOGS 0   Determines PFL0
 977   COMPLF1           Complementary condition LOGS 1   Determines PFL1
 978
 979   DEFF0             Definition of total deforestation 0
 980   DEFF1             Definition of total deforestation 1
 981
 982   DEFD0             Definition of supply of DLAND 0
 983   DEFD1             Definition of supply of DLAND 1
 984
 985
 986  * Prices
 987
 988   DEFPUDL0          Definition of PUDL0
 989   DEFPUDL1          Definition of PUDL1
 990
 991   DEFPUFL0          Definition of PUFL0
 992   DEFPUFL1          Definition of PUFL1
 993
 994   DEFPUK0           Definition of PUK0
 995   DEFPUK1           Definition of PUK1
 996
 997   DEFPUL0           Definition of PUL0
 998   DEFPUL1           Definition of PUL1
 999
1000   DEFPUU0           Definition of PUU0
1001   DEFPUU1           Definition of PUU1
1002
1003   DEFPYT0(T)        Definition of PYT0
1004   DEFPYT1(T)        Definition of PYT1
1005
1006   DEFPYN0(N)        Definition of PYN0
GAMS 2.25.059  386/486 DOS                      11/13/96 15:26:48  PAGE
20
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1007   DEFPYN1(N)        Definition of PYN1
1008
1009   DEFPVT0(T)        Definition of PVT0
1010   DEFPVT1(T)        Definition of PVT1
1011
1012   DEFPVN0(N)        Definition of PVN0
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1013   DEFPVN1(N)        Definition of PVN1
1014
1015   DEFPMT0(T)        Definition of PMT0
1016   DEFPMT1(T)        Definiton of PMT1
1017
1018   DEFPMN0(N)        Definition of PMN0
1019   DEFPMN1(N)        Definition of PMN1
1020
1021   DEFPRT0(T)        Definition of PRT0
1022   DEFPRT1(T)        Definition of PRT1
1023
1024   DEFPRN0(N)        Definition of PRN0
1025   DEFPRN1(N)        Definition of PRN1
1026
1027  * Partial derivatives
1028
1029   DDPYDPLT0(T)      Definition of DPYDPLT0
1030   DDPYDPLT1(T)      Definition of DPYDPLT1
1031
1032   DDPYDPLN0(N)      Definition of DPYDPLN0
1033   DDPYDPLN1(N)      Definiiton of DPYDPLN1
1034
1035   DDPYDPVT0(T)      Definition of DPYDPVT0
1036   DDPYDPVT1(T)      Definition of DPYDPVT1
1037
1038   DDPYDPVN0(N)      Definition of DPYDPVN0
1039   DDPYDPVN1(N)      Definition of DPYDPVN1
1040
1041   DDPVDPUT0(T)      Definition of DPVDPUT0
1042   DDPVDPUT1(T)      Definition of DPVDPUT1
1043
1044   DDPVDPUN0(N)      Definition of DPVDPUN0
1045   DDPVDPUN1(N)      Definition of DPVDPUN1
1046
1047   DDPVDPMT0(T)      Definition of DPVDPMT0
1048   DDPVDPMT1(T)      Definition of DPVDPMT1
1049
1050   DDPVDPMN0(N)      Definition of DPVDPMN0
1051   DDPVDPMN1(N)      Definition of DPVDPMN1
1052
1053   DDPMDPRT0(T)      Definition of DPMDPRT0
1054   DDPMDPRT1(T)      Definition of DPMDPRT1
1055
1056   DDPMDPRN0(N)      Definition of DPMDPRN0
1057   DDPMDPRN1(N)      Definition of DPMDPRN1
1058
1059   DDPMDPFT0(T)      Definition of DPMDPFT0
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1060   DDPMDPFT1(T)      Definition of DPMDPFT1
1061
```

```
1062   DDPMDPFN0(N)      Definition of DPMDPFN0
1063   DDPMDPFN1(N)      Definition of DPMDPFN1
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   DEFMCT0(T)        Definition of MCT0
1110   DEFMCT1(T)        Definition of MCT1
1111
1112   DEFMCN0(N)        Definition of MCN0
```

```
1113   DEFMCN1(N)        Definition of MCN1
1114
1115   DEFPN0(N)         Definition of user price of nontradables 0
1116   DEFPN1(N)         Definition of user price of nontradables 1
1117
1118     PRLMCT0(T)            Producer price marginal cost inequality
condition 0
1119     PRLMCT1(T)            Producer price marginal cost inequality
condotion 1
1120
1121     COMPL0(T)             Complementary condition for tradables 0
Determines

XT0
1122     COMPL1(T)             Complementary condition for tradables 1
Determines

XT1
1123
1124     PREMCN0(N)            Producer price marginal cost inequality
condition 0
1125     PREMCN1(N)            Producer price marginal cost inequality
condition 1
1126
1127    compln0(n)          Complementary condition for nontradables 0
Determines

XN0
1128    compln1(n)          Complementary condition for nontradables 1
Determines

XN1
1129
1130   LDEMANDT0(T)      Tradable demand for SKILLED LABOR 0
1131   LDEMANDT1(T)      Tradable demand for SKILLED LABOR 1
1132
1133   LDEMANDN0(N)      Nontradable demand for SKILLED LABOR 0
1134   LDEMANDN1(N)      Nontradable demand for SKILLED LABOR 1
1135
1136   UDEMANDT0(T)      Tradable demand for UNSKILLED LABOR 0
1137   UDEMANDT1(T)      Tradable demand for UNDKILLED LABOR 1
1138
1139   UDEMANDN0(N)      Nontradable demand for UNSKILLED LABOR 0
1140   UDEMANDN1(N)      Nontradable demand for UNSKILLED LABOR 1
1141
1142   FDEMANDT0(T)      Tradable demand for LOGS 0
1143   FDEMANDT1(T)      Tradable demand for LOGS 1
1144
1145   KDEMANDT0(T)      Tradable demand for CAPITAL 0
1146   KDEMANDT1(T)      Tradable demand for CAPITAL 1
1147
1148   KDEMANDN0(N)      Nontradable demand for CAPITAL 0
1149   KDEMANDN1(N)      Nontradable demand for CAPITAL 1
```

```
1150
1151   DDEMANDT0(T)      Tradable demand for DLAND 0
1152   DDEMANDT1(T)      Tradable demand for DLAND 1
1153
1154  * Investments and domestic interest rate
1155
1156   DEFPI0            Definition of PI0
1157
1158   DEFINVT0(T)        Investment demand for tradables period 0
1159
1160   DEFINVN0(N)        Investment demand for nontradables 0
1161
GAMS 2.25.059  386/486 DOS                        11/13/96 15:26:48  PAGE
23
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1162   DEFK1             Definition of capital stock period 1
1163
1164  * Rest of world
1165
1166   TRADEBAL0         Trade balance 0   Determines SBAR0
1167   TRADEBAL1         Trade balance 1   Determines SBAR2
1168
1169   DEFinv0           Arbitrage condition SBAR Det SAV0
1170
1171
1172  * Market clearing
1173
1174   TMARKET0(T)       Market clearing for tradables 0   Determines ZT0
1175   TMARKET1(T)       Market clearing for tradables 1   Determines ZT1
1176
1177   NMARKET0(N)        Market clearing for nontradables 0   Determines
PPN0
1178   NMARKET1(N)        Market clearing for nontradables 1   Determines
PPN1
1179
1180   FMARKET0          Market clearing for LOGS 0   Determines FEXP0
1181   FMARKET1          Market clearing for LOGS 1   Determines FEXP1
1182
1183   DMARKET0          Market clearing for DLAND 0   Determines PDL0
1184   DMARKET1          Market clearing for DLAND 1   Determines PDL1
1185
1186   CMARKET0          Market clearing for CAPITAL 0   Determines PK0
1187   CMARKET1          Market clearing for CAPITAL 1   Determines PK1
1188
1189   LMARKET0          Market clearing for SKILLED LABOR 0   Determines
PL0
1190   LMARKET1          Market clearing for SKILLED LABOR 1   Determines
PL1
1191
1192     UMARKET0               Market clearing for UNSKILLED LABOR 0
Determines PU0
1193     UMARKET1               Market clearing for UNDKILLED 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  * Slack variable equation
1205
1206  * Consumers
1207
1208                                                          DEFUTIL0..
UTIL0=E=LOG(PROD(T,DT0(T)**BT(T))*PROD(N,DN0(N)**BN(N))

);
1209                                                          DEFUTIL1..
UTIL1=E=LOG(PROD(T,DT1(T)**BT(T))*PROD(N,DN1(N)**BN(N))

);
1210
1211   DEFWELF..        WELF=E=UTIL0+1/RAU*UTIL1;
GAMS 2.25.059  386/486 DOS                      11/13/96 15:26:48  PAGE
24
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1212
1213   DEFDISP0..       DISP0=E=PUK0*K0+PUL0*L0+PUU0*U0+PUDL0*DSTAR+
1214                    SUM(T,TTAX0(T)*XT0(T))+SUM(N,NTAX0(N)*XN0(N))

+PROFSQ0+PROFLG0;
1215   DEFDISP1..       DISP1=E=PUK1*K1+PUL1*L1+PUU1*U1+PUDL1*D0+
1216                    SUM(T,TTAX1(T)*XT1(T))+SUM(N,NTAX0(N)*XN1(N))

+PROFSQ1+proflg1;
1217
1218   TCONS0(T)..      DT0(T)=E=BT(T)*(DISP0-SAV0)/PW0(T);
1219   TCONS1(T)..      DT1(T)=E=BT(T)*(DISP1+SAV0)/PW1(T)*IRATE/RAU;
1220
1221   NCONS0(N)..      DN0(N)=E=BN(N)*(DISP0-SAV0)/PN0(N);
1222   NCONS1(N)..      DN1(N)=E=BN(N)*(DISP1+SAV0)/PN1(N)*IRATE/RAU;
1223
1224  * Deforestation sectors
1225
1226  * Calculation of parameters
1227
```

```
1228   DEFALPHA..        lab=e=(1/(BETA*CAP**ALPHA))**(1/(BETA-1));
1229   DEFBETA..         cap=e=(1/(ALPHA*LAB**BETA))**(1/(ALPHA-1));
1230
1231  * Undefined property rights
1232  * Production functions
1233
1234  * Loggers
1235
1236   DEFFLOG0..        flog0=g=lgk0**alpha.l*logl0**beta.l;
1237
1238   DEFFLOG1..        flog1=g=lgk1**alpha.l*logl1**beta.l;
1239
1240            COMPLDF0..                              (flog0-low)*(flog0-
lgk0**alpha.l*logl0**beta.l)=e=0;
1241            COMPLDF1..                              (flog1-low)*(flog1-
lgk1**alpha.l*logl1**beta.l)=e=0;
1242
1243    DEFLOGL0..        logl0-(puU0/(PFL0*beta.l*lgk0**alpha.l))
                                                                **(1/(beta.l-
1))=l=0;
1244    DEFLOGL1..        logl1-(PUU1/(PFL1*beta.l*lgk1**alpha.l))
                                                                **(1/(beta.l-
1))=l=0;
1245
1246                 COMPLLF0..                         (LOGL0-low)*(logl0-
(PUU0/(PFL0*beta.l*lgk0**alpha.l))**
1247                  (1/(beta.l-1)))=E=0;
1248                 COMPLLF1..                         (LOGL1-low)*(logl1-
(PUU1/(PFL1*beta.l*lgk1**alpha.l))**
1249                  (1/(beta.l-1)))=E=0;
1250
1251                      DEFLGK0..                                  lGK0-
(PUK0/(PFL0*ALPHA.L*lOGL0**BETA.L))**(1/(ALPHA.L-1)

)-
1252                                                      1/IRATE*(lGK1-
(PUK1/(PFL1*ALPHA.L*lOGL1**BETA.L))**
1253                   (1/(ALPHA.L-1)))=l=LAMLG0;
1254                      DEFLGK1..                                  lGK1-
(PUK1/(PFL1*ALPHA.L*lOGL1**BETA.L))**(1/(ALPHA.L-1)

)=l=
1255                   LAMLG1;
1256
1257                          COMPLKF0..                 (lGK0-low)*(lGK0-
(PUK0/(PFL0*ALPHA.L*lOGL0**BETA.L))**
1258                                          (1/(ALPHA.L-1))-1/IRATE*(lGK1-
(PUK1/(PFL1*ALPHA.L*lOGL1**BET
GAMS 2.25.059  386/486 DOS                      11/13/96 15:26:48  PAGE
25
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n
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A.L))**
1259                (1/(ALPHA.L-1))))=E=LAMLG0;
1260                          COMPLKF1..                  (lGK1-low)*(lGK1-
(PUK1/(PFL1*ALPHA.L*lOGL1**BETA.L))**
1261                (1/(ALPHA.L-1)))=E=LAMLG1;
1262
1263   DEFLAMLG0..      LAMLG0*(TOTDEF-F0)=E=0;
1264   DEFLAMLG1..      LAMLG1*(TOTDEF-F0-F1)=E=0;
1265
1266   DPROFLG0..      PFL0*FLOG0-PUU0*LOGL0-PUK0*LGK0=E=PROFLG0;
1267   DPROFLG1..      PFL1*FLOG1-PUU1*LOGL1-PUK1*LGK1=E=PROFLG1;
1268
1269
1270  * Well defined property rights
1271
1272   DDEF01..         DOSQ0+DOSQ1+FLOG0+FLOG1=E=DEF01;
1273   DLAM..           DOSQ0+DOSQ1+FLOG0+FLOG1=L=TOTDEF;
1274
1275  * Squatters
1276
1277   DEFDOSQ0..        DOSQ0=g=LSQ0**GAMMA;
1278   DEFDOSQ1..        DOSQ1=g=LSQ1**GAMMA;
1279
1280   COMPLDQ0..         (DOSQ0-low)*(dosq0-lsq0**gamma)=e=0;
1281   COMPLDQ1..         (DOSQ1-low)*(dosq1-lsq1**gamma)=e=0;
1282
1283   DEFLSQ0..         pdl0*gamma*lsq0**(gamma-1)-puu0-
1284                                1/irate*(pdl1*gamma*lsq1**(gamma-1)-
puu1)=l=lamsq0;
1285   DEFLSQ1..         pdl1*gamma*lsq1**(gamma-1)-puu1=l=lamsq1;
1286
1287   COMPLLQ0..        (LSQ0-low)*(pdl0*gamma*lsq0**(gamma-1)-puu0-
1288                                1/irate*(pdl1*gamma*lsq1**(gamma-1)-
puu1))=E=lamsq0;
1289      COMPLLQ1..              (LSQ1-low)*(pdl1*gamma*lsq1**(gamma-1)-
puu1)=E=lamsq1;
1290
1291   DEFLAMSQ0..        LAMSQ0*(TOTDEF-f0)=E=0;
1292   deflamsq1..        LAMSQ1*(TOTDEF-F0-F1)=E=0;
1293
1294   DPROFSQ0..        PDL0*DOSQ0-PUU0*LSQ0=E=PROFSQ0;
1295   DPROFSQ1..        PDL1*DOSQ1-PUU1*LSQ1=E=PROFSQ1;
1296
1297  * Tradable logs equations
1298
1299   PRLF0..           PWF0-PFL0=L=0;
1300   PRLF1..           PWF1-PFL1=L=0;
1301
1302   COMPLF0..         FLOG0*(PWF0-PFL0)=E=0;
1303   COMPLF1..         FLOG1*(PWF1-PFL1)=E=0;
1304
1305  * Total deforestation
1306
1307   DEFD0..          D0=E=DSTAR+LSQ0;
1308   DEFD1..          D1=E=D0+LSQ1;
```

```
1309
1310   DEFF0..          F0=E=FLOG0+DOSQ0;
GAMS 2.25.059  386/486 DOS                        11/13/96 15:26:48  PAGE
26
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1311   DEFF1..          F1=E=FLOG1+DOSQ1;
1312
1313  * Prices
1314
1315   DEFPUFL0..        PUFL0=E=PWF0*(1+FTAX0);
1316   DEFPUFL1..        PUFL1=E=PWF1*(1+FTAX1);
1317
1318   DEFPUDL0..        PUDL0=E=PDL0*(1+DTAX0);
1319   DEFPUDL1..        PUDL1=E=PDL1*(1+DTAX1);
1320
1321   DEFPUK0..         PUK0=E=PK0*(1+KTAX0);
1322   DEFPUK1..         PUK1=E=PK1*(1+KTAX1);
1323
1324   DEFPUL0..         PUL0=E=PL0*(1+LTAX0);
1325   DEFPUL1..         PUL1=E=PL1*(1+LTAX1);
1326
1327   DEFPUU0..         PUU0=E=PU0*(1+UTAX0);
1328   DEFPUU1..         PUU1=E=PU1*(1+UTAX1);
1329
1330   DEFPYT0(T)..      PYT0(T)=E=(DELLYT(T)*PUL0**
1331                    (1-SIGYT(T))+(1-DELLYT(T))*PVT0(T)**
1332                    (1-SIGYT(T)))**(1/(1-SIGYT(T)));
1333
1334   DEFPYT1(T)..      PYT1(T)=E=(DELLYT(T)*PUL1**
1335                    (1-SIGYT(T))+(1-DELLYT(T))*PVT1(T)**
1336                    (1-SIGYT(T)))**(1/(1-SIGYT(T)));
1337
1338   DEFPYN0(N)..      PYN0(N)=E=(DELLYN(N)*PUL0**
1339                    (1-SIGYN(N))+(1-DELLYN(N))*PVN0(N)**
1340                    (1-SIGYN(N)))**(1/(1-SIGYN(N)));
1341
1342   DEFPYN1(N)..      PYN1(N)=E=(DELLYN(N)*PUL1**
1343                    (1-SIGYN(N))+(1-DELLYN(N))*PVN1(N)**
1344                    (1-SIGYN(N)))**(1/(1-SIGYN(N)));
1345
1346   DEFPVT0(T)..      PVT0(T)=E=(DELUVT(T)*PUU0**(1-SIGVT(T))+
1347                    (1-DELUVT(T))*PMT0(T)**
1348                    (1-SIGVT(T)))**(1/(1-SIGVT(T)));
1349
1350   DEFPVT1(T)..      PVT1(T)=E=(DELUVT(T)*PUU1**(1-SIGVT(T))+
1351                    (1-DELUVT(T))*PMT1(T)**
1352                    (1-SIGVT(T)))**(1/(1-SIGVT(T)));
1353
1354   DEFPVN0(N)..      PVN0(N)=E=(DELUVN(N)*PUU0**(1-SIGVN(N))+
1355                    (1-DELUVN(N))*PMN0(N)**
1356                    (1-SIGVN(N)))**(1/(1-SIGVN(N)));
1357
```

```
1358   DEFPVN1(N)..      PVN1(N)=E=(DELUVN(N)*PUU1**(1-SIGVN(N))+
1359                    (1-DELUVN(N))*PMN1(N)**
1360                    (1-SIGVN(N)))**(1/(1-SIGVN(N)));
1361
1362   DEFPMT0(T)..      PMT0(T)=E=(DELFMT(T)*PUFL0**(1-SIGMT(T))+
1363                    (1-DELFMT(T))*PRT0(T)**
GAMS 2.25.059  386/486 DOS                        11/13/96 15:26:48  PAGE
27
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1364                    (1-SIGMT(T)))**(1/(1-SIGMT(T)));
1365
1366   DEFPMT1(T)..      PMT1(T)=E=(DELFMT(T)*PUFL1**(1-SIGMT(T))+
1367                    (1-DELFMT(T))*PRT1(T)**
1368                    (1-SIGMT(T)))**(1/(1-SIGMT(T)));
1369
1370   DEFPMN0(N)..      PMN0(N)=E=(DELFMN(N)*PUFL0**(1-SIGMN(N))+
1371                    (1-DELFMN(N))*PRN0(N)**
1372                    (1-SIGMN(N)))**(1/(1-SIGMN(N)));
1373
1374   DEFPMN1(N)..      PMN1(N)=E=(DELFMN(N)*PUFL1**(1-SIGMN(N))+
1375                    (1-DELFMN(N))*PRN1(N)**
1376                    (1-SIGMN(N)))**(1/(1-SIGMN(N)));
1377
1378   DEFPRT0(T)..      PRT0(T)=E=(DELKRT(T)*PUK0**(1-SIGRT(T))
1379                   +(1-DELKRT(T))*PUDL0**
1380                   (1-SIGRT(T)))**(1/(1-SIGRT(T)));
1381
1382   DEFPRT1(T)..      PRT1(T)=E=(DELKRT(T)*PUK1**(1-SIGRT(T))
1383                   +(1-DELKRT(T))*PUDL1**
1384                   (1-SIGRT(T)))**(1/(1-SIGRT(T)));
1385
1386   DEFPRN0(N)..     PRN0(N)=E=(DELKRN(N)*PUK0**(1-SIGRN(N))
1387                   +(1-DELKRN(N))*PUDL0**
1388                   (1-SIGRN(N)))**(1/(1-SIGRN(N)));
1389
1390   DEFPRN1(N)..     PRN1(N)=E=(DELKRN(N)*PUK1**(1-SIGRN(N))
1391                   +(1-DELKRN(N))*PUDL1**
1392                   (1-SIGRN(N)))**(1/(1-SIGRN(N)));
1393
1394  * Partial derivatives
1395
1396   DDPYDPLT0(T).. DPYDPLT0(T)=E=DELLYT(T)*(PYT0(T)
1397                  **SIGYT(T))*(PUL0**(-SIGYT(T)));
1398
1399   DDPYDPLT1(T).. DPYDPLT1(T)=E=DELLYT(T)*(PYT1(T)
1400                  **SIGYT(T))*(PUL1**(-SIGYT(T)));
1401
1402   DDPYDPLN0(N).. DPYDPLN0(N)=E=DELLYN(N)*(PYN0(N)
1403                  **SIGYN(N))*(PUL0**(-SIGYN(N)));
1404
1405   DDPYDPLN1(N).. DPYDPLN1(N)=E=DELLYN(N)*(PYN1(N)
1406                  **SIGYN(N))*(PUL1**(-SIGYN(N)));
```

```
1407
1408   DDPYDPVT0(T).. DPYDPVT0(T)=E=(1-DELLYT(T))*(PYT0(T)
1409                 **SIGYT(T))*(PVT0(T)**(-SIGYT(T)));
1410
1411   DDPYDPVT1(T).. DPYDPVT1(T)=E=(1-DELLYT(T))*(PYT1(T)
1412                 **SIGYT(T))*(PVT1(T)**(-SIGYT(T)));
1413
1414   DDPYDPVN0(N).. DPYDPVN0(N)=E=(1-DELLYN(N))*(PYN0(N)
1415                 **SIGYN(N))*(PVN0(N)**(-SIGYN(N)));
1416
GAMS 2.25.059  386/486 DOS                    11/13/96 15:26:48  PAGE
28
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1417   DDPYDPVN1(N).. DPYDPVN1(N)=E=(1-DELLYN(N))*(PYN1(N)
1418                 **SIGYN(N))*(PVN1(N)**(-SIGYN(N)));
1419
1420   DDPVDPMT0(T).. DPVDPMT0(T)=E=(1-DELUVT(T))*(PVT0(T)**
1421                   SIGVT(T))*(PMT0(T)**(-SIGVT(T)));
1422
1423   DDPVDPMT1(T).. DPVDPMT1(T)=E=(1-DELUVT(T))*(PVT1(T)**
1424                   SIGVT(T))*(PMT1(T)**(-SIGVT(T)));
1425
1426   DDPVDPMN0(N).. DPVDPMN0(N)=E=(1-DELUVN(N))*(PVN0(N)**
1427                   SIGVN(N))*(PMN0(N)**(-SIGVN(N)));
1428
1429   DDPVDPMN1(N).. DPVDPMN1(N)=E=(1-DELUVN(N))*(PVN1(N)**
1430                   SIGVN(N))*(PMN1(N)**(-SIGVN(N)));
1431
1432   DDPVDPUT0(T).. DPVDPUT0(T)=E=DELUVT(T)*(PVT0(T)**SIGVT(T))*
1433                  (PUU0**(-SIGVT(T)));
1434
1435   DDPVDPUT1(T).. DPVDPUT1(T)=E=DELUVT(T)*(PVT1(T)**SIGVT(T))*
1436                  (PUU1**(-SIGVT(T)));
1437
1438   DDPVDPUN0(N).. DPVDPUN0(N)=E=DELUVN(N)*(PVN0(N)**SIGVN(N))*
1439                  (PUU0**(-SIGVN(N)));
1440
1441   DDPVDPUN1(N).. DPVDPUN1(N)=E=DELUVN(N)*(PVN1(N)**SIGVN(N))*
1442                  (PUU1**(-SIGVN(N)));
1443
1444   DDPMDPRT0(T).. DPMDPRT0(T)=E=(1-DELFMT(T))*(PMT0(T)**
1445                   SIGMT(T))*(PRT0(T)**(-SIGMT(T)));
1446
1447   DDPMDPRT1(T).. DPMDPRT1(T)=E=(1-DELFMT(T))*(PMT1(T)**
1448                   SIGMT(T))*(PRT1(T)**(-SIGMT(T)));
1449
1450   DDPMDPRN0(N).. DPMDPRN0(N)=E=(1-DELFMN(N))*(PMN0(N)**
1451                  SIGMN(N))*(PRN0(N)**(-SIGMN(N)));
1452
1453   DDPMDPRN1(N).. DPMDPRN1(N)=E=(1-DELFMN(N))*(PMN1(N)**
1454                  SIGMN(N))*(PRN1(N)**(-SIGMN(N)));
1455
```

```
1456   DDPMDPFT0(T).. DPMDPFT0(T)=E=DELFMT(T)*(PMT0(T)**SIGMT(T))*
1457                   (PUFL0**(-SIGMT(T)));
1458
1459   DDPMDPFT1(T).. DPMDPFT1(T)=E=DELFMT(T)*(PMT1(T)**SIGMT(T))*
1460                   (PUFL1**(-SIGMT(T)));
1461
1462   DDPMDPFN0(N).. DPMDPFN0(N)=E=DELFMN(N)*(PMN0(N)**SIGMN(N))*
1463                   (PUFL0**(-SIGMN(N)));
1464
1465   DDPMDPFN1(N).. DPMDPFN1(N)=E=DELFMN(N)*(PMN1(N)**SIGMN(N))*
1466                   (PUFL1**(-SIGMN(N)));
1467
1468   DDPRDPKT0(T).. DPRDPKT0(T)=E=DELKRT(T)*(PRT0(T)**SIGRT(T))*
1469                  (PUK0**(-SIGRT(T)));
GAMS 2.25.059  386/486 DOS                        11/13/96 15:26:48  PAGE
29
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1470
1471   DDPRDPKT1(T).. DPRDPKT1(T)=E=DELKRT(T)*(PRT1(T)**SIGRT(T))*
1472                  (PUK1**(-SIGRT(T)));
1473
1474   DDPRDPKN0(N).. DPRDPKN0(N)=E=DELKRN(N)*(PRN0(N)**SIGRN(N))*
1475                  (PUK0**(-SIGRN(N)));
1476
1477   DDPRDPKN1(N).. DPRDPKN1(N)=E=DELKRN(N)*(PRN1(N)**SIGRN(N))*
1478                  (PUK1**(-SIGRN(N)));
1479
1480   DDPRDPDT0(T).. DPRDPDT0(T)=E=(1-DELKRT(T))*(PRT0(T)**SIGRT(T))
1481                  *(PUDL0**(-SIGRT(T)));
1482
1483   DDPRDPDT1(T).. DPRDPDT1(T)=E=(1-DELKRT(T))*(PRT1(T)**SIGRT(T))
1484                  *(PUDL1**(-SIGRT(T)));
1485
1486   DDPRDPDN0(N).. DPRDPDN0(N)=E=(1-DELKRN(N))*(PRN0(N)**SIGRN(N))*
1487                   (PUDL0**(-SIGRN(N)));
1488
1489   DDPRDPDN1(N).. DPRDPDN1(N)=E=(1-DELKRN(N))*(PRN1(N)**SIGRN(N))*
1490                   (PUDL1**(-SIGRN(N)));
1491
1492   DDPXDPDT0(T)..  DPXDPDT0(T)=E=AT(T)*DPYDPVT0(T)*DPVDPMT0(T)
1493                   *DPMDPRT0(T)*DPRDPDT0(T);
1494
1495   DDPXDPDT1(T)..  DPXDPDT1(T)=E=AT(T)*DPYDPVT1(T)*DPVDPMT1(T)
1496                   *DPMDPRT1(T)*DPRDPDT1(T);
1497
1498                                                    DDPXDPDN0(N)..
DPXDPDN0(N)=E=AN(N)*DPYDPVN0(N)*DPVDPMN0(N)*DPMDPRN0(N)*
1499                    DPRDPDN0(N);
1500
1501                                                    DDPXDPDN1(N)..
DPXDPDN1(N)=E=AN(N)*DPYDPVN1(N)*DPVDPMN1(N)*DPMDPRN1(N)*
1502                    DPRDPDN1(N);
```

```
1503
1504                                                        DDPXDPKT0(T)..
DPXDPKT0(T)=E=AT(T)*DPYDPVT0(T)*DPVDPMT0(T)*DPMDPRT0(T)*
1505                    DPRDPKT0(T);
1506
1507                                                        DDPXDPKT1(T)..
DPXDPKT1(T)=E=AT(T)*DPYDPVT1(T)*DPVDPMT1(T)*DPMDPRT1(T)*
1508                    DPRDPKT1(T);
1509
1510                                                        DDPXDPKN0(N)..
DPXDPKN0(N)=E=AN(N)*DPYDPVN0(N)*DPVDPMN0(N)*DPMDPRN0(N)*
1511                    DPRDPKN0(N);
1512
1513                                                        DDPXDPKN1(N)..
DPXDPKN1(N)=E=AN(N)*DPYDPVN1(N)*DPVDPMN1(N)*DPMDPRN1(N)*
1514                    DPRDPKN1(N);
1515
1516                                                        DDPXDPFT0(T)..
DPXDPFT0(T)=E=AT(T)*DPYDPVT0(T)*DPVDPMT0(T)*DPMDPFT0(T);
1517
1518                                                        DDPXDPFT1(T)..
DPXDPFT1(T)=E=AT(T)*DPYDPVT1(T)*DPVDPMT1(T)*DPMDPFT1(T);
1519
1520                                                        DDPXDPFN0(N)..
DPXDPFN0(N)=E=AN(N)*DPYDPVN0(N)*DPVDPMN0(N)*DPMDPFN0(N);
1521
1522                                                        DDPXDPFN1(N)..
DPXDPFN1(N)=E=AN(N)*DPYDPVN1(N)*DPVDPMN1(N)*DPMDPFN1(N);
```



