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SPATIAL EQUILIBRIUM MODELING FOR INTER-REGIONAL TRADE FLOW ESTIMATION AND AGRICULTURAL POLICY ANALYSIS IN COSTA RICA

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THE REPOSA PROJECT

The Research Program on Sustainability in Agriculture (REPOSA) is a cooperation between Wageningen Agricultural University (WAU), the Center for Research and Education in Tropical Agriculture (CATIE), and the Costa Rican Ministry of Agriculture and Livestock (MAG). In addition, REPOSA has signed memoranda of understanding with numerous academic, governmental, international and non-governmental organizations in Costa Rica.
The overall objective of REPOSA is the development of an interdisciplinary methodology for land use evaluation at various levels of aggregation. The methodology, based on a modular approach to the integration of different models and data bases, is denominated *USTED* (*Uso Sostenible de Tierras En el Desarrollo*; Sustainable Land Use in Development).
REPOSA provides research and practical training facilities for students from WAU as well as from other Dutch and regional educational institutions.
REPOSA's research results are actively disseminated through scientific publications, internal reports, students' thesis, and presentations at national and international conferences and symposia. Demonstrations are conducted regularly to familiarize interested researchers and organizations from both within and outside Costa Rica with the *USTED* methodology.
REPOSA is financed entirely by WAU under its Sustainable Land Use in the Tropics program, sub-program Sustainable Land Use in Central America. It operates mainly out of Guápiles where it is located on the experimental station *Los Diamantes* of MAG.

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REPOSA (*Research Program on Sustainability in Agriculture*, o sea Programa de Investigación sobre la Sostenibilidad en la Agricultura) es una cooperación entre la Universidad Agrícola de Wageningen, Holanda (UAW), el Centro Agronómico Trópical de Investigación y Enseñanza (CATIE) y el Ministerio de Agricultura y Ganadería de Costa Rica (MAG). Además REPOSA ha firmado cartas de entendimiento con organizaciones académicas, gubernamentales, internacionales y non-gubernamentales en Costa Rica.
REPOSA ha desarollado una metodología cuantitativa para el análisis del uso sostenible de la tierra para apoyar la toma de decisiones a nivel regional. Esta metodología, llamada USTED (Uso Sostenible de Tierras En el Desarollo) involucra dimensiones económicas y ecológicas, incluyendo aspectos edafológicos y agronómicos.
REPOSA ofrece facilidades para investigaciones y enseñanza para estudiantes tanto de la UAW, como de otras institutiones educacionales holandesas y regionales.
REPOSA publica sus resultados en revistas científicas, tesis de grado, informes informales, y ponencias en conferencias y talleres. REPOSA regularmente organiza demostraciones para investigadores de Costa Rica y de otros países para familiarizarlos con la metodología USTED.
REPOSA es financiado por la UAW bajo su Programa del Uso Sostenible de la Tierra en los Areas Trópicos. La sede de REPOSA está ubicada en la Estación Experimental Los Diamantes del MAG en Guápiles.

1. Introduction

Issues relating to the efficiency in the allocation, pricing and distribution of agricultural products across space are of primary importance in the development of agricultural markets and trade. An effective marketing system is one which efficiently links the different regions of surplus and deficit production within a country (including taking account of the role of foreign trade) in order to achieve optimal exploitation of the comparative advantages of all regions. Even though there now exists considerable methodological research on the trade of market commodities under spatially dispersed competitive markets (*e.g.*, Samuelson, 1952; Takamaya and Judge, 1964; Takamaya and Judge, 1971), as well as a clear theoretical exposition of models of spatial equilibrium (Martin, 1981), applied research is much less[1]. This is particularly so for developing countries where data limitations often prevent successful development and application of Spatial Equilibrium Models (SEMs). Arguably, insights that result from spatial equilibrium analysis are even more important in developing as opposed to in developed countries, given that resources in the former are more limited, making their optimal allocation particularly imperative.

For Costa Rica, previous research at the micro and meso levels in the Atlantic Zone (Jansen and van Tilburg, 1996) suggests serious agricultural marketing deficiencies in terms of sub-optimal marketing structure, conduct and performance. However, no information was available or could be generated regarding trade flows between regions within Costa Rica. Analysis of inter-regional trade is relevant because several constraints may prevent an optimal flow between regions and, consequently, reduce consumer and producer welfare. While the size of trade flows is determined by conditions of supply (*e.g.*, costs of production) and demand (*e.g.*, purchasing power), these may be sub-optimal as a result of conditions related to transaction costs (*e.g.*, high transport costs) and government policies (*e.g.*, measures to prevent free trade in basic staples to control food security in the country). Once bottlenecks in trade flows have been identified, measures can be taken to change particular conditions in order to increase national welfare. Therefore, it is important to design a theoretical framework for macro analysis of optimal production, consumption and trade for the most important agricultural commodities in Costa Rica, with which current and possible future government policies can be analyzed.

In principle, actual trade flows between regions can be measured. For example, studies have been conducted in Indonesia in which transport flows of certain commodities (*e.g.*, fruits and vegetables) were measured by checking trucks at weighing bridges to determine types and weight of the cargo, as well as to estimate the origin of commodities to be supplied to the wholesale market (van Tilburg, 1981). However, such studies tend to be prohibitively expensive, while providing only snapshot-type information about the actual situation at a given moment in time. Therefore, a preferred method to obtain trade flow estimates of agricultural commodities is based on quantitative modelling and consists of the development of a Spatial Equilibrium Model (SEM). These kind of models are based on behavioral relations of producers and consumers, while simultaneously taking transaction costs and government policies into account. This method is an indirect one and its usefulness depends on the quality of the underlying data, the econometric analyses, and the optimization model, as well as the analytical skills of the researchers involved. Once all these

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[1] Examples include Martin and Zwart (1975), Pieri *et al.* (1977) and Krishnaiah & Krishnamoorthy (1988).

factors are firmly in place, the resulting SEM will be a useful tool for the simulation and analysis of the effects of alternative policy measures in the short to medium term (up to 10-15 years).

Consequently, the objectives of this study are: (1) to model the actually prevailing spatial patterns of supply, demand, trade flows and prices for major agricultural commodities in Costa Rica; (2) to assess the degree to which current trade policies lead to sub-optimal welfare levels; and (3) to determine the effect on social welfare of expected future supply and demand developments as well as of possible infra-structural government policies. A SEM for Costa Rica was developed, considering the 17 most important agricultural commodities in Costa Rica, the six planning regions as defined by the Costa Rican government, as well as the rest-of-the-world (ROW) as a seventh region in order to take international trade into account.

The remainder of this paper is structured as follows: whereas the next paragraph justifies the regional analysis and selects commodities, the third section provides a mathematical description of the SEM in which aggregate welfare is maximized subject to supply, demand and resource restrictions. Moreover, results of model parameter estimation are presented, including demand and supply elasticities as well as transport costs for the identified commodities and regions. In the fourth section, results of the base run as well as of a number of policy simulations are discussed. The base run model specification reflects the prevailing situation in terms of regional equilibrium commodity supply and demand, corresponding prices, inter-regional trade flows, as well as levels of imports and exports. The base model is validated against actual 1995 data, and used as the basis for policy simulations. The latter include specifications relating to government trade policies, infra-structural development, technological progress in agricultural production, and changes in demand as a result of income and population growth. Each scenario is evaluated in terms of changes in welfare, land use and trade patterns. Finally, the last section provides a summary of the main results as well as some concluding observations.

2. Regional analysis and commodity selection

For the analysis in this paper, Costa Rica is divided into six planning regions including the Central, Pacifico, Chorotega, Brunca, Norte and the Atlantica regions. These planning regions correspond to those distinguished by the Costa Rican government during the period 1986-1988 (Figure 1 and Geurts *et al.*, 1997). Distinguishing between these regions is important for a number of reasons. First, since agro-ecological conditions tend to differ significantly across space, they determine to a large extent the commodities that can be produced in each region. In addition, bio-physical factors are important determinants of production technologies and corresponding yield levels. Second, demand for agricultural products has been shown to significantly differ by region, mainly due to spatial differences in per capita household income, household size, degree of urbanization, and consumption preferences (Geurts *et al.*, 1997).

In this study 17 agricultural products (fifteen crops as well as beef and milk) are considered, selected on the basis of their relative importance (at the national level) in terms of cultivated area and value of production. Crops included in the study are basic grains (rice, maize and beans), traditional export crops (coffee, banana and sugar), non-traditional export crops (plantain, palm heart, mango, melon, pineapple and cassava) and fruits and vegetables (orange, onion and potato).

3. Methodology

3.1 Specification of the SEM

In this section, a mathematical description of the SEM is presented. Each of the regions included in the SEM may be a producer of a commodity, a consumer of that commodity, or a combination of the two. While it is assumed that in principle each region can trade any commodity with any other region (including the ROW region), actual production of a given commodity in a given region is limited by bio-physical conditions that prevail in that region. Given a set of user-specified restrictions (including those determined by bio-physical conditions as well as those based on socio-economic policies), a SEM allocates resources in an efficient manner across space by maximizing a quasi-welfare function that consists of the sum of the domestic consumer and domestic producer surplus across commodities and regions net of transportation costs, plus exports minus imports. Regarding the objective function of a SEM, the term 'quasi-welfare', rather than 'welfare', is appropriate because of the fact that consumer surplus (as measured from a Marshallian demand function) is only an approximate welfare measure in the presence of income effects (Willig, 1976). However, for the sake of simplicity, the term 'welfare' instead of 'quasi-welfare' will be used in the remainder of this paper.

A SEM can be considered as a particular case of a sector model (Hazell and Norton, 1986) in which a spatial dimension is introduced on the supply side as well as in consumer demand. The following is a mathematical representation of the SEM as developed in this study, whereas Tables 3.1 to 3.4 provide a description of the notation used. The objective function to be maximized represents Net Social Welfare (*NSW*), as follows:

$$\begin{aligned} Max\ NSW = & \sum_{c}\sum_{j \neq world}\left[\frac{1}{2\varepsilon_{cj}^{D'}}Q_{cj}^{D^2} - \frac{\overline{q_{cj}}(1-\varepsilon_{cj}^{D})}{\varepsilon_{cj}^{D'}}Q_{cj}^{D}\right] - \sum_{c}\sum_{i \neq world}\left[\frac{1}{2\varepsilon_{ci}^{S'}}Q_{ci}^{S^2} - \frac{\overline{q_{ci}}(1-\varepsilon_{ci}^{S})}{\varepsilon_{ci}^{S'}}Q_{ci}^{S}\right] \\ & + \sum_{c}\left[p_c^X X_c - p_c^M M_c\right] - \sum_{c}\sum_{i}\sum_{j} t_{cij}T_{cij} \end{aligned} \tag{1}$$

where

$$\varepsilon_{cj}^{D'} = \varepsilon_{cj}^{D}\frac{\overline{q_{cj}}}{p_{cj}} \qquad \text{for all } c,j \tag{2}$$

and

$$\varepsilon_{ci}^{S'} = \varepsilon_{ci}^{S}\frac{\overline{q_{ci}}}{p_{ci}} \qquad \text{for all } c,i \tag{3}$$

Here ε_{cj}^{D} represents the own-price elasticity of demand of commodity *c* in demand region, ε_{ci}^{S} is the own-price elasticity of supply of commodity c in supply region i, and $\overline{q_c}$ and $\overline{p_c}$ are actual equilibrium commodity production and price levels, respectively. The first two terms in equation (1) represent the sum of consumer and producer surplus resulting from domestic demand (Q_{cj}^D) and domestic supply (Q_{ci}^S) of commodities (c) in demand regions (j) and supply regions (i), respectively. The third term represents the surplus from exports (X_c) and imports (M_c), where p_c^X and p_c^M are constant export (f.o.b.) and import (c.i.f.) prices corrected for export taxes and import duties, respectively[2]. The last term represents total transport costs related to the trade flows (T_{cij}) of commodities between supply and demand regions valued at the unit transport cost (t_{cij}).

NSW is maximized subject to supply, demand and resource restrictions. Supply restrictions per region state that supply (Q_{ci}^S) of commodity c by supply region i is greater than or equal to the sum of shipments (T_{cij}) of commodity c from this supply region i to all demand regions j:

$$Q_{ci}^S \geq \sum_j T_{cij} \qquad \text{for all } c,i \qquad (4)$$

Similarly, demand restrictions per region state that demand (Q_{cj}^D) of commodity c in demand region j is smaller than or equal to the sum of shipments (T_{cij}) of commodity c to this demand region j from all supply regions i:

$$Q_{cj}^D \leq \sum_i T_{cij} \qquad \text{for all } c,j \qquad (5)$$

National commodity balances are defined for market clearance, thus guaranteeing supply and demand equilibrium conditions, and state that total demand equals total supply for each commodity c:

$$\sum_j Q_{cj}^D = \sum_i Q_{ci}^S \qquad \text{for all } c \qquad (6)$$

Total national exports (X_c) of commodity c equal the sum of shipments T_{cij} of commodity c from each supply region i (except $i{=}ROW$) to demand region $j{=}ROW$:

$$X_c = \sum_{i \neq ROW} T_{j=ROW,ci} \qquad \text{for all } c \qquad (7)$$

Similarly, total national imports (M_c) of commodity c equal the sum of shipments T_{cij} of commodity c to each demand region j (except $j{=}ROW$) from supply region $i{=}ROW$:

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[2] Domestic consumer surplus on imported products and domestic producer surplus on exported products are taken into account in the calculation of net social welfare. On the other hand, neither producer nor consumer surpluses in the ROW are taken into account in our national sector model. In the case of completely elastic import supply, producer surplus in the ROW is zero, while in the case of completely elastic export demand, consumer surplus in the ROW is zero.

$$M_c = \sum_{\substack{j \neq ROW \\ d}} T_{i=ROW,cj} \qquad \text{for all } c \qquad (8)$$

Finally, the land resource restriction states that the supply (Q_{ci}^S) of all commodities c in supply region i divided by the commodity-specific yield per hectare (y_{ci}) is smaller than or equal to the total regional area availability (l_i)[3]:

$$\sum_c Q_{ci}^S / y_{ci} \leq l_i \qquad \text{for all } i \qquad (9)$$

Prices are determined endogenously on the basis of consumer behavior (as expressed in the demand functions that underlie the demand elasticity estimates) and producer behavior (as expressed in the production functions that underlie the supply elasticity estimates), assuming competitive market clearing processes. However, unlike in a general equilibrium model, incomes are kept exogenous. In addition, data limitations prevented the inclusion in the model of interdependencies among commodities on the supply side of the agricultural sector (as would be captured by cross-price elasticities of supply) and product substitution on the demand side (as would be represented by cross-price elasticities of demand). Equilibrium supply (P_{ci}^S) and demand (P_{cj}^D) prices are calculated as follows:

$$P_{ci}^S = \overline{p_{ci}} + \frac{(Q_{ci}^S - \overline{q_{ci}})}{\frac{\varepsilon_{ci}^S}{\overline{p_{ci}} / q_{ci}}} \qquad \text{for all } c,i \qquad (10)$$

$$P_{cj}^D = \overline{p_{cj}} + \frac{(Q_{cj}^D - \overline{q_{cj}})}{\frac{\varepsilon_{cj}^D}{\overline{p_{cj}} / q_{cj}}} \qquad \text{for all } c,j \qquad (11)$$

Table 3.1 Superscripts

Indices	Description
X	exports
M	imports
S	supply
D	demand

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[3] Yield levels per hectare for the commodities beef and milk are based on the average pasture carrying capacity for each of the production systems and the corresponding production levels.

Table 3.2 Subscripts

Indices	Description
i	supply region
j	demand region
c	commodity

Table 3.3 Variables

Variables	Description	Unit of measurement
NSW	net social welfare	10^3 US$ per year
Q^S_{ci}	supply quantity of crop c in region i	MT per year
Q^D_{cj}	demand quantity of crop c in region j	MT per year
T_{cij}	trade flow of crop c from region i to region j	MT per year
X_c	export quantity of crop c	MT per year
M_c	import quantity of crop c	MT per year
P^S_{ci}	equilibrium supply price of crop c	US$ per kg
P^D_{cj}	equilibrium demand price of crop c	US$ per kg

Table 3.4 Parameters

Parameters	Description	Unit of measurement
t_{cij}	transport costs of commodity c from region i to region j	US$ per kg
$\overline{p_{ci}} = \overline{p_{cj}}$	actual equilibrium price of commodity c in supply (i) and demand (j) regions	US$ per kg
p^X_c	actual export price of commodity c	US$ per kg
p^M_c	actual import price of commodity c	US$ per kg
$\overline{q_{ci}}$	actual equilibrium production of commodity c in supply regions i	MT
$\overline{q_{cj}}$	actual equilibrium consumption of commodity c in demand regions j	MT
ε^S_{ci}	supply elasticity of commodity c in supply regions i	-
ε^D_{cj}	demand elasticity of commodity c in demand regions j	-
y_{ci}	yield of commodity c in supply regions i	MT per hectare
l_i	land availability in supply regions i	hectares

3.2 Estimation of regional demand elasticities

Geurts *et al.* (1997) used budget data for nearly 4000 households from the 1987-1988 National Household and Income and Expenditure Survey (DGEC, 1988) for the estimation of demand models from which expenditure and own-price elasticities for 24 major food categories were calculated. Each food category consisted of a variety of agricultural products and estimations were made at the national level. Since for the SEM regional elasticities are required, the same data set was used to obtain domestic regional elasticity estimates for the 17 agricultural commodities included in the SEM, for each of the six planning regions.