```
1523
1524   DDPXDPUT0(T).. DPXDPUT0(T)=E=AT(T)*DPYDPVT0(T)*DPVDPUT0(T);
1525
1526   DDPXDPUT1(T).. DPXDPUT1(T)=E=AT(T)*DPYDPVT1(T)*DPVDPUT1(T);
1527
1528   DDPXDPUN0(N).. DPXDPUN0(N)=E=AN(N)*DPYDPVN0(N)*DPVDPUN0(N);
1529
1530   DDPXDPUN1(N).. DPXDPUN1(N)=E=AN(N)*DPYDPVN1(N)*DPVDPUN1(N);
1531
1532   DDPXDPLT0(T).. DPXDPLT0(T)=E=AT(T)*DPYDPLT0(T);
1533
1534   DDPXDPLT1(T).. DPXDPLT1(T)=E=AT(T)*DPYDPLT1(T);
1535
1536   DDPXDPLN0(N).. DPXDPLN0(N)=E=AN(N)*DPYDPLN0(N);
1537
1538   DDPXDPLN1(N).. DPXDPLN1(N)=E=AN(N)*DPYDPLN1(N);
1539
1540  * Producers
1541
1542   DEFMCT0(T)..      MCT0(T)=E=AT(T)*PYT0(T)+SUM(TT,PW0(TT)*
1543                     ATT(TT,T))+SUM(N,PN0(N)*ANT(N,T))+TTAX0(T);
```

```
1544
1545   DEFMCT1(T)..      MCT1(T)=E=AT(T)*PYT1(T)+SUM(TT,PW1(TT)*
1546                     ATT(TT,T))+SUM(N,PN1(N)*ANT(N,T))+TTAX1(T);
1547
1548   DEFMCN0(N)..      MCN0(N)=E=AN(N)*PYN0(N)+SUM(TT,PW0(TT)*
1549                     ATN(TT,N))+SUM(NN,PN0(NN)*ANN(NN,N))+NTAX0(N);
1550
1551   DEFMCN1(N)..      MCN1(N)=E=AN(N)*PYN1(N)+SUM(TT,PW1(TT)*
1552                     ATN(TT,N))+SUM(NN,PN1(NN)*ANN(NN,N))+NTAX0(N);
1553
1554   DEFPN0(N)..       PN0(N)=E=PPN0(N);
1555   DEFPN1(N)..       PN1(N)=E=PPN1(N);
1556
1557   PRLMCT0(T)..      PW0(T)-MCT0(T)=L=0;
1558   PRLMCT1(T)..      PW1(T)-MCT1(T)=L=0;
1559
1560   COMPL0(T)..       XT0(T)*(PW0(T)-MCT0(T))=E=0;
1561   COMPL1(T)..       XT1(T)*(PW1(T)-MCT1(T))=E=0;
1562
1563   PREMCN0(N)..      PPN0(N)-MCN0(N)=e=0;
1564   PREMCN1(N)..      PPN1(N)-MCN1(N)=e=0;
1565
1566   compln0(n)..      xn0(n)*(PPN0(N)-MCN0(N))=e=0;
1567   compln1(n)..      xn1(n)*(PPN1(N)-MCN1(N))=e=0;
1568
1569   LDEMANDT0(T)..    LLT0(T)=E=DPXDPLT0(T)*XT0(T);
1570   LDEMANDT1(T)..    LLT1(T)=E=DPXDPLT1(T)*XT1(T);
1571
1572   LDEMANDN0(N)..    LN0(N)=E=DPXDPLN0(N)*XN0(N);
1573   LDEMANDN1(N)..    LN1(N)=E=DPXDPLN1(N)*XN1(N);
1574
1575   UDEMANDT0(T)..    UT0(T)=E=DPXDPUT0(T)*XT0(T);
GAMS 2.25.059  386/486 DOS                        11/13/96 15:26:48  PAGE
31
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1576   UDEMANDT1(T)..    UT1(T)=E=DPXDPUT1(T)*XT1(T);
1577
1578   UDEMANDN0(N)..    UN0(N)=E=DPXDPUN0(N)*XN0(N);
1579   UDEMANDN1(N)..    UN1(N)=E=DPXDPUN1(N)*XN1(N);
1580
1581   FDEMANDT0(T)..    FLT0(T)=E=DPXDPFT0(T)*XT0(T);
1582   FDEMANDT1(T)..    FLT1(T)=E=DPXDPFT1(T)*XT1(T);
1583
1584   KDEMANDT0(T)..    KT0(T)=E=DPXDPKT0(T)*XT0(T);
1585   KDEMANDT1(T)..    KT1(T)=E=DPXDPKT1(T)*XT1(T);
1586
1587   KDEMANDN0(N)..    KN0(N)=E=DPXDPKN0(N)*XN0(N);
1588   KDEMANDN1(N)..    KN1(N)=E=DPXDPKN1(N)*XN1(N);
1589
1590   DDEMANDT0(T)..    DLT0(T)=E=DPXDPDT0(T)*XT0(T);
1591   DDEMANDT1(T)..    DLT1(T)=E=DPXDPDT1(T)*XT1(T);
1592
```

```
1593  * Investments and interest
1594
1595    DEFPI0..              PI0*INV0=E=SUM(T,  INVT0(T)*PW0(T))+  SUM(N,
INVN0(N)

*PN0(N));
1596
1597   DEFINVT0(T)..     INVT0(T)=E=INVSHRT(T)*INV0/PW0(T);
1598
1599   DEFINVN0(N)..     INVN0(N)=E=INVSHRN(N)*INV0/PN0(N);
1600
1601   DEFK1..            K1=e=K0+INV0-KDEPL*K0;
1602
1603  * Rest of world
1604
1605   TRADEBAL0..       SUM(T,PW0(T)*ZT0(T))+PWF0*FEXP0=E=SBAR0;
1606   TRADEBAL1..       SUM(T,PW1(T)*ZT1(T))+PWF1*FEXP1=E=-IRATE*SBAR0;
1607
1608   definv0..        pk0=e=1/irate*pk1;
1609
1610  * Market clearing
1611
1612                                                        TMARKET0(T)..
XT0(T)=E=SUM(TT,ATT(T,TT)*XT0(TT))+SUM(N,ATN(T,N)*
1613                      XN0(N))+ZT0(T)+DT0(T)+INVT0(T);
1614
1615                                                        TMARKET1(T)..
XT1(T)=E=SUM(TT,ATT(T,TT)*XT1(TT))+SUM(N,ATN(T,N)*
1616                     XN1(N))+ZT1(T)+DT1(T)+INVT1(T);
1617
1618   NMARKET0(N)..    XN0(N)=E=SUM(T,ANT(N,T)*XT0(T))+SUM(NN,ANN(N,NN)*
1619                    XN0(NN))+DN0(N)+INVN0(N);
1620
1621   NMARKET1(N)..    XN1(N)=E=SUM(T,ANT(N,T)*XT1(T))+SUM(NN,ANN(N,NN)*
1622                    XN1(NN))+DN1(N)+INVN1(N);
1623
1624   FMARKET0..       flog0=E=SUM(T,PWF0*FLT0(T))+PWF0*FEXP0;
1625
1626   FMARKET1..       flog1+LGK1=E=SUM(T,PWF1*FLT1(T))+PWF1*FEXP1;
1627
GAMS 2.25.059  386/486 DOS                        11/13/96 15:26:48  PAGE
32
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1628   DMARKET0..       SUM(T,DLT0(T))-DSTAR-dosq0=E=0;
1629
1630   DMARKET1..       SUM(T,DLT1(T))-D0-dosq1=E=0;
1631
1632   CMARKET0..       K0=E=SUM(T,KT0(T))+SUM(N,KN0(N))+LGK0;
1633
1634   CMARKET1..       K1=E=SUM(T,KT1(T))+SUM(N,KN1(N))+LGK1;
1635
1636   LMARKET0..       L0=E=SUM(T,LLT0(T))+SUM(N,LN0(N));
```

```
1637
1638   LMARKET1..       L1=E=SUM(T,LLT1(T))+SUM(N,LN1(N));
1639
1640   UMARKET0..       U0=E=SUM(T,UT0(T))+SUM(N,UN0(N))+LOGL0+LSQ0;
1641
1642   UMARKET1..       U1=E=SUM(T,UT1(T))+SUM(N,UN1(N))+LOGL1+LSQ1;
1643
1644  * Model closure
1645
1646                                                          DEFGNP0..
PUK0*K0+PUL0*L0+PUU0*U0+PUDL0*DSTAR+SUM(T,TTAX0(T)*
1647                  XT0(T))+SUM(N,NTAX0(N)*XN0(N))=E=YY0;
1648
1649
1650   DEFGNP1..        PUK1*K1+PUL1*L1+PUU1*U1+PUDL1*D0+SUM(T,TTAX1(T)*
1651                  XT1(T))+SUM(N,NTAX0(N)*XN1(N))=E=YY1;
1652
1653
1654
1655
1656
1657  * LOWER BOUNDS
1658                  ALPHA.LO=0.1; BETA.LO=0.1;
1659
1660                  ALPHA.UP=1; BETA.UP=1;
1661
1662                  dosq0.lo=low; dosq1.lo=low;
1663
1664                  lsq0.lo=low; lsq1.lo=low;
1665
1666                  flog0.lo=low; flog1.lo=low;
1667
1668                  lgk0.lo=low; lgk1.lo=low;
1669
1670                  logl0.lo=low; logl1.lo=low;
1671
1672                  DN1.LO(N)=0.001; DT1.LO(T)=0.001; DN0.LO(N)=0.001;

DT0.LO(T)=0.001;
1673
1674                  PN0.LO(N)=0.10; PYT0.LO(T)=0.10; PVT0.LO(T)=0.10;
1675
1676                  PMT0.LO(T)=0.10; PRT0.LO(T)=0.10;
1677
1678                  PK0.LO=0.10; PU0.LO=0.10;PL0.LO=0.10;
1679
GAMS 2.25.059  386/486 DOS                      11/13/96 15:26:48  PAGE
33
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1680                  PDL0.LO=0.50; PFL0.LO=0.10;
1681
1682                  PYN0.LO(N)=0.10; PVN0.LO(N)=0.10; PMN0.LO(N)=0.10;
```

```
1683
1684                    PPN0.LO(N)=0.10; PRN0.LO(N)=0.10;
1685
1686                    PUDL0.LO=0.10; PUFL0.LO=0.10;
1687
1688                    PUL0.LO=0.10; PUK0.LO=0.10; PUU0.LO=0.10;
1689
1690                    PN1.LO(N)=0.10; PYT1.LO(T)=0.10; PVT1.LO(T)=0.10;
1691
1692                    PMT1.LO(T)=0.10; PRT1.LO(T)=0.10;
1693
1694                    PK1.LO=0.10; PU1.LO=0.10;PL1.LO=0.10;
1695
1696                    PDL1.LO=0.50; PFL1.LO=0.10;
1697
1698                    PYN1.LO(N)=0.10; PVN1.LO(N)=0.10; PMN1.LO(N)=0.10;
1699
1700                    PPN1.LO(N)=0.10; PRN1.LO(N)=0.10;
1701
1702                    PUDL1.LO=0.10; PUFL1.LO=0.10;
1703
1704                    PUL1.LO=0.10; PUK1.LO=0.10; PUU1.LO=0.10;
1705
1706                    DT0.LO(T)=0.0001; DT1.LO(T)=0.0001;
1707                    DN0.LO(N)=0.0001; DN1.LO(N)=0.0001;
1708
1709
1710
1711
1712
1713
1714
1715  *INITIAL VALUES
1716
INCLUDE    C:\GAMS\CRMOD\INITIAL.INC
1718  * INITIAL VALUES FOM BASE SOLUTION
1719    PI0.L=0.9582;
1720  * IRATE.L=1.000;
1721   WELF.L=-0.1995;
1722   UTIL0.L=-0.1366;
1723   UTIL1.L=-0.3465;
1724   SAV0.L=0;
1725   INV0.L=0.3382;
1726   SBAR0.L=-0.3382;
1727   YY0.L=yy01;
1728   YY1.L=yy11;
1729   DISP0.L=3.2017;
1730   DISP1.L=3.5688;
1731   XT0.L(T)=XT01(T);
1732   XT1.L(T)=XT11(T);
GAMS 2.25.059  386/486 DOS                    11/13/96 15:26:48  PAGE
34
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n
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1733    XN0.L(N)=XN01(N);
1734    XN1.L(N)=XN11(N);
1735    DT0.L(T)=DT01(T);
1736    DT1.L(T)=DT11(T);
1737    DN0.L(N)=DN01(N);
1738    DN1.L(N)=DN11(N);
1739    ZT0.L(T)=ZT01(T);
1740    ZT1.L(T)=ZT11(T);
1741    KT0.L(T)=KT01(T);
1742    KT1.L(T)=KT11(T);
1743    KN0.L(N)=KN01(N);
1744    KN1.L(N)=KN11(N);
1745    LLT0.L(T)=LLT01(T);
1746    LLT1.L(T)=LLT11(T);
1747    LN0.L(N)=LN01(N);
1748    LN1.L(N)=LN11(N);
1749    UT0.L(T)=UT01(T);
1750    UT1.L(T)=UT11(T);
1751    UN0.L(N)=UN01(N);
1752    UN1.L(N)=UN11(N);
1753    DLT0.L(T)=DLT01(T);
1754    DLT1.L(T)=DLT11(T);
1755    DOSQ0.L=dosq01;
1756    DOSQ1.L=dosq11;
1757    LSQ0.L=lsq01;
1758    LSQ1.L=lsq11;
1759    FLOG0.L=flog01;
1760    FLOG1.L=flog11;
1761    LOGL0.L=LOGL01;
1762    LOGL1.L=LOGL11;
1763    LGK0.L=LGK01;
1764    LGK1.L=LGK11;
1765    FEXP0.L=FEXP01;
1766    FEXP1.L=FEXP11;
1767    D0.L=D01;
1768    D1.L=D11;
1769    F0.L=F01;
1770    F1.L=F11;
1771    DEF01.L=0.0134;
1772
1773                    PN0.L(N)=1.000; PYT0.L(T)=1.000; PVT0.L(T)=1.000;
1774
1775                    PMT0.L(T)=1.000; PRT0.L(T)=1.000; PL0.L=1;
1776                    PK0.L=0.9911; PFL0.L=0.9810; PU0.L=1.0318;
1777
1778                    PDL0.L=0.9702;
1779
1780                    MCT0.L(T)=1.000;
1781
1782                    PYN0.L(N)=1.000; PMN0.L(N)=1.000;
1783
1784                    PRN0.L(N)=1.000; PVN0.L(N)=1.000;
1785
```

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35
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n

1786                    MCN0.L(N)=1.000;
1787
1788                    DPXDPKT0.L(T)=KXT0(T); DPXDPKN0.L(N)=KXN0(N);
1789
1790                    DPXDPLT0.L(T)=LXT0(T); DPXDPLN0.L(N)=LXN0(N);
1791
1792                    DPXDPUT0.L(T)=UXT0(T); DPXDPUN0.L(N)=UXN0(N);
1793
1794                                           DPXDPFT0.L('FOREST')=0.039655;
DPXDPFN0.L(N)=FXN0(N);
1795
1796                    DPXDPDT0.L('AGRI')=0.1486931; DPXDPDN0.L(N)=0 ;
1797
1798                    DPYDPLT0.L(T)=DELLYT(T); DPYDPLN0.L(N)=DELLYN(N);
1799
1800                    DPYDPVT0.L(T)=DELVYT(T); DPYDPVN0.L(N)=DELVYN(N);
1801
1802                    DPVDPUT0.L(T)=DELUVT(T); DPVDPUN0.L(N)=DELUVN(N);
1803
1804                    DPVDPMT0.L(T)=DELMVT(T); DPVDPMN0.L(N)=DELMVN(N);
1805
1806                    DPMDPFT0.L(T)=DELFMT(T); DPMDPFN0.L(N)=DELFMN(N);
1807
1808                    DPMDPRT0.L(T)=DELRMT(T); DPMDPRN0.L(N)=DELRMN(N);
1809
1810                    DPRDPKT0.L(T)=DELKRT(T); DPRDPKN0.L(N)=DELKRN(N);
1811
1812                    DPRDPDT0.L(T)=DELDRT(T); DPRDPDN0.L(N)=DELDRN(N);
1813
1814                    PPN0.L(N)=1.000;
1815
1816                    PUK0.L=PK0.L;
1817
1818                    PUL0.L=PL0.L; PUFL0.L=PFL0.L; PUDL0.L=PDL0.L;

PUU0.L=PU0.L;
1819
1820                    PN1.L(N)=1.000; PYT1.L(T)=1.000; PVT1.L(T)=1.000;
1821
1822                    PMT1.L(T)=1.000; PRT1.L(T)=1.000; PL1.L=1.0455;
1823
1824                    PK1.L=0.8750;  PFL1.L=1.0000; PU1.L=1.1786;
1825
1826                    PDL1.L=0.9162;
1827
1828                    MCT1.L(T)=1.000;
1829
1830                    PYN1.L(N)=1.000; PMN1.L(N)=1.000;
1831
1832                    PRN1.L(N)=1.000; PVN1.L(N)=1.000;
```

```
1833
1834                    MCN1.L(N)=1.000;
1835
1836                    DPXDPKT1.L(T)=KXT0(T); DPXDPKN1.L(N)=KXN0(N);
1837
GAMS 2.25.059  386/486 DOS                          11/13/96 15:26:48  PAGE
36
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1838                    DPXDPLT1.L(T)=LXT0(T); DPXDPLN1.L(N)=LXN0(N);
1839
1840                    DPXDPUT1.L(T)=UXT0(T); DPXDPUN1.L(N)=UXN0(N);
1841
1842                                        DPXDPFT1.L('FOREST')=0.039655;
DPXDPFN1.L(N)=FXN0(N);
1843
1844                    DPXDPDT1.L('AGRI')=0.1486931; DPXDPDN1.L(N)=0 ;
1845
1846                    DPYDPLT1.L(T)=DELLYT(T); DPYDPLN1.L(N)=DELLYN(N);
1847
1848                    DPYDPVT1.L(T)=DELVYT(T); DPYDPVN1.L(N)=DELVYN(N);
1849
1850                    DPVDPUT1.L(T)=DELUVT(T); DPVDPUN1.L(N)=DELUVN(N);
1851
1852                    DPVDPMT1.L(T)=DELMVT(T); DPVDPMN1.L(N)=DELMVN(N);
1853
1854                    DPMDPFT1.L(T)=DELFMT(T); DPMDPFN1.L(N)=DELFMN(N);
1855
1856                    DPMDPRT1.L(T)=DELRMT(T); DPMDPRN1.L(N)=DELRMN(N);
1857
1858                    DPRDPKT1.L(T)=DELKRT(T); DPRDPKN1.L(N)=DELKRN(N);
1859
1860                    DPRDPDT1.L(T)=DELDRT(T); DPRDPDN1.L(N)=DELDRN(N);
1861
1862                    PPN1.L(N)=1.000;
1863
1864                    PUK1.L=pk1.l;
1865
1866                    PUL1.L=pl1.l; PUFL1.L=pfl1.l; PUDL1.L=pdl1.l;

PUU1.L=pu1.l;
1867
1868                    ALPHA.L=0.5;
1869                    BETA.L=0.4;
1870
1871                    K1.L=K0+0.3;
1872
1873
1874
1875
1876   model defpar /defalpha, defbeta/
1877   solve defpar using nlp maximizing alpha;
1878
```

```
1879   MODEL CRTWO     /ALL/;
1880
1881   CRTWO.OPTFILE=1;
1882
1883   SOLVE CRTWO USING NLP MAXIMIZING WELF;
1884   crtwo.optfile=0;
1885   SOLVE CRTWO USING NLP MAXiMIZING WELF;
1886  * crtwo.optfile=0;
1887   SOLVE CRTWO USING NLP MAXIMIZING WELF;
1888  * SOLVE CRTWO USING NLP MAXIMIZING WELF;
1889  * SOLVE CRTWO USING NLP MAXIMIZING WELF;
GAMS 2.25.059  386/486 DOS                      11/13/96 15:26:48  PAGE
37
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1890  * DISPLAY
1891
INCLUDE    C:\GAMS\CRMOD\DISPL.INC
1893
1894   DISPLAY     mct0.l, pw0, mcn0.l, pn0.l,
1895
1896                lamsq0.l, lamsq1.l, LAMLG0.L, LAMSQ1.L,
1897                 profsq0.l, profsq1.l, proflg0.l, proflg1.l,
1898
1899                 welf.l, util0.l, util1.l, DISP0.L, DISP1.L,
1900
1901                 SAV0.L, INV0.L, sbar0.l,
1902
1903                 XT0.L, DT0.L, ZT0.L, PK0.L, PUK0.L,
1904
1905                     PL0.L, PUL0.L, PU0.L, PUU0.L, PFL0.L, PUFL0.L,
PDL0.L,

PUDL0.L,
1906
1907                 LTAX0, UTAX0, KTAX0, DTAX0, FTAX0, XN0.L, DN0.L,
1908
1909                 YY0.L,
1910
1911                 DOSQ0.L, FLOG0.L, LSQ0.L, LOGL0.L,
1912
1913                 LGK0.L, FEXP0.L, D0.L, F0.L,
1914
1915                 XT1.L, DT1.L, ZT1.L,  PK1.L, PUK1.L,
1916
1917                     PL1.L, PUL1.L, PU1.L, PUU1.L, PFL1.L, PUFL1.L,
PDL1.L,

PUDL1.L,
1918
1919                 LTAX1, UTAX1, KTAX1, DTAX1, FTAX1, XN1.L, DN1.L,
1920
1921                 YY1.L,
```

```
1922
1923                 DOSQ1.L, FLOG1.L, LSQ1.L, LOGL1.L,
1924
1925                 LGK1.L, FEXP1.L, D1.L, F1.L;
1926
1927  * OUTPUT FILE
1928
1929     PUT RES;
1930     PUT 'KTAX         ',KTAX0:7:4,KTAX1:7:4/;
1931     PUT 'LTAX         ',LTAX0:7:4,LTAX1:7:4/;
1932     PUT 'UTAX         ',UTAX0:7:4,UTAX1:7:4/;
1933     PUT 'DTAX         ',DTAX0:7:4,dTAX1:7:4/;
1934     PUT 'FTAX         ',FTAX0:7:4,FTAX1:7:4/;
1935     LOOP(T,PUT T.TL;
1936             PUT TAX0(T):7:4, TAX1(T):7:4 /;);
1937
1938     PUT /'WELFARE      ',WELF.L:7:4 /;
1939     PUT 'UTILITY      ',UTIL0.L:7:4, UTIL1.L:7:4 /;
1940     PUT 'GNP          ', YY0.L:7:4, YY1.L:7:4 /;
```



```
1941     PUT 'INCOME       ',DISP0.L:7:4, DISP1.L:7:4 //;
1942     PUT 'PUK          ',PUK0.L:7:4, PUK1.L:7:4 /;
1943     PUT 'PUL          ',PUL0.L:7:4, PUL1.L:7:4 /;
1944     PUT 'PUU          ',PUU0.L:7:4, PUU1.L:7:4 /;
1945     PUT 'PUDL         ',PUDL0.L:7:4, PUDL1.L:7:4 /;
1946     PUT 'PUFL         ',PUFL0.L:7:4, PUFL1.L:7:4 //;
1947     PUT 'DEFORESTATION'/
1948     PUT 'SQUATTERS    ',DOSQ0.L:8:4, DOSQ1.L:8:4 /;
1949     PUT 'LOGGERS      ',FLOG0.L:8:4, FLOG1.L:8:4 /;
1950     PUT 'TOTAL EA PER',F0.L:8:4, F1.L:8:4 /;
1951     PUT 'TOTAL DEF    ' DEF01.L:8:4 /;
1952     PUT 'TOTAL ALLOW ',TOTDEF:8:4 //;
1953     PUT 'STOCK LAND  ',D0.L:7:4, D1.L:7:4 /;
1954     PUT 'PRODUCTION'/;
1955     LOOP(T,PUT T.TL ;
1956            PUT XT0.L(T):7:4, XT1.L(T):7:4 /;);
1957
1958
1959
1960
1961
1962
```


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         G960611:1335CR-MW2
      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
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


   1  * SRI LANKA DYNAMIC MODEL
   2  *
   3  * ANNIKA PERSSON
   4
   5  *$OFFSYMLIST OFFSYMXREF
   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 teh result file -- res is just a file to
handle

data
  19  * Definition of the sets of producing sectors in the macro model
  20
  21
  22    SET P Treecrop sectors
  23
  24   /  TEA          Tea Plantations
  25      RUBBER       Rubber plantations
  26      COCO         Coconot plantations /
  27
  28   set n Colombo sectors
  29   / colombo /
  30
  31   set C Colombo sectors
  32   /  RICEMI
  33      FLRMIL
  34      TEXTIL
  35      GARMEN
  36      TRSPQP
  37      ELECQP
  38      OTHMAC
  39      LGTENG
  40      FOODPR
```

```
 41       AGROCH
 42       CLAY
 43       MANUF
 44       METAL
 45       CONSTR  /
 46
 47     SET E  Energy sectors
 48    /    PETR
 49         ELEC   /
 50
 51     SET E1(E)
 52     / ELEC /
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
2
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 53
 54     SET E2(E)
 55     /PETR/
 56
 57     SET O  Other sectors
 58    /    PADDY
 59         OTHAGR
 60         MINING
 61         TRADE
 62         SERVICE  /
 63
 64    SET H HOUSEHOLDS
 65
 66    /  URBAN
 67       RURAL
 68       ESTATE/
 69
 70   * Conversion of the column vectors to row vectors
 71
 72    ALIAS (P,PP);
 73    ALIAS (C,CC);
 74    alias (n,nn);
 75    ALIAS (E,EE);
 76    ALIAS (O,OO);
 77    ALIAS (H,HH);
 78    DISPLAY PP;
 79    DISPLAY CC;
 80    DISPLAY EE;
 81    DISPLAY OO;
 82    DISPLAY HH;
 83
 84   * Policy variables
 85
 86    parameter sshare(p) Share of holdings in smallholdings
 87    / tea    0.644000
 88      rubber 0.452082
 89      coco   0.750000 /
```

```
  90
  91   parameter erosion(p) Rate of soil erosion
  92   / tea     0.066
  93     rubber 0.025
  94     coco   0.013  /
  95
    96      parameter  dxddp(p)  change  in  output  per  unit  of  soil
conservation;
  97     dxddp(p)=1-erosion(p);
  98
  99   parameter pgamma(p)  shares of labor in soil conservation
 100   / tea      0.0376
 101     rubber  0.3079
 102     coco    0.0223 /
 103
 104   set t time periods /1*5/
 105   alias (t,tt);
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
3
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 106   scalar tau  years per time period /4/
 107   parameter m last time period;
 108      m=card(t);
 109
 110   parameter TIME Years forward we want to solve the model for;
 111      time=m*tau;
 112
 113
 114
 115    SCALAR POPG Annual growth rate of non-plantation labor force
/1.016/
 116   SCALAR CAPG Annual growth rate of capital stock /1/
 117  *.04/
 118  * Both according to wber 1994
 119   SCALAR APOPG Annual growth rate in estate labor stock /1.016/
 120
 121   scalar depl Rate of depletion /0.05/
 122
 123   PARAMETER interest(t) Interest rate;
 124     Interest(t)=0.0;
 125
 126   parameter KTAX(t) Tax on capital;
 127    ktax(t)=0.000;
 128   parameter ATAX(t) Tax on ESTATE lab;
 129    atax(t)=0.000;
 130   parameter LTAX(t) Tax on URBAN lab;
 131    ltax(t)=0.000;
 132   parameter RTAX(t) Tax on RURAL lab;
 133    rtax(t)=0.000;
 134
 135   parameter XR(t)    Exchange rate;
 136    xr(t)=1.000;
```

```
 137
 138   PARAMETER DPE(E,t) Price of energy products;
 139    dpe('elec',t)=1.0;
 140    dpe('petr',t)=1.0;
 141
 142   PARAMETER XE91(E)  Production in energy sectors 1991
 143   / ELEC   2.255979
 144     PETR   1.129127 /
 145
 146   PARAMETER EXPTP(P,t) Export tax on treecrops;
 147    exptp(p,t)=0;
 148
 149   PARAMETER EXPTn(n,t) Export tax on Colombo;
 150    exptn(n,t)=0;
 151
 152   PARAMETER EXPTE(E,t) Export tax on energy;
 153    expte(e,t)=0;
 154
 155   PARAMETER EXPTO(O,t) Export tax on other;
 156    expto(o,t)=0;
 157
 158  * Retrieve 1991 IO table
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
4
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


INCLUDE    C:\SLMOD\SLIO91.INC
 160  * Benchmark data from REVISED 1991 IO table
 161
 162   TABLE XPC0(P,CC) Benchmark inputs of treecrop goods in Colombo

production
 163
 164          FOODPR   MANUF
 165   TEA    0        0
 166   RUBBER 0        0.146519
 167   COCO   0.387683 0
 168
 169    TABLE    XPO0(P,OO) Benchmark inputs of treecrop goods in Other
sectors
 170
 171          SERVICE
 172   TEA    0.003920
 173   RUBBER 0
 174   COCO   0.005014
 175
 176    TABLE  XCP0(C,PP) Benchmark inputs of Colombo goods in Treecrop
prod
 177
 178          TEA       RUBBER   COCO
 179   TEXTIL 0.000171  0        0
 180   TRSPQP 0.000038  0.000009 0.000028
 181   ELECQP 0.001479  0.000031 0.000066
```

```
 182    OTHMAC 0.000196  0.000008 0.000026
 183    LGTENG 0.010681  0.000984 0.007757
 184    AGROCH 0.224984  0.005589 0.042249
 185    MANUF  0.061705  0.001946 0.003763
 186    METAL  0.001033  0        0
 187    CONSTR 0.022913  0.001594 0.016642
 188
 189     TABLE   XCC0(C,CC) Benchmark inputs of Colombo goods in Colombo
prod
 190
 191              RICEMI    FLRMIL    TEXTIL    GARMEN    TRSPQP    ELECQP
OTHMAC
                     LGTENG    FOODPR    AGROCH    CLAY      MANUF     METAL
CONSTR
 192    RICEMI  0         0         0         0         0         0         0
                         0         0.032407 0         0         0         0
0
 193    FLRMIL  0         0.003320 0         0         0         0         0
                         0         0.451691 0         0         0         0
0
 194     TEXTIL   0           0           0           0.249505 0           0
0.000012
                         0         0         0         0         0.001654 0
0
 195    GARMEN  0         0         0         0         0         0         0
                     0           0.340379 0           0           0.250562 0
0.509857
 196     TRSPQP   0.000397 0.000106 0           0           0.005185 0.000686
0.000073
                   0.000742 0.000323 0         0.000042 0.000079 0.000513
0.002153
  197      ELECQP    0.000880  0.000117  0.000587  0.011630  0.000920  0
0.000108
                   0.000411 0.000313 0         0.000063 0.000066 0.000227
0.012425
 198     OTHMAC   0.000146  0.000026  0.000648  0.012987  0.000127  0.000126
0.001033
                   0.000522 0.000099 0         0.000047 0.000035 0.000314
0.001040
 199     LGTENG   0.001179  0.000157  0.004717  0.056799  0.007392  0.005346
0.002018
                   0.006199 0.000060 0         0.000419 0.001868 0.004263
0.004836
 200    FOODPR  0         0         0         0         0         0         0
                         0         0.010507 0         0         0         0
0
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
5
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 201    CLAY     0           0           0           0           0           0
0.000088
                     0.000052 0.000471 0           0           0.000605 0
```

```
0.323953
 202    MANUF    0.013612 0.007411 0.012148 0.306212 0.001860 0.009072
0.003019
                 0.001468 0.000490 0.009925 0.010432 0.032861 0.019092
0.369471
 203    METAL    0         0         0         0         0.003978 0.001096
0.018383
                    0.012605 0          0          0.000023 0.000463 0
0.472319
 204    CONSTR   0.004298 0.001287 0.057320 0.223747 0.002245 0.000619
0.000427
                 0.001632 0.091048 0.001019 0.000802 0.028139 0.002359
0.031149
 205
 206
 207
 208
 209
 210    TABLE XCE0(C,EE)   Benchmark inputs of Colombo goods in Energy
production
 211
 212            PETR     ELEC
 213    TRSPQP  0.000235 0.000073
 214    ELECQP  0.000423 0.003076
 215    OTHMAC  0.000137 0.000080
 216    LGTENG  0.001221 0.000217
 217    MANUF   0.000434 0.000077
 218    METAL   0        0.001867
 219    CONSTR  0.000318 0.002766
 220
 221
 222    TABLE XCO0(C,OO)   Benchmark inputs of Colomo goods in Other
production
 223
 224            PADDY    OTHAGR   MINING   TRADE    SERVICE
 225    RICEMI  0        0.018312 0        0        0.105180
 226    FLRMIL  0        0.005464 0        0        0.019002
 227    TEXTIL  0        0.009903 0        0        0
 228    GARMEN  0        0        0        0.178937 0.469107
 229    TRSPQP  0.000365 0.000464 0.000731 0.014257 0.056328
 230    ELECQP  0.000078 0        0.000405 0.002380 0.018243
 231    OTHMAC  0.000023 0        0.000078 0.000763 0.000137
 232    LGTENG  0.002692 0.013941 0.001220 0.003970 0.021743
 233    FOODPR  0        0.005402 0        0        0.023821
 234    AGROCH  0.245764 0.031941 0        0        0
 235    MANUF   0.000515 0.027512 0.001927 0.035081 0.009233
 236    METAL   0        0        0        0.008676 0.000105
 237    CONSTR  0        0.280925 0.000989 0.685172 0.408185
 238
 239   TABLE XEP0(E,PP) Benchmark inputs of Energy in Treecrop Production
 240
 241            TEA      RUBBER   COCO
 242    PETR    0.042948 0.000836 0.005276
 243    ELEC    0.034460 0.001756 0.003636
 244
```

```
 245     TABLE  XEC0(E,CC)    Benchmark  inputs  of  Energy  in  Colombo
production
 246
 247              RICEMI    FLRMIL    TEXTIL    GARMEN    TRSPQP    ELECQP
OTHMAC
                    LGTENG    FOODPR    AGROCH    CLAY      MANUF     METAL
CONSTR
 248    PETR      0.021389 0.000889 0.053777 0.276957 0.015596 0.003591
0.008904
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
6
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


                  0.025613 0.044277 0.128570 0.039218 0.025460 0.000748
0.091376
 249    ELEC      0.014108 0.019304 0.078208 0.300632 0.025267 0.006265
0.008793
                  0.027878 0.012579 0.022473 0.035030 0.015921 0.009369
0.017035
 250
 251   TABLE XEE0(E,EE)  Benchmark inputs of Energy in Energy production
 252            PETR     ELEC
 253   PETR     0        0.166656
 254   ELEC     0.000865 0.002223
 255
 256   TABLE XEO0(E,OO)  Benchmark inputs of Energy in Other production
 257
 258            PADDY    OTHAGR   MINING   TRADE    SERVICE
 259   PETR     0.007829 0.196363 0.003126 0.391971 0.033476
 260   ELEC     0        0.169446 0.001854 0.073771 0.037613
 261
 262     TABLE  XOP0(O,PP)     Benchmark  inputs  of  Other  in  Treecrop
production
 263
 264            TEA      RUBBER   COCO
 265   OTHAGR   0.055054 0.002982 0.012328
 266   TRADE    0.065899 0.003007 0.013474
 267   SERVICE  0.129634 0.012709 0.049682
 268
 269     TABLE    XOC0(O,CC)    Benchmark  inputs  of  Other  in  Colombo
production
 270
 271              RICEMI    FLRMIL    TEXTIL    GARMEN    TRSPQP    ELECQP
OTHMAC
                    LGTENG    FOODPR    AGROCH    CLAY      MANUF     METAL
CONSTR
 272   PADDY    1.470689 0         0         0         0         0         0
                        0         0         0         0         0         0
0
 273   OTHAGR   0.032381 0         0         0         0         0         0
                      0           0.304394  0           0.008688  0.108083  0
0.157852
 274   MINING   0         0         0         0         0         0         0
```

```
                    0          0          0.000483 0.034966 0.000161 0
0.149520
 275   TRADE     0.893085 0.213635 0.120408 1.071044 0.063651 0.027563
0.009149
                 0.039195 0.251639 0.019497 0.027452 0.081823 0.063854
0.691460
 276   SERVICE   0.004496 0.027909 0.029974 0.812616 0.005479 0.002157
0.004304
                 0.007003 0.030160 0.022224 0.010808 0.129039 0.005031
0.343532
 277
 278
 279  TABLE XOE0(O,EE)    Benchmark inputs of Other in Energy production
 280            PETR     ELEC
 281   OTHAGR   0        0.001832
 282   TRADE    0.105544 0.043252
 283   SERVICE  0.005543 0.265340
 284
 285
 286   TABLE XOO0(O,OO)    Benchmark inputs of Other in Other production
 287
 288             PADDY    OTHAGR   MINING   TRADE    SERVICE
 289   PADDY     0.002196 0        0        0        0
 290   OTHAGR    0.028881 0.139250 0        0        0.341637
 291   TRADE     0.025220 0.156960 0.009426 0.238049 0.199378
 292   SERVICE   0.087316 0.126425 0.021714 0.443482 0.056628
 293
GAMS 2.25.059  386/486 DOS                      11/13/96 17:16:17  PAGE
7
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 294
 295   PARAMETER IMPP0(P) Benchmark imports in Treecrop sectors
 296   / TEA          0.208967
 297     RUBBER       0.059379
 298     COCO         0.021873/
 299
 300   PARAMETER IMPDP0(P)  Benchmark import duty in Treecrop sectors
 301   / TEA          0.004472
 302     RUBBER       0.000080
 303     COCO         0.000087 /
 304
 305   PARAMETER IMPC0(C) Benchmark import in Colombo sectors
 306   / RICEMI  0.015257
 307     FLRMIL  0.310828
 308     TEXTIL  0.638507
 309     GARMEN  1.649885
 310     TRSPQP  0.039583
 311     ELECQP  0.137548
 312     OTHMAC  0.055431
 313     LGTENG  0.099902
 314     FOODPR  0.497144
 315     AGROCH  0.007490
```

```
 316      CLAY     0.043122
 317      MANUF    1.232410
 318      METAL    0.321793
 319      CONSTR   0.870210 /
 320
 321
 322    PARAMETER IMPDC0(C)  Benchmark import duty in Colombo sectors
 323    / RICEMI  0.000468
 324      FLRMIL  0.014262
 325      TEXTIL  0.034754
 326      GARMEN  0.099031
 327      TRSPQP  0.006479
 328      ELECQP  0.011033
 329      OTHMAC  0.015547
 330      LGTENG  0.010393
 331      FOODPR  0.176817
 332      AGROCH  0.002511
 333      CLAY    0.003420
 334      MANUF   0.240444
 335      METAL   0.030530
 336      CONSTR  0.136838  /
 337
 338
 339    PARAMETER IMPE0(E)   Benchmark import in Energy sectors
 340    / PETR         1.592480
 341      ELEC         0.004328 /
 342
 343    PARAMETER IMPDE0(E)  Benchmark import duty in Energy sectors
 344    / PETR         0.086575
 345      ELEC         0.000964 /
 346
GAMS 2.25.059  386/486 DOS                      11/13/96 17:16:17  PAGE
8
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 347    PARAMETER IMPO0(O)   Benchmark import in Other sectors
 348
 349     / PADDY    0.111186
 350       OTHAGR   0.224857
 351       MINING   0.082098
 352       TRADE    0.222750
 353       SERVICE  1.349097 /
 354
 355
 356   PARAMETER IMPDO0(O)   Benchmark import duty in Other sectors
 357    / PADDY     0.004715
 358      OTHAGR    0.002453
 359      MINING    0.000665
 360      TRADE     0.179857
 361      SERVICE   0.110481  /
 362
 363    PARAMETER LP0(P)     Benchmark inputs of URBAN labor in Treecrop
sectors
```

```
 364    / TEA          0.004160
 365      RUBBER       0.000980
 366      COCO         0.002850 /
 367
 368    PARAMETER RP0(P)     Benchmark inputs of RURAL labor in Treecrops

sectors
 369    / TEA          0.253890
 370      RUBBER       0.059640
 371      COCO         0.071280 /
 372
  373       PARAMETER  AP0(P)       Benchmark  inputs  of  ESTATE  labor  in
treecrops

sectors
 374    / TEA          0.170870
 375      RUBBER       0.089520
 376      COCO         0.246230 /
 377
 378     PARAMETER LC0(C)      Benchmark inputs of URBAN labor in Colombo
sectors
 379
 380    / RICEMI  0.001200
 381      FLRMIL  0.001910
 382      TEXTIL  0.015290
 383      GARMEN  0.058540
 384      TRSPQP  0.004330
 385      ELECQP  0.012070
 386      OTHMAC  0.035850
 387      LGTENG  0.016960
 388      FOODPR  0.231970
 389      AGROCH  0.039530
 390      CLAY    0.013380
 391      MANUF   0.117120
 392      METAL   0.001640
 393      CONSTR  0.303070 /
 394
 395    PARAMETER RC0 Input of RURAL labor in Colombo sectors
 396
 397    / RICEMI   0.046090
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
9
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 398      FLRMIL   0.015840
 399      TEXTIL   0.181750
 400      GARMEN   0.247420
 401      TRSPQP   0.073070
 402      ELECQP   0.011320
 403      OTHMAC   0
 404      LGTENG   0.033360
 405      FOODPR   1.480550
 406      AGROCH   0.102100
```

```
 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
 414    / RICEMI    0.001350
 415      FLRMIL    0.000510
 416      TEXTIL    0.005710
 417      GARMEN    0.010300
 418      trspqp    0.002240
 419      elecqp    0.000690
 420      OTHMAC    0
 421      LGTENG    0.001460
 422      FOODPR    0.049640
 423      AGROCH    0.004250
 424      CLAY      0.005370
 425      MANUF     0.013780
 426      METAL     0.001020
 427      CONSTR    0.044850  /
 428
 429
 430    PARAMETER LE0(E)      Benchmark inputs of URBAN labor in Energy
sectors
 431    /PETR      0.021570
 432     ELEC      0.063540   /
 433
 434    PARAMETER RE0(E)      Benchmark inputs of RURAL labor in Energy
sectors
 435    / PETR     0.030210
 436      ELEC     0.061820    /
 437
 438    PARAMETER AE0(E)      Benchmark inputs of ESTATE labor in Energy
sectors
 439    / PETR     0.001500
 440      ELEC     0.003640    /
 441
 442    PARAMETER LO0(O)      Benchmark inputs of URBAN labor in Other
sectors
 443    / PADDY      0.005370
 444      OTHAGR     0.096890
 445      MINING     0.006340
 446      TRADE      0.946100
 447      SERVICE    1.421140  /
 448
 449    PARAMETER RO0(O)      Benchmark input of RURAL labor in Other
sectors
 450    / PADDY      0.485270
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
10
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n
```

```
451      OTHAGR     1.460620
452      MINING     0.110710
453      TRADE      2.232050
454      SERVICE    3.247290  /
455
456    PARAMETER AO0(O)       Benchmark input of ESTATE labor in Other
sectors
457    / PADDY      0.010050
458      OTHAGR     0.173000
459      MINING     0.003360
460      TRADE      0.092260
461      SERVICE    0.135320  /
462
463    PARAMETER KP0(P)       Benchmark inputs of capital in Treecrop
sectors
464    / TEA          0.741520
465      RUBBER       0.263730
466      COCO         0.575000 /
467
468    PARAMETER KC0(C)       Benchmark inputs of capital in Colombo
sectors
469   /  RICEMI    0.010680
470      FLRMIL    0.001585
471      TEXTIL    0.046770
472      GARMEN    0.067650
473      TRSPQP    0.019470
474      ELECQP    0.006350
475      OTHMAC    0.011060
476      LGTENG    0.016030
477      FOODPR    0.442600
478      AGROCH    0.082700
479      CLAY      0.043690
480      MANUF     0.145920
481      METAL     0.010030
482      CONSTR    0.736830  /
483
484
485   PARAMETER KE0(E)      Benchmark inputs of capital in Energy sector
486    / PETR      0.106800
487      ELEC      0.297694    /
488
489    PARAMETER KO0(O)       Benchmark inputs of capital in Other sector
490
491   /  PADDY      0.852800
492      OTHAGR     3.081720
493      MINING     0.262630
494      TRADE      6.771610
495      SERVICE    0.470640  /
496
497   PARAMETER DEPLP0(P)      Benchmark depletion of capital in Treecrop

sectors
498    / TEA          0.034960
499      RUBBER       0.008060
500      COCO         0.004950  /
```

```
 501
 502   PARAMETER DEPLC0(C)     Benchmark depletion of capital in Colombo
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
11
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


sectors
 503  /  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     LGTENG   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  /
 517
 518
 519  PARAMETER DEPLE0  Benchmark depletion of capital in Energy sector
 520   / PETR     0.015689
 521     ELEC     0.206366    /
 522
 523     PARAMETER  DEPLO0(O)  Benchmark  depletion  of  capital  in  Other
sector
 524
 525  /  PADDY     0.053610
 526     OTHAGR    0.051070
 527     MINING    0.021650
 528     TRADE     0.403180
 529     SERVICE   0.413510  /
 530
 531  PARAMETER ITAXP0(P) Benchmark indirect taxes in Treecrop sector
 532   / TEA          0.003920
 533     RUBBER       0.000448
 534     COCO         0.001057    /
 535
 536   PARAMETER SUBSP0(P)  Benchmark subsidy in Treecrop sector
 537   / TEA          0.015200
 538     RUBBER       0.014730
 539     COCO         0.006110  /
 540
 541   PARAMETER ITAXC0(C)  Benchmark indirect tax in Colombo sector
 542  /  RICEMI   0.000208
 543     FLRMIL   0.019600
 544     TEXTIL   0.184202
 545     GARMEN   0.039151
 546     TRSPQP   0.010517
```

```
 547     ELECQP   0.020377
 548     OTHMAC   0.006157
 549     LGTENG   0.049076
 550     FOODPR   1.397622
 551     AGROCH   0.015120
 552     CLAY     0.035674
 553     MANUF    0.161769
 554     METAL    0.053730
GAMS 2.25.059  386/486 DOS                    11/13/96 17:16:17  PAGE
12
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 555     CONSTR   0.012998  /
 556
 557   PARAMETER ITAXE0(E)  Benchmark indirect tax in Energy sector
 558   / PETR         0.294535
 559     ELEC         0.003316 /
 560
 561   PARAMETER SUBSE0(E)  Benchmark subsidy in Energy sector
 562   / PETR         0.008100 /
 563
 564   PARAMETER ITAXO0(O)  Benchmark indirect tax in Other sectors
 565
 566  /  PADDY     0.007977
 567     OTHAGR    0.046875
 568     MINING    0.020000
 569     TRADE     0.088944
 570     SERVICE   0.308917  /
 571
 572   PARAMETER SUBSO0(O)  Benchmark subsidy in Other sectors
 573   / OTHAGR    0.006610
 574     TRADE     0.349440
 575     SERVICE   0.006190  /
 576
  577     TABLE  PCONS0(P,H)   Benchmark  private  final  consumption  of
treecrops per

household type
 578
 579                URBAN    RURAL    ESTATE
 580     TEA        0.049520 0.181272 0.017888
 581     RUBBER     0        0        0
 582     COCO       0.135261 0.456390 0.043859
 583
 584    TABLE CCONS0(C,H) Benchmark private final consumption of Colombo

products
 585                URBAN   RURAL    ESTATE
 586     RICEMI    0.424276 1.780549 0.178779
 587     FLRMIL    0.018805 0.068375 0.077314
 588     TEXTIL    0.250953 0.777558 0.068903
 589     GARMEN    0.119878 0.371429 0.032857
 590     TRSPQP    0.042293 0.098545 0.003020
```

```
 591      ELECQP    0.016029 0.037350 0.001146
 592      OTHMAC    0.002925 0.006824 0.000219
 593      LGTENG    0.037073 0.086378 0.002650
 594      FOODPR    1.390953 4.152560 0.392320
 595      AGROCH    0         0        0
 596      CLAY      0.030269 0.070523 0.002155
 597      MANUF     0.394482 0.919111 0.028167
 598      METAL     0         0        0
 599      CONSTR    1.422066 1.432848 0.045645
 600
 601    TABLE ECONS0(E,H)  Benchmark private final consumption of Energy

products
 602                URBAN    RURAL    ESTATE
 603      PETR      0.198129 0.130028 0.014031
 604      ELEC      0.121960 0.080137 0.008544
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
13
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 605
 606    TABLE OCONS0(O,H)  Benchmark private final consumption of Other
products
 607                URBAN    RURAL    ESTATE
 608      PADDY     0.081702 0.342842 0.034428
 609      OTHAGR    1.069719 3.179999 0.302252
 610      MINING    0.014101 0.032864 0.001018
 611      TRADE     1.919573 2.508489 0.067484
 612      SERVICE   1.729594 4.210668 0.011928
 613
 614    PARAMETER INVP0(P) Benchmark Treecrops in investment
 615    /  COCO      0.028610 /
 616
 617    PARAMETER INVC0(C) Benchmark Colombo products in investments
 618   /  TRSPQP    0.033067
 619      ELECQP    0.074050
 620      OTHMAC    0.077450
 621      LGTENG    0.020195
 622      MANUF     0.013530
 623      CONSTR    1.870100  /
 624
 625    PARAMETER INVO0(O) Benchmark Other products in investments
 626    / OTHAGR        0.029730
 627      TRADE         2.630426 /
 628
 629    PARAMETER PEXP0(P) Benchmark export of treecrops
 630    / TEA           1.806154
 631      RUBBER        0.352039
 632      COCO          0.015327    /
 633
 634    PARAMETER CEXP0(C) Benchmark export of Colombo products
 635    / TEXTIL    0.135511
 636      GARMEN    3.272270
```

```
 637      TRSPQP   0.038077
 638      ELECQP   0.076106
 639      OTHMAC   0.076750
 640      LGTENG   0.047956
 641      FOODPR   0.478690
 642      AGROCH   0.082195
 643      CLAY     0.084020
 644      MANUF    0.835885
 645      METAL    0.040675  /
 646
 647    PARAMETER EEXP0(E) Benchmark export of Energy products
 648    / PETR         0.328945  /
 649
 650    PARAMETER OEXP0(O) Benchmark export of Other products
 651    / OTHAGR    0.538121
 652      MINING    0.315810
 653      TRADE     1.104184
 654      SERVICE   0.673560  /
 655
 656   * Retrieve elasticities
INCLUDE    C:\SLMOD\SLELAA.INC
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
14
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 658   * Elasticities of substitution
 659
 660    PARAMETER SIGAKP(P) Elasticity of substitution between L and K in
P
 661
 662    /  TEA 0.800
 663       RUBBER  0.800
 664       COCO    0.800  /
 665
 666    parameter sigakn(n);
 667     sigakn(n)=0.8;
 668
 669    PARAMETER SIGAKC(C) Elasticity of substitution between L and K in
C
 670
 671    / RICEMI  0.800
 672       FLRMIL 0.800
 673       TEXTIL 0.800
 674      GARMEN 0.800
 675      TRSPQP 0.800
 676      ELECQP 0.800
 677      OTHMAC 0.800
 678      LGTENG 0.800
 679      FOODPR 0.800
 680      AGROCH 0.800
 681      CLAY 0.800
 682      MANUF 0.800
 683      METAL  0.800
```

```
 684      CONSTR   0.800 /
 685
 686   PARAMETER SIGAKE(E) Elasticity of substitution between L and K in
E
 687
 688    /  ELEC        0.800
 689       PETR    0.800   /
 690
 691    PARAMETER SIGAKO(O)  Elasticity of substitution between L and K
in O
 692
 693    /    PADDY   0.800
 694         OTHAGR 0.800
 695         MINING 0.800
 696         TRADE 0.800
 697         SERVICE   0.800  /
 698
 699   PARAMETER SIGR1P(P) Elasticity of substitution between R AND 1 in
P
 700
 701    /  TEA 0.800
 702       RUBBER  0.800
 703       COCO    0.800  /
 704
 705    parameter sigr1n(n);
 706       sigr1n(n)=0.8;
 707
 708    PARAMETER SIGR1C(C) Elasticity of substitution between R AND 1 in
C
 709
 710    / RICEMI  0.800
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
15
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 711       FLRMIL 0.800
 712       TEXTIL 0.800
 713      GARMEN 0.800
 714      TRSPQP 0.800
 715      ELECQP 0.800
 716      OTHMAC 0.800
 717      LGTENG 0.800
 718      FOODPR 0.800
 719      AGROCH 0.800
 720      CLAY 0.800
 721      MANUF 0.800
 722      METAL  0.800
 723      CONSTR   0.800 /
 724
 725   PARAMETER SIGR1E(E) Elasticity of substitution between R AND 1 in
E
 726
 727    /  ELEC        0.800
```

```
 728      PETR    0.800   /
 729
 730   PARAMETER SIGR1O(O)  Elasticity of substitution between R AND 1
in O
 731
 732   /    PADDY   0.800
 733        OTHAGR 0.800
 734        MINING 0.800
 735        TRADE 0.800
 736        SERVICE   0.800  /
 737
 738
 739  PARAMETER SIGL2P(P) Elasticity of substitution between L AND 2 in
P
 740
 741   /  TEA 0.800
 742      RUBBER  0.800
 743      COCO    0.800  /
 744
 745   parameter sigl2n(n);
 746      sigl2n(n)=0.8;
 747
 748   PARAMETER SIGL2C(C) Elasticity of substitution between L AND 2 in
C
 749
 750   / RICEMI  0.800
 751      FLRMIL 0.800
 752      TEXTIL 0.800
 753     GARMEN 0.800
 754     TRSPQP 0.800
 755     ELECQP 0.800
 756     OTHMAC 0.800
 757     LGTENG 0.800
 758     FOODPR 0.800
 759     AGROCH 0.800
 760     CLAY 0.800
 761     MANUF 0.800
 762     METAL  0.800
 763     CONSTR   0.800 /
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
16
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 764
 765  PARAMETER SIGL2E(E) Elasticity of substitution between L AND 2 in
E
 766
 767   /  ELEC        0.800
 768      PETR    0.800   /
 769
 770   PARAMETER SIGL2O(O)  Elasticity of substitution between L AND 2
in O
 771
```

```
 772   /    PADDY   0.800
 773        OTHAGR 0.800
 774        MINING 0.800
 775        TRADE 0.800
 776        SERVICE   0.800  /
 777
 778
 779  PARAMETER SIGE3P(P) Elasticity of substitution between E AND 3 in
P
 780
 781   /  TEA 0.800
 782      RUBBER  0.800
 783      COCO    0.800  /
 784
 785   parameter sige3n(n);
 786      sige3n(n)=0.8;
 787
 788   PARAMETER SIGE3C(C) Elasticity of substitution between E AND 3 in
C
 789
 790   / RICEMI  0.800
 791      FLRMIL 0.800
 792      TEXTIL 0.800
 793     GARMEN 0.800
 794     TRSPQP 0.800
 795     ELECQP 0.800
 796     OTHMAC 0.800
 797     LGTENG 0.800
 798     FOODPR 0.800
 799     AGROCH 0.800
 800     CLAY 0.800
 801     MANUF 0.800
 802     METAL  0.800
 803     CONSTR   0.800 /
 804
 805  PARAMETER SIGE3E(E) Elasticity of substitution between E AND 3 in
E
 806
 807   /  ELEC        0.800
 808      PETR    0.800   /
 809
 810   PARAMETER SIGE3O(O)  Elasticity of substitution between E AND 3
in O
 811
 812   /    PADDY   0.800
 813        OTHAGR 0.800
 814        MINING 0.800
 815        TRADE 0.800
 816        SERVICE   0.800  /
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
17
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n
```

```
 817
 818
 819  PARAMETER SIGM4P(P) Elasticity of substitution between M AND 4 in
P
 820
 821   /  TEA 0.800
 822      RUBBER  0.800
 823      COCO    0.800  /
 824
 825   parameter sigm4n(n);
 826     sigm4n(n)=0.8;
 827
 828   PARAMETER SIGM4C(C) Elasticity of substitution between M AND 4 in
C
 829
 830   / RICEMI  0.800
 831      FLRMIL 0.800
 832      TEXTIL 0.800
 833     GARMEN 0.800
 834     TRSPQP 0.800
 835     ELECQP 0.800
 836     OTHMAC 0.800
 837     LGTENG 0.800
 838     FOODPR 0.800
 839     AGROCH 0.800
 840     CLAY 0.800
 841     MANUF 0.800
 842     METAL  0.800
 843     CONSTR   0.800 /
 844
 845  PARAMETER SIGM4E(E) Elasticity of substitution between M AND 4 in
E
 846
 847   /  ELEC        0.800
 848      PETR    0.800   /
 849
 850   PARAMETER SIGM4O(O)  Elasticity of substitution between M AND 4
in O
 851
 852   /    PADDY   0.800
 853        OTHAGR 0.800
 854        MINING 0.800
 855        TRADE 0.800
 856        SERVICE   0.800  /
 857
 858
 859
 860    PARAMETER  MUP(P)   Elasticity of transformation betw dom and
exports
 861
 862   / tea      1.00
 863     rubber   1.00
 864     coco     1.00 /
 865
 866   parameter  mun(n);
```

```
 867     mun(n)=1;
 868
 869       parameter muc(c) Elasticity of transformation betw dom and
exports
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
18
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 870
 871   / RICEMI  1.000
 872      FLRMIL 1.000
 873      TEXTIL 1.000
 874     GARMEN 1.000
 875     TRSPQP 1.000
 876     ELECQP 1.000
 877     OTHMAC 1.000
 878     LGTENG 1.000
 879     FOODPR 1.000
 880     AGROCH 1.000
 881     CLAY 1.000
 882     MANUF 1.000
 883     METAL  1.000
 884     CONSTR   1.000 /
 885
 886       parameter muo(o) Elasticity of transformation betw dom and
exports
 887
 888   / PADDY   1.000
 889        OTHAGR 1.000
 890        MINING 1.000
 891        TRADE 1.000
 892        SERVICE   1.000  /
 893
 894  parameter mue(e) Elasticity of transformation betw dom and exports
 895   /   PETR    1.0
 896       ELEC   1.0 /
 897
 898
 899  * Retrieve WM prices
 900  *$INCLUDE SLPRICEa.INC
 901
 902
 903  * Calculate parameters
INCLUDE    C:\SLMOD\SLAPRL.INC
 905  * Submodel using simultaneous equations to calculate parameters
 906
 907   VARIABLES
 908
 909   PQP0(P)       Initial price of composite output P
 910   IMPSHP(P)     Share of imports in  QP
 911   IMPDP(P,t)      Ad valorem imort duty rate P
 912   PQC0(C)       Initial price of composite output C
 913   pqn0(n)
```

```
 914   IMPSHC(C)     Share of imports in QC
 915   impshn(n)
 916   IMPDC(C,t)      Ad valorem import duty rate C
 917   impdn(n,t)
 918   PQE0(E)       Initial price of composite output E
 919   IMPSHE(E)     Share of imports in QE
 920   IMPDE(E,t)      Ad valorem import duty rate E
 921   PQO0(O)       Initial price of composite output O
 922   IMPSHO(O)     Share of imports in QO
GAMS 2.25.059  386/486 DOS                      11/13/96 17:16:17  PAGE
19
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 923   IMPDO(O,t)      Ad valorem import duty rate O
 924   QP0(P)        Initial quantity of composite ourput QP
 925   QC0(C)        Initial quantity of composite ourput QC
 926   qn0(n)
 927   QO0(O)        Initial quantity of composite ourput QO
 928   QE0(E)        Initial quantity of composite ourput QE
 929   PX0(P)        Initial quantity of domestic production XP
 930   CX0(C)        Initial quantity of domestic production XC
 931   nx0(n)
 932   EX0(E)        Initial quantity of domestic production XE
 933   OX0(O)        Initial quantity of domestic production XO
 934   OBJ           Objective function has no meaning all variables are

predetermined;
 935
 936   EQUATIONS
 937   DPQP0(P)      Definition of PQP0
 938   DIMPSHP(P)    Definition of IMPSHP
 939   DIMPDP(P,t)     Definition of IMPDP
 940   DPQC0(C)      Definition of PQC0
 941   dpqn0(n)
 942   DIMPSHC(C)    Definition of IMPSHC
 943   dimpshn(n)
 944   DIMPDC(C,t)     Definition of IMPDC
 945   dimpdn(n,t)
 946   DPQE0(E)      Definition of PQE0
 947   DIMPSHE(E)    Definition of IMPSHE
 948   DIMPDE(E,t)     Definition of IMPDE
 949   DPQO0(O)      Definition of PQO0
 950   DIMPSHO(O)    Definition of IMPSHO
 951   DIMPDO(O,t)     Definition of IMPDO
 952   DQP0(P)       Definition of QP0
 953   DQC0(C)       Definition of QC0
 954   dqn0(n)
 955   DQE0(E)       Definition of QE0
 956   DQO0(O)       Definition of QO0
 957   DPX0(P)       Definition of PX0
 958   DCX0(C)       Definition of CX0
 959   dnx0(n)
 960   DEX0(E)       Definition of EX0
```