3.2.1 *Specification and estimation of demand models*

The specification of the demand models for the estimation of regional demand elasticities was based on the model presented in Geurts *et al.* (1997), as follows:

$$\ln \exp_c = \alpha_c + \beta_c \ln x + \gamma_c (\ln x)^2 + \delta_c \ln p_c + \varphi_c (\ln p_c . \ln x) + \lambda_c \ln N + \kappa_c \ln CPI \qquad (12)$$

Per capita expenditure (*exp$_c$*) on agricultural commodity *c* was hypothesized to depend on (1) per capita total monthly consumption expenditure (*x*) as a proxy for total income; (2) own-price (*p$_c$*); (3) number of household members per household (*N*); and (4) the general monthly consumer price index (*CPI*) as a proxy for the general price level. Per capita expenditure can be expected to be negatively influenced by household size, as larger households normally have lower per capita income as well as expenditure and may be more efficient in their use of foods. The monthly overall consumer price index (the CPI for food products only was unavailable) was included for two reasons, the first of which is to pick up effects of other prices on the demand for a particular category where the share of the latter in total expenditure is assumed to be small. In this way, a potential source of missing variable bias is eliminated (Deaton and Case, 1988). The second reason to include the CPI as an explanatory variable in the model is its traditional role of deflating nominal economic variables. Finally, a quadratic logarithmic expenditure term was included to allow for the possibility that commodities be luxury, necessity or inferior goods at different levels of income (Timmer, 1981), while the interaction term of per capita expenditure with unit price also allows price elasticities to vary according to total expenditure level. The two latter explanatory variables provided elasticity estimates by income quartile.

Equation (12) was estimated using the so-called 'double hurdle' approach (or Cragg specification) which permits separate analysis of the decisions whether, and how much, to consume (Cragg, 1971; Haines *et al.*, 1988). This approach involves the combination of a Probit regression for all observations, and a separate truncated regression for positive expenditures. Probit models (Maddala, 1992) assume that the basic regression model is specified as follows:

$$\exp_i^* = \beta_0 + \sum_{j=1}^{k} \beta_j x_{ij} + u_i \qquad (13)$$

where $\exp_i^*$ is a 'latent' variable which is not observed, x denotes a vector of explanatory variables, and u_i represents an error term. Observed is a dummy variable $\exp_i$ which is defined as follows:

$$\exp_i = \begin{cases} 1 & \text{if} \exp^* > 0 \\ 0 & \text{if otherwise} \end{cases} \qquad (14)$$

All available observations are used for the Probit model, where the dependent variable assumes a value of either zero (no purchase) or one (purchase). If $\exp_i$ is observed (*i.e.*, $\exp_i > 0$), the βs in (14) can be estimated. Combining (13) and (14) yields:

$$
\begin{aligned}
P_i &= \mathrm{Prob}\left(\exp_i = 1\right) = \mathrm{Prob}\left[u_i > -\left(\beta_0 + \sum_{j=1}^{k} \beta_i x_{ij}\right)\right] \\
&= 1 - F\left[-\left(\beta_0 + \sum_{j=1}^{k} \beta_i x_{ij}\right)\right]
\end{aligned}
\tag{15}
$$

where F is the cumulative distribution function (CDF) of u. If this CDF is symmetric, *i.e.*, $1 - F(-Z) = F(Z)$, we can write:

$$
P_i = F\left(\beta_0 + \sum_{j=1}^{k} \beta_j x_{ij}\right) \tag{16}
$$

If the errors u_i in (13) follow a normal distribution, the Probit model results.

The Cragg specification thus uses a Probit model as an indicator of whether $\exp_i^*$ is positive or not, while a truncated regression model is employed for the nonlimit (positive) observations. Both Probit and the truncated regression estimate equation (12) with the same set of explanatory variables; the only difference is that Probit uses a dummy dependent variable while the truncated regression uses only observations with a positive value for $\exp_i$.

3.2.2 Estimation results

Based on econometric estimation of equation (12), own-price elasticities of demand were estimated for each of the 17 commodities included in the SEM, as follows:

$$
\varepsilon_c^D = \delta + \varphi \ln x - 1 \tag{17}
$$

Results are shown in Table 3.5. A t-test was used to determine whether the elasticity estimates are significantly different from zero (Lizano, 1994). All own-price elasticities have the expected negative sign, with the exception of the positive demand elasticities for palmheart in the Norte and Atlantica regions. In the SEM model these demand elasticities were assigned their corresponding national demand elasticity value.

Table 3.5 Regional and national own-price elasticities of demand, by commodity

	Central	Pacifico	Chorotega	Brunca	Norte	Atlantica	Costa Rica
Rice	-0.83*	-0.89*	-0.99*	-0.77*	-0.85*	-0.99*	-0.86*
Maize	-0.93*	-0.97*	-0.89*	-1.09*	-0.81*	-0.84*	-0.94*
Beans	-0.93*	-0.98*	-0.67*	-0.89*	-0.87*	-0.93*	-0.89*
Coffee	-0.84*	-0.92*	-0.81*	-0.78*	-0.90*	-0.82*	-0.86*
Banana	-0.68**	-0.98*	-0.42	-0.53	-0.51	-0.61	-0.71*
Sugar	-0.88*	-1.07*	-1.10*	-0.94*	-0.95*	-1.05*	-0.99*
Plantain	-0.91*	-0.91*	-0.85**	-0.83**	-0.77**	-0.82**	-0.83*
Palm heart	-1.13	-1.22	-1.17	0.25	0.32	-1.11	-1.19*
Mango	-0.67**	-0.85**	-0.64**	-0.91**	-0.56**	-0.61**	-0.97*
Melon	-0.81*	-1.42*	-1.02*	-0.21*	-0.92*	-0.91*	-0.81*
Pineapple	-0.81*	-0.69**	-1.27	-0.95**	-0.14	-0.95**	-0.74*
Cassava	-0.75*	-0.74*	-0.53	-0.39	-0.56*	-0.43	-0.59*
Onion	-0.88*	-0.95*	-0.74*	-0.89*	-0.66*	-0.81*	-0.85*
Orange	-0.73*	-0.73**	-0.95**	-0.42	-0.08	-0.44	-0.74*
Potato	-0.86*	-0.85*	-0.82*	-0.82*	-0.75*	-0.80*	-0.82*
Beef	-0.92*	-0.93*	-0.91*	-0.94*	-0.78*	-0.90*	-0.90*
Milk	-0.85*	-0.98*	-0.83*	-0.89*	-0.93*	-0.83*	-0.88*

Significance level: * (**) significantly different from zero at the five (ten) percent level according to the t-test.

3.3 Estimation of regional supply elasticities

The estimation of regional supply elasticities requires time series data regarding prices and production of the respective commodities. Such data are not readily available in Costa Rica and construction of the necessary data base turned out to be a tedious and time consuming exercise. Nevertheless, time series data could be obtained from various sources either on a yearly basis (18 years or longer) or on a monthly basis (120 months or longer). Price data refer to the average annual or monthly price, while production data represent total annual or monthly production.

Yearly production and producer price data for coffee and sugar at the regional level were obtained from the Costa Rica Coffee Institute (ICAFE) and the Sugarcane Agroindustrial Association (LAICA), respectively. Regional production and national price data for basic grains were available from the National Production Council (CNP), while regional banana production data were obtained from the National Banana Corporation (CORBANA). Export prices for banana were taken from the FAO statistical database. For non-traditional export crops, fruits and vegetables, regional production and national price data on a monthly basis could be constructed from data available at the national wholesale market called the National Center for Supply and Distribution of Food Products (CENADA) where an estimated 60% to 70% of total national production of these products is traded. Finally, yearly production and price data for beef and milk were obtained from Montenegro and Abarca (1998).

3.3.1 Specification and estimation of supply models

Supply response models for annual crops were based on the standard Nerlove model (Askari and

Cummings, 1976), which includes the effects of price expectations and adjustment lags in production on agricultural supply, leading to the following reduced form equation:

$$Q_t = c_0 + c_1 Q_{t-1} + c_2 P_{t-1} + c_3 Z_t + v_t \tag{18}$$

Actual production Q_t is considered a function of lagged deflated prices P_{t-1}, lagged production Q_{t-1} and a non-price variable Z_t. The term c_0 represents the intercept and v_t is the disturbance term. Model coefficient estimates provide information on the area adjustment coefficient $(1-c_1)$ as well as on short-term (c_2) and long term supply response $(c_2/(1-c_1))$, respectively.

Often the use of harvested or planted area is preferred as a proxy for production since the latter is influenced by factors that can not be controlled by the producer (Rao, 1989). However, since data on harvested or planted area were not available at the regional level, regional production data were used as the dependent variable in equation (18). The assumption that farmers consider only last year's prices for this year's planting decisions, even though restrictive, is convenient in terms of simplicity of estimation. Moreover, in the case of time series with a limited number of observations, the inclusion of 2 or more lags may lead to insufficient degrees of freedom.

The supply response model used in this study is an adaptation of the standard Nerlove model, since it includes additional explanatory variables such as lagged deflated prices of competitive crops $(P_{c,t-1})$, lagged deflated prices of major inputs $(P_{i,t-1})$ for inputs i, and a time trend (T) to correct for the possibility of technical change, improvements in infrastructure or other structural factors. This resulted in the following supply response model to be estimated for annual crops:

$$Q_t = c_0 + c_1 Q_{t-1} + c_2 P_{t-1} + c_3 P_{c,t-1} + c_4 P_{i,t-1} + c_5 T + v_t \tag{19}$$

Commodities for which supply response was estimated on the basis of monthly data (due to a lack of a sufficiently long time series with yearly observations), a seasonal dummy S_t was introduced in the above specification to correct for seasonalities in production, as well as an auto-regressive term *AR* to correct for serial correlation of residuals by taking into account slowly moving influences (Maddala, 1992).

Supply response models for perennial tree crops require a slightly different approach, since planting and harvesting decisions reflect two different moments in time. Stryker (1990) and Frimpong-Ansah (1992) suggest that production of perennials in a given time period is also determined by the so-called "normal" production N_t. Normal production in this context refers to the level of production that can be expected from a given planted area. On the basis of time series data on planted area, yield levels over the lifetime of the tree, as well as the average tree life, normal production corresponding to the planted area is calculated. The specification of the supply response model for perennial crops is given by:

$$lnQ_t = c_0 + c_1 lnQ_{t-1} + c_2 lnP_{t-1} + c_3 lnP_{c,t-1} + c_4 lnP_{i,t-1} + c_5 lnN_t + c_6 T + v_t \tag{20}$$

The short term price elasticity (c_2) reflects adjustments in the application of variable production factors, while the long term price elasticity (calculated as $c_2/(1-c_1)$) reflects the area adjustment coefficient (Nerlove, 1958). Although these price elasticities do not capture the effect of prices on planting decisions (since these are incorporated in the normal production variable), the long term price elasticity gives an indication of farmers' behavior with respect to maintenance and improvement of the planted area (Frimpong-Ansah, 1992).

The inclusion of lagged prices of competitive crops as explanatory variables requires time series data for the largest possible number of years. As some time series were incomplete or lacking for recent years, data were respectively interpolated and extrapolated in order to be able to work with the longest possible set of time series data. Interpolation was performed by assuming a gradual change between points of observation for which data were missing, while extrapolation or forecasting of non-available data was performed by using the Box-Jenkins approach (Maddala, 1992)[4].

The inclusion of lagged prices of competitive crops also requires the identification of the latter. This was done on the basis of agro-ecological factors such as climate and soil, with the help of information in Cortes (1994). Unlike individual crops, cattle can be raised everywhere and indeed beef and milk production takes place all across Costa Rica.

3.3.2 Estimation results

Supply elasticities were estimated for all commodities included in this study in each of the relevant planning regions as well as at the national level, and calculated on the basis of the short term supply response or own-price coefficient ($dq/dp=c_2$ in equations 19 and 20). Supply elasticities are defined as follows:

$$\varepsilon_s = \frac{dq}{dp} * \frac{\bar{p}}{\bar{q}}$$

where $\bar{p}$ and $\bar{q}$ represent the average own-price and production levels for the number of observations included in the regression model.

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[4] The Box-Jenkins approach is a widely used methodology for time-series analysis and subsequent forecasting (Maddala, 1992). The core of the approach exists in the determination of the order of autoregressive (AR) and moving-average (MA) processes of a stationary time series, after which the ARMA model can be used for forecasting. A moving-average (MA) forecasting model uses lagged values of the forecast error to improve upon the current forecast, while each autoregressive (AR) term corresponds to the use of a lagged value of the residual in the forecasting equation for the residual.

Table 3.6 Regional and national supply elasticity estimates, by commodity

	Central	Pacifico	Chorotega	Brunca	Norte	Atlantica	Costa Rica
Rice	-	0.54*	0.74**	0.18	0.90*	0.26	0.82*
Maize	0.54*	0.61	0.35*	0.37**	0.24*	0.64	0.56*
Beans	0.20	0.25**	0.33*	0.40**	0.11	-	0.18
Coffee[1]	0.08	0.08	0.05	-	-	0.18**	0.08*
Banana	-	-	-	1.07*	-	1.78*	1.75*
Sugar	0.11*	0.39*	0.13*	0.49*	0.20*	-	0.29*
Plantain	n.a.	n.a.	-	-	0.63	0.53	0.53**
Palm heart	-	-	-	-	n.a.	n.a.	n.a.
Mango	n.a.	n.a.	n.a.	n.a.	n.a.	-	n.a.
Melon	0.44**	0.76*	0.55*	n.a.	-	n.a.	0.65*
Pineapple	n.a.	n.a.	-	n.a.	0.51*	n.a.	0.51*
Cassava	0.36*	-	-	-	0.23*	0.21*	0.24**
Onion	0.23*	-	0.68*	-	-	-	0.22*
Orange	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Potato	0.12	-	-	-	-	-	0.12
Beef	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.46*
Milk	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.56*

Significance level: * (**) significantly different from zero at the five (ten) percent level according to the t-test.

Notes: [1] Long term supply elasticities.

"n.a.": supply elasticities could not be calculated due to too few observations or total absence of regional production data.

"-" : no supply elasticity is determined as the product is not produced in the region.

Table 3.6 provides a summary of the estimation results. All supply elasticity estimates have the expected positive sign, and most are significantly different from zero according to the standard t-test. In some cases, regional supply elasticities could not be estimated due to a limited number of observations or a lack of data. For such cases it is assumed that the regional supply elasticity equals the corresponding national estimate. Detailed results are discussed in Appendix 1.

3.4 Inter-regional transport costs

Transportation costs determine to a significant extent comparative advantages of a particular region in the production of a specific commodity. Given prices as determined in properly functioning markets, farm gate prices depend mainly on transportation costs which thus are an important determinant of the economics of production of a given region. In this research, transportation costs between regions as well as to major export ports were calculated on the basis of an adaptation of regression models estimated for the Atlantica region as described in Jansen and Stoorvogel (1998).

In the original models used by Jansen and Stoorvogel (1998), transportation costs were hypothesized to depend on geographical distances between markets and farms (Dis_n) and quality of the road infrastructure (n). These models were estimated with farm-level data on transportation costs of commodities from farms to farmers' markets or to the national wholesale market (CENADA). Using a GIS, these survey data were combined with geographical data on the approximate location of sample farms and distances specified for four road types, and used to econometrically estimate a number of alternative regression models to assess the influence of road type on transportation costs. This resulted in the following preferred transportation cost model, where all estimated coefficients are statistically significantly different from zero at the 1% level or better:

$$UC = 0.0028 + 0.00022\,(Dis_1+Dis_2) + 0.00055\,(Dis_3+Dis_4) \qquad (21)$$

$$(N=56, R^2=0.72)$$

where UC represents the unit transport cost in US$ per kilogram, and Dis_n the distance on road type n (in kilometers), $n = 1,...,4$, ranging from best to worst type of road.

For the SEM, the model as depicted by equation (21) needed to be adjusted in several ways in order to obtain inter-regional transport costs for the considered commodities. First, the SEM considers inter-regional transport flows, taking into account only the best type of road, since inter-regional road connections are all qualified as type 1 roads. Second, distances between regions are calculated as the average distance between the geographical centers between each pair of regions, while distances to export harbors were calculated as the average distance from each region's geographical center to the nearest export harbor (Table 3.7). Distances were calculated on the basis of a digital road map for Costa Rica.

Table 3.7 Distances between regions wholesale markets and to export harbors (in km)

	Central	Pacifico	Chorotega	Brunca	Norte	Atlantica	World
Central	0.0	110.0	261.0	189.0	129.3	150.7	130.3
Pacifico	110.0	0.0	159.0	299.0	143.3	260.7	102.5
Chorotega	261.0	159.0	0.0	450.0	209.3	411.7	159.0
Brunca	189.0	299.0	450.0	0.0	318.3	339.7	299.0
Norte	129.3	143.3	209.3	318.3	0.0	219.7	181.5
Atlantica	150.7	260.7	411.7	339.7	219.7	0.0	88.0
World	130.3	102.5	159.0	299.0	181.5	88.0	0.0

Finally, for products that permit bulk transport (rice, maize, beans, banana and sugar), variable transport costs were estimated at $0.066*10^{-3}$ US$ per kilogram product (Schipper *et al.*, 1998). To summarize, total transport costs per kilogram product between regions were calculated as the sum of fixed costs ($2.8*10^{-3}$ US$/kg) and variable transport costs ($0.22*10^{-3}$ US$/kg or $0.066*10^{-3}$ US$/kg), where the latter are determined as the multiplicate of distance and variable transport cost per kilogram.