```
 961   DOX0(O)       Definition of OX0
 962   DOBJ          Definition of objective function;
 963
 964   DPQP0(P)..     PQP0(P)=E=1;
 965
 966   DIMPSHP(P)..  IMPSHP(P)=E=(IMPP0(P)+impdp0(p))/(qp0(P)/PQP0(P));
 967
 968   DIMPDP(P,t)..   IMPDP(P,t)=E=IMPDP0(P)/(IMPP0(P)+impdp0(p));
 969
 970   DPQC0(C)..     PQC0(C)=E=1;
 971
 972   dpqn0(n)..     pqn0(n)=e=1;
 973   DIMPSHC(C)..  IMPSHC(C)=E=(IMPC0(C)+impdc0(c))/(qc0(C)/PQC0(C));
 974   dimpshn(n)..  impshn(n)=e= sum(c,IMPC0(C)+impdc0(c))/
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
20
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


 975                                sum(c,qc0(C)/PQC0(C));
 976   DIMPDC(C,t)..   IMPDC(C,t)=E=IMPDC0(C)/(IMPC0(C)+impdc0(c));
             977                                          dimpdn(n,t)..
impdn(n,t)=e=sum(c,IMPDC0(C))/sum(c,(IMPC0(C)+impdc0(c))

);
 978
 979   DPQE0(E)..     PQE0(E)=E=1;
 980
 981   DIMPSHE(E)..  IMPSHE(E)=E=(IMPE0(E)+impde0(e))/(qe0(E)/PQE0(E));
 982
 983   DIMPDE(E,t)..   IMPDE(E,t)=E=IMPDE0(E)/(IMPE0(E)+impde0(e));
 984
 985   DPQO0(O)..     PQO0(O)=E=1;
 986
 987   DIMPSHO(O)..     IMPSHO(O)=E=(impo0(o)+IMPDO0(O))/qo0(O);
 988
 989   DIMPDO(O,t)..   IMPDO(O,t)=E=IMPDO0(O)/(IMPO0(O)+impdo0(o));
 990
 991   DQP0(P)..      QP0(P)=E=(PX0(P)+IMPP0(P)+impdp0(p))/PQP0(P);
 992
 993   DQC0(C)..      QC0(C)=E=(CX0(C)+IMPC0(C)+impdc0(c))/PQC0(C);
 994
 995   dqn0(n)..       qn0(n)=e=sum(c,qc0(c));
 996   DQE0(E)..      QE0(E)=E=(EX0(E)+IMPE0(E)+impde0(e))/PQE0(E);
 997
 998   DQO0(O)..      QO0(O)=E=(OX0(O)+IMPO0(O)+impdo0(o))/PQO0(O);
 999
1000   DPX0(P)..     PX0(P)=E=SUM(C,XCP0(C,P))+SUM(E,XEP0(E,P))+
1001                 SUM(O,XOP0(O,P))+AP0(P)+rp0(p)+lp0(p)+KP0(P)+
1002                 deplp0(p)+ITAXP0(P)-SUBSP0(P);
1003
1004                                                        DCX0(C)..
CX0(C)=E=SUM(P,XPC0(P,C))+SUM(CC,XCC0(CC,C))+SUM(E,XEC0(E,
```

```
C))+
1005                SUM(O,XOC0(O,C))+LC0(C)+rc0(c)+ac0(c)+KC0(C)+
1006                deplc0(c)+ITAXC0(C);
1007
1008   dnx0(n)..    nx0(n)=e=sum(c,cx0(c));
1009
1010   DEX0(E)..    EX0(E)=E=SUM(C,XCE0(C,E))+SUM(EE,XEE0(EE,E))+
1011                SUM(O,XOE0(O,E))+LE0(E)+re0(e)+ae0(e)+KE0(E)+
1012                deple0(e)+ITAXE0(E)-SUBSE0(E);
1013
1014                                                          DOX0(O)..
OX0(O)=E=SUM(P,XPO0(P,O))+SUM(C,XCO0(C,O))+SUM(E,XEO0(E,O))+
1015               SUM(OO,XOO0(OO,O))+LO0(O)+ro0(o)+ao0(o)+KO0(O)+
1016               deplo0(o)+ITAXO0(O)-SUBSO0(O);
1017
1018   DOBJ..        OBJ=E=SUM(P,PQP0(P)+sum(t,IMPDP(p,t)));
1019
1020  * Initial values
1021   pqp0.l(p)=1; pqc0.l(c)=1; pqe0.l(e)=1; pqo0.l(o)=1;
1022   qp0.l(p)=1; qc0.l(c)=1; qe0.l(e)=1; qo0.l(o)=1;
1023
1024   MODEL PREL /ALL/;
1025   SOLVE PREL USING NLP MAXIMIZING OBJ;
GAMS 2.25.059  386/486 DOS                    11/13/96 17:16:17  PAGE
21
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1026    DISPLAY  cx0.l, PQP0.L, IMPSHP.L,IMPDP.L, PQC0.L,
1027    IMPSHC.L, IMPDC.L, PQE0.L,
1028    IMPSHE.L,IMPDE.L, PQO0.L,IMPSHO.L,IMPDO.L;
INCLUDE    C:\SLMOD\SLCLCAGG.INC
1030  * Calculation of parameters
1031
1032  * Total production
1033
1034   PARAMETER  CP0(PP) Dom PROD plus IMPORTS P;
1035     CP0(P)=PX0.L(P)+IMPP0(P)+IMPDP0(P);
1036   DISPLAY CP0;
1037
1038   PARAMETER CC0(CC) Dom PROD plus IMPORTS C;
1039     CC0(C)=CX0.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,cc0(c));
1044
1045   PARAMETER CE0(EE) Dom PROD plus IMPORTS E;
1046     CE0(E)=EX0.L(E)+IMPE0(E)+IMPDE0(E);
1047   DISPLAY CE0;
1048
1049   PARAMETER CO0(OO)  Dom PROD plus IMPORTS O;
1050     CO0(O)=OX0.L(O)+IMPO0(O)+IMPDO0(O);
1051   DISPLAY CO0;
```

```
1052
1053
1054  * Input coefficients in treecrop production
1055
1056   PARAMETER ACP(C,PP) Shares of C in P production;
1057      ACP(C,P)=(XCP0(C,P)/PQC0.L(C))/(CP0(P)/PQP0.L(P));
1058   DISPLAY ACP;
1059
1060   parameter anp(n,pp) Shares of N in P production;
1061      anp(n,p)=sum(c,acp(c,p));
1062
1063   PARAMETER AEP(E,PP) Shares of E in P production;
1064      AEP(E,P)=(XEP0(E,P)/PQE0.L(E))/(CP0(P)/PQP0.L(P));
1065   DISPLAY AEP;
1066
1067   PARAMETER AOP(O,PP) Shares of O in P production;
1068      AOP(O,P)=(XOP0(O,P)/PQO0.L(O))/(CP0(P)/PQP0.L(P));
1069   DISPLAY AOP;
1070
1071   PARAMETER EXPSHP(PP)  Exports as share of total consumption;
1072      EXPSHP(P)=PEXP0(P)/(cp0(P));
1073   DISPLAY EXPSHP;
1074
1075     PARAMETER  AAP(PP)       Initial  input  coeff  for  labor  in  P
production;
1076      AAP(P)=AP0(P)/(CP0(P)/PQP0.L(P));
1077   DISPLAY AAP;
1078
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
22
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1079   PARAMETER ALP(PP)    Initial input coeff for urban labor in P

production;
1080      alp(p)=lp0(p)/(cp0(p)/pqp0.l(p));
1081
1082    parameter arp(pp)     Initial input coeff for rural labor in P
prod;
1083      ARp(p)=rp0(p)/(cp0(p)/pqp0.l(p));
1084
1085     PARAMETER  AKP(PP)       Initial  input  coeff  for  capital  in  P
production;
1086      AKP(P)=(KP0(P)+deplp0(p))/(CP0(P)/PQP0.L(P));
1087   DISPLAY AKP;
1088
1089   PARAMETER ITAXP(PP,tt)  Indirect tax rate in P sectors;
1090      ITAXP(P,t)=ITAXP0(P)/(CP0(P)/PQP0.L(P));
1091   DISPLAY ITAXP;
1092
1093   PARAMETER SUBSP(PP,tt)  Subsidy rate in P sectors;
1094      SUBSP(P,t)=SUBSP0(P)/(CP0(P)/PQP0.L(P));
1095   DISPLAY SUBSP;
```

```
1096
1097   PARAMETER otaxp(PP,tt) Net tax rate on p products;
1098      OTAXP(P,t)=ITAXP(P,t)-SUBSP(P,t);
1099
1100   parameter deplp(p)  Depletion rate of capital in P sectors;
1101      deplp(p)=deplp0(p)/kp0(p);
1102   display deplp;
1103
1104   parameter deplc(c)  Depletion rate of capital in C sectors;
1105      deplc(c)=deplc0(c)/kc0(c);
1106   display deplc;
1107
1108   parameter depln(n);
1109       depln(n)=sum(c,deplc0(c))/sum(c,kc0(c));
1110
1111   parameter deple(e)  Depletion rate of capital in E sectors;
1112      deple(e)=deple0(e)/ke0(e);
1113   display deple;
1114
1115    parameter deplo(o)  Depletion rate of capital in O sectors;
1116      deplo(o)=deplo0(o)/ko0(o);
1117   display deplo;
1118
1119  * Input coefficients in Colombo production
1120
1121   PARAMETER APC(P,CC) Shares of P in C production;
1122      APC(PP,C)=(XPC0(PP,C)/PQP0.L(PP))/(CC0(C)/PQC0.L(C));
1123   DISPLAY APC;
1124
1125   parameter xpn0(p);
1126     xpn0(p)=sum(c,xpc0(p,c));
1127
1128   parameter xnn0(n);
1129     xnn0(n)=sum(c,sum(cc,xcc0(c,cc)));
1130
```



```
1131   parameter apn(p,n);
1132      apn(p,n)=xpn0(p)/PQP0.L(P)/sum(c,cC0(C)/PQC0.L(C));
1133
1134   PARAMETER ACC(C,CC) Shares of C in C production;
1135      ACC(CC,C)=(Xcc0(CC,C)/PQC0.L(C))/(CC0(C)/PQC0.L(C));
1136   DISPLAY ACC;
1137
1138   parameter ann(n);
1139      ann(n)=Xnn0(n)/PQn0.L(n)/sum(c,(CC0(C)/PQC0.L(C)));
1140   DISPLAY Ann;
1141
1142   PARAMETER AEC(E,CC) Shares of E in C production;
1143      AEC(E,C)=(XEC0(E,C)/PQE0.L(E))/(CC0(C)/PQC0.L(C));
1144   DISPLAY AEC;
```

```
1145
1146   parameter aen(e,nn);
1147
aen(e,n)=sum(c,(XEC0(E,C)/PQE0.L(E)))/sum(c,(CC0(C)/PQC0.L(C)));
1148
1149   PARAMETER AOC(O,CC) Shares of O in C production;
1150      AOC(O,C)=(XOC0(O,C)/PQO0.L(O))/(CC0(C)/PQC0.L(C));
1151   DISPLAY AOC;
1152
1153   parameter aon(o,nn);
1154
aon(o,n)=sum(c,(XOC0(O,C)/PQO0.L(O)))/sum(c,(CC0(C)/PQC0.L(C)));
1155   DISPLAY AOn;
1156
1157   PARAMETER EXPSHC(CC)  Export share of total consumption;
1158      EXPSHC(C)=CEXP0(C)/(cc0(C));
1159   DISPLAY EXPSHC;
1160
1161   parameter expshn(nn);
1162      expshn(n)=sum(c,CEXP0(C))/sum(c,(cc0(C)));
1163
1164
1165   PARAMETER ALC(CC)    Initial input coeff for urban labor in C

production;
1166      ALC(C)=LC0(C)/CC0(C);
1167   DISPLAY ALC;
1168
1169   parameter aln(nn);
1170      aln(n)=sum(c,LC0(C))/sum(c,CC0(C));
1171
1172   PARAMETER arc(cc)    Initial input coeff for rural labor in C

production;
1173      ARC(c)=rc0(c)/(cc0(c)/pqc0.l(c));
1174
1175   parameter arn(nn);
1176     arn(n)=sum(c,rC0(C))/sum(c,CC0(C));
1177
1178   PARAMETER aac(cc)    Initial input coeff for estate labor in C

production;
1179      AAC(C)=ac0(c)/(cc0(c)/ pqc0.l(c));
1180   display aac;
GAMS 2.25.059  386/486 DOS                      11/13/96 17:16:17  PAGE
24
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1181
1182   parameter aan(nn);
1183      aan(n)=sum(c,aC0(C))/sum(c,CC0(C));
1184
1185    PARAMETER AKC(CC)      Initial input coeff for capital in C
```

```
production;
1186      AKC(C)=(KC0(C)+deplc0(c))/(CC0(C)/PQC0.L(C));
1187   DISPLAY AKC;
1188
1189   parameter akn(nn);
1190        akn(n)=sum(c,aC0(C)+deplc0(c))/sum(c,CC0(C));
1191
1192   PARAMETER ITAXC(CC,tt)  Indirect tax rate in C sectors;
1193      ITAXC(C,t)=ITAXC0(C)/(CC0(C))/PQC0.L(C);
1194   DISPLAY ITAXC;
1195
1196   parameter itaxn(nn,t);
1197      itaxn(n,t)=sum(c,ITAXC0(C))/sum(c,(CC0(C))/PQC0.L(C));
1198
1199   PARAMETER OTAXn(nn,tt)  Net tax rate on C products;
1200      OTAXn(n,t)=ITAXn(n,t);
1201
1202   parameter otaxc(cc,t);
1203      otaxc(c,t)=itaxc(c,t);
1204
1205  * Input coefficients in Energy production
1206
1207   PARAMETER ACE(C,EE) Shares of C in E production;
1208      ACE(C,E)=(XCE0(C,E)/PQC0.L(C))/(CE0(E)/PQE0.L(E));
1209   DISPLAY ACE;
1210
1211   parameter ane(n,ee);
1212      ane(n,e)=(sum(c,XCE0(C,E)/PQC0.L(C)))/(CE0(E)/PQE0.L(E));
1213
1214   PARAMETER AEE(E,EE) Shares of E in E production;
1215      AEE(EE,E)=(XEE0(EE,E)/PQE0.L(E))/(CE0(E)/PQE0.L(E));
1216   DISPLAY AEE;
1217
1218   PARAMETER AOE(O,EE) Shares of O in E production;
1219      AOE(O,E)=(XOE0(O,E)/PQO0.L(O))/(CE0(E)/PQE0.L(E));
1220   DISPLAY AOE;
1221
1222   PARAMETER EXPSHE(EE) Export share of consumption;
1223      EXPSHE(E)=eexp0(e)/(ce0(E));
1224   DISPLAY EXPSHE;
1225
1226   PARAMETER ALE(EE)    Initial input coeff for urban labor in E

production;
1227      ALE(E)=LE0(E)/(CE0(E)/PQE0.L(E));
1228   DISPLAY ALE;
1229
1230   PARAMETER ARE(EE)    Initial input coeff for rural labor in E

production;
1231      ARE(E)=re0(e)/(ce0(e)/pqe0.l(e));
```

```
1232
1233   PARAMETER AAE(EE)     Initial input coeff for estate labor in E

production;
1234      AAE(E)=ae0(e)/(ce0(e)/pqe0.l(e));
1235
1236    PARAMETER AKE(EE)      Initial input coeff for capital in E
production;
1237      AKE(E)=(KE0(E)+deple0(e))/(CE0(E)/PQE0.L(E));
1238   DISPLAY AKE;
1239
1240   PARAMETER ITAXE(EE,tt)  Indirect tax rate in E sectors;
1241      ITAXE(E,t)=ITAXE0(E)/(CE0(E)/PQE0.L(E));
1242   DISPLAY ITAXE;
1243
1244   PARAMETER SUBSE(EE,T)  Subsidy rate in E sectors;
1245      SUBSE(e,t)=subse0(e)/(ce0(e)/pqe0.l(e));
1246
1247   PARAMETER otaxe(EE,tt)  Net tax rate on E products;
1248      OTAXE(E,t)=ITAXE(E,t)-subse(e,t);
1249
1250  * Input coefficients in Other production
1251
1252   PARAMETER APO(P,OO) Shares of P in O production;
1253      APO(P,O)=(XPO0(P,O)/PQP0.L(P))/(CO0(O)/PQO0.L(O));
1254   DISPLAY APO;
1255
1256   PARAMETER ACO(C,OO) Shares of C in O production;
1257      ACO(C,O)=(XCO0(C,O)/PQC0.L(C))/(CO0(O)/PQO0.L(O));
1258   DISPLAY ACO;
1259
1260   parameter ano(n,oo) Shares ..;
1261      ano(n,o)=sum(c,(XCO0(C,O)/PQC0.L(C)))/(CO0(O)/PQO0.L(O));
1262
1263   PARAMETER AEO(E,OO) Shares of E in O production;
1264      AEO(E,O)=(XEO0(E,O)/PQE0.L(E))/(CO0(O)/PQO0.L(O));
1265   DISPLAY AEO;
1266
1267   PARAMETER AOO(O,OO) Shares of O in O production;
1268      AOO(OO,O)=(XOO0(OO,O)/PQO0.L(O))/(CO0(O)/PQO0.L(O));
1269   DISPLAY AOO;
1270
1271   PARAMETER EXPSHO(OO) Export share of total consumption;
1272      EXPSHO(O)=OEXP0(O)/(co0(O));
1273   DISPLAY EXPSHO;
1274
1275   PARAMETER ALO(OO)     Initial input coeff for urban labor in O

production;
1276      ALO(O)=LO0(O)/(CO0(O)/PQO0.L(O));
1277   DISPLAY ALO;
1278
1279   PARAMETER ARO(OO)     Initial input coeff for rural labor in O
```

```
production;
1280      ARO(O)=RO0(O)/(CO0(O)/PQO0.l(O));
1281
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
26
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1282   PARAMETER AAO(OO)    Initial input coeff for estate labor in O

production;
1283      AAO(O)=AO0(O)/(CO0(O)/PQO0.l(O));
1284
1285    PARAMETER AKO(OO)      Initial input coeff for capital in O
production;
1286      AKO(O)=(KO0(O)+deplo0(o))/(CO0(O)/PQO0.L(O));
1287   DISPLAY AKO;
1288
1289   PARAMETER ITAXO(OO,tt)  Indirect tax rate in O sectors;
1290      ITAXO(O,t)=ITAXO0(O)/(CO0(O)/PQO0.L(O));
1291   DISPLAY ITAXO;
1292
1293   PARAMETER SUBSO(OO,tt)  Subsidy rate in O sectors;
1294      SUBSO(O,t)=subso0(o)/(co0(o)/pqo0.l(o));
1295
1296   PARAMETER OTAXO(OO,tt)  net tax rate O products;
1297      OTAXO(O,t)=ITAXO(O,t)-subso(o,t);
1298
1299   PARAMETER PTCONS0(PP)  Total consumption of P goods in period 0;
1300      PTCONS0(P)=sum(h,PCONS0(P,h))/PQP0.L(P)+INVp0(P)/PQP0.L(P);
1301   DISPLAY PTCONS0;
1302
1303   PARAMETER CTCONS0(CC)  Total consumption of C goods in period 0;
1304      CTCONS0(C)=sum(h,CCONS0(C,h))/PQC0.L(C)+INVc0(C)/PQC0.L(C);
1305   DISPLAY CTCONS0;
1306
1307   parameter ntcons0(n);
1308      ntcons0(n)=sum(c,ctcons0(c));
1309
1310   PARAMETER ETCONS0(EE)   Total consumption of E goods in period 0;
1311      ETCONS0(E)=(sum(h,ECONS0(E,h)))/PQE0.L(E);
1312   DISPLAY ETCONS0;
1313
1314   PARAMETER OTCONS0(OO)  Total consumption of O goods in period 0;
1315      OTCONS0(O)=(sum(h,OCONS0(O,h))+INVo0(O))/PQO0.L(O);
1316   DISPLAY OTCONS0;
1317
1318   PARAMETER TOTEXP0  Total exports;
1319       TOTEXP0=SUM(P,PEXP0(P))+SUM(C,CEXP0(C))+sum(e,eexp0(e))
1320              +SUM(O,OEXP0(O));
1321   DISPLAY TOTEXP0;
1322
1323   PARAMETER TOTIMP0   Total imports;
```

```
1324        TOTIMP0=SUM(P,IMPP0(P))+SUM(C,IMPC0(C))+SUM(E,IMPE0(E))+
1325               SUM(O,IMPO0(O));
1326
1327   PARAMETER TIMPD0     Total import duty;
1328        TIMPD0=SUM(P,IMPDP0(P))+SUM(C,IMPDC0(C))+SUM(E,IMPDE0(E))
1329              +SUM(O,IMPDO0(O));
1330   DISPLAY TIMPD0;
1331
1332   PARAMETER TOTCONS0       Total consumption;
1333
TOTCONS0=SUM(P,PTCONS0(P))+SUM(C,CTCONS0(C))+SUM(E,ETCONS0(E))+
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
27
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1334                SUM(O,OTCONS0(O));
1335   DISPLAY TOTCONS0;
1336
1337  PARAMETER TOTL0     Total urban labor supply;
1338      TOTL0=sum(p,lp0(p))+SUM(C,LC0(C))+SUM(E,LE0(E))+SUM(O,LO0(O));
1339   DISPLAY TOTL0;
1340
1341  PARAMETER TOTr0     Total rural labor supply;
1342      TOTr0=sum(p,rp0(p))+SUM(C,rC0(C))+SUM(E,rE0(E))+SUM(O,rO0(O));
1343   DISPLAY TOTr0;
1344
1345  PARAMETER TOTa0     Total estate labor supply;
1346      TOTa0=sum(p,ap0(p))+SUM(C,aC0(C))+SUM(E,aE0(E))+SUM(O,aO0(O));
1347   DISPLAY TOTa0;
1348
1349   PARAMETER TOTK0   Total capital supply;
1350
TOTK0=SUM(P,KP0(P)+deplp0(p))+SUM(C,KC0(C)+deplc0(c))+SUM(E,KE0(E)
1351            +deple0(e))+SUM(O,KO0(O)+deplo0(o));
1352   DISPLAY TOTK0;
1353
1354   PARAMETER TTAX0     Total benchmark taxes EXCEPT direct taxes;
1355                                          TTAX0=SUM(P,(ITAXP0(P)-
SUBSP0(P)))+SUM(C,ITAXC0(C))+SUM(E,(ITAXE0(E)
1356           -SUBSE0(E)))+SUM(O,(ITAXO0(O)-SUBSO0(O)));
1357   DISPLAY TTAX0;
1358
1359   PARAMETER TB0     Initial trade balance;
1360       TB0=TOTEXP0-TOTIMP0;
1361   DISPLAY Tb0;
1362
1363    PARAMETER DISP0(h)     Benchmark disposable income for household
h;
1364
1365   DISP0(h)=sum(p,pcons0(p,h))+sum(c,ccons0(c,h))+sum(e,econs0(e,h))
1366           +sum(o,ocons0(o,h));
1367   DISPLAY DISP0;
1368
```

```
1369   PARAMETER TOTINV0    Benchmark investment level;
1370   totinv0=sum(p,invp0(p))+sum(c,invc0(c))+sum(o,invo0(o));
1371   display totinv0;
1372
1373
1374   parameter tr  Total transfers and capital incomes not;
1375  *  tr=sum(h,disp0(h))-(tota0+totr0+totl0);
1376    tr=totk0+ttax0+timpd0;
1377   display tr;
1378
1379   parameter KH(h)      Share of transfers and capital income to HH;
1380   kh('urban')=(totl0-disp0('urban'))/(tb0+totinv0-tr);
1381   kh('rural')=(totr0-disp0('rural'))/(tb0+totinv0-tr);
1382   kh('estate')=(tota0-disp0('estate'))/(tb0+totinv0-tr);
1383   display kh;
1384
1385
1386   parameter test ;
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
28
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1387    test=sum(h,disp0(h))+tb0+totinv0-totl0-tota0-totr0-tr;
1388   display test;
1389
1390   parameter sav0(h);
1391                sav0('urban')=totl0+kh('urban')*(totk0+ttax0+timpd0)-
disp0('urban');
1392                sav0('rural')=totr0+kh('rural')*(totk0+ttax0+timpd0)-
disp0('rural');
1393              sav0('estate')=tota0+kh('estate')*(totk0+ttax0+timpd0)-
disp0('estate');
1394   display sav0;
1395
1396
1397   parameter disp01;
1398   disp01=totl0+kh('urban')*(totk0+ttax0+timpd0-totinv0-tb0);
1399   display disp01;
1400   display disp0;
1401
1402      PARAMETER  PALPHA(PP,h)    Expenditure  share  on  P  goods  for
household h;
1403       PALPHA(P,h)=PCONS0(P,h)*PQP0.L(P)/DISP0(h);
1404   DISPLAY PALPHA;
1405
1406   PARAMETER CALPHA(CC,h)  Expenditure share on C goods;
1407       CALPHA(C,h)=CCONS0(C,h)*PQC0.L(C)/DISP0(h);
1408   DISPLAY CALPHA;
1409
1410   parameter nalpha(nn,h);
1411       nalpha(n,h)=sum(c,calpha(c,h));
1412
1413   PARAMETER EALPHA(EE,h)  Expenditure share on E goods;
```

```
1414       EALPHA(E,h)=ECONS0(E,h)*PQE0.L(E)/DISP0(h);
1415    DISPLAY EALPHA;
1416
1417    PARAMETER OALPHA(OO,h)  Expenditure share on O goods;
1418       OALPHA(O,h)=OCONS0(O,h)*PQO0.L(O)/DISP0(H);
1419    DISPLAY OALPHA;
1420
1421    PARAMETER TALPHA(h) Total share check;
1422
TALPHA(h)=SUM(P,PALPHA(P,h))+SUM(C,CALPHA(C,h))+SUM(E,EALPHA(E,h))
1423       +SUM(O,OALPHA(O,h));
1424    DISPLAY TALPHA;
1425
1426    parameter pbeta(p) Investment share of P goods;
1427       pbeta(p)=invp0(p)/totinv0;
1428    display pbeta;
1429
1430    parameter cbeta(c) Investment share of C goods;
1431       cbeta(c)=invc0(c)/totinv0;
1432    display cbeta;
1433
1434    parameter nbeta(n);
1435       nbeta(n)=sum(c,cbeta(c));
1436
1437    parameter obeta(o) Investment share of O goods;
1438       obeta(o)=invo0(o)/totinv0;
1439    display obeta;
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
29
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1440
1441    parameter tbeta Total share check;
1442       tbeta=sum(p,pbeta(p))+sum(c,cbeta(c))+sum(o,obeta(o));
1443    display tbeta;
1444
1445
1446    PARAMETER NIP0  Initial National Income from prod side;
1447       NIP0=TOTL0+tota0+totl0+TOTK0+TOTIMP0+TTAX0;
1448    DISPLAY NIP0;
1449
1450    PARAMETER NIC0  Initial National income from cons side;
1451       NIC0=TOTCONS0+TOTEXP0;
1452    DISPLAY NIC0;
1453
1454      PARAMETER  AP(PP,t)    Production  function  scale  parameter  P
sectors;
1455                                                          AP(P,t)=1-
(SUM(C,ACP(C,P))+SUM(O,AOP(O,P))+SUM(E2,AEP(E2,P)))
1456            -oTAXP(P,t);
1457    DISPLAY AP;
1458
1459      PARAMETER  AC(CC,t)    Production  function  scale  parameter  C
```

```
sectors;
1460                AC(C,t)=1-(SUM(P,APC(P,C))+SUM(CC,ACC(CC,C))+SUM(E2,
AEC(E2,C))
1461            +SUM(O,AOC(O,C)))-OTAXC(C,t);
1462   DISPLAY AC;
1463
1464   parameter an(nn,t);
1465            an(n,t)=1-(SUM(P,APn(P,n))+Ann(n)+SUM(E2, AEn(E2,n))
1466            +SUM(O,AOn(O,n)))-OTAXn(n,t);
1467   display an;
1468
1469
1470      PARAMETER  AE(EE,t)    Production  function  scale  parameter  E
sectors;
1471            AE(E,t)=1-(SUM(C,ACE(C,E))+SUM(E2,AEE(E2,E))+
1472            SUM(O,AOE(O,E)))-OTAXE(E,t);
1473   DISPLAY AE;
1474
1475      PARAMETER  AO(OO,t)    Production  function  scale  parameter  O
sectors;
1476                                                          AO(O,t)=1-
(SUM(P,APO(P,O))+SUM(C,ACO(C,O))+SUM(E2,AEO(E2,O))+
1477            SUM(OO,AOO(OO,O)))-OTAXO(O,t);
1478   DISPLAY AO;
1479
1480   PARAMETER  DELA1(PP) Share of estate labor in k+a factors P;
1481            DELA1(P)=AP0(P)/(AP0(P)+KP0(P)+deplp0(p));
1482   DISPLAY DELA1;
1483
1484   PARAMETER  delr2(PP) Share of rural labor in k+a+r factors P;
1485            DELR2(P)=rP0(P)/(AP0(P)+KP0(P)+deplp0(p)+rp0(p));
1486   DISPLAY DELr2;
1487
1488   PARAMETER  delL3(PP) Share of URBAN labor in k+a+r+L factors P;
1489            DELl3(P)=LP0(P)/(AP0(P)+KP0(P)+deplp0(p)+rp0(p)+LP0(P));
1490   DISPLAY DELL3;
1491
1492   parameter DELe4(PP) Share of electricity in total k+a+r+l+elec P;
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
30
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1493
DELE4(p)=xep0('elec',p)/(ap0(p)+kp0(p)+deplp0(p)+LP0(P)+RP0(P)+
1494            xep0('elec',p));
1495   display dele4;
1496
1497   PARAMETER DELMY(PP) share of imports in total factors P;
1498
DELMY(P)=(IMPP0(P)+impdp0(p))/(ap0(p)+kp0(p)+deplp0(p)+LP0(P)+
1499            RP0(P)+xep0('elec',p)+
1500                     IMPP0(P)+impdp0(p));
1501   DISPLAY DELMY;
```