4. Results

4.1 Model validation

Model calibration was performed with data for the year 1995, the most recent year for which a complete set of agricultural statistics could be constructed for each commodity. The model's base run is based on 1995 data for production, consumption, imports and exports; corresponding prices in regional markets as well as in the relevant world markets; transport costs; own-price elasticities of supply and demand; and prevailing national trade policies. The latter include both tariff and non-tariff measures, including import taxes for a number of products, as well as export quota for basic grains, potato, onion and milk, with export levels for these crops determined by the government.

Commodities for which Costa Rica is engaged in international trade, supply of imports as well as demand for exports are assumed completely elastic (*i.e.*, infinitely large elasticities in absolute terms). The underlying assumption that neither Costa Rican import demand nor export supply will significantly affect international prices is justified given the relatively limited quantities traded[5]. The implication is that, in our model, even though exports contribute to domestic producer surplus, surplus that accrues to consumers in foreign countries is disregarded. Similarly, while imports contribute to the surplus of domestic consumers in Costa Rica, possible contributions to the surplus of foreign producers are disregarded as well. Finally, total land use is limited to the total agricultural area as determined by the CNP for 1988 (CNP, 1990).

Table 4.1 Agricultural production situation in 1995 and base run simulation

	Data 1995[1]						Base run results					
	Area (10^3 ha)	%[3]	Production (MT)	Prod.value[2] (10^6 US$)	%[4]	Price US$/kg	Area (10^3 ha)	%[3]	Production (MT)	Prod.value[2] (10^6 US$)	%[4]	Price US$/kg
Rice	48.3	1.7	178,249	43.4	2.8	0.24	44.3	1.7	174,860	41.1	2.5	0.23
Maize	16.9	0.6	28,138	5.0	0.3	0.18	14.2	0.5	26,213	3.8	0.2	0.15
Beans	36.2	1.3	24,148	12.8	0.8	0.53	37.5	1.4	24,318	13.3	0.8	0.54
Coffee	109.0	3.9	800,000	313.6	20.1	0.39	106.7	4.0	833,301	462.3	27.8	0.55
Banana	52.2	1.9	2,033,494	614.4	39.3	0.30	49.2	1.9	1,919,289	560.7	33.7	0.29
Sugar	43.0	1.5	2,950,000	77.4	5.0	0.03	40.8	1.5	2,954,340	76.9	4.6	0.03
Plantain	6.5	0.2	136,800	27.7	1.8	0.20	6.4	0.2	134,964	26.6	1.6	0.20
Palm heart	4.2	0.2	21,000	5.2	0.3	0.25	4.4	0.2	21,880	5.8	0.3	0.26
Mango	6.7	0.2	13,500	7.5	0.5	0.55	6.7	0.3	13,592	7.6	0.5	0.56
Melon	4.0	0.1	110,504	62.6	4.0	0.57	3.1	0.1	85,553	33.3	2.0	0.39
Pineapple	6.1	0.2	164,000	44.0	2.8	0.27	6.6	0.2	179,459	57.0	3.4	0.32
Cassava	7.3	0.3	87,000	16.3	1.0	0.19	6.5	0.2	97,773	28.0	1.7	0.29
Onion	0.7	0.0	16,488	5.1	0.3	0.31	0.7	0.0	16,335	4.8	0.3	0.29
Orange	22.5	0.8	150,000	14.3	0.9	0.10	21.5	0.8	143,579	12.8	0.8	0.09
Potato	2.2	0.1	43,606	20.3	1.3	0.47	2.2	0.1	43,748	20.9	1.3	0.48
Beef	2,057.0	73.8	93,586	145.0	9.3	1.55	1,957.2	73.6	97,860	167.5	10.1	1.71
Milk	363.0	13.0	539,300	147.8	9.5	0.27	352.2	13.2	528,369	140.1	8.4	0.27
Total	2,785.8	100.0		1,562.3	100.0		2,660.5	100.0		1.662.4	100.0	

Notes: [1] Based on 1995 data from the Executive Secretariat for Agricultural Sector Planning (SEPSA).
[2] Production value represents national production as valued against national prices.
[3] Cultivated area as percentage of total cultivated area.
[4] Commodity production value as a percentage of total production value.

Actual data for the year 1995 indicate that about 87% of the total agricultural area under the 17 commodities considered in this study was dedicated to pasture for beef and milk production, while

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[5] While this is true even for coffee, Costa Rica's share in total world exports of banana is about 15%, making export demand for Costa Rican bananas less than infinitely elastic. Nevertheless, also for banana an infinitely elastic demand in the world market was assumed given the absence of reliable estimates regarding elasticities of demand in Costa Rica's major export markets (*i.e.*, Europe and the USA).

the remaining 13% was used for crop production (Table 4.1)[6]. Most of the total crop area (56%) is still used for the production of traditional export crops, while basic grains and horticultural products occupy respectively 28% and 16% of the total crop area. In terms of production value, traditional export crops are most important (66% of the total for the 17 commodities), with livestock a distant second (18.5%), followed by horticultural crops (12%). Basic grains account for only 3.5% of total production value, even though they are important from a food security point of view (Stewart, 1991).

Validation of an agricultural sector model typically starts with a comparison of reported actual values and model results with respect to a series of variables which are used in a number of tests (Hazell and Norton, 1986). The latter usually include the capacity test, production test and price test. The model is validated by comparing base run results with the actual situation of 1995, in terms of area allocation (capacity test), agricultural production levels (production test), and production value, including product prices (price test). In general, our model is able to track the actual 1995 situation quite well, *i.e.*, base run results are very close to the actual 1995 situation (Table 4.1). The total area devoted to the 17 commodities in the base run is about 4% lower than in the actual situation, due to the slightly higher yield levels used in the base run. With the exception of melon and cassava, production of individual commodities in the base run nowhere deviates more than 10% from the actual 1995 production levels. Total production value in the base run exceeds the actual 1995 value by about 6%. This difference can be explained by the larger importance of export production in the base run for a number of commodities, leading to higher domestic prices (Table 4.2)[7].

One additional test was included which concerns the internal consistency of the model, considering the product-product dimension (Hazell and Norton, 1986). For the model to be internally consistent, for each commodity the sum of domestic supply and import quantities must be exactly balanced by the sum of domestic demand and export quantities. Since these variables are typically not measured in the same units, conversion factors had to be used to convert existing demand, supply, import and export data into the same units of measurements (Appendix 2). The data referring to the actual 1995 situation in Table 4.2 indicate that basic grains and milk are mainly produced for the national market, with exports and imports only being allowed by the government in the case of over-production and production shortfalls, respectively. In our model, banana and pineapple are exclusively produced for the export market, whereas coffee and sugar constitute other important traditional export crops. Palm heart, mango, melon and cassava are important non-traditional export crops. Other horticultural products are mainly for domestic consumption while beef is an important commodity in both the domestic and the export market.

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[6] However, the share of pastures in total cultivated area is certainly overestimated since not all crops were taken into account in the calculation of the total cultivated area.

[7] In the calculation of the production value, all production was valued against regional commodity producer prices instead of world market prices.

Table 4.2 Agricultural production balance in 1995 and base run simulation (MT)

	Year 1995					Base run				
	Domestic demand	Domestic supply	Imports	Exports	%[1]	Domestic demand	Domestic supply	Imports	Exports	%[1]
Rice	175,774	178,249	0	2,475	1.4	174,859	174,860	0	0	0.0
Maize	23,087	28,138	0	5,051	18.0	26,213	26,213	0	0	0.0
Beans	26,088	24,148	7,747	5,807	24.0	24,319	24,318	0	0	0.0
Coffee	113,043	800,000	0	686,957	85.9	61,025	833,301	0	772,276	92.7
Banana	0	2,033,494	0	2,033,494	100.0	0	1,919,289	0	1,919,288	100.0
Sugar	1,287,736	2,950,000	0	1,662,264	56.3	1,251,583	2,954,340	0	1,702,757	57.6
Plantain	120,540	136,800	0	16,260	11.9	103,106	134,964	0	31,859	23.6
Palm heart	8,115	21,000	0	12,885	61.4	6,565	21,880	0	15,315	70.0
Mango	7,662	13,500	0	5,838	43.2	7,545	13,592	0	6,047	44.5
Melon	6,610	110,504	0	103,894	94.0	8,294	85,553	0	77,259	90.3
Pineapple	0	164,000	0	164,000	100.0	0	179,459	0	179,459	100.0
Cassava	19,611	87,000	0	67,389	77.5	10,364	97,773	0	87,409	89.4
Onion	16,265	16,488	5,409	5,632	34.2	16,336	16,335	0	0	0.0
Orange	149,995	150,000	0	5	0.0	143,580	143,579	0	0	0.0
Potato	47,604	43,606	4,550	552	1.3	45,766	43,748	2,018	0	0.0
Beef	44,084	93,586	115	49,618	53.0	41,646	97,860	0	56,213	57.4
Milk	538,132	539,300	49,857	51,025	9.5	528,368	528,369	0	0	0.0

Source: Domestic supply, import and export quantities for 1995 were derived from SEPSA data. Quantities demanded for 1995 are based on data from the 1987-1988 National Household and Income and Expenditure Survey (DGEC, 1988) and extrapolated towards 1995 using (1) 1995 population figures (FAO statistical database); (2) data regarding GDP growth income growth figures between 1988 and 1995 (Central Bank of Costa Rica); and (3) income elasticity estimates for the commodities considered in this study (Geurts *et al.* 1997, Van der Valk 1998).

Note: [1] Exports as a percentage of total supply (*i.e.*, sum of domestic supply and imports).

Imports and exports of basic grains, potato, onion and milk were all subject to government trade regulations in 1995, either directly via import and export quota or indirectly through subsidies or tariffs. The latter often are determined in a rather *ad-hoc* way. The base run therefore assumes that no exports of these products take place, while import prices equal world market prices plus import tariffs. For all other commodities, simulated exports in the base run situation generally exceed actual values, suggesting that as of 1995 there may have been trade barriers in effect that are not considered by the model. In the case of coffee, for example, it is well known that by law part of the harvest with a specified quality has to be directed to the national instead of the world market.

On the other hand, import tariffs on virtually all agricultural commodities are such that imports are limited to an absolute minimum. Imports that were allowed in 1995 were mostly determined by the CNP (basic grains), Dos Pinos (milk and milk products) and government regulations, guided by temporary shortages in the national market due to seasonal fluctuations in supply and/or demand (potato and onions). Import restrictions, in combination with a slight overestimation of exports, result in levels of domestic demand in the base run situation that are generally below actual 1995 demand.

4.2 Base run results

Regional and national land use patterns for Costa Rica according to the base run situation are given in Table 4.3. While in the Chorotega and Norte regions virtually all of the available agricultural area is utilized by the 17 commodities included in this study, in the Central region they cover 83% of the available area, whereas in the Pacifico, Brunca and Atlantica regions they account for between 60% and 70% of the total available agricultural area. The Chorotega and Central regions together account for over half of the total cultivated area in Costa Rica.

According to the base run, in all regions the major part of agricultural land is used for beef and milk production, with pastures covering 87% of the cultivated area in Costa Rica. Consequently, crop production covers only 13% of the cultivated area, and is concentrated towards traditional export crops (mainly coffee and banana) and/or basic grain production (mainly rice and beans). In terms of land use, production of non-traditional export crop production is relatively unimportant in all regions except in the Norte region. Most important non-traditional export crops include plantain, mango, pineapple and cassava, while orange is an important crop for the domestic market (consumed mainly in the form of juice).

Table 4.3 Base run regional and national land use (10^3 ha)

	Central	%[1]	Pacifico	%[1]	Chorotega	%[1]	Brunca	%[1]	Norte	%[1]	Atlantica	%[1]	Total	%[1]
Rice	**0.0**	0.0	**9.1**	0.3	**19.5**	0.7	**12.2**	0.5	**3.5**	0.1	**0.0**	0.0	**44.3**	1.7
Maize	**1.1**	0.0	**1.2**	0.0	**5.0**	0.2	**4.1**	0.2	**2.3**	0.1	**0.6**	0.0	**14.2**	0.5
Beans	**2.1**	0.1	**1.5**	0.1	**3.1**	0.1	**7.7**	0.3	**22.9**	0.9	**0.2**	0.0	**37.5**	1.4
Coffee	**94.9**	3.6	**9.8**	0.4	**1.6**	0.1	**0.0**	0.0	**0.0**	0.0	**0.3**	0.0	**106.7**	4.0
Banana	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**2.4**	0.1	**0.0**	0.0	**46.9**	1.8	**49.2**	1.9
Sugar	**10.6**	0.4	**4.8**	0.2	**16.8**	0.6	**2.4**	0.1	**6.1**	0.2	**0.0**	0.0	**40.8**	1.5
Plantain	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.7**	0.0	**5.7**	0.2	**6.4**	0.2
Palm heart	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**2.1**	0.1	**2.3**	0.1	**4.4**	0.2
Mango	**5.4**	0.2	**1.0**	0.0	**0.1**	0.0	**0.3**	0.0	**0.0**	0.0	**0.0**	0.0	**6.7**	0.3
Melon	**0.1**	0.0	**2.6**	0.1	**0.3**	0.0	**0.1**	0.0	**0.0**	0.0	**0.0**	0.0	**3.1**	0.1
Pineapple	**0.2**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**6.4**	0.2	**0.0**	0.0	**6.6**	0.2
Cassava	**0.2**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**6.3**	0.2	**0.0**	0.0	**6.5**	0.2
Onion	**0.7**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.7**	0.0
Orange	**11.4**	0.4	**0.0**	0.0	**0.3**	0.0	**0.8**	0.0	**7.5**	0.3	**1.6**	0.1	**21.5**	0.8
Potato	**2.2**	0.1	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**2.2**	0.1
Beef	**311.5**	11.7	**90.7**	3.4	**746.8**	28.1	**227.9**	8.6	**333.1**	12.5	**247.3**	9.3	**1,957.2**	73.6
Milk	**140.4**	5.3	**26.2**	1.0	**50.8**	1.9	**23.6**	0.9	**72.5**	2.7	**38.8**	1.5	**352.2**	13.2
Total	**580.8**	21.8	**147.0**	5.5	**844.3**	31.7	**281.4**	10.6	**463.3**	17.4	**343.7**	12.9	**2,660.5**	100.0
Available	**697.2**	26.2	**217.2**	8.2	**844.3**	31.7	**464.8**	17.5	**463.3**	17.4	**504.6**	19.0	**3,190.1**	119.9

Note: [1] Cultivated area as a percentage of total cultivated area.

Basic grain production accounts for only 3.6% of agricultural land use at the national level. Relatively important regions for basic grain production include Chorotega, Brunca, Norte and (only for rice) Pacifico. The regions Chorotega, Brunca and Pacifico are the most important rice producing regions and cover 92% of the total rice area, while the production of beans is largely concentrated in the Norte region which holds over 60% of the total bean area. Maize production is relatively unimportant in all regions (on average maize accounts for less than 15% of the total regional basic grain area), with the Chorotega and Brunca regions being the major maize producing regions.

Production of traditional export crops is relatively important, on average determining 7.4% of total regional land use. Geographical diversification of coffee and banana production is relatively limited, due to the specific agro-ecological requirements of these crops. Coffee production is concentrated in the elevated and therefore relatively cool Central region which accounts for 90% of the total coffee area. Also banana production is highly concentrated, with over 95% of the total banana production area located in the hot and humid lowlands of the Atlantica region. Sugar production, on the other hand, is geographically more diversified, with the major production regions (Chorotega and Central) covering 67% of the total sugar cane area.

At the national level, non-traditional export crops account for just over 2% of total agricultural land use. Most important production regions include Norte, Atlantica, Central and Pacifico, each of which specializes in one or more non-traditional export crops. The Atlantica region specializes in plantain production and is responsible for nearly 90% of the total national plantain area. Mango production mainly takes place in the Central region where over 80% of the total mango area in Costa Rica is located. Finally, production of both pineapple and cassava is concentrated in the Norte region, covering over 95% of the total crop area of each crop.

Pasture production is predominant in all regions, determining about 87% of total national land use. Of the total national pasture area, about 85% is destined towards beef production and only 15% towards milk production. Pasture for beef production is most important in the Chorotega and Brunca regions where, respectively, 94% and 90% of the regional pasture area is for beef production. On the other hand, pasture for milk production is most important in the Central and Norte regions where, respectively, 31% and 18% of the regional pasture area is dedicated to milk cattle. By far the most important beef producing region is Chorotega, covering 38% of the total national pasture area for beef production. The Central region is the most important milk producing region, accounting for 40% of the national pasture area for milk production purposes.

Values of production (calculated as regional production times regional price) at the regional and national levels are presented in Table 4.4. Comparisons of land use (Table 4.3) and value of production (Table 4.4) at the regional level reveal that regions which account for a large share of total cultivated area in Costa Rica do not necessarily account for a large share of total national agricultural income. For example, while the Chorotega region holds 32% of the total cultivated area in Cost Rica, it contributes only 9% to national agricultural income. On the other hand, the Atlantica and Central regions generate the lion's share of national agricultural income: together these regions are responsible for 70% of national agricultural income but for only 35% of the total cultivated area. Annual gross agricultural income at the national level is 519 US$/ha, ranging from 160 US$/ha in Brunca to 1,188 US$/ha in Atlantica.

Regions with relatively large pasture areas for beef production (Chorotega and Brunca) contribute relatively little to national agricultural income since returns to beef production per unit land area are relatively low (Jansen *et al.*, 1997). On the other hand, livestock keeping geared towards milk production (mainly in the Central and Norte regions) contributes substantially to national agricultural income. However, regions with relatively large areas of traditional export crops (particularly coffee and banana in respectively the Central and Atlantica regions) have the highest contribution to national agricultural income since returns to land are relatively high for both of these export crops. Non-traditional export crops that make significant contributions to national agricultural income include pineapple and cassava in the Norte region and plantain in the Atlantica region. Even though important from a food security point of view, basic grains are relatively unimportant in terms of national agricultural income.

Table 4.4 Base run regional and national production values (10^6 US$)

	Central	%[1]	Pacifico	%[1]	Chorotega	%[1]	Brunca	%[1]	Norte	%[1]	Atlantica	%[1]	Total	%[1]
Rice	0.0	0.0	8.6	0.5	17.9	1.1	11.2	0.7	3.4	0.2	0.0	0.0	41.1	2.5
Maize	0.3	0.0	0.3	0.0	0.3	0.1	1.1	0.1	0.6	0.0	0.2	0.0	3.8	0.2
Beans	0.8	0.0	0.6	0.0	1.3	0.1	2.7	0.2	7.9	0.5	0.1	0.0	13.3	0.8
Coffee	411.0	24.7	42.7	2.6	7.0	0.4	0.0	0.0	0.0	0.0	1.5	0.1	462.3	27.8
Banana	0.0	0.0	0.0	0.0	0.0	0.0	25.6	1.5	0.0	0.0	535.1	32.2	560.7	33.7
Sugar	19.9	1.2	9.3	0.6	31.6	1.9	4.6	0.3	11.5	0.7	0.0	0.0	76.9	4.6
Plantain	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.2	23.3	1.4	26.6	1.6
Palm heart	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	0.2	3.1	0.2	5.8	0.3
Mango	6.0	0.4	1.1	0.1	0.2	0.0	0.3	0.0	0.0	0.0	0.0	0.0	7.6	0.5
Melon	0.7	0.0	28.4	1.7	3.5	0.2	0.6	0.0	0.0	0.0	0.2	0.0	33.3	2.0
Pineapple	2.1	0.1	0.0	0.0	0.0	0.0	0.3	0.0	54.5	3.3	0.1	0.0	57.0	3.4
Cassava	0.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0	27.0	1.6	0.1	0.0	28.0	1.7
Onion	4.8	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.8	0.3
Orange	7.7	0.5	0.0	0.0	0.2	0.0	0.7	0.0	3.4	0.2	0.7	0.0	12.8	0.8
Potato	20.9	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.9	1.3
Beef	25.7	1.5	7.4	0.4	71.8	4.3	18.3	1.1	24.0	1.4	20.3	1.2	168.0	10.1
Milk	60.8	3.7	10.3	0.6	18.2	1.1	8.6	0.5	27.4	1.6	14.7	0.9	140.1	8.4
Total	561.7	33.8	108.6	6.5	152.5	9.2	73.9	4.4	165.8	10.0	599.4	36.1	1,662.4	100.0

Note: [1] Production value as a percentage of total production value.

Basic grain production generates 3.5% of total agricultural income on 3.6% of the total cultivated area. Rice and bean production account for respectively 71% and 23% of agricultural income obtained from basic grain production, while revenues from maize production are relatively minor. Traditional export crops are the major source of agricultural income, generating 66% of total national agricultural income while occupying just above 7% of the total cultivated area. Banana and coffee are the most important traditional export crops, accounting for 51% and 42% of total traditional export crop earnings, respectively. Non-traditional export crop production generates 12% of total agricultural income, while responsible for only just over 2% of the total cultivated area. Pineapple, melon, cassava and plantain prove to be most profitable non-traditional export crops, respectively accounting for 29%, 17%, 14% and 13% of total earnings from non-traditional export crops. Finally, beef and milk together generate 19% of total agricultural income, of which 55% is generated by beef production. Even though beef production is the third most important source of agricultural income (after banana and coffee), it occupies the major share of the total cultivated area (87%).

Values of inter-regional product flows are shown in Table 4.5, representing product shipments from supply to demand regions valued at regional supply prices. As already noted before, the Central and Atlantica are important export regions (together these regions are responsible for 76% of total exported production value), as major suppliers of coffee and banana exports, respectively. Major supply regions for the domestic market include the Norte, Brunca and Chorotega regions, with basic grains, beef and milk as the most important traded commodities. Supply from the ROW region (*i.e.*, imports) is negligible for the considered commodities, due to relatively high import taxes and other trade barriers.

The ROW and Central regions constitute the major demand regions, absorbing 76% and 17% of the value of total national production, respectively. The Central region is the major domestic demand region, responsible for nearly 70% of the value of national demand. This is explained by the fact that over 60% of the Costa Rican population lives in the Central region (DGEC, 1997). Moreover, average per capita income in the Central region is about 55% higher than in other regions of Costa Rica (Geurts *et al.*, 1997). This leads to larger quantities consumed, as well as to consumption of higher quality goods in the Central region as compared to other regions in Costa Rica.

Table 4.5 Base run value of product flows between supply and demand regions (10^6 US$)

			Supply regions							
			Central	Pacifico	Chorotega	Brunca	Norte	Atlantica	ROW	Total
	Central		141.7	13.9	27.1	28.6	46.6	22.5	0.0	280.5
		%[1]	8.5	0.8	1.6	1.7	2.8	1.4	0.0	16.9
	Pacifico		2.5	14.2	0.0	0.0	0.6	0.9	0.0	18.1
		%[1]	0.1	0.9	0.0	0.0	0.04	0.1	0.0	1.1
	Chorotega		2.7	0.2	18.6	0.0	2.1	0.0	0.7	24.3
Demand		%[1]	0.2	0.01	1.1	0.0	0.1	0.0	0.04	1.5
	Brunca		8.6	0.0	0.0	19.5	0.3	1.6	0.0	30.0
regions		%[1]	0.5	0.0	0.0	1.2	0.02	0.1	0.0	1.8
	Norte		7.6	0.0	0.6	0.0	21.9	0.0	0.0	30.2
		%[1]	0.5	0.0	0.0	0.0	1.3	0.0	0.0	1.8
	Atlantica		3.3	2.7	0.0	0.0	1.0	13.6	0.2	20.8
		%[1]	0.2	0.2	0.0	0.0	0.1	0.8	0.01	1.3
	World		395.2	77.7	106.7	25.9	93.2	560.8	0.0	1,259.4
		%[1]	23.8	4.7	6.4	1.6	5.6	33.7	0.0	75.7
	Total		561.7	108.6	152.5	73.9	165.8	599.4	1.0	1,662.4
		%[1]	33.8	6.5	9.2	4.4	10.0	36.0	0.1	100.0

Note: [1] Value of product flow as a percentage of value of the sum of all product flows.

In general, all regions primarily produce for the export market, in the second place for the Central region, and in the third place for other regions in Costa Rica. On average, 66% of the total national production value is exported, while about 21% is directed towards the Central region. All regions are self-sufficient for at least 65% in terms of value of regional commodity demand, apart from the Central region which is self-sufficient for only 50%. This is not only explained by the fact that the Central region is responsible for most domestic demand, but also by the fact that transport costs from other regions to the Central region are relatively low because of the latter's geographical location. Product flows between regions other than the ROW and the Central region are rather insignificant, constituting only about 2% of the total trade flow value of some 1.7 billion US dollars.

4.3 Policy simulations

In this section the SEM is used to evaluate a number of hypothetical policy measures in terms of their effect on welfare, land use and trade patterns. These hypothetical policy measures were chosen on the basis of issues that are widely considered as important in the agricultural policy arena in Costa Rica. In this context, the next section provides a brief sketch of the evolution of Costa Rican agricultural policies over time.

The resulting simulations can be divided into three broad groups. First, ample attention is given to an assessment of the potential effects of trade liberalization measures. Second, as in many other developing countries, marketing of agricultural products in Costa Rica is hampered by the poor state of the road infrastructure (Jansen and van Tilburg, 1996). Consequently, a number of simulations are carried out to analyze the effects of road improvements. Finally, continuing economic development and technological progress ensure that demand for, as well as supply of, most agricultural commodities will keep on shifting in the future, both of which may have important welfare effects with corresponding adjustments in land use patterns and trade flows. A detailed description of each individual simulation is provided in section 4.3.2, whereas the results are discussed in section 4.3.3.

4.3.1 Main agricultural policies in Costa Rica

From the 1950s onwards and until 1983, Costa Rica's economic policies were largely based on the so-called import substitution model, aided by traditional agricultural export commodities and foreign aid (Schipper *et al.*, 1998). Agrarian policies were directed primarily towards the production of traditional export crops such as banana, coffee, sugarcane, cacao and beef, along with self-sufficiency in the production of basic food crops for domestic consumption including maize, rice, beans, and sorghum (Celís and Lizano, 1993; Gonzalez, 1994). Import and export regulation played an important role in policies aimed at food security (Cartín and Piszk, 1980; Sain and López Pereira, 1997; Wattel and Ruben, 1992). Marketing of basic food crops was regulated by the parastatal CNP which guaranteed fixed producers' prices for any quantity supplied. Most of the produce was sold on the domestic market at below such guaranteed prices, with any surplus production exported to other Central American and Caribbean countries. Imports of basic food grains were only allowed in times of shortages (Guardia *et al.*, 1987; Stewart, 1991).

However, during the second half of the 1970s, growth of agricultural production substantially slowed and it was increasingly realized that the size of the domestic market is too small to serve as a base for rapid and sustained growth of the agricultural sector. After 1980 a series of structural adjustment programs was introduced. Structural reform consisted mainly of lowering trade barriers, financial sector reform, and reform of the state sector. These measures have had clear positive effects on both economic growth and employment (Schipper *et al.*, 1998). The main consequence of the structural adjustment measures for the agricultural sector consisted of a much higher degree of integration into the world market (Pomareda, 1996; SEPSA, 1997). The system of guaranteed producer prices and consumer subsidies was gradually phased out, while production of agricultural export crops was promoted through a 100% reduction in export taxes to new markets, a 100% reduction in import taxes for inputs such as agrochemicals and agricultural equipment, as well as credit at favorable terms for export activities (Mora Alfaro *et al.*, 1994). These measures resulted in a strengthening of the comparative advantage of traditional export crops (*e.g.*, banana, coffee, sugarcane) relative to basic food crops, as well as in a promotion of non-traditional export crops (*e.g.*, pineapple, palm heart, flowers, ornamental plants, root and tuber crops). Regarding the latter, an incentive system centered around tax rebates called Tax Credit Certificates (CATs, initiated in 1984 and to be phased out by late 1999) played an important role in boosting earnings from non traditional export crops, despite a lax accounting system which left it open to abuses. Overall, the dependence of total export earnings on banana and coffee decreased as a result of the stimulation of non-traditional export crops (Gonzales, 1994). Exports in general were further stimulated by the exchange rate policy which through a system of mini-devaluations aims at maintaining the competitive position of Costa Rica *vis-a-vis* its main trading partners.

At present the role of the CNP, as far as agricultural policy is concerned, is largely restricted to basic food grains where it has an exclusive privilege regarding the determination of imported and exported quantities (by means of selectively issuing import and export permits). Imports of many commodities other than basic grains is regulated via a variable tariff system. In addition, the CNP is involved in the determination of maximum prices for specified qualities of certain basic staple foods.

Table 4.6 Import prices, export prices and import tariffs of agricultural commodities as of 1998 (US$/kg)

	Cassava	Maize	Mango	Melon	Orange	Beef	Plantain	Beans	Rice	Potato	Onion	Sugar	Milk
p^{export} f.o.b.	0.33	0.15	0.59	0.40	0.09	1.66	0.21	0.35	0.30	0.17	0.20	0.028	0.17
$p^{Costa\ Rica}$	0.19	0.18	0.55	0.57	0.10	1.55	0.20	0.53	0.24	0.47	0.31	0.027	0.27
p^{import} c.i.f.	0.35	0.16	0.62	0.42	0.10	1.85	0.22	0.48	0.33	0.33	0.25	0.029	0.19
p^{import} +tax	0.40	0.18	0.73	0.49	0.11	2.20	0.27	0.58	0.45	0.49	0.38	0.044	0.39
DAI	14%	14%	18%	18%	18%	18%	18%	20%	35%	45%	52%	55%	102%
Law 6946	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Total	15%	15%	19%	19%	19%	19%	19%	21%	36%	46%	53%	56%	103%

Source: Unpublished information from the Ministry of Trade and Commerce

Structural adjustment in Costa Rica in general has been qualified as incomplete (Hausmann, 1998), and considerable trade barriers still exist (Table 4.6). Import tariffs have their legal base in the so-called Import Duties Law (DAI) and Law No. 6946. The DAI defines commodity-specific preferential import taxes which are calculated on the basis of *c.i.f.*-import prices. DAI tax levels differ by country of origin; the figures presented in Table 4.6 are those that apply to countries outside Central America. Law No. 6946 defines relatively minor non-preferential import taxes which are calculated on the basis of *c.i.f.*-import prices of all commodities, independent of the country of origin.

4.3.2 Description and justification of model simulations

4.3.2.1 Trade liberalization

As a member of the World Trade Organization and as a signee to its various international agreements, Costa Rica has committed itself to move towards free trade in basic food grains at first and eventually for all agricultural commodities. Especially several non-basic grain commodities are heavily protected by import taxes (Table 4.6). This policy simulation therefore allows an assessment of the likely effects on welfare, agricultural land use and trade flows (both between regions and internationally) of partial trade liberalization (*i.e.* free trade in basic grains only) and complete trade liberalization (*i.e.*, free trade in all agricultural commodities).

4.3.2.2 Transport costs

Cost of transportation generally is an important determinant of farmers' production decisions and, as a result, of aggregate land use which in turn influences aggregate welfare and trade flows. Even though virtually all major interregional Costa Rican road connections are paved, the quality of the pavement is usually poor, leading to high variable transport costs (Hausmann, 1998). Moreover, high vehicle import and road taxes as well as high insurance costs, result in high fixed transport costs as well. A number of policy runs were carried out simulating the effects of a 20% reduction in variable and/or fixed transport costs.

Besides by road conditions, transportation costs are obviously influenced by geographical distance. The highway between the harbor city of Limon in the Atlantic Zone and the capital of San Jose constitutes the country's main trunk road over which a large part of both agricultural and non-agricultural commodities get hauled to and from the Central Valley. However, the part of this road that runs through the scenic Braulio Carillo national park is often closed since it suffers from frequent land slides, forcing traffic to look for alternative routes which have transport costs that are some 2.7 times higher (calculated with a digital road map as part of a GIS). A model simulation was carried out in which the Braulio Carillo was assumed to be closed.

4.3.2.3 Future perspectives

Improvements in production technologies resulting from research lead to outward shifts of the supply curve and therefore to lower marginal production costs. A number of commodities that form part of our analysis are included in the mandate of international agricultural research organizations. These include rice, beans, cassava and pastures (International Center for Tropical Agriculture, CIAT) as well as maize (International Maize and Wheat Improvement Center, CIMMYT). Consequently, for each of these commodities model simulations were carried out assuming a 20% outward shift of the supply curve. Similar advances in production technology are less likely for crops such as banana, coffee and sugar, since production of these crops already takes place near to their respective technological frontiers.

Besides by population growth, demand for agricultural commodities is significantly determined by income (Geurts *et al.*, 1997), thus making income growth an important determinant of future shifts in commodity demand. Population growth during the next 25 years or so is largely determined by currently prevailing birth and mortality rates. The long lag involved in the response of the absolute population size to population control policies makes the scope for scenario analysis with regard to population very limited (at least with a time horizon of less than 25 years). Unlike population, income growth in the short-to-medium term does react to policy measures and scenario analysis based on different levels of income growth therefore makes sense. A number of model simulations were carried out, each of which assumes a certain rise in average per capita real income over the next 10 years: a pessimistic scenario (zero per capita income growth), a medium scenario (2.5% per capita income growth per year), and an optimistic scenario (5% per capita income growth per year). Shifts in demand curves were calculated on the basis of regional income elasticities which were estimated using the data and methodology employed in Geurts *et al.* (1997) and Van der Valk (1998).

4.3.3 Simulation results

The results of each model simulation are compared to either the base run simulation (trade liberalization scenarios and transport costs scenarios) or to a situation of complete trade liberalization (future perspective scenarios), while focussing on changes in land use patterns, trade flows, and shifts in producer and consumer surpluses. In all simulations it was assumed that the maximum available area for cultivation equals the cultivated area as determined in the base run.