```
1502
1503   PARAMETER  DELA1C(CC) Share of estate labor in k+a factors C;
1504           DELA1C(C)=AC0(C)/(AC0(C)+KC0(C)+deplc0(c));
1505   DISPLAY DELA1C;
1506
1507   parameter dela1n(nn);
1508           dela1n(n)=sum(c,AC0(C))/sum(c,(AC0(C)+KC0(C)+deplc0(c)));
1509
1510   PARAMETER  delr2C(C) Share of rural labor in k+a+r factors C;
1511           DELR2C(C)=rC0(C)/(AC0(C)+KC0(C)+DEPLC0(C)+rC0(C));
1512   DISPLAY DELr2C;
1513
1514   parameter delr2n(n);
1515
delr2n(n)=sum(c,rC0(C))/sum(c,(AC0(C)+KC0(C)+DEPLC0(C)+rC0(C)));
1516
1517   PARAMETER  delL3C(CC) Share of URBAN labor in k+a+r+L factors C;
1518           DELl3C(C)=LC0(C)/(AC0(C)+KC0(C)+DEPLC0(C)+rC0(C)+LC0(C));
1519   DISPLAY DELL3C;
1520
1521   parameter dell3n(n);
1522
dell3n(n)=sum(c,LC0(C))/sum(c,(AC0(C)+KC0(C)+DEPLC0(C)+rC0(C)

+LC0(C))
1523           );
1524
1525   parameter DELe4C(CC) Share of electricity in K+A+R+L+ELEC factors
C;
1526
DELE4C(C)=xeC0('elec',C)/(aC0(C)+kc0(c)+deplc0(c)+LC0(C)+RC0(C)+
1527                                      XEC0('ELEC',C));
1528  display dele4C;
1529
1530   parameter dele4n(n);
1531
dele4n(n)=sum(c,xeC0('elec',C))/sum(c,(aC0(C)+kc0(c)+deplc0(c)+
1532                                 LC0(C)+RC0(C)+
1533                                      XEC0('ELEC',C)));
1534
1535   PARAMETER DELMYC(CC) share of imports in total factors C;
1536
DELMYC(C)=(IMPC0(C)+impdc0(c))/(aC0(C)+kc0(c)+deplc0(c)+LC0(C)

+RC0(C)+
1537                      xeC0('elec',C)+
1538                     IMPC0(C)+impdc0(c));
1539   DISPLAY DELMYC;
1540
1541   parameter delmyn(n);
1542
delmyn(n)=sum(c,IMPC0(C)+impdc0(c))/sum(c,(aC0(C)+kc0(c)+deplc0(c)+
1543                      LC0(C)+RC0(C)+
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
31
```

```
                    xeC0('elec',C)+
                   IMPC0(C)+impdc0(c)));
display delmyn;

PARAMETER  DELA1E(EE) Share of estate labor in k+a factors E;
        DELA1E(E)=AE0(E)/(AE0(E)+KE0(E)+DEPLE0(E));
DISPLAY DELA1E;

PARAMETER  delr2E(EE) Share of rural labor in k+a+r factors E;
        DELR2E(E)=rE0(E)/(AE0(E)+KE0(E)+DEPLE0(E)+rE0(E));
DISPLAY DELr2E;

PARAMETER  delL3E(EE) Share of URBAN labor in k+a+r+L factors E;
        DEL13E(E)=LE0(E)/(AE0(E)+KE0(E)+DEPLE0(E)+rE0(E)+LE0(E));
DISPLAY DELL3E;

parameter DELe4E(EE) Share of electricity in K+A+R+L+ELEC factors
E;

DELE4E(E)=xeE0('elec',E)/(aE0(E)+ke0(e)+deple0(e)+LE0(E)+rE0(E)+
                 XEE0('ELEC',E))
display dele4E;

PARAMETER DELMYE(EE) share of imports in total factors E;

DELMYE(E)=(IMPE0(E)+impde0(e))/(aE0(E)+ke0(e)+deple0(e)+LE0(E)

+RE0(E)+xeE0('elec',E)+
                   IMPE0(E)+impde0(e));
DISPLAY DELMYE;

PARAMETER  DELA1O(OO) Share of estate labor in k+a factors O;
        DELA1O(O)=AO0(O)/(AO0(O)+KO0(O)+DEPLO0(O));
DISPLAY DELA1O;

PARAMETER  delr2O(OO) Share of rural labor in k+a+r factors O;
        DELR2O(O)=rO0(O)/(AO0(O)+KO0(O)+DEPLO0(O)+rO0(O));
DISPLAY DELr2O;

PARAMETER  delL3O(OO) Share of URBAN labor in k+a+r+L factors O;
        DEL13O(O)=LO0(O)/(AO0(O)+KO0(O)+DEPLO0(O)+rO0(O)+LO0(O));
DISPLAY DELL3O;

parameter DELe4O(OO) Share of electricity in K+L+A+R+ELEC factors
O;

DELE4O(O)=xeO0('elec',O)/(aO0(O)+ko0(o)+deplo0(o)+LO0(O)+rO0(O)+
                XEO0('ELEC',O))
display dele4O;

PARAMETER DELMYO(OO) share of imports in total factors O;
```

```
1588
DELMYO(O)=(IMPO0(O)+impdo0(o))/(aO0(O)+ko0(o)+deplo0(o)+LO0(O)

+RO0(O)+xeO0('elec',O)+
1589                    IMPO0(O)+impdo0(o));
1590   DISPLAY DELMYO;
1591
1592  * Definition of trade substitution elasticity IMPORTS
1593   * The smaller the elasticity the more imperfect substitutes are
dom and

imp
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
32
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1594
1595   PARAMETER EPSP(PP,t);
1596       EPSP(P,t)=LOG((IMPP0(P)+impdp0(p))/PX0.L(P)) /
1597   LOG(IMPSHP.L(P)/(1-IMPSHP.L(P))*1/(1+IMPDP.L(P,t)));
1598   DISPLAY EPSP;
1599
1600   PARAMETER EPSC(CC,t);
1601                    EPSC(C,t)=LOG((IMPC0(C)+impdc0(c))/CX0.L(C))   /
LOG(IMPSHC.L(C)/
1602       (1-IMPSHC.L(C))*1/(1+IMPDC.L(C,t)));
1603   DISPLAY EPSC;
1604
1605   parameter epsn(nn,t);
1606       epsn(n,t)=LOG((sum(c,IMPC0(C)+impdc0(c)))/sum(c,CX0.L(C)) /
1607                  LOG(IMPSHn.L(n)/
1608       (1-IMPSHn.L(n))*1/(1+IMPDn.L(n,t)));
1609
1610   PARAMETER EPSO(OO,t);
1611                    EPSO(O,t)=LOG((IMPO0(O)+impdo0(o))/OX0.L(O))   /
LOG(IMPSHO.L(O)/
1612       (1-IMPSHO.L(O))*1/(1+IMPDO.L(O,t)));
1613   DISPLAY EPSO;
1614
1615   PARAMETER EPSE(EE,t);
1616                    EPSE(E,t)=LOG((IMPE0(E)+impde0(e))/EX0.L(E))   /
LOG(IMPSHE.L(E)/
1617       (1-IMPSHE.L(E))*1/(1+IMPDE.L(E,t)));
1618   DISPLAY EPSE;
1619
1620  * Definition of world market price for exports
1621
1622   parameter wmep(pp,t);
1623     wmep(p,t)=1;
1624  **1.01**(time*tau);
1625
1626   parameter wmeC(CC,t);
1627     wmeC(C,t) $ (EXPSHC(C) GT 0)=1;
```

```
1628  *(Cexp0(C)/(SUM(P,XCP0(C,P))+SUM(CC,XCC0(C,CC))+
1629                                                                    *
SUM(O,XCO0(C,O))+SUM(E,XCE0(C,E))+CTCONS0(C)+cexp0(c))/
1630  *    (expshC(C)/(1-expshC(C)))**muC(C))**(1/muC(C));
1631     display wmeC;
1632   parameter wmen(n,t);
1633   wmen(n,t)=1;
1634
1635   parameter wmeo(oo,t);
1636     wmeo(o,t) $ (EXPSHo(o) GT 0)=1;
1637  *(oexp0(o)/(SUM(P,XoP0(o,P))+SUM(oo,Xoo0(o,oo))+
1638                                                                    *
SUM(c,XOc0(O,c))+SUM(E,XoE0(o,E)+oexp0(o))+oTCONS0(o))/
1639  *    (expsho(o)/(1-expsho(o)))**muo(o))**(1/muo(o));
1640     display wmeo;
1641
1642   parameter wmee(ee,t);
1643     wmee(e,t) $ (EXPSHe(e) GT 0)=1;
1644  *(eexp0(e)/(SUM(P,XeP0(e,P))+SUM(ee,Xee0(e,ee))+
1645  *            SUM(O,XeO0(e,O))+SUM(c,XEc0(E,c))+eTCONS0(e))/
1646  *    (expshe(e)/(1-expshe(e)))**mue(e))**(1/mue(e));
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
33
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1647     display wmee;
1648
1649
1650
1651
1652  * Definition of CES function exponent IMPORTS
1653
1654
1655   PARAMETER RHOP(PP,t);
1656      RHOP(P,t)=1/EPSP(P,t)-1;
1657   DISPLAY RHOP;
1658
1659   PARAMETER RHOC(CC,t);
1660      RHOC(C,t)=1/EPSC(C,t)-1;
1661   DISPLAY RHOC;
1662
1663   parameter rhon(nn,t);
1664      rhon(n,t)=1/epsn(n,t)-1;
1665   display rhon;
1666
1667   PARAMETER RHOE(EE,t);
1668      RHOE(E,t)=1/EPSE(E,t)-1;
1669   DISPLAY RHOE;
1670
1671   PARAMETER RHOO(OO,t);
1672      RHOO(O,t)=1/EPSO(O,t)-1;
1673   DISPLAY RHOO;
1674
```

```
INCLUDE    C:\SLMOD\SLPRICEA.INC
1676  * World market prices
1677
1678   PARAMETER WMP(PP,t) World market price for imports to P;
1679      WMP(P,t)=1/(1+impdp.l(p,t));
1680   DISPLAY WMP;
1681
1682   PARAMETER WMN(n,t) World market price for imports to C;
1683      WMN(n,t)=1/(1+impdn.l(n,t));
1684   DISPLAY WMn;
1685
1686   PARAMETER WME(EE,t) World market price for imports to E;
1687      WME(E,t)=1/(1+impde.l(e,t));
1688   DISPLAY WME;
1689
1690   PARAMETER WMO(OO,t) World market price for imports to O;
1691      WMO(O,t)=1/(1+impdo.l(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
GAMS 2.25.059  386/486 DOS                      11/13/96 17:16:17  PAGE
34
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


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 WMEO(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 PCP0(P);
1722     PCP0(PP)=1;
1723
```

```
1724   PARAMETER Pnn0(n);
1725     Pnn0(nn)=1;
1726
1727   PARAMETER PCE0(E);
1728     PCE0(EE)=1;
1729
1730   PARAMETER PCO0(O);
1731     PCO0(OO)=1;
1732
1733
1734
1735    parameter l(tt);
1736   l(t)$(ord(t) eq 1)=totl0;
1737   l(t)$(ord(t) ne 1)=totl0*popg**((ord(t)-1)*tau);
1738    display l;
1739
1740   parameter r(tt);
1741   r(t)$(ord(t) eq 1)=totr0;
1742   r(t)$(ord(t) ne 1)=totr0*popg**((ord(t)-1)*tau);
1743    display r;
1744
1745    parameter a(tt);
1746   a(t)$(ord(t) eq 1)=tota0;
1747   a(t)$(ord(t) ne 1)=tota0*apopg**((ord(t)-1)*tau);
1748    display a;
1749  * List of variables
INCLUDE    C:\SLMOD\SLVARA.INC
1751  * List of variables
1752
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
35
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1753   VARIABLES
1754    totimp
1755    tottax
1756  * slack
1757  * ks(t)
1758  * as(t)
1759  * ls(t)
1760  * rs(t)
1761
1762   PUA(t)            User price of estate labor
1763
1764   PUR(T)            USER PRICE OF RURAL LABOR
1765
1766   PUL(t)            User price of URBAN labor
1767
1768   PUK(t)            User price of capital
1769
1770   P1P(P,t)         Price of factor aggregate 1 in P sectors
1771
1772   P2P(P,T)         Price of factor aggregate 2 in P sectors
```

```
1773
1774   P3P(P,T)          Price of factor agregate 3 in P sectors
1775
1776   P4P(P,T)          Price of factor aggregate 4 in P sectors
1777
1778   PYP(P,t)          Price of composite input Y in P sectors
1779
1780   P1N(N,t)          Price of factor aggregate 1 in C sectors
1781
1782   P2N(N,T)          Crice of factor aggregate 2 in C sectors
1783
1784   P3N(N,T)          Price of factor agregate 3 in C sectors
1785
1786   P4N(N,T)          Crice of factor aggregate 4 in C sectors
1787
1788   PYN(N,t)          Price of composite input Y in C sectors
1789
1790   PYE(E,t)          Price of composite input Y in E sectors
1791
1792   P1E(E,T)          Price of factor aggregate 1 in E sectors
1793
1794   P2E(E,T)          Price of factor aggregate 2 in E sectors
1795
1796   P3E(E,T)          Price of factor agregate 3 in E sectors
1797
1798   P4E(E,T)          Erice of factor aggregate 4 in E sectors
1799
1800   P1O(O,t)          Price of factor aggregate 1 in O sectors
1801
1802   P2O(O,T)          Price of factor aggregate 2 in O sectors
1803
1804   P3O(O,T)          Price of factor agregate 3 in O sectors
1805
GAMS 2.25.059  386/486 DOS                      11/13/96 17:16:17  PAGE
36
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1806   P4O(O,T)          Orice of factor aggregate 4 in O sectors
1807
1808   PYO(O,t)          Price of composite input Y in O sectors
1809
1810   DPYDPAP(P,t)      Partial derivative of PY wrt PL in P sectors
1811
1812   DPYDPRP(P,T)      Partial derivative of PY wrt PR in P sectors
1813
1814   DPYDPLP(P,T)      Partial derivative of PY wrt PL in P sectors
1815
1816   DPYDPKP(P,t)      Partial derivative of PY wrt PK in P sectors
1817
1818   DPYDPEP(P,t)      Partial derivative of PY wrt PE in P sectors
1819
1820   DPYDPMP(P,T)      Partial derivative of PY wrt PM in P sectors
1821
```

```
1822   DPYDP4P(P,t)      Partial derivative of PY wrt P4 in P sectors
1823
1824   DP4DP3P(P,T)      Partial derivative of P4 wrt P3 in P sectors
1825
1826   DP3DP2P(P,T)      Partial derivative of P3 wrt P2 in P sectors
1827
1828   DP2DP1P(P,T)      Partial derivative of P2 wrt P1 in P sectors
1829
1830   DP4DPEP(P,T)      Partial derivative of P4 wrt PE in P sectors
1831
1832   DP3DPLP(P,T)      Partial derivative of P3 wrt PL in P sectors
1833
1834   DP2DPRP(P,T)      Partial derivative of P2 wrt PR in P sectors
1835
1836   DP1DPKP(P,t)      Partial derivative of P1 wrt PK in P sectors
1837
1838   DP1DPAP(P,t)      Partial derivative of P1 wrt PL in P sectors
1839
1840   DPYDPAN(N,t)      Partial derivative of PY wrt PL in C sectors
1841
1842   DPYDPRN(N,T)      Partial derivative of PY wrt PR in C sectors
1843
1844   DPYDPLN(N,T)      Partial derivative of PY wrt PL in C sectors
1845
1846   DPYDPKN(N,t)      Partial derivative of PY wrt PK in C sectors
1847
1848   DPYDPEN(N,t)      Partial derivative of PY wrt PE in C sectors
1849
1850   DPYDPMN(N,T)      Partial derivative of PY wrt PM in C sectors
1851
1852   DPYDP4N(N,t)      Partial derivative of PY wrt P4 in C sectors
1853
1854   DP4DP3N(N,T)      Partial derivative of P4 wrt P3 in C sectors
1855
1856   DP3DP2N(N,T)      Partial derivative of P3 wrt P2 in C sectors
1857
1858   DP2DP1N(N,T)      Partial derivative of P2 wrt P1 in C sectors
GAMS 2.25.059  386/486 DOS                      11/13/96 17:16:17  PAGE
37
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1859
1860   DP1DPKN(N,t)      Partial derivative of P1 wrt PK in C sectors
1861
1862   DP1DPAN(N,t)      Partial derivative of P1 wrt PL in C sectors
1863
1864   DP4DPEN(N,T)      Partial derivative of P4 wrt PE in C sectors
1865
1866   DP3DPLN(N,T)      Partial derivative of P3 wrt PL in C sectors
1867
1868   DP2DPRN(N,T)      Partial derivative of P2 wrt PR in C sectors
1869
1870   DPYDPAE(E,t)      Partial derivative of PY wrt PA in E sectors
```

```
1871
1872   DPYDPRE(E,T)     Partial derivative of PY wrt PR in E sectors
1873
1874   DPYDPLE(E,T)     Partial derivative of PY wrt PL in E sectors
1875
1876   DPYDPKE(E,t)     Partial derivative of PY wrt PK in E sectors
1877
1878   DPYDPEE(E,t)     Partial derivative of PY wrt PE in E sectors
1879
1880   DPYDPME(E,T)     Partial derivative of PY wrt PM in E sectors
1881
1882   DPYDP4E(E,t)     Partial derivative of PY wrt P4 in E sectors
1883
1884   DP4DP3E(E,T)     Partial derivative of P4 wrt P3 in E sectors
1885
1886   DP3DP2E(E,T)     Partial derivative of P3 wrt P2 in E sectors
1887
1888   DP2DP1E(E,T)     Partial derivative of P2 wrt P1 in E sectors
1889
1890   DP1DPKE(E,t)     Partial derivative of P1 wrt PK in E sectors
1891
1892   DP1DPAE(E,t)     Partial derivative of P1 wrt PA in E sectors
1893
1894   DP4DPEE(E,T)     Partial derivative of P4 wrt PE in E sectors
1895
1896   DP3DPLE(E,T)     Partial derivative of P3 wrt PL in E sectors
1897
1898   DP2DPRE(E,T)     Partial derivative of P2 wrt PR in E sectors
1899
1900   DPYDPAO(O,t)     Partial derivative of PY wrt PA in O sectors
1901
1902   DPYDPRO(O,T)     Partial derivative of PY wrt PR in O sectors
1903
1904   DPYDPLO(O,T)     Partial derivative of PY wrt PL in O sectors
1905
1906   DPYDPKO(O,t)     Partial derivative of PY wrt PK in O sectors
1907
1908   DPYDPEO(O,t)     Partial derivative of PY wrt PE in O sectors
1909
1910   DPYDPMO(O,T)     Partial derivative of PY wrt PM in O sectors
1911
GAMS 2.25.059  386/486 DOS                      11/13/96 17:16:17  PAGE
38
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1912   DPYDP4O(O,t)     Partial derivative of PY wrt P4 in O sectors
1913
1914   DP4DP3O(O,T)     Partial derivative of P4 wrt P3 in O sectors
1915
1916   DP3DP2O(O,T)     Partial derivative of P3 wrt P2 in O sectors
1917
1918   DP2DP1O(O,T)     Partial derivative of P2 wrt P1 in O sectors
1919
```

```
1920   DP1DPKO(O,t)      Partial derivative of P1 wrt PK in O sectors
1921
1922   DP1DPAO(O,t)      Partial derivative of P1 wrt PA in O sectors
1923
1924   DP4DPEO(O,T)      Partial derivative of P4 wrt PE in O sectors
1925
1926   DP3DPLO(O,T)      Partial derivative of P3 wrt PL in O sectors
1927
1928   DP2DPRO(O,T)      Partial derivative of P2 wrt PR in O sectors
1929
1930
1931
1932   DPXDPAP(P,t)      Partial derivative of PX wrt PA in P sectors
1933
1934   DPXDPRP(P,t)      Partial derivative of PX wrt PR in P sectors
1935
1936   DPXDPLP(P,t)      Partial derivative of PX wrt PL in P sectors
1937
1938   DPXDPKP(P,t)      Partial derivative of PX wrt PK in P sectors
1939
1940   DPXDPEP(P,t)      Partial derivative of PX wrt PE in P sectors
1941
1942   DPXDPMP(P,T)      Partial derivative of PX wrt PM in P sectors
1943
1944
1945   DPXDPAN(N,t)      Partial derivative of PX wrt PA in C sectors
1946
1947   DPXDPRN(N,t)      Partial derivative of PX wrt PR in C sectors
1948
1949   DPXDPLN(N,t)      Partial derivative of PX wrt PL in C sectors
1950
1951   DPXDPKN(N,t)      Partial derivative of PX wrt PK in C sectors
1952
1953   DPXDPEN(N,t)      Partial derivative of PX wrt PE in C sectors
1954
1955   DPXDPMN(N,T)      Partial derivative of PX wrt PM in C sectors
1956
1957
1958   DPXDPAE(E,t)      Partial derivative of PX wrt PA in E sectors
1959
1960   DPXDPRE(E,t)      Partial derivative of PX wrt PR in E sectors
1961
1962   DPXDPLE(E,t)      Partial derivative of PX wrt PL in E sectors
1963
1964   DPXDPKE(E,t)      Partial derivative of PX wrt PK in E sectors
GAMS 2.25.059  386/486 DOS                    11/13/96 17:16:17  PAGE
39
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


1965
1966   DPXDPEE(E,t)      Partial derivative of PX wrt PE in E sectors
1967
1968   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)           Demcna for urban labor in P sectors
1989
1990   KP(P,t)           Demand for capital in P sectors
1991
1992   EP(P,t)           Demand for electricity in P sectors
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)           Demcna 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)           Demcna for urban labor in E sectors
2015
2016   KE(E,t)           Demand for capital in E sectors
2017
GAMS 2.25.059  386/486 DOS                    11/13/96 17:16:17  PAGE
40
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n
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```
2018   EDEME(EE,t)        Demand for electricity in E sectors
2019
2020   IMPE(E,t)         Demand for imports in E sectors
2021
2022
2023   AALO(O,t)          Demand for estate labor in O sectors
2024
2025   RO(O,t)           Demand for rural labor in O sectors
2026
2027   LO(O,T)           Demcna for urban labor in O sectors
2028
2029   KO(O,t)           Demand for capital in O sectors
2030
2031   EO(O,t)           Demand for electricity in O sectors
2032
2033   IMPO(O,t)         Demand for imports in O sectors
2034
2035   XP(P,t)           Production in P sectors
2036
2037   XN(N,t)           Production in C sectors
2038
2039   XE(E,t)           Production in E sectors
2040
2041   XO(O,t)           Production in O sectors
2042
2043   MCP(P,t)          Marginal cost in P sectors
2044
2045   MCN(N,t)          Marginal cost in C sectors
2046
2047   MCE(E,t)          Marginal cost in E sectors
2048
2049   MCO(O,t)          Marginal cost in O sectors
2050
2051   DPP(P,t)          Domestic price of domestically produced P goods
2052
2053   DPN(N,t)          Domestic price of domestically produced C goods
2054
2055  * DPE(E)          Domestic price of domestically produced E goods
2056
2057   DPO(O,t)          Domestic price of domestically produced O goods
2058
2059   DDP(P,h,t)           Domestic demand for composite P goods per hh
type
2060
2061   DDN(N,h,t)           Domestic demand for composite C goods per hh
type
2062
2063   DDE(E,h,t)          Domestic demand for E goods per hh type
2064
2065   INTERE(e,t)          Intermediate demand for E  products
2066
2067  * INTERF(t)          Intermediate demand for Fuel products
2068
2069   DDO(O,h,t)           Domestic demand for composite O goods per hh
type
```

```
2070
GAMS 2.25.059  386/486 DOS                    11/13/96 17:16:17  PAGE
41
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


2071   PMP(P,t)         Domestic price of P imports in local currency
2072
2073   PMN(N,t)         Domestic price of C imports in local currency
2074
2075   PME(E,t)         Domestic price of E imports in local currency
2076
2077   PMO(O,t)         Domestic price of O imports in local curreny
2078
2079  * QP(P,t)           Quantity of composite P produced and imported
goods
2080
2081  * QN(N,t)           Quantity of composite C produced and imported
goods
2082
2083  * QE(E)            Quantity of composite E produced and imported
goods
2084
2085  * QO(O,t)           Quantity of composite O produced and imported
goods
2086
2087  * IMPP(P,t)        Import of P goods
2088
2089  * IMPN(N,t)        Import of C goods
2090
2091  * IMPE(E)        Import of E goods
2092
2093  * IMPO(O,t)        Import of O goods
2094
2095   PEP(P,t)         Domestic price of P exports in local currency
2096
2097   PEN(N,t)         Domestic price of C exports in local currency
2098
2099   PEE(E,t)         Domestic price of E exports in local currency
2100
2101   PEO(O,t)         Domestic price of O exports in local currency
2102
2103    CP(P,t)             Total domestic and foreign consumption of P
products
2104
2105    CCN(N,t)            Total domestic and foreign consumption of C
products
2106
2107    CE(E,t)             Total domestic and foreign consumption of E
products
2108
2109    CO(O,t)             Total domestic and foreign consumption of O
products
2110
```

```
2111   EXPP(P,t)        Exports of P goods
2112
2113   EXPN(N,t)        Exports of C goods
2114
2115   EXPE(E,t)        Exports of E goods
2116
2117   EXPO(O,t)        Exports of O goods
2118
2119   PL(t)             Price of labor services
2120
2121   PR(T)             Price of estate labor services
2122
2123   PA(t)             Price of estate labor services
GAMS 2.25.059  386/486 DOS                      11/13/96 17:16:17  PAGE
42
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


2124
2125   PK(t)             Price of capital services
2126
2127   k(t)
2128
2129  * PQP(P,t)         Price of composite output goods P
2130
2131  * PQN(N,t)         Price of composite output goods C
2132
2133  * PQE(E)         Price of composite output goods E
2134
2135  * PQO(O,t)         Price of composite output goods O
2136
2137   PCP(P,t)         Price of composite consumption good P
2138
2139   PCN(N,t)         Price of composite consumption good C
2140
2141   PCE(E,t)         Price of composite consumption good E
2142
2143   PCO(O,t)         Price of composite consumption good O
2144
2145  * sav(t)           Total savings
2146
2147   savh(h,t)        Savings by household type h
2148
2149   domsav(t)        Domestic savings
2150
2151   invest(t)
2152
2153   pi(t)            Price of investments in period t
2154
2155   invp(p,t)
2156
2157   invn(n,t)
2158
2159   invo(o,t)
```

```
2160
2161   mrscs(p,t)
2162
2163   mrsce(p,t)
2164
2165   lscs(p,t)       Labor input in soil conservation in smallholdings
2166
2167     cscs(p,t)             Capital  input  in  soil  conservation  in
smallholdings
2168
2169   scs(p,t)          Soil conservation on smallholdings
2170
2171   lsce(p,t)       Labor input in soil conservation in estates
2172
2173   csce(p,t)       Capital input in soil conservation in estates
2174
2175   sce(p,t)          Soil conservation on estates
2176
GAMS 2.25.059  386/486 DOS                      11/13/96 17:16:17  PAGE
43
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


2177   q(p,t)            Soil quality index
2178
2179   tb(t)             trade balance
2180
2181   DISP(t)           Total Disposable income
2182
2183   disph(h,t)        Disposable income per hh type
2184
2185   tdisph(h,t)       Total income per hh type
2186
2187   totdisp
2188
2189   GDP(t)            Gross domestic product
2190
2191  * The following variables are restircted to nonnegative values
2192
2193   POSITIVE VARIABLES
2194             sce(p,t),  scs(p,t),  lscs(p,t),  kscs(p,t),  lsce(p,t),
csce(p,t),
2195       EXPP(P,t), EXPN(N,t), EXPO(O,t), EXPE(E,t), IMPP(P,t),
2196       IMPN(N,t), k(t),
2197      IMPO(O,t), IMPE(E,t), XP(P,t), XN(N,t), XO(O,t), xe(e,t),
2198        ddp(p,h,t), ddn(n,h,t), dde(e,h,t), ddo(o,h,t), invp(p,t),
invn(n,t),
2199      invo(o,t),invest(t), disph(h,t), tdisph(h,t);
2200
2201
2202
2203
2204
2205
```

```
2206
2207
2208  * List of equations
INCLUDE    C:\SLMOD\SLEQUA.INC
2210  * List of equations
2211
2212   EQUATIONS
2213
2214   dtottax
2215   dtotimp
2216  * dslack
2217
2218   DEFPUA(t)          Definition of user price of estate labor
2219
2220   DEFPUR(T)          Definition of user price of rural labor
2221
2222   DEFPUL(t)          Definition of user price of urban labor
2223
2224   DEFPUK(t)          Definition of user price of capital
2225
2226   DEFP1P(P,t)        Definition of price of factor aggregate 1 in P
sectors
2227
2228   DEFP2P(P,t)        Definition of price of factor aggregate 2 in P
sectors
2229
GAMS 2.25.059  386/486 DOS                      11/13/96 17:16:17  PAGE
44
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


2230   DEFP3P(P,T)        Definition of price of factor aggregate 3 in P
sectors
2231
2232   DEFP4P(P,T)        Definition of price of factor aggregate 4 in P
sectors
2233
2234   DEFPYP(P,t)         Definition of price of composite input Y in P
sectors
2235
2236
2237   DEFP1N(N,t)        Definition of price of factor aggregate 1 in C
sectors
2238
2239   DEFP2N(N,t)        Definition of price of factor aggregate 2 in C
sectors
2240
2241   DEFP3N(N,T)        Definition of price of factor aggregate 3 in C
sectors
2242
2243   DEFP4N(N,T)        Definition of price of factor aggregate 4 in C
sectors
2244
2245   DEFPYN(N,t)         Definition of price of composite input Y in C
```

```
sectors
2246
2247
2248   DEFP1E(E,t)       Definition of price of factor aggregate 1 in E
sectors
2249
2250   DEFP2E(E,t)       Definition of price of factor aggregate 2 in E
sectors
2251
2252   DEFP3E(E,T)       Definition of price of factor aggregate 3 in E
sectors
2253
2254   DEFP4E(E,T)       Definition of price of factor aggregate 4 in E
sectors
2255
2256   DEFPYE(E,t)       Definition of price of composite input Y in E
sectors
2257
2258
2259   DEFP1O(O,t)       Definition of price of factor aggregate 1 in O
sectors
2260
2261   DEFP2O(O,t)       Definition of price of factor aggregate 2 in O
sectors
2262
2263   DEFP3O(O,T)       Definition of price of factor aggregate 3 in O
sectors
2264
2265   DEFP4O(O,T)       Definition of price of factor aggregate 4 in O
sectors
2266
2267   DEFPYO(O,t)       Definition of price of composite input Y in O
sectors
2268
2269
2270   DDPYDPAP(P,t)    Definition of partial derivative of PY wrt PA in
P

sectors
2271
2272   DDPYDPRP(P,t)    Definition of partial derivative of PY wrt PR in
P

sectors
2273
2274   DDPYDPLP(P,t)    Definition of partial derivative of PY wrt PL in
P

sectors
2275
2276   DDPYDPKP(P,t)    Definition of partial derivative of PY wrt PK in
P

sectors
2277
```

```
2278   DDPYDPEP(P,T)    Definition of partial derivative of PY wrt PE in
P
GAMS 2.25.059  386/486 DOS                      11/13/96 17:16:17  PAGE
45
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


sectors
2279
2280   DDPYDPMP(P,T)    Definition of partial derivative of PY wrt PM in
P

sectors
2281
2282   DDPYDP4P(P,t)    Definition of partial derivative of PY wrt P4 in
P

sectors
2283
2284   DDP4DP3P(P,t)    Definition of partial derivative of P4 wrt P3 in
P

sectors
2285
2286   DDP3DP2P(P,t)    Definition of partial derivative of P3 wrt P2 in
P

sectors
2287
2288   DDP2DP1P(P,t)    Definition of partial derivative of P2 wrt P1 in
P

sectors
2289
2290   DDP1DPAP(P,t)    Definition of partial derivative of P1 wrt PA in
P

sectors
2291
2292   DDP1DPKP(P,t)    Definition of partial derivative of P1 wrt PK in
P

sectors
2293
2294   DDP4DPEP(P,t)    Definition of partial derivative of P4 wrt PE in
P

sectors
2295
2296   DDP3DPLP(P,t)    Definition of partial derivative of P3 wrt PL in
P

sectors
```

```
2297
2298   DDP2DPRP(P,t)    Definition of partial derivative of P2 wrt PR in
P

sectors
2299
2300
2301   DDPYDPAN(N,t)    Definition of partial derivative of PY wrt PA in
C

sectors
2302
2303   DDPYDPRN(N,t)    Definition of partial derivative of PY wrt PR in
C

sectors
2304
2305   DDPYDPLN(N,t)    Definition of partial derivative of PY wrt PL in
C

sectors
2306
2307   DDPYDPKN(N,t)    Definition of partial derivative of PY wrt PK in
C

sectors
2308
2309   DDPYDPEN(N,T)    Definition of partial derivative of PY wrt PE in
C

sectors
2310
2311   DDPYDPMN(N,T)    Definition of partial derivative of PY wrt PM in
C

sectors
2312
2313   DDPYDP4N(N,t)    Definition of partial derivative of PY wrt P4 in
C

sectors
GAMS 2.25.059  386/486 DOS                      11/13/96 17:16:17  PAGE
46
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


2314
2315   DDP4DP3N(N,t)    Definition of partial derivative of P4 wrt P3 in
C

sectors
2316
2317   DDP3DP2N(N,t)    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   ddp1dpa1(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   ddp2dpr1(n,t)
2331
2332   DDPYDPAE(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
```

```
E

sectors
2341
2342   DDPYDPME(E,T)    Definition of partial derivative of PY wrt PM in
E

sectors
2343
2344   DDPYDP4E(E,t)    Definition of partial derivative of PY wrt P4 in
E

sectors
2345
2346   DDP4DP3E(E,t)    Definition of partial derivative of P4 wrt P3 in
E

sectors
2347
2348   DDP3DP2E(E,t)    Definition of partial derivative of P3 wrt P2 in
E

sectors
2349
GAMS 2.25.059  386/486 DOS                    11/13/96 17:16:17  PAGE
47
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


2350   DDP2DP1E(E,t)    Definition of partial derivative of P2 wrt P1 in
E

sectors
2351
2352   DDP1DPAE(E,t)    Definition of partial derivative of P1 wrt PA in
E

sectors
2353
2354   DDP1DPKE(E,t)    Definition of partial derivative of P1 wrt PK in
E

sectors
2355
2356   DDP4DPEE(E,t)    Definition of partial derivative of P4 wrt PE in
E

sectors
2357
2358   DDP3DPLE(E,t)    Definition of partial derivative of P3 wrt PL in
E

sectors
2359
```

```
2360   DDP2DPRE(E,t)    Definition of partial derivative of P2 wrt PR 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 P4 in
O

sectors
2376
2377   DDP4DP3O(O,t)    Definition of partial derivative of P4 wrt P3 in
O

sectors
2378
2379   DDP3DP2O(O,t)    Definition of partial derivative of P3 wrt P2 in
O

sectors
2380
2381   DDP2DP1O(O,t)    Definition of partial derivative of P2 wrt P1 in
O

sectors
```

```
2382
2383   DDP1DPAO(O,t)    Definition of partial derivative of P1 wrt PA in
O

sectors
2384
2385   DDP1DPKO(O,t)    Definition of partial derivative of P1 wrt PK in
O
GAMS 2.25.059  386/486 DOS                      11/13/96 17:16:17  PAGE
48
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


sectors
2386
2387   DDP4DPEO(O,t)    Definition of partial derivative of P4 wrt PE in
O

sectors
2388   ddp4dpel(o,t)
2389   DDP3DPLO(O,t)    Definition of partial derivative of P3 wrt PL in
O

sectors
2390
2391   DDP2DPRO(O,t)    Definition of partial derivative of P2 wrt PR in
O

sectors
2392
2393
2394   DDPXDPAP(P,t)    Definition of partial derivative of PX wrt PA in
P

sector
2395
2396   DDPXDPRP(P,t)    Definition of partial derivative of PX wrt PR in
P

sectors
2397
2398   DDPXDPLP(P,t)    Definition of partial derivative of PX wrt PL in
P

sectors
2399
2400   DDPXDPKP(P,t)    Definition of partial derivative of PX wrt PK in
P

sectors
2401
2402   DDPXDPEP(P,T)    Definition of partial derivative of PX wrt PE in
P
```

```
sectors
2403
2404    DDPXDPMP(P,T)      Definition of partial derivative of PX wrt PM
in P

sectors
2405
2406
2407   DDPXDPAN(N,t)    Definition of partial derivative of PX wrt PA in
C

sectors
2408
2409   DDPXDPRN(N,t)    Definition of partial derivative of PX wrt PR in
C

sectors
2410
2411   DDPXDPLN(N,t)    Definition of partial derivative of PX wrt PL in
C

sectors
2412
2413   DDPXDPKN(N,t)    Definition of partial derivative of PX wrt PK in
C

sectors
2414
2415   DDPXDPEN(N,T)    Definition of partial derivative of PX wrt PE in
C

sectors
2416
2417    DDPXDPMN(N,T)      Definition of partial derivative of PX wrt PM
in C

sectors
2418
2419
2420   DDPXDPAE(E,t)    Definition of partial derivative of PX wrt PA in
E

sectors
2421
GAMS 2.25.059  386/486 DOS                      11/13/96 17:16:17  PAGE
49
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


2422   DDPXDPRE(E,t)    Definition of partial derivative of PX wrt PR in
E

sectors
```

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2423
2424   DDPXDPLE(E,t)    Definition of partial derivative of PX wrt PL in
E

sectors
2425
2426   DDPXDPKE(E,t)    Definition of partial derivative of PX wrt PK in
E

sectors
2427
2428   DDPXDPEE(E,T)    Definition of partial derivative of PX wrt PE in
E

sectors
2429
2430   DDPXDPME(E,T)      Definition of partial derivative of PX wrt PM
in E

sectors
2431
2432
2433   DDPXDPAO(O,t)    Definition of partial derivative of PX wrt PA in
O

sectors
2434
2435   DDPXDPRO(O,t)    Definition of partial derivative of PX wrt PR in
O

sectors
2436
2437   DDPXDPLO(O,t)    Definition of partial derivative of PX wrt PL in
O

sectors
2438
2439   DDPXDPKO(O,t)    Definition of partial derivative of PX wrt PK in
O

sectors
2440
2441   DDPXDPEO(O,T)    Definition of partial derivative of PX wrt PE in
O

sectors
2442
2443   DDPXDPMO(O,T)    Definition of partial derivative of PX wrt PM in
O

sectors
2444
2445
2446   ADEMP(P,t)         Shephards lemma demand for estate labor in P
sectors
```

```
2447
2448    RDEMP(P,t)          Shephards lemma demand for rural labor in P
sectors
2449
2450    LDEMP(P,t)          Shephards lemma demand for urban labor in P
sectors
2451
2452   KDEMP(P,t)       Shephards lemma demand for capital in P sectors
2453
2454    EDEMP(P,t)          Shephards lemma demand for electricity in P
sectors
2455
2456   MDEMP(P,T)       Shephards lemma demand for imports in P sectors
2457
2458
2459    ADEMN(N,t)         Shephards lemma demand for estate labor in C
sectors
2460
2461    RDEMN(N,t)          Shephards lemma demand for rural labor in C
sectors
2462
2463    LDEMN(N,t)          Shephards lemma demand for urban labor in C
sectors
GAMS 2.25.059  386/486 DOS                      11/13/96 17:16:17  PAGE
50
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


2464
2465   KDEMN(N,t)       Shephards lemma demand for capital in C sectors
2466
2467    EDEMN(N,t)          Shephards lemma demand for electricity in C
sectors
2468
2469   MDEMN(N,T)       Shephards lemma demand for imports in C sectors
2470
2471
2472    ADEME(E,t)         Shephards lemma demand for estate labor in E
sectors
2473
2474    RDEME(E,t)          Shephards lemma demand for rural labor in E
sectors
2475
2476    LDEME(E,t)          Shephards lemma demand for urban labor in E
sectors
2477
2478   KDEME(E,t)       Shephards lemma demand for capital in E sectors
2479
2480    DEDEME(EE,t)         Shephards lemma demand for electricity in E
sectors
2481
2482   MDEME(E,T)       Shephards lemma demand for imports in E sectors
2483
2484
```

```
2485    ADEMO(O,t)          Shephards lemma demand for estate labor in O
sectors
2486
2487    RDEMO(O,t)          Shephards lemma demand for rural labor in O
sectors
2488
2489    LDEMO(O,t)          Shephards lemma demand for urban labor in O
sectors
2490
2491   KDEMO(O,t)        Shephards lemma demand for capital in O sectors
2492
2493    EDEMO(O,t)          Shephards lemma demand for electricity in O
sectors
2494
2495   MDEMO(O,T)        Shephards lemma demand for imports in O sectors
2496
2497  * DEDEME(EE,E,t)
2498
2499
2500   DEFMCP(P,t)       Definition of marginal cost in P sectors
2501
2502   DEFMCN(N,t)       Definition of marginal cost in C sectors
2503
2504   DEFMCE(E,t)       Definition of marginal cost in E sectors
2505
2506   DEFMCO(O,t)       Definition of marginal cost in O sectors
2507
2508     PRMCP(P,t)           Price equals marginal cost in P sectors
determines dom

price
2509   ppcomp(p,t)
2510
2511     PRMCN(N,t)           Price equals marginal cost in C sectors
determines dom

price
2512   nncomp(n,t)
2513
2514  * PRMCE(E,t)        Demand equals supply in E sectors
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
51
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


2515
2516     PRMCO(O,t)           Price equals marginal cost in O sectors
determines dom

price
2517   oocomp(o,t)
2518
2519   PCONS(P,h,t)        Consumption demand function for P goods
2520
```

```
2521   pcons1(p,h,t)
2522
2523   nCONS(n,h,t)        Consumption demand function for C goods
2524
2525   ncons1(n,h,t)
2526
2527   ECONS(E,h,t)        Consumption demand function for E goods
2528
2529   econs1(e,h,t)
2530
2531   EINTERE(t)        INTERMEDIATE DEM FOR ELEC GOODS
2532
2533   EINTERF(t)        INTERMEDIATE DEM FOR FUEL
2534
2535   OCONS(O,h,t)        Consumption demand function for O goods
2536
2537   ocons1(o,h,t)
2538    DEFPMP(P,t)        Definition of domestic price of P imports in
local

currency
2539
2540    DEFPMN(N,t)        Definition of domestic price of C imports in
local

currency
2541
2542    DEFPME(E,t)        Definition of domestic price of E imports in
local

currency
2543
2544    DEFPMO(O,t)        Definition of domestic price of O imports in
local

curreny
2545
2546  * DQP(P,t)         Definition of quantity of composite P goods
2547
2548  * DQN(N,t)         Definition of quantity of composite C goods
2549
2550  * DQE(E)         Definition of quantity of composite E goods
2551
2552  * DQO(O,t)         Definition of quantity of composite O goods
2553
2554  * PRAT(P,t)         Ratio of import of P goods to dom P goods det
IMP
2555
2556  * pcompl(p,t)
2557
2558  * nRAT(n,t)         Ratio of import of C goods to dom C goods det
IMP
2559
2560  * ncompl(n,t)
2561
```

```
2562  * ERAT(E)        Ratio of import of E goods to dom E goods det IMP
GAMS 2.25.059  386/486 DOS                      11/13/96 17:16:17  PAGE
52
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


2563
2564  * ORAT(O,t)        Ratio of import of O goods to dom O goods det
IMP
2565
2566  * ocompl(o,t)
2567
2568   DPEP(P,t)          Definition of domestic price of P exports in
local

currency
2569
2570   DPEN(N,t)          Definition of domestic price of C exports in
local

currency
2571   dpenb(n,t)
2572
2573   DPEE(E,t)          Definition of domestic price of E exports in
local

currency
2574   dpeeb(e,t)
2575
2576   DPEO(O,t)          Definition of domestic price of O exports in
local

currency
2577   dpeob(o,t)
2578
2579    DCP(P,t)             Definition of total domestic and foreign
consumption
                                                                  of P
products
2580
2581    DCN(N,t)             Definition of total domestic and foreign
consumption
                                                                  of C
products
2582
2583    DCE(E,t)             Definition of total domestic and foreign
consumption
                                                                  of E
products
2584
2585    DCO(O,t)             Definition of total domestic and foreign
consumption
                                                                  of O
products
```

```
2586
2587   DEXPP(P,t)        Ratio of export of P goods to dom P goods det
EXP
2588
2589   DEXPnA(n,t)        Ratio of export of C goods to dom C goods det
EXP
2590   DEXPnB(n,t)
2591
2592   DEXPEA(E,t)        Ratio of export of E goods to dom E goods det
EXP
2593   DEXPEB(E,t)
2594
2595   DEXPOA(O,t)        Ratio of export of O goods to dom O goods det
EXP
2596   DEXPOB(O,t)
2597
2598   kstock(t)
2599
2600   kstock1(t)
2601
2602  * kstock2(t)
2603
2604   dinvest(t)          definition of investments
2605
2606  * dinvestm(t)         defintion of investments in period m
2607  * dinvest1(t)
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
53
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


2608  * invlow(t)         Lower bound on disinvestments
2609
2610   dlabscs(p,t)      labor input in soil conservation
2611   dlscsc(p,t)
2612   dlabsce(p,t)      labor input in soil conservation
2613   dlscec(p,t)
2614
2615   dcapscs(p,t)      capital input in soil conservation
2616   dcscsc(p,t)
2617   dcapsce(p,t)      capital input in soil conservation
2618   dcscec(p,t)
2619
2620   * dmrscs(p,t)          definition of marginal revenue of soil
conservation
2621  * dmrsce(p,t)
2622
2623   dscs(p,t)        soil conservation level smallh
2624   dscsc(p,t)
2625   dsce(p,t)        soil conservation level estates
2626   dscec(p,t)
2627
2628   dq(p,t)           Land quality index
2629
```

```
2630  * dq1(p,t)          Land quality index when no soil conservation
2631
2632  * dsav(t)           definition of urban savings
2633
2634  * dsav1(t)
2635
2636   dsavh(h,t)        defintion of savings for hh H h no urban
2637
2638   dsavh1(h,t)
2639   ddomsav(t)        definition of domestic savings
2640
2641   LMARKET(t)        Urban labor market equilibrium condition
2642
2643   RMARKET(t)        Rural labor market equilibrium condition
2644
2645   rmarket1(t)              Rural labor market equilibrium condition
whe no
                                                                    soil
conservation
2646
2647   AMARKET(t)        Estate labor market equilibrium condition
2648
2649   KMARKET(t)        Capital market equilibrium condition
2650
2651   KMARKET1(T)     Capital market equilibrium condition when no soil

conservation
2652
2653  * DPQP(P,t)        defintion of PQP
2654
2655  * DPQN(N,t)        Defintion of PQC
2656
2657  * DPQE(E)        Definition of PQE
2658
GAMS 2.25.059  386/486 DOS                      11/13/96 17:16:17  PAGE
54
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


2659  * DPQO(O,t)        Definition of PQO
2660
2661   DPCP(P,t)        Definition of PCP
2662
2663   DPCN(N,t)        Definition of PCC
2664
2665   DPCE(E,t)        Definition of PCE
2666
2667   DPCO(O,t)        Definition of PCO
2668
2669   PMARKET(P,t)     P product market equilibrium conditions det XP
2670
2671   nMARKET(n,t)     C product market equilibrium conditions det XC
2672
2673   emarket(e,t)
```

```
2674
2675   DPI(T)                Determination of price of investments
2676
2677   DPINV(P,t)            Determination of P goods in investments
2678   dpinv1(p,t)
2679
2680   DnINV(n,t)            Determination of C goods in investments
2681   dninv1(n,t)
2682
2683   DOINV(O,t)            Determination of O goods in investments
2684   doinv1(o,t)
2685
2686  * EMARKETE(t)        Energy  product market equilibrium conditions
det

NEXPE
2687
2688  * EMARKETF(t)        Fuel product market equilibrium condition det

NEXPE(fuel)
2689
2690  * ECOMPL(t)          Complemetary condition for the energy market
2691
2692  * EPOS(t)             Exports of electricity are non-positive
2693
2694   OMARKET(O,t)      O product market equilibrium conditions det XO
2695
2696   dtb(t)            definition of trade balance
2697
2698  * dtb1(t)
2699
2700   INCOME(t)          Det DISP
2701
2702   incomeu(t)        Income for urban households
2703
2704   incomer(t)        Income for rural households
2705
2706   incomee(t)        Income for estate households
2707
2708   consinc(h,t)      Income used for consumption
2709
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
55
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


2710   DEFGDP(t)          Definition of gross domestic product
2711
2712   dtotdisp                                                  ;
2713
2714
2715
2716
2717
```

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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    DEFP1P(P,t)..      P1P(P,t)=E=(DELA1(P)*PUA(t)**(1-SIGAKP(P))+(1-
DELA1(P))

*
2732                                        PUK(t)**(1-SIGAKP(P)))**(1/(1-
SIGAKP(P)));
2733
2734    DEFP2P(P,T)..      P2P(P,T)=E=(DELR2(P)*PUR(T)**(1-SIGR1P(P))+(1-
DELR2(P))

*
2735                                     P1P(P,T)**(1-SIGR1P(P)))**(1/(1-
SIGR1P(P)));
2736
2737    DEFP3P(P,T)..      P3P(P,T)=E=(DELL3(P)*PUL(T)**(1-SIGL2P(p))+(1-
DELL3(P))

*
2738                                     P2P(P,T)**(1-SIGL2P(p)))**(1/(1-
SIGL2P(P)));
2739
2740       DEFP4P(P,T)..          P4P(P,T)=E=(DELE4(P)*DPE('ELEC',T)**(1-
SIGE3P(P))+
2741                                            (1-DELE4(P))*P3P(P,T)**(1-
SIGE3P(P)))**
2742                                (1/(1-SIGE3P(P)));
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-
SIGM4P(P)))**
2746                                (1/(1-SIGM4P(P)));
2747
2748   DEFP1N(N,t)..     P1N(N,t)=E=(DELA1N(N)*PUA(t)**(1-SIGAKN(N))+(1-
2749  DELA1N(N))*
2750                                        PUK(t)**(1-SIGAKN(N)))**(1/(1-
SIGAKN(N)));
2751
2752   DEFP2N(N,T)..     P2N(N,T)=E=(DELR2N(N)*PUr(T)**(1-SIGR1N(N))+(1-
2753  DELR2N(N))*
2754                                     P1N(N,T)**(1-SIGR1N(N)))**(1/(1-
SIGR1N(N)));
2755
```

```
2756   DEFP3N(N,T)..     P3N(N,T)=E=(DELL3N(N)*PUL(T)**(1-SIGL2N(N))+(1-
2757  DELL3N(N))*
2758                                    P2N(N,T)**(1-SIGL2N(N)))**(1/(1-
SIGL2N(N)));
2759
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
56
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


2760        DEFP4N(N,T)..        P4N(N,T)=E=(DELE4N(N)*DPE('ELEC',T)**(1-
SIGE3N(N))+
2761                                          (1-DELE4N(N))*P3N(N,T)**(1-
SIGE3N(N)))**
2762                                 (1/(1/SIGE3N(N)));
2763
2764    DEFPYN(N,t)..     PYN(N,t)=E=(DELMYN(N)*PMN(N,t)**(1-SIGM4N(N))+
2765                                          (1-DELMYN(N))*(P4N(N,t))**(1-
SIGM4N(N)))**
2766                                 (1/(1-SIGM4N(N)));
2767
2768    DEFP1E(E,t)..     P1E(E,t)=E=(DELA1E(E)*PUA(t)**(1-SIGAKE(E))+(1-
2769  DELA1E(E))*
2770                                          PUK(t)**(1-SIGAKE(E)))**(1/(1-
SIGAKE(E)));
2771
2772   DEFP2E(E,T)..     P2E(E,T)=E=(DELR2E(E)*PUR(T)**(1-SIGR1E(E))+(1-
2773  DELR2E(E))*
2774                                    P1E(E,T)**(1-SIGR1E(E)))**(1/(1-
SIGR1E(E)));
2775
2776   DEFP3E(E,T)..     P3E(E,T)=E=(DELL3E(E)*PUL(T)**(1-SIGL2E(E))+(1-
2777  DELL3E(E))*
2778                                    P2E(E,T)**(1-SIGL2E(E)))**(1/(1-
SIGL2E(E)));
2779
2780       DEFP4E(E,T)..        P4E(E,T)=E=(DELE4E(E)*DPE('ELEC',T)**(1-
SIGE3E(E))+
2781                                          (1-DELE4E(E))*P3E(E,T)**(1-
SIGE3E(E)))**
2782                                 (1/(1/SIGE3E(E)));
2783
2784    DEFPYE(E,t)..     PYE(E,t)=E=(DELMYE(E)*PME(E,t)**(1-SIGM4E(E))+
2785                                          (1-DELMYE(E))*(P4E(E,t))**(1-
SIGM4E(E)))**
2786                                 (1/(1-SIGM4E(E)));
2787
2788
2789   DEFP1O(O,t)..     P1O(O,t)=E=(DELA1O(O)*PUA(t)**(1-SIGAKO(O))+(1-
2790  DELA1O(O))*
2791                                          PUK(t)**(1-SIGAKO(O)))**(1/(1-
SIGAKO(O)));
2792
2793   DEFP2O(O,T)..     P2O(O,T)=E=(DELR2O(O)*PUR(T)**(1-SIGR1O(O))+(1-
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```
2794  DELR2O(O))*
2795                                    P1O(O,T)**(1-SIGR1O(O)))**(1/(1-
SIGR1O(O)));
2796
2797   DEFP3O(O,T)..    P3O(O,T)=E=(DELL3O(O)*PUL(T)**(1-SIGL2O(O))+(1-
2798  DELL3O(O))*
2799                                    P2O(O,T)**(1-SIGL2O(O)))**(1/(1-
SIGL2O(O)));
2800
2801       DEFP4O(O,T)..        P4O(O,T)=E=(DELE4O(O)*DPE('ELEC',T)**(1-
SIGE3O(O))+
2802                                          (1-DELE4O(O))*P3O(O,T)**(1-
SIGE3O(O)))**
2803                               (1/(1/SIGE3O(O)));
2804
2805    DEFPYO(O,t)..    PYO(O,t)=E=(DELMYO(O)*PMO(O,t)**(1-SIGM4O(O))+
2806                                        (1-DELMYO(O))*(P4O(O,t))**(1-
SIGM4O(O)))**
2807                               (1/(1-SIGM4O(O)));
2808
2809  * Partial derivatives of PY wrt PUK and PUA and PUL
2810
2811   DDPYDPMP(P,t)..   DPYDPMP(P,t)=E=DELMY(P)*PMP(P,T)**SIGM4P(P)*
2812                                   P4P(P,t)**(-SIGM4P(P));
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
57
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


2813
2814   DDPYDP4P(P,t)..  DPYDP4P(P,t)=E=(1-DELMY(P))*P4P(P,t)**SIGM4P(P)*
2815                                   PMP(P,T)**(-SIGM4P(P));
2816
2817                                                     DDP4DPEP(P,t)..
DP4DPEP(P,t)=E=DELE4(P)*DPE('ELEC',T)**SIGE3P(P)*
2818                                   P3P(P,t)**(-SIGE3P(P));
2819
2820   DDP4DP3P(P,t)..  DP4DP3P(P,t)=E=(1-DELE4(P))*P3P(P,t)**SIGE3P(P)*
2821                                   DPE('ELEC',T)**(-SIGE3P(P));
2822
2823   DDP3DPLP(P,t)..   DP3DPLP(P,t)=E=DELL3(P)*PUL(T)**SIGL2P(P)*
2824                                   P2P(P,t)**(-SIGL2P(P));
2825
2826   DDP3DP2P(P,t)..  DP3DP2P(P,t)=E=(1-DELL3(P))*P2P(P,t)**SIGL2P(P)*
2827                                   PUL(T)**(-SIGL2P(P));
2828
2829   DDP2DPRP(P,t)..   DP2DPRP(P,t)=E=DELR2(P)*PUR(T)**SIGR1P(P)*
2830                                  P1P(P,t)**(-SIGR1P(P));
2831
2832   DDP2DP1P(P,t)..  DP2DP1P(P,t)=E=(1-DELR2(P))*P1P(P,t)**SIGR1P(P)*
2833                                   PUR(T)**(-SIGR1P(P));
2834
2835   DDP1DPAP(P,t)..   DP1DPAP(P,t)=E=DELA1(P)*PUA(T)**SIGAKP(P)*
2836                                   PUK(t)**(-SIGAKP(P));
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2837
2838   DDP1DPKP(P,t)..  DP1DPKP(P,t)=E=(1-DELA1(P))*PUK(t)**SIGAKP(P)*
2839                                   PUA(T)**(-SIGAKP(P));
2840
2841                                                        DDPYDPAP(P,t)..
DPYDPAP(P,t)=E=DPYDP4P(P,t)*DP4DP3P(P,t)*DP3DP2P(P,T)*
2842                                    DP2DP1P(P,T)*DP1DPAP(P,T);
2843
2844                                                        DDPYDPKP(P,t)..
DPYDPKP(P,t)=E=DPYDP4P(P,t)*DP4DP3P(P,t)*DP3DP2P(P,T)*
2845                                    DP2DP1P(P,T)*DP1DPKP(P,T);
2846
2847                                                        DDPYDPRP(P,t)..
DPYDPRP(P,t)=E=DPYDP4P(P,t)*DP4DP3P(P,t)*DP3DP2P(P,T)*
2848                                    DP2DPRP(P,T);
2849
2850                                                        DDPYDPLP(P,t)..
DPYDPLP(P,t)=E=DPYDP4P(P,t)*DP4DP3P(P,t)*DP3DPLP(P,T);
2851
2852   DDPYDPEP(P,t)..  DPYDPEP(P,t)=E=DPYDP4P(P,t)*DP4DPEP(P,t);
2853
2854   DDPYDPMN(N,t)..   DPYDPMN(N,t)=E=DELMYN(N)*PMN(N,T)**SIGM4N(N)*
2855                                   P4N(N,t)**(-SIGM4N(N));
2856
2857                     DDPYDP4N(N,t)..              DPYDP4N(N,t)=E=(1-
DELMYN(N))*P4N(N,t)**SIGM4N(N)*
2858                                   PMN(N,T)**(-SIGM4N(N));
2859
2860                                                        DDP4DPEN(N,t)..
DP4DPEN(N,t)=E=DELE4N(N)*DPE('ELEC',T)**SIGE3N(N)*
2861                                   P3N(N,t)**(-SIGE3N(N));
2862
2863                     DDP4DP3N(N,t)..              DP4DP3N(N,t)=E=(1-
DELE4N(N))*P3N(N,t)**SIGE3N(N)*
2864                                   DPE('ELEC',T)**(-SIGE3N(N));
2865
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
58
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


2866   DDP3DPLN(N,t)..   DP3DPLN(N,t)=E=DELL3N(N)*PUL(T)**SIGL2N(N)*
2867                                   P2N(N,t)**(-SIGL2N(N));
2868
2869                     DDP3DP2N(N,t)..              DP3DP2N(N,t)=E=(1-
DELL3N(N))*P2N(N,t)**SIGL2N(N)*
2870                                   PUL(T)**(-SIGL2N(N));
2871
2872                       DDP2DPRN(N,t)$(delr2n(n)        gt        0)..
DP2DPRN(N,t)=E=DELR2N(N)*PUR(T)**
2873                                   SIGR1N(N)*
2874                                   P1N(N,t)**(-SIGR1N(N));
2875
2876   ddp2dpr1(n,t)$(delr2n(n) eq 0)..  dp2dprn(n,t)=e=0;
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2877
2878
2879                    DDP2DP1N(N,t)..              DP2DP1N(N,t)=E=(1-
DELR2N(N))*P1N(N,t)**SIGR1N(N)*
2880                                  PUR(T)**(-SIGR1N(N));
2881
2882                     DDP1DPAN(N,t)$(dela1n(n)        gt        0)..
DP1DPAN(N,t)=E=DELA1N(N)*PUA(T)**
2883                                  SIGAKN(N)*
2884                                  PUK(t)**(-SIGAKN(N));
2885
2886   ddp1dpa1(n,t)$(dela1n(n) eq 0)..  dp1dpan(n,t)=e=0;
2887
2888   DDP1DPKN(N,t)..  DP1DPKN(N,t)=E=(1-DELA1N(N))*PUK(t)**SIGAKN(N)*
2889                                  PUA(T)**(-SIGAKN(N));
2890
2891   DDPYDPAN(N,t)..
2892  DPYDPAN(N,t)=E=DPYDP4N(N,t)*DP4DP3N(N,t)*DP3DP2N(N,T)*
2893                                   DP2DP1N(N,T)*DP1DPAN(N,T);
2894
2895   DDPYDPKN(N,t)..
2896  DPYDPKN(N,t)=E=DPYDP4N(N,t)*DP4DP3N(N,t)*DP3DP2N(N,T)*
2897                                   DP2DP1N(N,T)*DP1DPKN(N,T);
2898
2899   DDPYDPRN(N,t)..
2900  DPYDPRN(N,t)=E=DPYDP4N(N,t)*DP4DP3N(N,t)*DP3DP2N(N,T)*
2901                                   DP2DPRN(N,T);
2902
2903   DDPYDPLN(N,t)..
2904  DPYDPLN(N,t)=E=DPYDP4N(N,t)*DP4DP3N(N,t)*DP3DPLN(N,T);
2905
2906   DDPYDPEN(N,t)..  DPYDPEN(N,t)=E=DPYDP4N(N,t)*DP4DPEN(N,t);
2907
2908   DDPYDPMO(O,t)..   DPYDPMO(O,t)=E=DELMYO(O)*PMO(O,T)**SIGM4O(O)*
2909                                  P4O(O,t)**(-SIGM4O(O));
2910
2911                    DDPYDP4O(O,t)..              DPYDP4O(O,t)=E=(1-
DELMYO(O))*P4O(O,t)**SIGM4O(O)*
2912                                  PMO(O,T)**(-SIGM4O(O));
2913
2914   DDP4DPEO(O,t)$(dele4o(o) gt 0)..
2915  DP4DPEO(O,t)=E=DELE4O(O)*DPE('ELEC',T)**SIGE3O(O)*
2916                                  P3O(O,t)**(-SIGE3O(O));
2917
2918   ddp4dpe1(o,t)$(dele4o(o) eq 0)..   dp4dpeo(o,t)=e=0;
GAMS 2.25.059  386/486 DOS                      11/13/96 17:16:17  PAGE
59
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