4.3.3.1 Trade liberalization

Trade liberalization simulations include a partial liberalization scenario (*i.e.*, free trade in basic grains only) and a complete liberalization scenario (*i.e.*, free trade in all commodities). Trade liberalization refers to the lowering or abolishment of tariff and non-tariff (*i.e.*, quota etc.) measures. Under free trade, producers face f.o.b. world market export prices while consumers are confronted with c.i.f. world market import prices (Table 4.6).

Changes in land use patterns are relatively minor in both trade liberalization simulations (Table 4.7). This is because trade liberalization mainly affects import prices and therefore exerts its main effect on the domestic consumption side which is relatively unimportant (only 24% of the total national production value is for internal consumption in the base run).

Partial trade liberalization results in increased rice and maize production for export purposes, at the expense of bean and beef production. Rice exports take place as both the f.o.b. export price and the c.i.f. import price exceed the domestic price as determined by the CNP. In the case of beans, the f.o.b. export price and the c.i.f. import price are both lower than the domestic price, resulting in imports up to a level where the regional equilibrium price plus transport costs equal the c.i.f. import price. The domestic maize price also exceeds both the f.o.b. export and the c.i.f. import price, even though the differences are smaller than in the case of beans, with the f.o.b. export and the c.i.f. import price also differing less. Given regional differences in supply and demand functions, both maize imports (Atlantica region) and maize exports (Chorotega) take place.

Table 4.7 Trade liberalization simulations: optimal land use distribution

	Free trade basic grains		Free trade all products	
	(10^3 ha)	%[1]	(10^3 ha)	%[1]
Rice	50.3	13.5	50.4	13.7
Maize	14.2	0.4	14.3	1.0
Beans	36.6	-2.4	36.7	-2.2
Coffee	106.7	0.0	106.7	0.0
Banana	49.2	0.0	49.3	0.1
Sugar	40.8	0.0	40.8	0.1
Plantain	6.4	0.0	6.4	0.0
Palm heart	4.4	0.0	4.4	0.2
Mango	6.7	0.0	6.8	0.4
Melon	3.1	0.0	3.1	0.0
Pineapple	6.6	0.0	6.6	0.0
Cassava	6.5	0.0	6.5	0.0
Onion	0.7	0.0	0.7	-3.6
Orange	21.6	0.5	21.7	0.8
Potato	2.2	0.0	2.1	-2.8
Beef	1952.5	-0.2	1996.8	2.0
Milk	352.2	0.0	307.6	-12.7
Total	2660.9	0.0	2660.9	0.0

Note: [1] Percentage change as compared to base run.

Complete trade liberalization results in a substitution of bean, onion, potato and milk production, in favor of rice, maize and beef production. Domestic prices for onion, potato and milk considerably exceed their respective f.o.b. export and c.i.f. import prices, providing a strong incentive for imports of these products (at the expense of domestic production). Trade restrictions cause inflated opportunity costs of land, since land use is not determined by international comparative advantage but rather by artificially high domestic prices. Under a regime of complete trade liberalization one may therefore expect a decrease in production of commodities that previously were protected by import barriers. A salient example in this context is milk which domestic production decreases substantially (in favor of beef production) under conditions of free trade.

Partial trade liberalization results in an increase in the total value of agricultural production, while complete trade liberalization leads to a net decrease in agricultural income (Table 4.8). Both forms of trade liberalization lead to increased levels of exports and imports, but the latter is considerably larger under complete trade liberalization, leading to a deterioration of the trade balance.

While the opening up of the basic grain markets under a regime of partial trade liberalization leads to higher agricultural income in all regions, the largest gains are obtained in the Chorotega, Brunca and Pacifico regions. The region with the largest comparative advantage in rice and maize production (Chorotega) increases production for the export market at the expense of production for the Central region. Demand in the latter is satisfied by supply from the Brunca and Pacifico regions. The overall result is increased export earnings, even though import expenditures also rise as a result of increased imports of beans because of lower c.i.f. import prices.

Table 4.8 Trade liberalization simulations: value of production and international transport flows

	Free trade basic grains		Free trade all products	
	(10^6 US$)	%[1]	(10^6 US$)	%[1]
Central	561.7	0.0	542.7	-3.4
Pacifico	111.7	2.8	109.4	0.7
Chorotega	160.5	4.9	155.8	1.8
Brunca	77.0	4.2	75.6	2.2
Norte	166.1	0.2	158.7	-4.2
Atlantica	599.4	0.0	595.9	-0.6
Total	1,676.4	0.9	1,638.1	-1.4
Export	1,275.7	1.3	1,285.0	2.0
Import	2.7	170.0	42.0	4142.1
Trade balance	1,273.0	1.2	1,243.0	-1.2

Note: [1] Percentage change as compared to base run.

Complete trade liberalization leads to a net decline in agricultural income. Domestic prices for beans, onion, potato and milk decrease under influence of the lower c.i.f. import prices, resulting in decreased quantities and values of domestic production of these commodities. These tendencies are especially strong in the Norte and Central regions, the former being the major bean and milk producing region and the latter being the major onion, potato and (to a lesser extent) milk producing region. An increasing portion of total demand for these products is met by imports. Changes in the relative price structure causes most of the agricultural area that is no longer needed to satisfy domestic demand to be allocated to production for exports which in turn leads to higher export earnings. Even though both import expenditures and export earnings increase as a result of complete trade liberalization, imports rise faster than exports, while negatively effecting the trade balance.

The small share of consumer surplus in the total economic surplus in Costa Rica of just about one sixth, has two main reasons. First, a major part of total agricultural production is exported. Even though such exports can be expected to generate surplus for foreign consumers, this surplus is not considered in the objective function of the SEM. Second, for most commodities, demand is relatively elastic while supply is relatively inelastic, resulting in a relatively small consumer surplus but relatively high producer surplus.

Table 4.9 Trade liberalization simulatious: producer and consumer surpluses

	Free trade basic grains		Free trade all products	
	(10^6 US$)	%[1]	(10^6 US$)	%[1]
Producer surplus	1,096.1	0.5	1,096.0	0.5
Consumer surplus	210.6	-3.5	255.6	17.1
Economic surplus	1,306.7	-0.2	1,351.6	3.3

Note: [1] Percentage change as compared to base run.

Partial trade liberalization results in small gains in producer surplus, since higher f.o.b. export prices for rice and maize induce an increase in production for export. The latter, however, is achieved at the expense of domestic consumption of these commodities, leading to a decline in consumer surplus. This effect is partially compensated by a rise in domestic bean consumption, triggered by lower c.i.f. import prices that cause consumption of beans to shift towards imported produce at the expense of domestically produced beans.

Complete trade liberalization only affects import prices of commodities other than basic grains. The net effect on producer surplus is, again, small since gains in the latter obtained through free trade in basic grains are compensated by a decline in production of other commodities (particularly milk, potato and onion) whose imports increase (which in turn result in a decrease in domestic prices). Lower import prices permit higher levels of consumption through the substitution of imports for domestic production, and as a result consumer surplus increases in the complete trade liberalization.

4.3.3.2 Transport costs scenarios

Optimal land use patterns under the different transport cost simulations are shown in Table 4.10. Changes in land use relative to the base run as a result of reductions in the cost of transportation are not dramatic, since transport costs are already low relative to total production value. Decreases in transport costs lead to a decline in pasture area for beef production while favoring crop production and milk cattle raising. Exports of both traditional and non-traditional crops increase, while growth in basic grain production is much lower. Contrary to the results obtained for reductions in transport costs, increases in transport costs resulting from the closure of the Braulio Carillo passway lead to a reduction in crop area in favor of pastures for beef production. Especially the traditional export crop coffee is affected, as transport costs of this bulky product between the Central Valley and the nearest export harbor rise considerably.

Table 4.10 Transport cost simulations: optimal land use distribution

	Variable costs -20%		Fixed costs -20%		Variable & fixed -20%		Closed Braulio	
	(10^3 ha)	%[1]	(10^3 ha)	%[1]	(10^3 ha)	%[1]	(10^3 ha)	%[1]
Rice	44.5	0.3	44.4	0.0	44.5	0.3	44.3	0.0
Maize	14.2	0.2	14.2	0.0	14.2	0.2	14.2	0.0
Beans	37.6	0.1	37.5	0.0	37.6	0.1	37.5	0.0
Coffee	106.8	0.1	106.7	0.0	106.8	0.1	106.2	-0.4
Banana	49.6	0.8	49.4	0.4	49.8	1.2	49.3	0.0
Sugar	40.9	0.2	40.9	0.1	40.9	0.2	40.8	-0.1
Plantain	6.5	1.0	6.4	0.2	6.5	1.2	6.4	0.5
Palm heart	4.4	1.6	4.4	0.2	4.5	1.7	4.4	0.1
Mango	6.8	0.5	6.7	0.1	6.8	0.5	6.6	-1.8
Melon	3.1	0.2	3.1	0.1	3.1	0.3	3.1	0.0
Pineapple	6.7	1.4	6.6	0.1	6.7	1.5	6.6	-0.1
Cassava	6.6	0.9	6.5	0.1	6.6	0.9	6.5	0.0
Onion	0.7	0.1	0.7	0.0	0.7	0.1	0.7	-0.2
Orange	21.7	0.8	21.7	0.6	21.7	0.9	21.7	0.5
Potato	2.2	0.1	2.2	0.0	2.2	0.1	2.2	-0.3
Beef	1,954.8	-0.1	1,956.8	0.0	1,954.5	-0.1	1,959.2	0.1
Milk	353.5	0.4	352.3	0.0	353.5	0.4	350.7	-0.4
Total	2,660.6	0.0	2,660.6	0.0	2,660.6	0.0	2,660.4	0.0

Note:[1] Percentage change as compared to base run.

Changes in land use are larger for a 20% decline in variable transport costs as compared to a 20% decline in fixed transport costs, as variable transport costs account for between 73% (between Central and Pacifico) and 92% (between Brunca and Chorotega) of total transport costs. The results for the simulation that involves a reduction in both variable and fixed transport costs are just about equal to the sum of the two separate simulations. Closure of the Braulio Carillo passway has a much stronger effect on land use than a 20% decline in either variable or fixed transport costs, because of the considerable cost increases associated with reaching the major export harbor (Limón). Since about three-quarters of the total agricultural production value of Costa Rica is exported, the consequences of such a closure are substantial.

A reduction in transport costs is equivalent to a decline in production costs, and therefore to an outward shift of the supply curve. Production response is determined by the combination of regional supply and demand elasticities, and is larger the higher are the supply and demand elasticities (in absolute terms). In general, supply elasticities of both traditional (*e.g.*, banana) as well as non-traditional export crops (*e.g.*, plantain, palm heart and pineapple) are relatively high, while foreign demand for these export products as faced by domestic producers is completely elastic. As a consequence, these commodities respond most to a shift in transport costs. On the other hand, both demand and supply of basic grains (which are nearly exclusively produced for the national market) are usually relatively inelastic, resulting in a relatively low production response.

Reductions in transport costs result in higher agricultural incomes in all regions, as well as in increases in both exports and inter-regional transport flows (Table 4.11). While imports are negatively affected by a decrease in variable transport costs, they show an increase as a result of a decrease in fixed transport costs, even though in both cases the total volume of trade (*i.e.*, the sum of inter-regional and international trade) increases. Again, the combined simulation of reduced variable and fixed transport costs is about the sum of the partial simulations. Closure of the Braulio Carillo results in a decline in national agricultural income due to reduced exports and lower inter-regional transport flows. This decline in exports, combined with increased imports, results in a deteriorating trade balance.

Table 4.11 Transport cost simulations: production value and international transport flows

	Variable costs -20%		Fixed costs -20%		Variable & fixed -20%		Closed Braulio	
	(10^6 US$)	%[1]	(10^6 US$)	%[1]	(10^6 US$)	%[1]	(10^6 US$)	%[1]
Central	566.2	0.8	562.2	0.1	567.1	1.0	540.4	-3.8
Pacifico	109.3	0.6	108.8	0.2	109.7	0.8	108.8	0.2
Chorotega	154.7	1.1	153.1	0.0	154.8	1.2	153.2	0.1
Brunca	75.0	1.4	74.1	0.3	75.1	1.6	74.1	0.3
Norte	169.8	2.4	166.1	0.2	170.0	2.6	166.5	0.5
Atlantica	606.2	1.1	602.9	0.6	609.7	1.7	597.1	-0.4
Total	1,681.3	1.1	1,667.2	0.3	1,686.2	1.4	1,640.2	-1.3
Export	1,275.7	1.3	1,264.0	0.4	1,280.6	1.7	1,241.8	-1.4
Import	0.9	-6.3	1.0	1.3	0.9	-5.1	1.6	58.4
Trade balance	1,274.8	1.3	1,263.0	0.4	1,279.7	1.7	1,240.2	-1.5

Note: [1] Percentage change as compared to base run.

Since a reduction in variable transport costs mainly favors export crops, regions with a relatively distant location from export harbors (*i.e.*, Brunca and Norte) benefit most from a reduction in variable (*i.e.*, distance related) transport costs (Table 4.11). On the other hand, a decline in fixed transport costs benefits all regions equally and therefore the region that houses the major export harbor (Limón in the Atlantica region) shows the largest relative decline in transport costs, and thus the largest response reaction. Inter-regional transport flows increase in both the variable and the fixed transport cost simulation, as lower transport costs allow for higher levels of regional specialization in agricultural production. The latter also causes a decrease in imports, even though the overall effect on imports of a reduction in fixed transport costs is positive since prices of imported commodities in the region that houses the major export harbor fall relatively more than prices of commodities obtained from other regions (because inter-regional transport costs are largely determined by variable transport costs).

Closure of the Braulio Carillo passover in the road connecting the Atlantica region with the Central region leads to lower levels of agricultural income in these regions while income in the other regions increases (Table 4.11). Exports from the Central region decrease as a result of increased transport costs to the major export harbor (Limón) and because of less inter-regional trade with the Atlantic region. Trade between the Atlantic and other regions decreases while trade among the latter increases. On the other hand, imports into the Atlantica region increase as a result of the isolating effect that a closure of the Braulio Carillo exerts on this region. At the national level, lower exports and higher imports result in reduced gains from trade.

The substitution of pasture for crop production as a result of a decline in transport costs, involves relatively low opportunity costs since beef production activities have much lower returns per hectare than most crop activities. As a consequence, despite losses in the surpluses of beef producer and consumer surpluses, increased production levels and subsequent lower prices of substitute crop activities cause an increase in both producer and consumer surplus.

Table 4.12 Transport cost simulations: producer and consumer surpluses

	Variable costs -20%		Fixed costs -20%		Variable & fixed -20%		Closed Braulio	
	(10^6 US$)	%[1]	(10^6 US$)	%[1]	(10^6 US$)	%[1]	(10^6 US$)	%[1]
Producer surplus	1,114.2	2.2	1,093.4	0.3	1,118.9	2.6	995.6	-8.7
Consumer surplus	218.8	0.2	218.1	0.0	218.8	0.2	216.1	-1.0
Economic surplus	1,333.0	1.8	1,311.5	0.3	1,337.8	2.2	1,211.7	-7.4

Note: [1] Percentage change as compared to base run.

Decreases in transport costs lead to higher economic surplus, while reduced transport options result in a decrease in economic surplus (Table 4.12). Gains in producer surplus exceed those in consumer surplus. Gains in producer surplus result from the outward shift of the supply curves, even though part of the gains are lost due to commodity price decreases. Since most demand elasticities are high (in absolute terms) relative to supply elasticities, price decreases are relatively minor, with correspondingly small gains in consumer surplus.

Closure of the Braulio Carillo passover generates opposite effects. The Central region (where most consumption takes place) purchases less from the Atlantica region and more from other regions, even though at higher costs. Total consumption decreases in all regions, in the Central region because of higher prices and in the other regions because of larger shipments to the Central region. Production in other regions increases in order to meet the higher requirements of intra-regional trade as well as Central region demand, thus partially compensating for the decline in producer surplus (especially coffee in the Central region).

4.3.3.3 Future perspectives: supply shifts

Technological change (*e.g.*, improved varieties, improved crop husbandry methods etc.) results in increased productivity of production systems. An increase in productivity implies an outward or downward shift of the supply curve, resulting in lower unit production costs. Simulations were carried out for rice, maize, beans, cassava and beef, assuming a 20% outward shift of their respective supply curves. Contrary to the previous simulations, supply shift simulation results are based on, and evaluated relative to, the complete trade liberalization situation as presented in section 4.3.3.1, since supply response reactions can be expected to be relatively minor under the present restrictive trade policy regime. That is, currently existing export barriers would force any production increase resulting from a productivity increase to be absorbed by the domestic market whose limited size would lead to artificially low prices. Looking at this issue from another perspective, it may be argued that trade barriers effectively limit the incentive for investments in technological progress since they prevent the full capture of the potential rewards associated with such progress.

A downward shift in the supply curve for a particular commodity leads to an increase in the cultivated area of that commodity as a direct result of lower unit production costs. Thus, production is increased through increases in both cultivated area and productivity. No significant trade-offs were observed with respect to commodities that did not experience similar technological change. Because of the sheer size of pasture areas in Costa Rica, technological progress in the beef production sector has the largest impact on total land use (in terms of absolute area changes), followed by the rice and bean sectors (Table 4.13). The absolute area changes caused by productivity gains in maize and cassava are much less, mainly due to their initially much smaller areas.