2919
2920                    DDP4DP3O(O,t)..              DP4DP3O(O,t)=E=(1-
DELE4O(O))*P3O(O,t)**SIGE3O(O)*
2921                                  DPE('ELEC',T)**(-SIGE3O(O));
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2922
2923   DDP3DPLO(O,t)..   DP3DPLO(O,t)=E=DELL3O(O)*PUL(T)**SIGL2O(O)*
2924                                P2O(O,t)**(-SIGL2O(O));
2925
2926                     DDP3DP2O(O,t)..              DP3DP2O(O,t)=E=(1-
DELL3O(O))*P2O(O,t)**SIGL2O(O)*
2927                                PUL(T)**(-SIGL2O(O));
2928
2929   DDP2DPRO(O,t)..   DP2DPRO(O,t)=E=DELR2O(O)*PUR(T)**SIGR1O(O)*
2930                                P1O(O,t)**(-SIGR1O(O));
2931
2932                     DDP2DP1O(O,t)..              DP2DP1O(O,t)=E=(1-
DELR2O(O))*P1O(O,t)**SIGR1O(O)*
2933                                PUR(T)**(-SIGR1O(O));
2934
2935   DDP1DPAO(O,t)..   DP1DPAO(O,t)=E=DELA1O(O)*PUA(T)**SIGAKO(O)*
2936                                PUK(t)**(-SIGAKO(O));
2937
2938   DDP1DPKO(O,t)..  DP1DPKO(O,t)=E=(1-DELA1O(O))*PUK(t)**SIGAKO(O)*
2939                                PUA(T)**(-SIGAKO(O));
2940
2941   DDPYDPAO(O,t)..
2942  DPYDPAO(O,t)=E=DPYDP4O(O,t)*DP4DP3O(O,t)*DP3DP2O(O,T)*
2943                                 DP2DP1O(O,T)*DP1DPAO(O,T);
2944
2945   DDPYDPKO(O,t)..
2946  DPYDPKO(O,t)=E=DPYDP4O(O,t)*DP4DP3O(O,t)*DP3DP2O(O,T)*
2947                                 DP2DP1O(O,T)*DP1DPKO(O,T);
2948
2949   DDPYDPRO(O,t)..
2950  DPYDPRO(O,t)=E=DPYDP4O(O,t)*DP4DP3O(O,t)*DP3DP2O(O,T)*
2951                                 DP2DPRO(O,T);
2952
2953   DDPYDPLO(O,t)..
2954  DPYDPLO(O,t)=E=DPYDP4O(O,t)*DP4DP3O(O,t)*DP3DPLO(O,T);
2955
2956   DDPYDPEO(O,t)..  DPYDPEO(O,t)=E=DPYDP4O(O,t)*DP4DPEO(O,t);
2957
2958   DDPYDPME(E,t)..   DPYDPME(E,t)=E=DELMYE(E)*PME(E,T)**SIGM4E(E)*
2959                                P4E(E,t)**(-SIGM4E(E));
2960
2961                     DDPYDP4E(E,t)..              DPYDP4E(E,t)=E=(1-
DELMYE(E))*P4E(E,t)**SIGM4E(E)*
2962                                PME(E,T)**(-SIGM4E(E));
2963
2964                                                     DDP4DPEE(E,t)..
DP4DPEE(E,t)=E=DELE4E(E)*DPE('ELEC',T)**SIGE3E(E)*
2965                                P3E(E,t)**(-SIGE3E(E));
2966
2967                     DDP4DP3E(E,t)..              DP4DP3E(E,t)=E=(1-
DELE4E(E))*P3E(E,t)**SIGE3E(E)*
2968                                DPE('ELEC',T)**(-SIGE3E(E));
2969
2970   DDP3DPLE(E,t)..   DP3DPLE(E,t)=E=DELL3E(E)*PUL(T)**SIGL2E(E)*
2971                                P2E(E,t)**(-SIGL2E(E));
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GAMS 2.25.059  386/486 DOS                    11/13/96 17:16:17  PAGE
60
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


                    DDP3DP2E(E,t)..              DP3DP2E(E,t)=E=(1-
DELL3E(E))*P2E(E,t)**SIGL2E(E)*
                                  PUL(T)**(-SIGL2E(E));

  DDP2DPRE(E,t)..   DP2DPRE(E,t)=E=DELR2E(E)*PUR(T)**SIGR1E(E)*
                                  P1E(E,t)**(-SIGR1E(E));

                    DDP2DP1E(E,t)..              DP2DP1E(E,t)=E=(1-
DELR2E(E))*P1E(E,t)**SIGR1E(E)*
                                  PUR(T)**(-SIGR1E(E));

  DDP1DPAE(E,t)..   DP1DPAE(E,t)=E=DELA1E(E)*PUA(T)**SIGAKE(E)*
                                  PUK(t)**(-SIGAKE(E));

  DDP1DPKE(E,t)..  DP1DPKE(E,t)=E=(1-DELA1E(E))*PUK(t)**SIGAKE(E)*
                                  PUA(T)**(-SIGAKE(E));

  DDPYDPAE(E,t)..
 DPYDPAE(E,t)=E=DPYDP4E(E,t)*DP4DP3E(E,t)*DP3DP2E(E,T)*
                                   DP2DP1E(E,T)*DP1DPAE(E,T);

  DDPYDPKE(E,t)..
 DPYDPKE(E,t)=E=DPYDP4E(E,t)*DP4DP3E(E,t)*DP3DP2E(E,T)*
                                   DP2DP1E(E,T)*DP1DPKE(E,T);

  DDPYDPRE(E,t)..
 DPYDPRE(E,t)=E=DPYDP4E(E,t)*DP4DP3E(E,t)*DP3DP2E(E,T)*
                                   DP2DPRE(E,T);

  DDPYDPLE(E,t)..
 DPYDPLE(E,t)=E=DPYDP4E(E,t)*DP4DP3E(E,t)*DP3DPLE(E,T);

  DDPYDPEE(E,t)..  DPYDPEE(E,t)=E=DPYDP4E(E,t)*DP4DPEE(E,t);


 * Partial derivatives of PX wrt PUK PUL and PUA

  DDPXDPAP(P,t)..   DPXDPAP(P,t)=E=AP(P,t)*DPYDPAP(P,t);

  DDPXDPKP(P,t)..   DPXDPKP(P,t)=E=AP(P,t)*DPYDPKP(P,t);

  DDPXDPRP(P,T)..   DPXDPRP(P,T)=E=AP(P,T)*DPYDPRP(P,T);

  DDPXDPLP(P,T)..   DPXDPLP(P,T)=E=AP(P,T)*DPYDPLP(P,T);

  DDPXDPEP(P,T)..   DPXDPEP(P,T)=E=AP(P,T)*DPYDPEP(P,T);

  DDPXDPMP(P,T)..   DPXDPMP(P,T)=E=AP(P,T)*DPYDPMP(P,T);
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3019
3020
3021   DDPXDPAN(N,t)..   DPXDPAN(N,t)=E=AN(N,t)*DPYDPAN(N,t);
3022
3023   DDPXDPKN(N,t)..   DPXDPKN(N,t)=E=AN(N,t)*DPYDPKN(N,t);
3024
GAMS 2.25.059  386/486 DOS                    11/13/96 17:16:17  PAGE
61
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


3025   DDPXDPRN(N,T)..   DPXDPRN(N,T)=E=AN(N,T)*DPYDPRN(N,T);
3026
3027   DDPXDPLN(N,T)..   DPXDPLN(N,T)=E=AN(N,T)*DPYDPLN(N,T);
3028
3029   DDPXDPEN(N,T)..   DPXDPEN(N,T)=E=AN(N,T)*DPYDPEN(N,T);
3030
3031   DDPXDPMN(N,T)..   DPXDPMN(N,T)=E=AN(N,T)*DPYDPMN(N,T);
3032
3033
3034   DDPXDPAO(O,t)..   DPXDPAO(O,t)=E=AO(O,t)*DPYDPAO(O,t);
3035
3036   DDPXDPKO(O,t)..   DPXDPKO(O,t)=E=AO(O,t)*DPYDPKO(O,t);
3037
3038   DDPXDPRO(O,T)..   DPXDPRO(O,T)=E=AO(O,T)*DPYDPRO(O,T);
3039
3040   DDPXDPLO(O,T)..   DPXDPLO(O,T)=E=AO(O,T)*DPYDPLO(O,T);
3041
3042   DDPXDPEO(O,T)..   DPXDPEO(O,T)=E=AO(O,T)*DPYDPEO(O,T);
3043
3044   DDPXDPMO(O,T)..   DPXDPMO(O,T)=E=AO(O,T)*DPYDPMO(O,T);
3045
3046   DDPXDPAE(E,t)..   DPXDPAE(E,t)=E=AE(E,t)*DPYDPAE(E,t);
3047
3048   DDPXDPKE(E,t)..   DPXDPKE(E,t)=E=AE(E,t)*DPYDPKE(E,t);
3049
3050   DDPXDPRE(E,T)..   DPXDPRE(E,T)=E=AE(E,T)*DPYDPRE(E,T);
3051
3052   DDPXDPLE(E,T)..   DPXDPLE(E,T)=E=AE(E,T)*DPYDPLE(E,T);
3053
3054   DDPXDPEE(E,T)..   DPXDPEE(E,T)=E=AE(E,T)*DPYDPEE(E,T);
3055
3056   DDPXDPME(E,T)..   DPXDPME(E,T)=E=AE(E,T)*DPYDPME(E,T);
3057
3058  * Factor demand
3059  * According to Shephard's lemma EXCEPT FOR ENERGY (LEONTIEF)
3060
3061   ADEMP(P,t)..      AALP(P,t)=E=DPXDPAP(P,t)*XP(P,t);
3062   RDEMP(P,T)..      RP(P,T)=E=DPXDPRP(P,T)*XP(P,T);
3063   LDEMP(P,T)..      LP(P,T)=E=DPXDPLP(P,T)*XP(P,T);
3064   KDEMP(P,t)..      KP(P,t)=E=DPXDPKP(P,t)*XP(P,t);
3065   EDEMP(P,t)..      EP(P,t)=E=DPXDPEP(P,t)*XP(P,t);
3066   MDEMP(P,T)..      IMPP(P,T)=E=DPXDPMP(P,T)*XP(P,T);
3067
```

```
3068   ADEMN(N,T)..        AALN(N,T)=E=DPXDPAN(N,T)*XN(N,T);
3069   RDEMN(N,T)..        RN(N,T)=E=DPXDPRN(N,T)*XN(N,T);
3070   LDEMN(N,t)..        LN(N,t)=E=DPXDPLN(N,t)*XN(N,t);
3071   KDEMN(N,t)..        KN(N,t)=E=DPXDPKN(N,t)*XN(N,t);
3072   EDEMN(N,t)..        EN(N,t)=E=DPXDPEN(N,t)*XN(N,t);
3073   MDEMN(N,T)..        IMPN(N,T)=E=DPXDPMN(N,T)*XN(N,T);
3074
3075  * ADEME(E,T)..        AALE(E,T)=E=AAE(E)*XE(E,T);
3076  * RDEME(E,T)..        RE(E,T)=E=ARE(E)*XE(E,T);
3077  * LDEME(E,t)..        LE(E,t)=E=ale(e)*XE(E,t);
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
62
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


3078  * KDEME(E,t)..        KE(E,t)=E=ake(e)*XE(E,t);
3079  * DEDEME(EE,E,t)..   EDEME(EE,E,t)=E=AEE(EE,E)*XE(E,t);
3080  * MDEME(E,T)..        IMPE(E,T)=E=IMPSHE(E)*XE(E,T);
3081
3082   ADEME(E,T)..        AALE(E,T)=E=DPXDPAE(E,T)*XE(E,T);
3083   RDEME(E,T)..        RE(E,T)=E=DPXDPRE(E,T)*XE(E,T);
3084   LDEME(E,t)..        LE(E,t)=E=DPXDPLE(E,t)*XE(E,t);
3085   KDEME(E,t)..        KE(E,t)=E=DPXDPKE(E,t)*XE(E,t);
3086   DEDEME(E,t)..       EDEME(E,t)=E=DPXDPEE(E,t)*XE(E,t);
3087   MDEME(E,T)..        IMPE(E,T)=E=DPXDPME(E,T)*XE(E,T);
3088
3089   ADEMO(O,T)..        AALO(O,T)=E=DPXDPAO(O,T)*XO(O,T);
3090   RDEMO(O,T)..        RO(O,T)=E=DPXDPRO(O,T)*XO(O,T);
3091   LDEMO(O,t)..        LO(O,t)=E=DPXDPLO(O,t)*XO(O,t);
3092   KDEMO(O,t)..        KO(O,t)=E=DPXDPKO(O,t)*XO(O,t);
3093   EDEMO(O,t)..        EO(O,t)=E=DPXDPEO(O,t)*XO(O,t);
3094   MDEMO(O,T)..        IMPO(O,T)=E=DPXDPMO(O,T)*XO(O,T);
3095
3096  * Definition of marginal and average costs in different sectors
3097  * They are equal because we have CRS everywhere in this version
3098  * In the treecrops sectors the land quality index plays a role
3099
3100   DEFMCP(P,t)..       MCP(P,t)=E=((AP(P,t)*PYP(P,t))+
3101     SUM(n,DPN(N,t)*AnP(n,P))+DPE('PETR',t)*AEP('PETR',P)+
3102     SUM(O,DPO(O,t)*AOP(O,P))+ITAXP(P,t)-SUBSP(P,t))*1/q(p,t);
3103
3104
3105                                                    DEFMCN(N,t)..
MCN(N,t)=E=(AN(N,t)*PYN(N,t))+SUM(P,DPP(P,t)*APn(P,n))

+
3106     SUM(nn,DPN(N,t)*AnN(n))+ DPE('PETR',t)*AEn('PETR',n)+
3107     SUM(O,DPO(O,t)*AOn(O,n))+ITAXN(N,t);
3108
3109   DEFMCE(E,t)..       MCE(E,t)=E=(AE(E,t)*PYE(E,t))+
3110     SUM(n,DPN(N,t)*AnE(n,E))+DPE('petr',t)*AEE('petr',E)+
3111     SUM(O,DPO(O,t)*AOE(O,E))+otaxe(e,T);
3112
3113                                                    DEFMCO(O,t)..
```

```
MCO(O,t)=E=(AO(O,t)*PYO(O,t))+SUM(P,DPP(P,t)*APO(P,O))

+
3114      SUM(n,DPN(N,t)*AnO(n,O))+DPE('PETR',t)*AEO('PETR',O)+
3115      SUM(OO,DPO(OO,t)*AOO(OO,O))+ITAXO(O,t)-SUBSO(O,T);
3116
3117  * Price equals marginal cost
3118  * Determines output price
3119  * In the case of energy price is exogenous and output determined
from

demand
3120
3121   PRMCP(P,t)..       DPP(P,t)=l=MCP(P,t);
3122    ppcomp(p,t)..      xp(p,t)*(dpp(p,t)-mcp(p,t))=e=0;
3123
3124   PRMCN(N,t)..       DPN(N,t)=l=MCN(N,t);
3125   nncomp(n,t)..      xn(n,t)*(dpn(n,t)-mcn(n,t))=e=0;
3126
3127  * PRMCE(E,t)..         xe(E,t)=e=CE(E,t);
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
63
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


3128
3129   PRMCO(O,t)..       DPO(O,t)=l=MCO(O,t);
3130   oocomp(o,t)..      xo(o,t)*(dpo(o,t)-mco(o,t))=e=0;
3131
3132  * Domestic consumption demand functions for composite goods
3133
3134                          PCONS(P,h,t)$(ord(T)         NE         1)..
DDP(P,H,t)=E=PALPHA(P,H)*(DISPh(H,T)+
3135                                        (1+interest(t))**tau*savh(H,t-
1))/DPP(P,t);
3136   PCONS1(p,H,T)$(ord(t) EQ 1)..
3137  DDP(P,H,T)=E=PALPHA(P,H)*DISPh(H,T)/DPP(P,T);
3138
3139                          nCONS(n,H,t)$(ord(T)         NE         1)..
DDN(N,H,t)=E=nALPHA(n,H)*(DISPh(H,t)+
3140                                        (1+INTEREST(t))**tau*SAVh(H,T-
1))/DPN(N,t);
3141                         nCONS1(n,H,T)$(ord(T)         EQ         1)..
DDN(N,H,T)=E=nALPHA(n,H)*DISPh(H,T)
3142                                       /DPN(N,T);
3143
3144                          ECONS(E,H,t)$(ord(t)         NE         1)..
DDE(E,H,t)=E=EALPHA(E,H)*(DISPh(H,t)+
3145                                        (1+INTEREST(t))**tau*SAVh(H,T-
1))/DPE(E,t);
3146                         ECONS1(E,H,T)$(ord(T)         EQ         1)..
DDE(E,H,T)=E=EALPHA(E,H)*DISPh(H,T)
3147                                       /DPE(E,T);
3148
```

```
3149                          OCONS(O,H,t)$(ord(T)        NE        1)..
DDO(O,H,t)=E=OALPHA(O,H)*(DISPh(H,t)+
3150                                    (1+INTEREST(t))**tau*SAVh(H,T-
1))/DPO(O,t);
3151                         OCONS1(O,H,T)$(ord(t)        EQ        1)..
DDO(O,H,T)=E=OALPHA(O,H)*DISPh(H,T)
3152                                   /DPO(o,T);
3153
3154  *++++++++++*
3155  * Imports *
3156  *++++++++++*
3157
3158  * Definition of domestic price of imports
3159  * Small country assumption. Can purchase at constant WM prices
3160  * IMPDP is the ad valorem import duty rate
3161
3162   DEFPMP(P,t)..     PMP(P,t)=E=WMP(P,t)*(1+IMPDP(P,t))*XR(t);
3163
3164   DEFPMN(N,t)..     PMN(N,t)=E=WMN(N,t)*(1+IMPDN(N,t))*XR(t);
3165
3166   DEFPME(E,t)..       PME(E,t)=E=WME(E,t)*(1+IMPDE(E,t))*XR(t);
3167
3168   DEFPMO(O,t)..     PMO(O,t)=E=WMO(O,t)*(1+IMPDO(O,t))*XR(t);
3169
3170  * Armington assumption
3171
3172  *++++++++++*
3173  * EXPORTS *
3174  *++++++++++*
3175  * Assume domestic goods and export goods imperfect substitutes
3176  * Assume small country
3177
3178  * Domestic price of exports in local currency
3179  * Only definined if exports are possible -- $ is if statement
3180
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```
3181   DPEP(P,t)..      PEP(P,t)=E=WMEP(P,t)*(1+EXPTP(P,t))*XR(t);
3182
3183                  DPEN(N,t)      $      (expshn(n)      gt      0)..
PEN(N,t)=E=WMEN(N,t)*(1+EXPTN(N,t))

*XR(t);
3184   dpenb(n,t) $ (expshn(n) eq 0)..      pen(n,t)=e=.1;
3185
3186                  DPEE(E,t)      $      (expshe(e)      gt      0)..
PEE(E,t)=E=WMEE(E,t)*(1+EXPTE(E,t))

*XR(t);
3187   dpeeb(e,t) $ (expshe(e) eq 0)..      pee(e,t)=e=.1;
3188
```

```
3189                    DPEO(O,t)       $       (expsho(o)       gt       0)..
PEO(O,t)=E=WMEO(O,t)*(1+EXPTO(O,t))

*XR(t);
3190   dpeob(o,t) $ (expsho(o) eq 0)..       peo(o,t)=e=.1;
3191
3192
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                                                            DCP(P,t)..
CP(P,t)=E=SUM(H,DDP(P,H,t))+INVP(P,t)+EXPP(P,t)+
3200         SUM(n,APn(P,n)*XN(N,t))+
3201       SUM(O,APO(P,O)*XO(O,t));
3202
3203                                                            DCN(N,t)..
cCN(N,t)=E=SUM(H,DDN(N,H,t))+INVN(N,t)+EXPN(N,t)+
3204      SUM(P,AnP(n,P)*XP(P,t))
3205      +SUM(nn,AnN(nn)*XN(Nn,t))+sum(e,ane(n,e)*xe(e,t))+
3206      SUM(O,AnO(n,O)*XO(O,t));
3207
3208                                                            DCE(e,t)..
CE(E,t)=E=SUM(H,DDe(e,H,t))+intere(e,t)+expe(e,t);
3209
3210   DCO(O,t)..
3211
CO(O,t)=E=SUM(H,DDO(O,H,t))+INVO(O,t)+EXPO(O,t)+SUM(P,AOP(O,P)*XP(P,t))
3212      +SUM(n,AOn(O,n)*XN(N,t))+sum(e,aoe(o,e)*xe(e,t))+
3213      SUM(OO,AOO(O,OO)*XO(OO,t));
3214
3215
3216  * Find a ration of exp to domestic consumption so that the price
ratio

equals
3217  * the MRT for RoW.
3218  * Determine exports if exports possible else exports equal to 0
3219
3220
3221   DEXPP(P,t)..       EXPP(P,t)/(cp(p,t)-expp(p,t))=E=(EXPSHP(P)
                                                                    /(1-
EXPSHP(P)))
3222                      **MUP(P)*
3223      (PEP(P,t)/DPP(P,t))**MUP(P);
3224
3225      DEXPnA(N,t)$(EXPSHN(N)  NE  0)..            EXPN(N,t)/(CCN(N,t)-
expn(n,t))=E=
3226                     (EXPSHN(N)/(1-
3227  EXPSHN(N)))**MUN(N)*(PEN(N,t)/DPN(N,t))**MUN(N);
3228   DEXPnB(N,t)$(EXPSHN(N) EQ 0)..       EXPN(N,t)=E=0;
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
65
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3229
3230   DEXPEA(E,t)$(EXPSHE(E) NE 0)..      EXPE(E,t)/(CE(E,t)-
3231  expe(e,t))=E=(EXPSHE(E)/
3232                                                                (1-
EXPSHE(E)))**MUE(E)*(PEE(E,t)/DPE(E,t))**MUE(E);
3233   DEXPEB(E,t)$(EXPSHE(E) EQ 0)..      EXPE(E,t)=E=0;
3234
3235      DEXPOA(O,t)$(EXPSHO(O)  NE  0)..            EXPO(O,t)/(CO(O,t)-
expo(o,t))=E=
3236                     (EXPSHO(O)/(1-
3237  EXPSHO(O)))**MUO(O)*(PEO(O,t)/DPO(O,t))**MUO(O);
3238   DEXPOB(O,t)$(EXPSHO(O) EQ 0)..      EXPO(O,t)=E=0;
3239
3240  * Factor market equilibrium
3241  * Determine prices of production factors
3242  * Obs: Kmarket1 and Rmarket1 are used to obtained a base solution
w/o

soil
3243  * conservation
3244
3245                                                        LMARKET(t)..
L(t)=E=SUM(P,LP(P,T))+sum(n,LN(N,t))+sum(e,le(e,t))+
3246                            SUM(O,LO(O,t));
3247
3248   AMARKET(t)..
3249  A(t)=E=SUM(P,AALP(P,t))+SUM(n,AALN(N,T))+SUM(O,AALO(O,T))+
3250                              SUM(E,AALE(E,T));
3251
3252   RMARKET(T)..        R(T)=E=SUM(P,RP(P,T)+lscs(p,t)+lsce(p,t))+
3253                            sum(n,RN(N,t))+sum(e,Re(e,t))+
3254                            SUM(O,RO(O,t));
3255
3256  RMARKET1(T)..
3257  R(T)=E=SUM(P,RP(P,T))+SUM(n,RN(N,T))+SUM(O,RO(O,T))+
3258                               SUM(E,RE(E,T));
3259
3260   KMARKET(t)..        K(t)=E=SUM(P,KP(P,t)+cscs(p,t)+csce(p,t))+
3261                           SUM(n,KN(N,t))+sum(e,ke(e,t))+
3262                           SUM(O,KO(O,t));
3263   KMARKET1(T)..
3264  K(T)=E=SUM(P,KP(P,T))+SUM(n,KN(N,T))+SUM(O,KO(O,T))+
3265                              SUM(E,KE(E,T));
3266
3267  *INVESTMENTS
3268
3269   DPINV(P,T)..   INVP(P,T)=E=PBETA(P)*invest(t)*pi(t)/DPP(P,T);
3270   dpinv1(p,t)..                 invp(p,t)=e=0;
3271   DnINV(N,T)..   INVN(N,T)=E=nBETA(N)*invest(t)*pi(t)/DPN(N,T);
3272   dninv1(n,t)..                 invn(n,t)=e=0;
3273   DOINV(O,T)..   INVO(O,T)=E=OBETA(O)*invest(t)*pi(t)/DPO(O,T);
```

```
3274   doinv1(o,t)..                invo(o,t)=e=0;
3275
3276                                                          DPI(T)..
invest(t)=E=(SUM(P,INVP(P,T)*DPP(P,T))+SUM(n,INVN(N,T)*
3277
DPN(N,T))+SUM(O,INVO(O,T)*DPO(O,T)))/pi(t);
3278
3279   KSTOCK(T)$(ord(T) ne 1)..  K(t)=e=(1-depl)*k(t-1)+invest(t-1);
3280   kstock1(t)$(ord(T) eq 1).. K(t)=e=totk0;
GAMS 2.25.059  386/486 DOS                      11/13/96 17:16:17  PAGE
66
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


3281
3282  * Soil conservation
3283
3284   dlabscs(p,t)..         sum(tt$(ord(tt) gt ord(t)),(tau*dpp(p,tt)

*dxddp(p)*
3285                          (1/(1+
3286                                        interest(tt)))**(ord(tt)-
ord(t))))*pgamma(p)

*(lscs(p,t)
3287                                  **(pgamma(p)-1))*(cscs(p,t)**(1-
pgamma(p)))-
3288                          pgamma(p)*scs(p,t)/pur(t)=e=0;
3289
3290    dlscsc(p,t)..               (lscs(p,t)-low)*(sum(tt$(ord(tt)  gt
ord(t)),

(tau*dpp(p,tt)*
3291                          dxddp(p)*(1/(1+
3292                                 interest(tt)))**(ord(tt)-ord(t))))-
pur(t))=e=0;
3293
3294       dcapscs(p,t)..                           sum(tt$(ord(tt)   gt
ord(t)),(tau*dpp(p,tt)

*dxddp(p)*
3295                                    (1/(1+interest(tt)))**(ord(tt)-
ord(t))))*(lscs(p,

t)
3296                          **pgamma(p))*(1-pgamma(p))*(cscs(p,t)
                                                                    **(-
pgamma(p)))-
3297                          (1-pgamma(p))*scs(p,t)/puk(t)=e=0;
3298
3299    dcscsc(p,t)..               (cscs(p,t)-low)*(sum(tt$(ord(tt)  gt
ord(t)),
3300                          (tau*dpp(p,tt)*dxddp(p)*
3301                           (1/(1+interest(tt)))**(ord(tt)-ord(t))))-
```

```
puk(t))

=e=0;
3302
3303                                                        dscs(p,t)..
scs(p,t)=e=lscs(p,t)**pgamma(p)*cscs(p,t)**
3304                              (1-pgamma(p));
3305
3306     dlabsce(p,t)..                    sum(tt$((ord(tt)-ord(t)-1)  eq
0),(tau*dpp(p,tt)

*
3307                           dxddp(p)
3308                           *(1/(1+
3309                           interest(tt)))**(ord(tt)-ord(t))))
3310                           *pgamma(p)*(lscs(p,t)
3311                                     **(pgamma(p)-1))*(cscs(p,t)**(1-
pgamma(p)))-
3312                           pgamma(p)*sce(p,t)
3313                           /pur(t)=e=0;
3314
3315   dlscec(p,t)..            (lsce(p,t)-low)*(sum(tt$((ord(tt)-ord(t)-
1) eq 0)

,
3316                           (tau*dpp(p,tt)*dxddp(p)*(1/(1+
3317                                  interest(tt)))**(ord(tt)-ord(t))))-
pur(t))=e=0;
3318
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)-
ord(t))))*(lscs(p,t)
3323                           **pgamma(p))*(1-pgamma(p))*(cscs(p,t)
                                                                    **(-
pgamma(p)))-
GAMS 2.25.059  386/486 DOS                      11/13/96 17:16:17  PAGE
67
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


3324                           (1-pgamma(p))*
3325                           sce(p,t)/puk(t)=e=0;
3326
3327   dcscec(p,t)..            (csce(p,t)-low)*(sum(tt$((ord(tt)-ord(t)-
1) eq

0),
3328                           (tau*dpp(p,tt)*dxddp(p)*
3329                            (1/(1+interest(tt)))**(ord(tt)-ord(t))))-
puk(t))=e=0;
3330
```

```
3331
3332   dsce(p,t)..          sce(p,t)=e=lsce(p,t)**pgamma(p)*csce(p,t)
                                                                    **(1-
pgamma(p));
3333
3334   dq(p,t)..              q(p,t)=e=1-erosion(p)*tau*(ord(t)-1)

+sum(tt$(ord(tt) le
3335                          ord(t)),
3336                                          sshare(p)*scs(p,t)+(1-
sshare(p))*sce(p,t));
3337
3338  * Determine the savings by hh type
3339  * Assume rate of time preference equals interest rate
3340
3341     dinvest(t)$(ord(t) ne m)..   pk(t)=e=1/(1+interest(t))*pk(t+1);
3342
3343                          dsavh(h,t)$(ord(t)         ne         m)..
disph(h,t)=e=disph(h,t+1)+(1+interest(t))