Supply response to technological change in a relative sense (*i.e.*, reactions as a percentage of the initial situation) is highest for products that face favorable export markets (particularly cassava and to a lesser extent maize) and/or for products that are initially imported (beans and to a lesser extent maize). Exports take place at fixed f.o.b. prices without influencing regional price levels, and substitution of imports by domestic production (without trade-offs towards other products) generates producer surplus while lowering import expenditures.

Table 4.13 Supply shift simulations: optimal land use distribution

	Rice supply shift		Maize supply shift		Beans supply shift		Cassava supply shift		Beef supply shift	
	(10^3 ha)	%[1]	(10^3 ha)	%[1]	(10^3 ha)	%[1]	(10^3 ha)	%[1]	(10^3 ha)	%[1]
Rice	54.5	8.1	50.4	0.0	50.5	0.1	50.5	0.1	50.3	-0.3
Maize	14.3	0.1	16.2	13.4	14.3	0.0	14.3	0.0	14.2	-0.7
Beans	36.7	0.1	36.7	0.0	42.3	15.2	36.7	0.0	36.8	0.1
Coffee	106.7	0.0	106.7	0.0	106.7	0.0	106.7	0.0	106.7	0.0
Banana	49.3	0.0	49.3	0.0	49.3	0.0	49.3	0.0	49.2	-0.1
Sugar	40.8	0.0	40.8	0.0	40.8	0.0	40.8	0.0	41.0	0.3
Plantain	6.4	0.0	6.4	-0.1	6.4	-0.1	6.4	-0.1	6.4	0.0
Palm heart	4.4	0.0	4.4	0.0	4.4	0.0	4.4	0.0	4.4	0.6
Mango	6.8	0.0	6.8	0.0	6.8	0.0	6.8	0.0	6.7	-0.3
Melon	3.1	0.0	3.1	0.0	3.1	0.0	3.1	0.0	3.1	0.0
Pineapple	6.6	0.0	6.6	0.0	6.6	0.0	6.6	0.0	6.6	0.2
Cassava	6.5	0.0	6.5	0.0	6.5	0.0	7.4	13.7	6.5	0.2
Onion	0.7	0.0	0.7	0.0	0.7	0.0	0.7	0.0	0.7	0.0
Orange	21.7	0.0	21.6	-0.5	21.6	-0.5	21.7	0.1	21.7	-0.3
Potato	2.1	0.0	2.1	0.0	2.1	0.0	2.1	0.1	2.1	0.0
Beef	2,003.5	0.3	1,998.2	0.1	2,000.0	0.2	1,997.3	0.0	2,146.6	7.5
Milk	307.4	-0.1	307.6	0.0	307.6	0.0	307.6	0.0	307.0	-0.2
Total	2,671.6	0.4	2,664.2	0.1	2,669.7	0.3	2,662.4	0.1	2,810.0	5.6

Note: [1] Percentage change as compared to complete trade liberalization simulation.

All supply shifts lead to an increase in total agricultural income (Table 4.14). Particularly productivity improvements in the beef sector lead to relatively large increases in agricultural income, again due to the considerable area which would affected by such an improvement. Productivity gains in rice, beans and cassava lead to similar growth in agricultural income. On the other hand, the latter is hardly affected by productivity improvements in maize because: (1) the internal market for maize is relatively thin; and (2) since Costa Rica does not have a real comparative advantage in maize production, export possibilities are limited and the scope for substitution of domestic production for imports is small.

Production increases are either destined towards exports (rice, cassava, beef and to a minor extent maize) or used as a replacement for imports (beans), both resulting in an improved trade balance while maintaining domestic consumption levels. In this way, regional product prices are held constant while export earnings, valued at fixed world market prices, increase. A 20% reduction in unit production costs of beans results in domestic prices that can compete with c.i.f. import price while also leading to increased bean consumption.

Regions that benefit most from technical change-related productivity improvements (in terms of growth in agricultural income) include the Brunca region for rice and maize, and the Norte region for beans, cassava and beef. In the case of productivity gains in rice and maize, the resulting additional production of these crops in the regions Pacifico, Brunca and Norte is mostly shipped to the Central region. This lowers the demand pressure exerted by the Central region on the Chorotega region for these commodities, thus enabling Chorotega to fully exploit its comparative advantage in the production of rice and maize for the export market. A similar situation holds for productivity increases in cassava and beef for which the Norte region has a comparative export advantage while consumption requirements in the Central region can be satisfied by production increases in Brunca and the Central region itself. Finally, a productivity increase in bean cultivation causes bean imports to be substituted by production in the Norte and Brunca regions.

Table 4.14 Supply shift simulations: value production and international transport flows

	Rice		Maize		Beans		Cassava		Beef	
	(10^6 US$)	%[1]	(10^6 US$)	%[1]	(10^6 US$)	%[1]	(10^6 US$)	%[1]	(10^6 US$)	%[1]
Central	542.5	0.0	542.7	0.0	543.0	0.1	543.1	0.1	544.0	0.2
Pacifico	112.8	3.1	109.5	0.1	109.8	0.4	109.3	-0.1	112.7	3.0
Chorotega	159.5	2.4	156.8	0.6	156.4	0.4	155.8	0.0	156.1	0.2
Brunca	91.3	20.7	76.4	1.1	76.9	1.7	75.6	0.0	81.4	7.7
Norte	159.3	0.4	159.5	0.5	174.0	9.6	176.5	11.2	185.8	17.1
Atlantica	595.9	0.0	596.0	0.0	596.6	0.1	596.0	0.0	601.0	0.9
Total	1,661.3	1.6	1,640.9	0.2	1,656.7	1.2	1,656.2	1.2	1,681.0	2.9
Export	1,292.9	0.6	1,286.1	0.1	1,285.2	0.0	1,301.8	1.3	1,315.2	2.3
Import	42.2	0.6	42.0	0.0	40.8	-2.9	42.0	0.0	42.1	0.3
Trade balance	1,250.6	0.6	1,244.1	0.1	1,244.4	0.1	1,259.8	1.3	1,273.1	2.4

Note: [1] Percentage change as compared to complete trade liberalization simulation.

For each of the commodities analyzed in this section, an outward shift of the supply curve results in an increase in economic surplus which can be mainly attributed to a rise in producer surplus (Table 4.15). In line with the growth rates in production values presented in Table 4.14, productivity improvements are largest for beef and smallest for maize. Gains in producer surplus are obtained through increased export production and/or substitution of domestic production for imports, while production for internal consumption is maintained or increased. In combination with regional prices that either remain constant or decrease, consumer surplus remains either constant or increases.

Table 4.15 Supply shift simulations: producer and consumer surpluses

	Rice		Maize		Beans		Cassava		Beef	
	(10^6 US$)	%[1]	(10^6 US$)	%[1]	(10^6 US$)	%[1]	(10^6 US$)	%[1]	(10^6 US$)	%[1]
Producer surplus	1,099.0	0.3	1,098.1	0.2	1,111.5	1.4	1,099.4	0.3	1,138.4	3.9
Consumer surplus	255.6	0.0	255.7	0.0	256.4	0.3	255.6	0.0	256.1	0.2
Economic surplus	1,354.7	0.2	1,353.8	0.2	1,368.0	1.2	1,354.9	0.2	1,394.5	3.2

Note: [1] Percentage change as compared to complete trade liberalization simulation.

Shifts in the supply curves of rice, maize and cassava have no effect on domestic consumer surplus, since additional production is exported while domestic consumption and prices remain constant. On the other hand, a shift in the supply curve of beans positively affects domestic consumer surplus, since imports are substituted by domestic production at prices that are below c.i.f. import prices. Similarly, an outward shift in the beef supply curve also results in an (albeit relatively small) increase in consumer surplus. In the major beef cattle raising region of Chorotega, productivity improvements in beef production permit a reduction in the pasture area while maintaining beef production, thus liberating agricultural land for increased sugarcane production for the domestic market, which in turn leads to lower sugar prices.

4.3.3.4 Future perspectives: demand shifts

Demand shift simulations were based on different assumptions regarding annual per capita real income growth for the period 1995 to 2005 and included 0% (pessimistic), 2.5% (expected) and 5.0% (optimistic) scenarios, over and above the estimated 2.0% annual population growth rate for the same period. Demand curve shifts were calculated by region for each commodity on the basis of 1995 demand data which in turn were calculated from 1987-88 survey data obtained from DGEC (1988), using historical population and income growth data rates (by region) as well as income elasticities for the concerned commodities. Income elasticities were estimated by region (Table 4.16), using the same methodology as in Geurts *et al.* (1997). Estimates for 1995 demand quantities were further extrapolated up to the year 2005 using the population growth rate and the different assumptions regarding per capita income growth as specified above.

Table 4.16 Regional and national expenditure elasticities by commodity

	Central	Pacifico	Chorotega	Brunca	Norte	Atlantica	Costa Rica
Rice	0.21**	0.24**	0.25**	0.37*	0.13	0.39**	0.26*
Maize	0.26**	0.18	0.43**	0.41**	0.02	0.15	0.26*
Beans	0.19**	0.09	0.15	0.19	0.04	0.32**	0.17*
Coffee	0.22**	0.28**	0.29**	0.25**	0.12	0.36**	0.26*
Banana	0.26**	0.19	0.32	0.23	0.12	0.21	0.22*
Sugar	0.20**	0.23**	0.37*	0.31**	0.16	0.50*	0.29*
Plantain	0.31**	0.21	0.29	-0.02	0.18	-0.04	0.17*
Palm heart	1.86	1.73	1.88	0.33*	0.28*	2.09	0.41*
Mango	0.15	0.23	0.14	0.54	0.56	0.63	0.67*
Melon	0.42	0.94	1.27**	-6.63	0.94	0.95	0.36*
Pineapple	0.25	0.15	0.36	0.03	-0.30	0.09	0.08*
Cassava	0.13	0.06	0.35	-0.05	-0.02	0.17	0.08*
Onion	0.39**	0.22	0.39**	0.44**	0.14	0.50**	0.35*
Orange	0.65*	0.72**	0.62	0.62	0.18	0.46	0.60*
Potato	0.27**	0.32**	0.44**	0.36**	0.30**	0.36**	0.33*
Beef	0.58*	0.69*	0.63*	0.48**	0.35**	0.50*	0.55*
Milk	0.51*	0.45**	0.61*	0.60*	0.59*	0.56*	0.55*

Significance level: * (**) significantly different from zero at the five (ten) percent level according to the t-test.

Similar to supply shift simulations analyzed in the previous section, demand shift simulation results were compared to a situation of complete trade liberalization. If currently existing trade barriers in general, and restrictions on imports of many agricultural commodities in particular, would continue to prevail in the future, commodity prices can be expected to increase significantly as a result of increased demand. Even though production increases could be achieved by expansion of the agricultural area, the agricultural frontier has been virtually reached in many parts of Costa Rica, at least in the areas with reasonable road and marketing infrastructure (Quesada Mateo, 1990). In addition, government policies aimed at continued protection of potentially valuable agricultural land further limit the scope for area expansion. Finally, Costa Rica has subscribed to the world-wide trend (under the auspices of the WTO) towards further trade liberalization.

Table 4.17 shows the optimal land use distribution for the each of the demand shift simulations. Since the agricultural area is limited to the cultivated area of the base run situation, total land use remains unchanged. Increasing demand over time causes the area allocated to orange, rice and pasture for milk production to increase, at the expense of the pasture area for beef production. These tendencies are similar for all demand scenarios. A comparison between the demand scenarios indicates that, even though growth in real income does result in increased levels of consumption, its effect on consumption patterns is relatively minor. This can be explained by income elasticities that are generally low. Only beef, milk, orange, melon, mango and palm heart have income elasticities that exceed 0.50, while they exceed one only for the latter two commodities in some regions. On the other hand, the income elasticity estimates used in this study may not be valid much beyond the simulated period (*i.e.*, beyond the year 2000) since the country's demand structure can be expected to change in the long run with continued economic development (Jansen *et al.*, 1998).

Table 4.17 Demand shift simulations: optimal land use distribution

	Income + 0.0%		Income + 2.5%		Income + 5.0%	
	(10^3 ha)	%[1]	(10^3 ha)	%[1]	(10^3 ha)	%[1]
Rice	51.6	2.4	52.5	4.2	53.9	6.9
Maize	14.6	1.9	14.6	1.9	14.6	1.8
Beans	36.6	-0.2	36.6	-0.2	36.6	-0.2
Coffee	106.7	0.0	106.7	0.0	106.7	0.0
Banana	49.3	0.0	49.2	-0.1	49.3	0.0
Sugar	41.0	0.3	41.0	0.3	41.1	0.6
Plantain	6.5	1.2	6.8	6.1	6.9	7.6
Palm heart	4.4	-0.1	4.5	3.3	4.6	4.1
Mango	6.8	-0.1	6.8	-0.1	6.8	-0.1
Melon	3.1	0.0	3.1	0.0	3.1	0.0
Pineapple	6.6	0.0	6.6	0.0	6.6	0.0
Cassava	6.5	0.0	6.5	0.0	6.5	0.0
Onion	0.7	3.2	0.7	2.9	0.7	2.9
Orange	24.0	10.7	24.7	13.9	24.9	14.8
Potato	2.1	0.1	2.1	0.1	2.1	0.1
Beef	1,990.2	-0.3	1,988.7	-0.4	1,987.1	-0.5
Milk	310.2	0.9	309.7	0.7	309.6	0.7
Total	2,661.0	0.0	2,661.0	0.0	2,661.0	0.0

Note: [1] Percentage change as compared to complete trade liberalization simulation.

Continuing population growth combined with rising incomes results in increases in demand which, in turn, lead to four general developments. First, production of commodities with relatively unfavorable c.i.f. import prices increases, leading to increased importance of basic food crops such as rice and (to a lesser extent) maize in the overall cropping pattern. Similarly, the bean area decreases slightly as a consequence of more favorable c.i.f. import prices (Table 4.17).

Second, even though domestic income growth increases domestic demand and decreases total export earnings (Table 4.18), production of the most profitable traditional as well as non-traditional export crops is hardly affected (Table 4.17). For traditional export crops this is because the differences between the profitability of banana and coffee production (most of which are exported) and the profitability of other crops are of such a magnitude that these two crops continue to be responsible for the lion's share of agricultural income, despite increasing prices of other crops. Moreover, increased domestic demand for these commodities hardly affects the total demand for these crops which is nearly completely determined by foreign consumers. The area under sugarcane increases in order to satisfy increased domestic demand since c.i.f. import prices for sugar are unfavorable. Regarding non-traditional export crops, a similar argument holds as put forward earlier for traditional export crops, *i.e.*, exports of pineapple, melon and cassava are sufficiently profitable so as to not being significantly affected by domestic demand developments. In addition, since the share of the total production of non-traditional export crops that is exported is lower than for traditional export crops, the area of some of the former (orange, plantain, palmheart) increases as a result of increasing domestic demand and unfavorable c.i.f. import prices. Milk, potato, rice, beans and plantain all are crops for which imports increase significantly as a result of demand growth, while possible previous exports of these commodities disappear as regional prices exceed f.o.b. export prices due to higher domestic demand pressure.

Table 4.18 Demand shift simulations: value production and international transport flows

	Income + 0.0%		Income + 2.5%		Income + 5.0%	
	(10^6 US$)	%[1]	(10^6 US$)	%[1]	(10^6 US$)	%[1]
Central	544.9	0.4	546.5	0.7	548.8	1.1
Pacifico	110.6	1.1	110.8	1.3	111.7	2.1
Chorotega	157.4	1.1	158.7	1.9	160.8	3.2
Brunca	78.5	3.9	79.0	4.5	79.8	5.6
Norte	160.9	1.4	162.1	2.1	163.0	2.7
Atlantica	597.1	0.2	600.8	0.8	602.2	1.1
Total	1,649.5	0.7	1,657.8	1.2	1,666.2	1.7
Export	1,185.5	-7.7	1,139.3	-11.3	1,091.9	-15.0
Import	100.0	138.1	148.4	253.4	206.7	392.1
Trade balance	1,085.5	-12.7	990.9	-20.3	885.2	-28.8

Note: [1] Percentage change as compared to complete trade liberalization simulation.

Third, demand shifts lead to an increase in the importance of crop production in general (Table 4.17), at the expense of pastures for beef production since returns to the latter are low (Jansen *et al.*, 1997). Since growth in both population and income leads to higher demand as well as higher prices, production values increase concomitantly (Table 4.18). The largest growth in agricultural income occurs in regions which in the base run exhibited the lowest agricultural income (including Chorotega, Brunca and Norte regions), since these are the regions where beef production accounts for a large part of the cultivated area which gets converted into crop land as a result of increasing demand pressure. Thus, in this sense income and population growth acts as a catalyst towards a more egalitarian regional income distribution.

Finally, with rising income levels, exports diminish while imports increase, resulting in significant deterioration of the foreign trade balance.

Demand increases resulting from growth in population and real incomes has a positive effect on both producer and consumer surplus (Table 4.19, However, the increase in producer surplus is much lower than the rise in consumer surplus which is not surprising given the demand-driven character of increased crop production. The relatively large gains in consumer surplus are a result of the considerable upward shifts in the demand curves, generally between 25% and 50% of the initial level of consumption.

Table 4.19 Demand shift simulations: producer and consumer surpluses

	Income + 0.0%		Income + 2.5%		Income + 5.0%	
	(10^6 US$)	%[1]	(10^6 US$)	%[1]	(10^6 US$)	%[1]
Producer surplus	1,096.8	0.1	1,100.8	0.4	1,106.7	1.0
Consumer surplus	770.2	201.3	1,223.1	378.5	1.841.3	620.4
Total surplus	1,866.9	38.1	2,323.9	71.9	2,948.0	118.1

Note: [1] Percentage change as compared to complete trade liberalization simulation.

Due to area limitations, options for increasing the producer surplus are limited to the substitution of crop production systems at the expense of pasture-based beef production. Not only is this process completely demand-driven, but increases in producer surplus fully stem from the (limited) increase in crop production combined with higher (regional) equilibrium prices. The latter show a gradual increase due to increasing domestic demand which in turn negatively affects exports. On the other hand, prices are kept under control by the continuing possibility of importing against c.i.f. import prices.

5. Summary and conclusions

In this paper a Spatial Equilibrium Model (SEM) for Costa Rica is developed in order to model actually prevailing spatial patterns of supply, demand, trade flows and prices for major agricultural commodities, as well as to assess agricultural policy effectiveness in terms of social welfare. This type of model uses econometric estimates of behavioral relations of producers and consumers, while simultaneously taking transaction costs and government policies into account. The SEM developed in this paper considers the 17 main agricultural commodities in Costa Rica, its six planning regions as well as the rest-of-the-world as a seventh region in order to take international trade into account.

The SEM is based on supply response curves, demand response curves and transactions cost curves. It is considered a useful device as a decision support system for policy makers in the agricultural sector to evaluate alternative scenarios. The optimal welfare level of producers and consumers under a particular set of constraints (*e.g.*, the actual policy environment) can be compared with the optimal welfare level under another set of constraints (*e.g.*, the desired policy environment). However, the dynamic process of change from one market equilibrium (*e.g.*, the present one) to a new market equilibrium is not part of the analysis. Since a SEM is a sector model, transfers of income to and from the rest of the economy and the non agricultural part of the outside world are not explicitly taken into account.

In the supply response functions, not only product prices are taken into account but also prices of near substitutes in product markets as well as input prices. Factor markets are implicitly taken into account in the supply functions because of the fact that they reflect marginal production costs. Similarly, even though the SEM methodology lies within the domain of economics, bio-physical factors play a role via their implicit effect on commodity supply response as defined for each of the supply regions.

The model was validated by comparing base run results with the actual situation of 1995, in terms of area allocation, agricultural production levels, production value and product prices. The model specification and data reflected the actual 1995 situation quite well. Base run results show that, at the national level, about 87% of the total cultivated area is dedicated to pasture for beef and milk production, while the remainder is used for production of traditional (mainly banana and coffee) and non-traditional export crops (mainly plantain, mango, pineapple and cassava) as well as for basic grain production. More than half of the total crop area is still used for traditional export crop production, while basic grains and non-traditional export crops occupy, respectively, 28% and 16% of the total crop area. Production of traditional export crops is concentrated in the Central (coffee) and Atlantica (banana) regions, while non-traditional export crops are more geographically spread out. Basic grains are concentrated in the Western (rice) and Northern (beans) regions of Costa Rica. Pasture area for meat and milk production is predominant in all regions, with Chorotega (beef) and Central (milk) as the most important production regions.

Traditional export crops account for almost two-thirds of the total agricultural production value, while the shares of livestock and non-traditional export crop production are only 19% and 12%, respectively. About two-thirds of the total agricultural production value is exported, while about one-fifth is directed towards the Central region. Central and Atlantica are the most important export regions, while major supply regions for the domestic market include Norte, Brunca and Chorotega (mainly basic grains, beef and milk). Supply from the ROW (*i.e.*, imports) is negligible due to relatively high import duties. Product flows between regions other than the ROW and the Central region are negligible, constituting only 2% of the total trade flow value.

Policy scenarios include trade liberalization, reduced transport costs, technological improvements and shifts in demand and supply. In the first two scenarios, possible improvements were assessed in relation to the 1995 situation (base run). In the latter two scenarios, shifts in demand and supply were assessed relative to the outcome of the trade liberalization scenario because effects of supply or demand shifts are expected to be low under the restrictive trade policy regime represented in the base run. These alternative scenarios were evaluated in terms of their potential effects on land use, trade flows and welfare.

Trade liberalization scenarios

Implementation of a series of Structural Adjustment Programs from the late 1980s onwards resulted in a higher degree of integration of the agricultural sector into the world market because of improved comparative advantage of traditional export crops (banana, coffee and sugarcane) relative to basic food crops, and the promotion of non traditional export crops (pineapple, palm heart, ornamental plants, and roots and tubers). Costa Rica's dependence on traditional export crops decreased.

Trade liberalization simulations include partial (*i.e.*, free trade in basic grains only) and complete (*i.e.*, free trade in all commodities) liberalization scenarios. Complete trade liberalization refers to the abolishment of tariff and non-tariff measures and, in comparison with the reference situation (the "base run"), results in a new market equilibrium with higher national welfare derived from agriculture which is in agreement with economic theory.

Relative to the base run, both trade liberalization scenarios result in relatively small gains in producer surplus due to more favorable export prices for rice and maize. Subsequent higher domestic prices for these basic grains result in a decline in consumer surplus in the partial simulation, while complete trade liberalization largely favors consumers as a result of favorable import prices for particularly milk, potato and onion. In turn, domestic production of these latter commodities decreases in view of their lower equilibrium prices.

However, it is worth noting that the considerable increase in national welfare generated by the agricultural sector(some 3.3% or about 43 million US $ in the complete liberalization scenario) does not take into account the costs of the process of transition to the new market equilibrium. Examples of these costs are the development of new legislation and the net effect of reduced government income from import tariffs or export duties and increased revenue from income taxes on income or profit. Finally, the net effects on the trade balance are slightly positive for the partial liberalization and slightly negative for the complete liberalization scenario.

Improved transport infrastructure scenarios

Transport cost scenarios include a 20% decline in variable and/or fixed transport cost, and a closure of the Braulio Carillo passway. A distinction has been made between a reduction in variable transport costs (slope coefficient in the transport cost equation) and fixed transport costs (intercept in the transport costs equation). Fixed transport costs relate to the costs of capital invested in vehicles as well as import or periodic tax levies and insurance costs. Variable costs are related to costs per ton/km such as costs of petrol (including tax), vehicle maintenance and delays due to road maintenance problems. Reductions in variable transport costs have a larger (positive) impact on producer and consumer surplus compared to reductions in fixed transport costs, as variable transport costs account for more than 75% of total transport costs. This result suggests that road improvements leading to lower transport costs per ton/km and substitution of tax on petrol by tax on new cars will result in higher welfare levels. Of course, such welfare gains should be compared with the costs for such improvements.

The analysis in this study provides a clear justification for the past decision to construct the Braulio Carillo passway and for the costs involved in its maintaince. Closure of this passway in 1995 would result in a substantial decrease in producer surplus of nearly 10%, besides a more marginal reduction of 1% in consumer surplus. This result stems from the fact that such a closure would lead to a substantial increase in transport costs to reach the export harbor of Limon (given the latter's geographically isolated location from most other regions of Costa Rica) which has obvious consequences for a country that is exporting about 75% of the total value of its agricultural production.

Changes in land use as a result of a reduction in transport costs relative to the base run are small, since transport costs are low in relation to production value. Pasture area for beef production decreases in favor of crop and milk production for local consumption and export, resulting in relatively small increases in producer surplus and (to a minor extent) consumer surplus. On the other hand, an increase in transport costs resulting from the closure of the Braulio Carillo passway lead to a reduction in crop area in favor of pasture for beef production. Increased transport costs from the Central Valley to the major export harbor (Limón) result in lower exports and in higher domestic prices for crops originating from the Atlantica region.

Supply shift scenarios due to technological innovations

Advances in the production technology of a certain commodity lead to a downward shift of the supply curve and therefore to a reduction in marginal production costs. A number of commodities that form part of our analysis are included in the mandate of international agricultural research organizations. These commodities include rice, beans, cassava and pastures (all of which are researched by the International Center for Tropical Agriculture, CIAT) as well as maize (included in the mandate of the International Maize and Wheat Improvement Center, CIMMYT). Consequently, for each of these commodities model simulations were carried out assuming a 20% downward shift of the supply curve. Similar improvements in production technologies are less likely for traditional export crops such as banana, coffee and sugar, since production of these crops already takes place near to their respective technological frontiers.

Relative to the free trade simulation, a downward shift of the supply curve for a particular commodity leads to an increase in the cultivated area of that commodity as a direct result of lower unit production costs while prices remain the same as they are mainly related to world market prices in a free trade environment. Production is enhanced through increases in both cultivated area and productivity, while no significant trade-offs with other commodities are observed. Production increases are allocated to either exports (rice, cassava, beef and maize) or used for import substitution (beans). Producer surplus increases marginally, while consumer surplus stays about constant. Because of the sheer size of pasture areas in Costa Rica, technological progress in the beef production sector has the largest absolute impact on land use and producer surplus, followed by technological progress in the bean and rice sectors.

Demand shift scenarios

In agreement with projections of the World Bank (World Bank, 1997) and the Interamerican Development Bank (Hausmann, 1998), demand shift simulations were performed on the basis of annual per capita real income growth rates of 0%, 2.5% and 5.0% for the period 1995 to 2005, over and above the expected 2.0% annual population growth rate for the same period. If currently existing trade barriers would continue to prevail in the future, commodity prices can be expected to increase significantly as a result of increased demand. Though, relative to the free trade simulation, land allocated to orange, rice and pasture for milk production increases at the expense of pasture area for beef production, in view of the latter's relatively low returns. Demand increases are projected to be mainly met by increased imports and reduced exports although the area allocated to the most profitable traditional as well as non-traditional crops is hardly affected, while also domestic production shows a small increase. In turn, consumer surplus rises relatively more than the increase in producer surplus.

The foreign trade balance for agricultural products can be expected to deteriorate significantly as a result of continuing economic growth. This will need to be compensated by an increase in the export of industrial products or services. It is expected that the growth of industrial production will strengthen the position of these products in the overall trade balance relative to traditional export services and commodities such as tourism, banana and coffee.

In conclusion, this study has resulted, for the first time in Costa Rica, in shaping an agricultural sector model that can be used by policy makers to evaluate the likely outcomes of alternative policy measures in the domain of trade liberalization, improvement of the transport infrastructure, shifts in income, and technological progress in agriculture. Before the SEM could be constructed, validated and used for scenario analysis, considerable effort was spent on the construction of a previously non-existing data base needed to estimate regional supply elasticities for individual crops. In addition, regional demand elasticities for individual agricultural products were estimated using data from the latest national household expenditure survey (Geurts et al., 1997). Finally, data on road infrastructure were collected and stored in a GIS and used later as input in an econometric estimation of transport cost models (Jansen and Stoorvogel, 1998).

The successful sequence of data collection followed by the use of solid econometric methods to estimate both supply and demand response, combined with the use of a GIS and econometrics to estimate transport cost models and using of all these building blocks to construct a Spatial Equilibrium Model to analyze the effects of different (policy) scenarios is still quite unique for (small) developing countries.

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Appendix 1 Estimation results obtained with adapted Nerlove supply response models

Basic grains

Detailed estimation results for the basic grains rice, maize and beans (based on equation 19) are given in Tables A1.1 to A1.3, respectively. Initially, prices of all potentially competitive commodities (except for non-traditional export crops[8]) were included in the model specification which was gradually simplified through a stepwise exclusion of non-significant explanatory variables, as based on the standard t-test[9]. Regression statistics include the adjusted coefficient of determination (R^2) as a measure of the success of the regression in explaining the variability of the dependent variable within the sample, and tests for heteroskedasticity (White test criteria) as well as serial correlation (LM test criteria)[10].

Table A1.1 Supply response model for rice[1]

				Explanatory variables				Performance indicators		
Region	N (# of obs.)	C constant	Q_{t-1} rice	P_{t-1} rice	P_{t-1} sugar	P_{t-1} fertilizer	T Trend	R^2 (adj.)	LM (prob.)	White (prob.)
Pacifico	16			0.48	4.15			0.06	0.50	0.07
t-value				*4.05*	*3.25*					
Chorotega	15	86434		1.30		-20.05		0.33	0.93	0.62
t-value		*2.63*		*1.95*		*-2.93*				
Brunca	16			0.16	3.79		754.75	0.01	0.55	0.55
t-value				*1.10*	*2.71*		*2.15*			
Norte	16			0.22				-0.16	0.01	0.08
t-value				*3.54*						
Atlantica	16		0.78	0.04				0.70	0.08	0.00
t-value			*4.81*	*1.10*						
Costa Rica	15			3.20	33.54	-46.21		0.22	0.47	0.34
t-value				*4.10*	*3.51*	*-3.34*				

[1] Dependent variable is rice production in MT per year

Estimated own-price coefficients for rice are positive for all regions (Table A1.1), and significantly different from zero for all regions except Brunca and Atlantica. However, the latter is an unimportant rice producing region in absolute as well as relative terms. Last year's rice production does not seem to influence current rice production in the most important rice production regions. The sugarcane price positively influences rice production in the Pacifico and Brunca regions, contrary to an expected negative sugarcane price coefficient. However, both products are subject to a high level of price regulation. In Chorotega, the major rice producing region in Costa Rica,

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[8] Estimation of standard Nerlove models for basic grains, traditional export crops and livestock products did not permit the inclusion of potentially competitive non-traditional export crops, due to the absence of sufficiently long time-series of yearly price data for the latter.

[9] Based on the standard t-test, all included explanatory variables were statistically significant at the 10% level or better, with the exception of the own-price variable which was maintained independent of its statistical significance.

[10] A low probability of the F-test-statistic, on which the White test is based, indicates that the null-hypothesis of no heteroskedasticity should be rejected. Similarly, a low probability of the LM test statistic indicates that the null-hypothesis of no serial correlation should be rejected.

fertilizer prices are negatively correlated with rice production, which is not surprising given the considerable share of (particularly urea) fertilizer in the total production costs of rice (Cortes, 1994).

The insignificant time trend coefficient suggests that structural changes with respect to rice production were either absent or did not influence production decisions. Adjusted R^2 levels are generally low, indicating that the regressions are weak in explaining the variation of the dependent variable within the sample. The sparse and erratic rainfall for the periods 1982-83 and 1987-89 may be partially responsible for this result (Cortés, 1994). Apart from the Norte and Atlantica regions, the LM and White test indicate that neither serial correlation nor heteroskedasticity is a problem.

Table A1.2 Supply response model for maize[1]

		Explanatory variables								Performance indicators		
Region	N (# of obs.)	C constant	Q_{t-1} maize	P_{t-1} maize	P_{t-1} rice	P_{t-1} sugar	P_{t-1} beans	P_{t-1} coffee	T Trend	R^2 (adj.)	LM (prob.)	White (prob.)
Central	16		0.45	0.07						0.72	0.48	0.03
t-value			*2.35*	*2.43*								
Pacifico	16	55076		0.06	-0.16	-2.56	-0.06		-1196.81	0.81	0.42	0.06
t-value		*5.57*		*1.10*	*-3.57*	*-2.54*	*-3.48*		*-5.79*			
Chorotega	16		0.64	0.07						0.12	0.08	0.34
t-value			*4.08*	*2.24*								
Brunca	16		0.60	0.16						0.67	0.41	0.37
t-value			*3.13*	*1.78*								
Norte	16		0.80	0.04						0.62	0.14	0.44
t-value			*7.43*	*2.31*								
Atlantica	16	-25111	0.62	0.21	0.26			0.61		0.92	0.04	0.87
t-value		*-3.85*	*5.43*	*1.78*	*1.92*			*2.33*				
Costa Rica	16		0.72	0.75		-6.63		1.67		0.95	0.32	0.63
t-value			*9.71*	*4.61*		*-4.94*		*3.36*				

[1] Dependent variable is maize production in MT per year

For maize, all own-price coefficients are positive and significantly different from zero at the 10% level (Table A1.2), with the exception of the Pacifico region. Lagged maize production has a significant and relatively large positive coefficient, suggesting that production decisions are to a significant extent determined by last year's production performance (between 45% and 80%). Generally, lagged prices of other crops exert only limited influence on maize production decisions, even though at the national level sugar prices have a negative influence on maize production, while coffee prices exert an opposite effect.

Maize production in the most important maize producing regions (Chorotega, Brunca and Norte), was not influenced by structural changes. Heteroskedasticity and autocorrelation problems were generally absent as well, even though the regression results for the Central and Pacifico regions suggest that not all error terms exhibit identical variance. The maize regressions are able to explain a considerable part of the inter-temporal variability in maize production, as indicated by the adjusted R^2 values.