**tau*
3344                              savh(h,t);
3345
3346   dsavh1(h,t)$(ord(t) eq m).. sum(tt,tdisph(h,tt)-disph(h,tt))=e=0;
3347
3348   DDOMSAV(T)..   DOMSAV(T)=E=SUM(H,SAVH(H,T));
3349
3350  * Determine trade balance
3351
3352   dtb(t)..       tb(t)=e=SUM(P,PEP(P,t)*EXPP(P,t)-Pmp(P,t)
3353                          *IMPP(P,t))+
3354                          SUM(n,PEN(N,t)*EXPN(N,t)-pmn(n,t)*
3355                          IMPN(N,t))+
3356                          SUM(E,pee(e,t)*expe(e,t)-pme(e,t)
3357                          *impe(e,t))+
3358                          SUM(O,PEO(O,t)*EXPO(O,t)-pmO(O,t)*
3359                          IMPO(O,t));
3360
3361  * Define prices of composite (dom const plus exports) consumption
3362
3363     DPCP(P,t)..               PCP(P,t)*cp(p,t)=E=DPP(P,t)*(CP(P,t)-
EXPP(P,t))+
3364                      PEP(P,t)*
3365                      EXPP(P,t);
3366
3367     DPCN(N,t)..              PCN(N,t)*ccn(n,t)=e=DPN(N,t)*(CCN(N,t)-
EXPN(N,t))+
3368                      PEN(N,t)*
3369                      EXPN(N,t);
3370
3371     DPCO(O,t)..               PCO(O,t)*co(o,t)=E=DPO(O,t)*(CO(O,t)-
EXPO(O,t))

+PEO(O,t)*
```

```
3372                    EXPO(O,t);
3373
3374     DPCE(E,t)..              PCE(E,t)*ce(e,t)=E=DPE(E,t)*(CE(E,t)-
EXPE(E,t))

+PEE(E,t)*
3375                    EXPE(E,t);
3376
3377  * Product market equilibrium
3378
3379   PMARKET(P,t)..    DPP(P,t)*XP(P,t)=E=CP(P,t)*PCP(P,t);
3380
3381   nMARKET(N,t)..    DPN(N,t)*XN(N,t)=E=CCN(N,t)*PCN(N,t);
3382
3383   EINTERE(t)..
3384
INTERE('elec',t)=E=SUM(P,EP(p,t))+SUM(n,EN(n,t))+SUM(E,EDEMe(E,t))+
3385          SUM(O,EO(O,t));
3386
3387   EINTERF(t)..     INTERe('petr',t)=E=SUM(P,AEP('petr',P)*xp(p,t))+
3388       SUM(n,AEn('petr',n)*xn(n,t))+SUM(EE,
3389       AEE('petr',EE)*xe(ee,t))+SUM(O,AEO('petr',O)
3390       *xo(o,t));
3391
3392   EMARKET(e,t)..    XE(e,t)=e=ce(e,t);
3393
3394   OMARKET(O,t)..    DPO(O,t)*XO(O,t)=E=CO(O,t)*PCO(O,t);
3395
3396  * Welfare indicators
3397  * Spending
3398
3399   INCOMEU(t)..
3400   DISPH('URBAN',t)=E=PUL(t)*L(T)+kh('urban')*(PUK(t)*K(t)+
3401   SUM(P,OTAXP(P,t)*XP(P,t))+
3402   SUM(n,OTAXN(N,t)*XN(N,t))+SUM(E,OTAXE(E,t)*XE(E,t))+
3403   SUM(O,OTAXO(O,t)*XO(O,t))-tb(t)-invest(t));
3404
3405   dtottax(t)..  tottax(t)=e=SUM(P,OTAXP(P,t)*XP(P,t))+
3406   SUM(n,OTAXN(N,t)*XN(N,t))+SUM(E,OTAXE(E,t)*XE(E,t))+
3407   SUM(O,OTAXO(O,t)*XO(O,t));
3408
3409                                                    dtotimp(t)..
totimp(t)=e=SUM(P,IMPDP(P,t)*IMPP(P,t))+SUM(n,IMPDN(N,t)*
3410   IMPN(N,t))+
3411   SUM(O,IMPDO(O,t)*IMPO(O,t))+sum(e,impde(e,t)*impe(e,t));
3412
3413
3414                                                    incomer(t)..
DISPH('RURAL',t)=E=PUR(t)*R(T)+KH('RURAL')*(puk(t)*k(t)+
3415   SUM(P,(iTAXP(P,t)-subsp(p,t))*XP(P,t))+
```

```
3416   SUM(n,iTAXN(N,t)*XN(N,t))+SUM(E,(iTAXE(E,t)-subse(e,t))*XE(E,t))+
3417   SUM(O,(iTAXO(O,t)-subso(o,t))*XO(O,t))-tb(t)-invest(t));
3418
3419   INCOMEE(t)..
3420   DISPH('ESTATE',t)=E=PUA(t)*A(T)+KH('ESTATE')*(PUK(t)*K(T)+
3421   SUM(P,OTAXP(P,t)*XP(P,t))+
3422   SUM(n,OTAXN(N,t)*XN(N,t))+SUM(E,OTAXE(E,t)*XE(E,t))+
3423   SUM(O,OTAXO(O,t)*XO(O,t))-tb(t)-invest(t));
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
69
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


3424
3425   consinc(h,t)..  tdisph(h,t)-savh(h,t)=e=disph(h,t);
3426
3427   INCOME(T)..  SUM(H,DISPH(H,T))=E=DISP(T);
3428
3429
3430  * Gross domestic product
3431
3432   DEFGDP(t)..     PUA(t)*A(t)+PUK(t)*K(t)+PUL(t)*L(t)+PUR(T)*R(T)+
3433                   SUM(P,OTAXP(P,t)*XP(P,t))
3434
+SUM(n,OTAXN(N,t)+XN(N,t))+SUM(E,OTAXE(E,t)*XE(E,t))+
3435                   SUM(O,OTAXO(O,t)*XO(O,t))
3436                   =e=gdp(t);
3437
3438   dtotdisp..      totdisp=e=sum(t,disp(t));
3439
3440  * Set lower bounds for variables
INCLUDE    C:\SLMOD\SLLOWA.INC
3442  * Lower bounds for PRICES
3443
3444   q.lo(p,t)=0.001;
3445
3446            PUA.LO(T)=0.001;    PUL.LO(T)=0.001;    PUK.LO(T)=0.001;
pur.lo(t)=0.001;
3447
3448   pi.lo(t)=0.001;
3449
3450        PYP.LO(P,T)=0.001;   PYN.LO(N,T)=0.001;   PYE.LO(E,T)=0.001;
PYO.LO(O,T)

=0.001;
3451
3452        p1p.lo(p,t)=0.001;   p1n.lo(n,t)=0.001;   p1e.lo(e,t)=0.001;
p1o.lo(o,t)

=0.001;
3453
3454        p2p.lo(p,t)=0.001;   p2n.lo(n,t)=0.001;   p2e.lo(e,t)=0.001;
p2o.lo(o,t)
```

```
=0.001;
3455
3456        p3p.lo(p,t)=0.001;   p3n.lo(n,t)=0.001;   p3e.lo(e,t)=0.001;
p3o.lo(o,t)

=0.001;
3457
3458        p4p.lo(p,t)=0.001;   p4n.lo(n,t)=0.001;   p4e.lo(e,t)=0.001;
p4o.lo(o,t)

=0.001;
3459
3460
3461        MCP.LO(P,T)=0.001;   MCN.LO(N,T)=0.001;   MCE.LO(E,T)=0.001;
MCO.LO(O,T)

=0.001;
3462
3463   DPP.LO(P,T)=0.001; DPN.LO(N,T)=0.001;
3464
3465  * DPE.LO(E,T)=0.001;
3466
3467   DPO.LO(O,T)=0.001;
3468
3469            PMP.LO(P,T)=0.2;    PMN.LO(N,T)=0.2;    PMO.LO(O,T)=0.2;
pme.lo(e,t)=0.2;
3470
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
70
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


3471        PEP.LO(P,T)=0.001;   PEN.LO(N,T)=0.001;   pee.lo(e,t)=0.001;
PEO.LO(O,T)

=0.001;
3472
3473   PL.LO(T)=0.001; PK.LO(T)=0.001; PA.LO(T)=0.001; pr.lo(t)=0.001;
3474
3475  * PQP.LO(P,T)=0.2; PQN.LO(N,T)=0.2;  PQO.LO(O,T)=0.2;
3476
3477       PCP.LO(P,T)=0.001;  PCN.LO(N,T)=0.001;     pce.lo(e,t)=0.001;
PCO.LO(O,T)

=0.001;
3478
3479   cscs.lo(p,t)=low; lscs.lo(p,t)=low; csce.lo(p,t)=low;
3480
3481   lsce.lo(p,t)=low;
3482
3483   scs.lo(p,t)=low; sce.lo(p,t)=low;
3484
3485             dpydpmp.lo(p,t)=0.000001;     dpydpmn.lo(n,t)=0.000001;
dpydpme.lo(e,t)
```

```
=0.000001;
3486                dpydpmo.lo(o,t)=0.000001;     dpydp4p.lo(p,t)=0.000001;
dpydp4n.lo(n,t)

=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;
dp4dp3e.lo(e,t)

=0.000001;
3490                dp4dp3o.lo(o,t)=0.000001;     dp3dp1p.lo(p,t)=0.000001;
dp3dp1n.lo(n,t)

=0.000001;
3491            dp3dp1e.lo(e,t)=0.000001;         dp3dp1o.lo(o,t)=0.000001;
dp3dp2p.lo(p,t)

=0.000001;
3492                dp3dp2n.lo(n,t)=0.000001;     dp3dp2e.lo(e,t)=0.000001;
dp3dp2o.lo(o,t)

=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;     dp2dp1p.lo(p,t)=0.000001;
dp2dp1n.lo(n,t)

=0.000001;
3496            dp2dp1e.lo(e,t)=0.000001;         dp2dp1o.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    dp1dpae.lo(e,t)=0.000001;
3500    dp1dpao.lo(o,t)=0.000001;
3501
3502
3503
3504
3505
3506
3507
3508
3509
3510
```

```
3511  * Set initial values for variables
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
71
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


INCLUDE    C:\SLMOD\SLINIA.INC
3513  * Initial values for variables
3514    tottax.l(t)=ttax0; totimp.l(t)=timpd0;
3515    savh.l(h,t)=0; k.l(t)=totk0;
3516
3517    domsav.l(t)=0;
3518
3519  * MUP.L(P,T)=1; MUN.L(N,T)=1; MUO.L(O,T)=1; MUE.L(E,T)=1;
3520
3521  * NEXPE.L(E,T)=NEXPE0(E);
3522
3523    pi.l(t)=1;
3524
3525    PUA.L(T)=1; PUR.L(T)=1; PUL.L(T)=1; PUK.L(T)=1;
3526
3527    PYP.L(P,T)=1; PYN.L(N,T)=1; PYE.L(E,T)=1; PYO.L(O,T)=1;
3528    P4P.L(P,T)=1; P4N.L(N,T)=1; P4E.L(E,T)=1; P4O.L(O,T)=1;
3529    P3P.L(P,T)=1; P3N.L(N,T)=1; P3E.L(E,T)=1; P3O.L(O,T)=1;
3530    P2P.L(P,T)=1; P2N.L(N,T)=1; P2E.L(E,T)=1; P2O.L(O,T)=1;
3531    P1P.L(P,T)=1; P1N.L(N,T)=1; P1E.L(E,T)=1; P1O.L(O,T)=1;
3532
3533   DPYDPAP.L(P,T)=DELA1(P)*(1-DELr2(P))*(1-dell3(p))*(1-dele4(p))
                                                                    *(1-
delmy(p));
3534            dpydpkp.l(p,t)=(1-dela1(p))*(1-DELr2(P))*(1-dell3(p))*(1-
dele4(p))
                                                                    *(1-
delmy(p));
3535   dpydprp.l(p,t)=DELr2(P)*(1-dell3(p))*(1-dele4(p))*(1-delmy(p));
3536   dpydplp.l(p,t)=dell3(p)*(1-dele4(p))*(1-delmy(p));
3537   dpydpep.l(p,t)=dele4(p)*(1-delmy(p));
3538   dpydpmp.l(p,t)=delmy(p);
3539
3540             DPYDPAN.L(N,T)=DELA1n(n)*(1-DELr2N(N))*(1-dell3n(n))*(1-
dele4n(n))*
3541                   (1-delmyn(n));
3542         dpydpkn.l(n,t)=(1-dela1n(n))*(1-DELr2N(N))*(1-dell3n(n))*(1-
dele4n(n))*
3543   (1-delmyn(n));
3544             dpydprn.l(n,t)=DELr2N(N)*(1-dell3n(n))*(1-dele4n(n))*(1-
delmyn(n));
3545   dpydpln.l(n,t)=dell3n(n)*(1-dele4n(n))*(1-delmyn(n));
3546   dpydpen.l(n,t)=dele4n(n)*(1-delmyn(n));
3547   dpydpmn.l(n,t)=delmyn(n);
3548
3549             DPYDPAE.L(E,T)=DELA1e(e)*(1-DELr2E(E))*(1-dell3e(e))*(1-
dele4e(e))*
3550   (1-delmye(e));
```

```
3551        dpydpke.l(e,t)=(1-dela1e(e))*(1-DELr2E(E))*(1-dell3e(e))*(1-
dele4e(e))*
3552   (1-delmye(e));
3553            dpydpre.l(e,t)=DELr2E(E)*(1-dell3e(e))*(1-dele4e(e))*(1-
delmye(e));
3554   dpydple.l(e,t)=dell3e(e)*(1-dele4e(e))*(1-delmye(e));
3555   dpydpee.l(e,t)=dele4e(e)*(1-delmye(e));
3556   dpydpme.l(e,t)=delmye(e);
3557
3558            DPYDPAO.L(O,T)=DELA1o(o)*(1-DELr2O(O))*(1-dell3o(o))*(1-
dele4o(o))*
3559   (1-delmyo(o));
3560        dpydpko.l(o,t)=(1-dela1o(o))*(1-DELr2O(O))*(1-dell3o(o))*(1-
dele4o(o))*
3561   (1-delmyo(o));
3562            dpydpro.l(o,t)=DELr2O(O)*(1-dell3o(o))*(1-dele4o(o))*(1-
delmyo(o));
GAMS 2.25.059  386/486 DOS                      11/13/96 17:16:17  PAGE
72
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


3563   dpydplo.l(o,t)=dell3o(o)*(1-dele4o(o))*(1-delmyo(o));
3564   dpydpeo.l(o,t)=dele4o(o)*(1-delmyo(o));
3565   dpydpmo.l(o,t)=delmyo(o);
3566
3567   dpydp4p.l(p,t)=(1-delmy(p)); dp4dp3p.l(p,t)=(1-dele4(p));
3568   dp3dp2p.l(p,t)=(1-dell3(p)); dp2dp1p.l(p,t)=(1-delr2(p));
3569   dp4dpep.l(p,t)=dele4(p); dp3dp1p.l(p,t)=dell3(p); dp2dprp.l(p,t)

=delr2(P);
3570   dp1dpap.l(p,t)=dela1(p); dp1dpkp.l(p,t)=(1-dela1(p));
3571
3572   dpydp4n.l(n,t)=(1-delmyn(n)); dp4dp3n.l(n,t)=(1-dele4n(n));
3573   dp3dp2n.l(n,t)=(1-dell3n(n)); dp2dp1n.l(n,t)=(1-delr2n(n));
3574             dp4dpen.l(n,t)=dele4n(n);     dp3dp1n.l(n,t)=dell3n(n);
dp2dprn.l(n,t)

=delr2n(n);
3575   dp1dpan.l(n,t)=dela1n(n); dp1dpkn.l(n,t)=(1-dela1n(n));
3576
3577   dpydp4e.l(e,t)=(1-delmye(e)); dp4dp3e.l(e,t)=(1-dele4e(e));
3578   dp3dp2e.l(e,t)=(1-dell3e(e)); dp2dp1e.l(e,t)=(1-delr2e(e));
3579             dp4dpee.l(e,t)=dele4e(e);     dp3dple.l(e,t)=dell3e(e);
dp2dpre.l(e,t)

=delr2e(e);
3580   dp1dpae.l(e,t)=dela1e(e); dp1dpke.l(e,t)=(1-dela1e(e));
3581
3582   dpydp4o.l(o,t)=(1-delmyo(o)); dp4dp3o.l(o,t)=(1-dele4o(o));
3583   dp3dp2o.l(o,t)=(1-dell3o(o)); dp2dp1o.l(o,t)=(1-delr2o(o));
3584             dp4dpeo.l(o,t)=dele4o(o);     dp3dplo.l(o,t)=dell3o(o);
dp2dpro.l(o,t)
```

```
=delr2o(o);
3585    dp1dpao.l(o,t)=dela1o(o); dp1dpko.l(o,t)=(1-dela1o(o));
3586
3587
3588    DPXDPAP.L(P,T)=AP(P,t)*dpydpap.l(p,t); dpxdprp.l(p,t)=ap(p,t)

*dpydprp.l(p,t);
3589    dpxdplp.l(p,t)=ap(p,t)*dpydplp.l(p,t); DPXDPKP.L(P,T)=ap(P,t)

*dpydpkp.l(p,t);
3590    DPXDPEP.L(P,T)=Ap(P,t)*dpydpep.l(p,t); dpxdpmp.l(p,t)=ap(p,t)

*dpydpmp.l(p,t);
3591
3592    DPXDPAN.L(N,T)=AN(N,t)*dpydpan.l(n,t); dpxdprn.l(n,t)=an(n,t)

*dpydprn.l(n,t);
3593    dpxdpln.l(n,t)=an(n,t)*dpydpln.l(n,t); DPXDPKN.L(N,T)=an(n,t)

*dpydpkn.l(n,t);
3594    DPXDPEN.L(N,T)=An(n,t)*dpydpen.l(n,t); dpxdpmn.l(n,t)=an(n,t)

*dpydpmn.l(n,t);
3595
3596    DPXDPAE.L(E,T)=AE(E,t)*dpydpae.l(e,t); dpxdpre.l(e,t)=ae(e,t)

*dpydpre.l(e,t);
3597    dpxdple.l(e,t)=ae(e,t)*dpydple.l(e,t); DPXDPKE.L(E,T)=ae(e,t)

*dpydpke.l(e,t);
3598    DPXDPEE.L(E,T)=Ae(e,t)*dpydpee.l(e,t); dpxdpme.l(e,t)=ae(e,t)

*dpydpme.l(e,t);
3599
3600    DPXDPAO.L(O,T)=AO(O,t)*dpydpao.l(o,t); dpxdpro.l(o,t)=ao(o,t)

*dpydpro.l(o,t);
3601    dpxdplo.l(o,t)=ao(o,t)*dpydplo.l(o,t); DPXDPKO.L(O,T)=ao(o,t)
GAMS 2.25.059  386/486 DOS                      11/13/96 17:16:17  PAGE
73
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n



*dpydpko.l(o,t);
3602    DPXDPEO.L(O,T)=Ao(o,t)*dpydpeo.l(o,t); dpxdpmo.l(o,t)=ao(o,t)

*dpydpmo.l(o,t);
3603
3604
3605
3606    AALP.L(P,T)=AP0(P); rp.l(p,t)=rp0(p); lp.l(p,t)=lp0(p);
3607    KP.L(P,T)=KP0(P)+deplp0(p); EP.L(P,T)=XEP0('ELEC',P); impp.l(p,t)
```

```
=impp0(p)+
3608    impdp0(p);
3609
3610                AALN.L(N,T)=sum(c,AC0(C));      rn.l(n,t)=sum(c,rc0(c));
ln.l(n,t)=sum(c,

lc0(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,impc0(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)=XEE0('ELEC',e);
3617    impe.l(e,t)=impe0(e)+impde0(e);
3618
3619    AALO.L(O,T)=AO0(O); ro.l(o,t)=ro0(o); lo.l(o,t)=lo0(o);
3620    KO.L(O,T)=KO0(O)+deplo0(o); EO.L(O,T)=XEo0('ELEC',o); impo.l(o,t)

=impo0(o)+
3621    impdo0(o);
3622
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
```

```
3650   PEP.L(P,T)=wmep(p,t); PEN.L(N,T)=wmen(n,t); PEE.L(E,T)=wmee(e,t);
3651   PEO.L(O,T)=wmeo(o,t);
3652
3653      CP.L(P,T)=QP0.L(P);  CCN.L(N,t)=Qn0.L(n);    ce.l(e,t)=ce0(e);
CO.L(O,T)

=QO0.L(O);
3654
3655   EXPP.L(P,T)=PEXP0(P); EXPN.L(N,T)=sum(c,cEXP0(c));
3656
3657   EXPO.L(O,T)=OEXP0(O); expe.l(e,t)=eexp0(e);
3658
3659   PL.L(T)=1; PR.L(T)=1; PK.L(T)=1; PA.L(T)=1;
3660
3661   PCP.L(P,T)=1; PCN.L(N,T)=1; PCE.l(e,t)=1; PCO.L(O,T)=1;
3662
3663   invest.l(t)=0; q.l(p,t)=1;
3664
3665   cscs.l(p,t)=0.04; csce.l(p,t)=0.01;
3666
3667   lscs.l(p,t)=0.03; lsce.l(p,t)=0.01;
3668
3669   scs.l(p,t)=0.07; sce.l(p,t)=0.02;
3670
3671           invp.l(p,t)=invp0(p);        invn.l(n,t)=sum(c,invc0(c));
invo.l(o,t)=invo0(o)

;
3672
3673   DISPh.L(h,T)=disp0(h);
3674   tdisph.l(h,t)=disp0(h)+sav0(h);
3675
3676   disp.l(t)=sum(h,disp0(h));
3677
3678   totdisp.l=m*sum(h,disp0(h)); tb.l(t)=tb0-timpd0;
3679
3680   GDP.L(T)=sum(h,disp0(h))-tb0;
3681
3682   k.l(t)=totk0; q.l(p,t)=1
3683
3684
3685
3686
3687
3688
3689
3690
3691  * Solve the model
INCLUDE    C:\SLMOD\MOD.INC
3693   model mod1/
3694   dtottax,
3695   dtotimp,
3696   DEFPUA,
3697   DEFPUR,
```

```
3698   DEFPUL,
3699   DEFPUK,
3700   DEFP1P,
GAMS 2.25.059  386/486 DOS                    11/13/96 17:16:17  PAGE
75
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


3701   DEFP2P,
3702   DEFP3P,
3703   DEFP4P,
3704   DEFPYP,
3705   DEFP1N,
3706   DEFP2N,
3707   DEFP3N,
3708   DEFP4N,
3709   DEFPYN,
3710   DEFP1E,
3711   DEFP2E,
3712   DEFP3E,
3713   DEFP4E,
3714   DEFPYE,
3715   DEFP1O,
3716   DEFP2O,
3717   DEFP3O,
3718   DEFP4O,
3719   DEFPYO,
3720   DDPYDPAP,
3721   DDPYDPRP,
3722   DDPYDPLP,
3723   DDPYDPKP,
3724   DDPYDPEP,
3725   DDPYDPMP,
3726   DDPYDP4P,
3727   DDP4DP3P,
3728   DDP3DP2P,
3729   DDP2DP1P,
3730   DDP1DPAP,
3731   DDP1DPKP,
3732   DDP4DPEP,
3733   DDP3DPLP,
3734   DDP2DPRP,
3735   DDPYDPAN,
3736    DDPYDPRN,
3737    DDPYDPLN,
3738    DDPYDPKN,
3739    DDPYDPEN,
3740    DDPYDPMN,
3741    DDPYDP4N,
3742    DDP4DP3N,
3743    DDP3DP2N,
3744    DDP2DP1N,
3745    DDP1DPAN,
3746   ddp1dpa1,
```

```
3747   DDP1DPKN,
3748   DDP4DPEN,
3749   DDP3DPLN,
3750   DDP2DPRN,
3751   ddp2dpr1,
3752    DDPYDPAE,
3753    DDPYDPRE,
GAMS 2.25.059  386/486 DOS                    11/13/96 17:16:17  PAGE
76
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


3754    DDPYDPLE,
3755    DDPYDPKE,
3756    DDPYDPEE,
3757    DDPYDPME,
3758    DDPYDP4E,
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    DDPYDP4O,
3774    DDP4DP3O,
3775    DDP3DP2O,
3776    DDP2DP1O,
3777    DDP1DPAO,
3778    DDP1DPKO,
3779    DDP4DPEO,
3780    ddp4dpe1,
3781    DDP3DPLO,
3782    DDP2DPRO,
3783    DDPXDPAP,
3784    DDPXDPRP,
3785    DDPXDPLP,
3786    DDPXDPKP,
3787    DDPXDPEP,
3788    DDPXDPMP,
3789    DDPXDPAN,
3790    DDPXDPRN,
3791    DDPXDPLN,
3792    DDPXDPKN,
3793    DDPXDPEN,
3794    DDPXDPMN,
3795    DDPXDPAE,
```

```
3796    DDPXDPRE,
3797    DDPXDPLE,
3798    DDPXDPKE,
3799    DDPXDPEE,
3800    DDPXDPME,
3801    DDPXDPAO,
3802    DDPXDPRO,
3803    DDPXDPLO,
3804    DDPXDPKO,
3805    DDPXDPEO,
3806    DDPXDPMO,
GAMS 2.25.059  386/486 DOS                    11/13/96 17:16:17  PAGE
77
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


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   DEFMCN,
3834   DEFMCE,
3835   DEFMCO,
3836   PRMCP,
3837   ppcomp,
3838   PRMCN,
3839   nncomp,
3840  *PRMCE,
3841    PRMCO,
3842    oocomp,
3843   PCONS,
3844   pcons1,
```

```
3845   nCONS,
3846   ncons1,
3847   ECONS,
3848   econs1,
3849   EINTERE,
3850   EINTERF,
3851   OCONS,
3852   ocons1,
3853  DEFPMP,
3854   DEFPMN,
3855   DEFPME,
3856   DEFPMO,
3857   DPEP,
3858   DPEN,
3859   dpenb,
```



```
3860   DPEE,
3861   dpeeb,
3862   DPEO,
3863   dpeob,
3864   DCP,
3865   DCN,
3866   DCE,
3867   DCO,
3868   DEXPP,
3869   DEXPnA,
3870   DEXPnB,
3871    DEXPEA,
3872   DEXPEB,
3873    DEXPOA,
3874   DEXPOB,
3875    kstock,
3876    kstock1
3877    dinvest,
3878  * dinvestm,
3879  * dinvest1,
3880  * invlow,
3881    dlabscs,
3882    dlscsc,
3883    dlabsce,
3884    dlscec,
3885    dcapscs,
3886    dcscsc,
3887    dcapsce,
3888    dcscec,
3889  * dmrscs,
3890  *dmrsce,
3891    dscs,
3892  *  dscsc,
3893    dsce,
```

```
3894  * dscec,
3895    dq,
3896  * dq1,
3897  *dsav,
3898  * dsav1,
3899   dsavh,
3900  * dsavh1,
3901   ddomsav,
3902   LMARKET,
3903   RMARKET,
3904  * rmarket1,
3905   AMARKET,
3906   KMARKET,
3907  * kmarket1
3908  *DPQP,
3909  * DPQN,
3910  * DPQE,
3911  * DPQO,
3912   DPCP,
```



```
3913   DPCN,
3914   DPCE,
3915   DPCO,
3916   PMARKET,
3917   nMARKET,
3918   emarket,
3919   DPI,
3920   DPINV,
3921   dpinv1,
3922   DnINV,
3923   dninv1,
3924   DOINV,
3925   doinv1,
3926   OMARKET,
3927   dtb,
3928   INCOME,
3929   incomeu,
3930   incomer,
3931   incomee,
3932   consinc,
3933   DEFGDP,
3934   dtotdisp /;
3935
3936   mod1.optfile=1;
3937   SOLVE mod1 USING nlp MAXIMIZING totDISP;
3938   mod1.optfile=0;
3939  * solve sl1 using nlp maximizing totdisp;
3940  * solve sl1 using nlp maximizing totdisp;
3941  * solve sl1 using nlp maximizing totdisp;
3942  * Display variables
```

```
INCLUDE    C:\SLMOD\SLDISA.INC
3944  * Display variables
3945
3946   DISPLAY
3947
3948   k.l,
3949
3950   scs.l, sce.l, lscs.l, lsce.l, cscs.l, csce.l, q.l,
3951   savh.l, Xe.L, wmee, invest.l,
3952
3953   intere.l,
3954
3955  * MUP.L, MUN.L, MUE.L, MUO.L,
3956
3957   PUA.L, PUL.L, PUK.L, pur.l,
3958   pa.l, pl.l, pk.l, pr.l,
3959
3960  * PYP.L, PYN.L, PYE.L, PYO.L,
3961  * p1p.l, p1n.l, p1e.l, p1o.l,
3962  * p2p.l, p2n.l, p2e.l, p2o.l,
3963  * p3p.l, p3n.l, p3e.l, p3o.l,
3964  * p4p.l, p4n.l, p4e.l, p4o.l,
3965
GAMS 2.25.059  386/486 DOS                    11/13/96 17:16:17  PAGE
80
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
C o m p i l a t i o n


3966  * AALP.L, rp.l, lp.l,KP.L, EP.L,
3967  * aaln.l, rn.l, LN.L,  KN.L , EN.L,
3968
3969  * aaLE.L, re.l, le.l, KE.L, EDEME.L,
3970  * aaLO.L, ro.l, lo.l, KO.L, EO.L,
3971
3972   XP.L,  XN.L,
3973
3974   XO.L,  xe.l,
3975
3976   DPP.L  , DPN.L  , DPE  , DPO.L  ,
3977
3978   DDP.L , DDN.L ,
3979
3980   DDE.L , DDO.L ,
3981
3982  * PMP.L  , PMN.L    , PMO.L  ,
3983
3984
3985   IMPP.L , IMPN.L ,
3986
3987   impe.l, IMPO.L ,
3988
3989   PEP.L  , PEN.L  , PEE.L  , PEO.L  ,
3990
3991  * CP.L , CCN.L , CO.L  ,
```

```
3992
3993   EXPP.L , EXPN.L ,
3994
3995    EXPO.L , expe.l,
3996
3997  *  PCP.L  , PCN.L  , PCO.L  ,
3998   DISPh.L, disp.l, savh.l, tb.l, invest.l,
3999
4000   GDP.L;
4001
4002
4003
4004
4005
4006
4007
4008  *$include sl6put.inc
4009
GAMS 2.25.059  386/486 DOS                        11/13/96 17:16:17  PAGE
81
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
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\MOD.INC
    3943 INCLUDE        931  .C:\SLMOD\SLDISA.INC


COMPILATION TIME     =       15.370 SECONDS        VERID MW2-00-059


USER: The World Bank - for internal use only         G960611:1335CR-MW2
      For Modeling Support - J. Kreuser x32796

**** FILE SUMMARY

INPUT      C:\SLMOD\SL7FIN.GMS
OUTPUT     C:\SLMOD\SL7OUT.DOC
```