Table A1.3 Supply response model for beans[1]

		Explanatory variables			Performance indicators		
Region	N (# of obs.)	C constant	Q_{t-1} beans	P_{t-1} beans	R^2 (adj.)	LM (prob.)	White (prob.)
Central	16	2113		0.003	0.00	0.81	0.49
t-value		*3.65*		*0.98*			
Pacifico	16		0.74	0.002	0.09	0.09	0.49
t-value			*5.36*	*1.92*			
Chorotega	16		0.67	0.007	0.25	0.67	0.76
t-value			*5.52*	*2.88*			
Brunca	16		0.54	0.025	0.01	0.66	0.84
t-value			*2.56*	*1.78*			
Norte	16		0.93	0.008	0.71	0.00	0.08
t-value			*10.03*	*1.24*			
Costa Rica	16		0.82	0.032	0.27	0.30	0.86
t-value			*6.94*	*1.56*			

[1] Dependent variable is bean production in MT per year

Estimation results for beans are given in Table A1.3. For all regions, the only explanatory variables which were maintained in the regression model included own-price (lagged) and lagged production, since lagged prices of competitive crops and fertilizer quantities turned out to be insignificant. Own-price coefficients are significant at the 25% level or better, while lagged production explains between 54% and 93% of the actual bean production. The low adjusted R^2 values for all regions except the Norte region indicate that the explanatory power of the bean models is limited, while the test statistics point towards problems with heteroskedasticity and/or serial correlation in the major producing regions Norte and Pacifico.

Traditional export crops

Supply response model estimation results for non-traditional export crops (coffee, banana and sugarcane) are given in Tables A1.4-A1.6, respectively. Supply response models for banana and sugarcane are based on the adapted Nerlove model (equation 19), while the coffee model is based on equation (20) which includes 'normal' production as an additional explanatory variable.

Table A1.4 Supply response model for coffee[1]

		Explanatory variables				Performance indicators		
Region	N (# of obs.)	C constant	$\log(Q_{t-2})$ coffee	$\log(P_{t-1})$ coffee	$\log(Q_{normal})$ coffee	R^2 (adj.)	LM (prob.)	White (prob.)
Central	21		0.23	0.06	0.75	0.68	0.57	0.11
t-value			*0.98*	*1.06*	*3.27*			
Pacifico	21		0.41	0.05	0.57	0.91	0.63	0.70
t-value			*2.51*	*1.16*	*3.64*			
Chorotega	21		0.07	0.05	0.90	0.85	0.42	0.24
t-value			*0.74*	*1.07*	*8.40*			
Atlantica	21	-2.11	0.11	0.16	0.97	0.94	0.62	0.95
t-value		*-1.66*	*1.39*	*1.85*	*12.86*			
Costa Rica	21		0.30	0.06	0.67	0.74	0.48	0.11
t-value			*1.26*	*1.05*	*2.86*			

[1] Dependent variable is coffee production in Double Hectolitres per year.

The results for coffee show a much better fit (reflected in the generally high adjusted R^2 values) than the supply response models for basic grains discussed in the previous section. Moreover, the LM and White test statistics indicate that the probability of the existence of serial correlation and heteroskedasticity is low. Coffee models include an explanatory production variable with a two-year (instead of one-year) lag, since coffee production data over the last 20 years show a relative production decline every other year, despite the generally rising trend in coffee production. The explanatory variables lagged production (Q_{t-2}) and lagged price (P_{t-1}) were maintained in the model irrespective of their statistical significance, as these are required for the calculation of the long term price elasticity that reflects area adjustment.

The own-price coefficient, though positive for all coffee producing regions, is small and insignificant at the 5% level, which is not surprising for a perennial crop which prices are determined in a world market that shows large year-to-year price fluctuations (deviations of 50% of the long-term average coffee price level are no exception). Coffee producers are price takers (at least in the short and medium term) and will market their produce almost irrespective of the coffee price. Similarly, the coefficient of the lagged production variable is also insignificant at the 5% level while determining only 30% of current coffee production at the national level. Current coffee production is mainly determined by normal production as demonstrated by a coefficient estimate that is both high and statistically significant at the 5% level. At the national level, 67% of current coffee production is determined by the expected level of normal production at the time of planting. The low coefficient estimates for the lagged price variable result in correspondingly low supply elasticity estimates.

Estimation results for banana are given in Table A1.5. Highly significant explanatory variables include the lagged own-price as well as the lagged fertilizer price, while for the Brunca region also lagged production is significant. The Brunca region is a somewhat special case, as between 1982 and 1984 banana plantations were almost completely abandoned due to economic and political factors (Sauma and Zuniga, 1996). Consequently, in the Brunca region lagged production is a relatively important variable that keeps track of the subsequent decline in production, explaining 75% of current production.

Table A1.5 Supply response model for banana[1]

		Explanatory variables			Performance indicators		
Region	N (# of obs.)	Q_{t-1} banana	P_{t-1} banana	P_{t-1} fertilizer	R^2 (adj.)	LM (prob.)	White (prob.)
Brunca	15	0.75	1.16	-0.86	0.82	0.10	0.06
t-value		*7.63*	*3.56*	*-2.86*			
Atlantica	15		48.82	-19.65	0.88	0.21	0.39
t-value			*18.40*	*-8.71*			
Costa Rica	15		49.87	-19.62	0.86	0.23	0.29
t-value			*16.78*	*-7.76*			

[1] Dependent variable is banana production in 10^3 boxes of 18.14 kilograms per year

Lagged own-prices have the expected positive sign, while the (lagged) fertilizer price has the expected negative sign. Fertilizer application levels in banana production are extremely high, with average recommended N, P and K application levels of 360, 70 and 700 kg active ingredients per year (Cortes, 1994). Regression statistics for the Atlantica region show high adjusted R^2 values and low probabilities of serial correlation and heteroskedasticity. Since the Atlantica region is responsible for about 96% of total banana production in Costa Rica, estimation results for total Costa Rica are very similar.

Table A1.6 shows the estimation results for sugarcane. The lagged own-price variable has a positive coefficient estimate which is significant at the 5% level in all regions. Other significant explanatory variables include lagged production, the lagged bean price and the time trend. The significant and positive coefficient of the latter suggests that certain (unknown) structural factors tend to increase sugarcane production in the Chorotega and Norte regions which together account for more than 50% of national sugarcane production. In the less important sugarcane production regions of Pacifico and Brunca (together accounting for less than 20% of national production), bean production seems to compete with sugarcane production as reflected in the significant and negative coefficient of the bean price variable[11]. In the Central and Brunca regions last year's production determines about 85% of current production, the remainder being determined by the lagged own-price variable and/or prices of competitive crops.

Table A1.6 Supply response model for sugar cane[1]

			Explanatory variables				Performance indicators		
Region	N (# of obs.)	C constant	Q_{t-1} sugar	P_{t-1} sugar	P_{t-1} beans	T Trend	R^2 (adj.)	LM (prob.)	White (prob.)
Central	21		0.86	17.75			0.84	0.03	0.47
t-value			*17.70*	*2.25*					
Pacifico	16	323433		25.68	-0.84		0.66	0.29	0.61
t-value		*8.33*		*2.64*	*-5.41*				
Chorotega	21			25.83		53592	0.94	0.57	0.39
t-value				*3.04*		*20.55*			
Brunca	16		0.84	9.76	-0.23		0.92	0.48	0.64
t-value			*10.22*	*2.85*	*-2.32*				
Norte	21			11.91		14278	0.60	0.06	0.06
t-value				*2.09*		*8.67*			
Costa Rica	16		0.85	148.31	-2.19		0.82	0.05	0.11
t-value			*13.29*	*2.91*	*-2.11*				

[1] Dependent variable is sugarcane production in kg per year

The explanatory power of the sugarcane supply response models is quite reasonable, as reflected in relatively high adjusted R^2 values. Serial correlation as well as heteroskedasticity are generally absent, although according to the LM test there may exist a missing variable problem in the regressions for the Central and Norte regions.

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[11] It must, however, be noted that this result did not appear in the supply response models for beans presented above.

Non-traditional export crops

Supply response model estimates for the non-traditional export crops plantain, melon, pineapple, cassava, onion and potato are given in Tables A1.7 to A1.12 respectively, and are based on the adapted standard Nerlove model (as depicted by equation 19). These models are all based on monthly price and production data for the period 1988 to 1997, and as a consequence they all include an auto-regressive term (*AR*) in order to deal with serial correlation of residuals. Moreover, a seasonal dummy is introduced for crops that show clear seasonal trends in production (melon) or consumption (potato).

Model estimation results for plantain are given in Table A1.7. Price coefficients are lagged 15 months, based on the 9 to 18 months that elapse between planting and harvesting (Purseglove, 1985). Own- price coefficients are positive and significant at the 20% level. Atlantica is the major plantain producing region, accounting for 87% of national production in 1995. The supply response model for this region shows that plantain production is negatively affected by a rise in fertilizer prices, which can be explained by relatively high fertilizer application levels (Cortés, 1994).

Table A1.7 Supply response model for plantain[1]

	Explanatory variables						Performance indicators		
Region	N (# of obs.)	P_{t-15} plantain	P_{t-15} pineapple	P_{t-15} fertilizer	T Trend	AR(1)	R^2 (adj.)	LM (prob.)	White (prob.)
Norte	104	14.21	3.30		-2843	0.45	0.37	0.10	0.00
t-value		*1.35*	*2.24*		*-2.97*	*5.01*			
Atlantica	104	47.21		-36.31	21511	0.73	0.87	0.01	0.01
t-value		*1.27*		*-2.70*	*6.78*	*10.93*			
Costa Rica	104	59.92				0.93	0.78	0.00	0.90
t-value		*1.61*				*23.27*			

[1] Dependent variable is plantain production in kg per year

Structural changes in the most important plantain producing regions are significant for the concerned period, consistent with observed productivity increases (Cortés, 1994). As indicated by the adjusted R^2 value, the plantain regression for the Atlantica region is able to explain a considerable part of the variability in plantain production. The LM and White tests, however, indicate problems with respectively serial correlation and heteroskedasticity.

Melon is a highly seasonal product, production taking place between January and May. Consequently, the supply response model for melon (Table A1.8) includes a seasonal dummy, which turned out to be highly significant. Own-price coefficients were incorporated into the model with a time lag of three months, consistent with the 2 to 3 month planting period (Cortés, 1994). For the Pacifico region (which is the major melon producing region in Costa Rica, accounting for 85% of national production in 1995), the own-price coefficient is positive and significant at the 1% level. Relatively low adjusted R^2 values indicate that the explanatory power of the melon supply response model is somewhat limited, while the White test statistic suggests the existence of a heteroskedasticity problem.

Table A1.8 Supply response model for melon[1]

		Explanatory variables			Performance indicators		
Region	N (# of obs.)	P_{t-3} melon	Dummy season	AR(1)	R^2 (adj.)	LM (prob.)	White (prob.)
Central	116	49.00	10724	0.52	0.36	0.27	0.01
t-value		*1.71*	*3.84*	*6.47*			
Pacifico	116	488.40	23667	0.60	0.55	0.27	0.00
t-value		*6.13*	*3.11*	*7.33*			
Chorotega	116	96.05	16225	0.49	0.39	0.28	0.19
t-value		*2.15*	*3.33*	*5.45*			
Costa Rica	116	611.35	43280	0.66	0.57	0.06	0.30
t-value		*4.47*	*3.67*	*8.67*			

[1] Dependent variable is melon production in kg per year

Table A1.9 shows estimation results for pineapple. The Norte region is the major pineapple growing area, responsible for 96% of total pineapple production in Costa Rica in 1995. The own-price coefficient is positive and significant at the 5% level, while a time lag of 10 months is included in accordance with the growing and harvesting cycle (Cortés, 1994). The price of fertilizer negatively influences pineapple production, as adequate fertilization is extremely important for development of the pineapple crop (Cortés, 1994). The pineapple model has a good fit as evidenced by relatively high adjusted R^2 values. On the other hand, the probabilities of heteroskedasticity and serial correlation problems are relatively high.

Table A1.9 Supply response model for pineapple[1]

		Explanatory variables			Performance indicators		
Region	N (# of obs.)	P_{t-10} pineapple	P_{t-10} fertilizer	AR(1)	R^2 (adj.)	LM (prob.)	White (prob.)
Huetar Norte	109	20.98	-54.71	0.88	0.70	0.06	0.06
t-value		*2.24*	*-1.46*	*18.57*			

[1] Dependent variable is pineapple production in kg per year

Supply response model estimation results for cassava are given in Table A1.10. The Norte region is the most important cassava producing area, responsible for 97% of total cassava production in Costa Rica in 1995. Cassava harvesting can take place between 6 to 12 months after planting, depending on the cultivar and growing conditions (Purseglove, 1987; Cortés, 1994). As a consequence, different time lags for the own-price variable are included, reflecting prices just before planting and/or harvesting.

Table A1.10 Supply response model for cassava[1]

									Explanatory variables										Performance indicators		
Region	N (#)	C const.	Q_{t-11} cas.	P_{t-2} cas.	P_{t-4} cas.	P_{t-7} cas.	P_{t-8} cas.	P_{t-11} cas.	P_{t-11} rice	P_{t-11} coffee	P_{t-11} sugar	P_{t-11} beans	P_{t-11} maize	P_{t-11} plant.	P_{t-11} banana	P_{t-11} fert.	T Trend	AR (1)	R^2 (adj.)	LM (prob.)	White (prob.)
Central	109			-470.3	639.8	-468.9		366.5	-0.50	-0.75	8.4	-0.31							0.30	0.80	0.01
t-value				*-2.67*	*2.69*	*-2.16*		*2.64*	*-2.49*	*-2.61*	*4.86*	*-3.26*									
Norte	108					1617.1					46.8		-6.08	60.89				0.48	0.40	0.25	0.03
t-value						*2.06*					*3.47*		*-2.64*	*2.06*				*5.43*			
Atlantica	109	13805	-0.20	-265.2	267.2	392.8	-371.5							-5.51	-1820.6	3.73	-541.2		0.46	0.07	0.01
t-value		*2.21*	*-2.44*	*-2.92*	*2.13*	*2.23*	*-2.41*							*-2.75*	*-4.45*	*2.28*	*-2.10*				
Costa Rica	108					1757.8					58.3		-7.29					0.59	0.43	0.41	0.07
t-value						*1.79*					*5.03*		*-2.88*					*7.48*			

[1] Dependent variable is cassava production in kg per year

Focussing on the major cassava production region (Norte), the own-price coefficient is significant at the 5% level. The price of maize is negatively correlated with cassava production, while the prices of sugar and plantain exhibit a positive correlation. The latter may be explained by the fact that cassava frequently figures as the the last crop in a crop rotation since it is economically the best option in depleted soils (Purseglove, 1987). This argument is reinforced by the positive fertilizer price coefficient in the model for the Atlantica region. While problems with serial correlation seem to be absent, the explanatory power of the cassava supply response models is relatively low with high probability of heteroskedastic error terms.

For onion, all own-price coefficients are positive and significantly different from zero at the 5% level (Table A1.11). The own-price variable is included with a time lag of 3 or 5 months, in line with the growing period and depending on the growing conditions of the region, planting method (seed or seedlings) and the availability of irrigation (Purseglove, 1985). The Central region is the major onion growing region (accounting for 99% of national production in 1995), and as a consequence model estimates for the Central region also apply to the national level. Heteroskedasticity and serial correlation are absent in all estimations, while high adjusted R^2 values point towards a relatively good fit.

Table A1.11 Supply response model for onion[1]

		Explanatory variables			Performance indicators		
Region	N (# of obs.)	P_{t-3} onion	P_{t-5} onion	AR(1)	R^2 (adj.)	LM (prob.)	White (prob.)
Central	107	863.74		0.95	0.54	0.53	0.61
t-value		*2.59*		*28.51*			
Chorotega	41		51.11	0.39	0.07	0.77	0.95
t-value			*2.82*	*2.60*			
Costa Rica	107	833.08		0.95	0.55	0.61	0.60
t-value		*2.52*		*29.28*			

[1] Dependent variable is onion production in kg per year

Estimation results for potato are given in Table A1.12. Growing conditions allow potato cultivation to take place in the Central region only. The own-price coefficient (positive and significant at the 15% level) was included with a time lag of four months, consistent with a growing period of 3 to 5 months (Purseglove, 1985). Other significant explanatory variables included the lagged price of maize and a dummy to deal with seasonality, the latter reflecting the fact that most potato production takes place during the last five months of the calendar year.

Table A1.12 Supply response model for potato[1]

		Explanatory variables					Performance indicators		
Region	N	P_{t-4}	P_{t-4}	Dummy	T	AR(1)	R^2	LM	White
	(# of obs.)	potato	maize	season	Trend		(adj.)	(prob.)	(prob.)
Central	115	1948.98	11.67	122694	71034	0.72	0.73	0.34	0.10
t-value		*1.55*	*2.88*	*3.43*	*5.24*	*10.64*			

[1] Dependent variable is potato production in kg per year

Structural changes, as reflected in the time trend, were significant for the concerned period and reflect productivity increases over the last ten years (Cortés, 1994). The adjusted R^2 value shows that the potato regression is able to explain a considerable part of the variability in potato production. Moreover, heteroskedasticity and autocorrelation problems were generally absent.

Livestock products

Estimation results for beef and milk (based on the adapted standard Nerlove model depicted by equation 19) are shown in Tables A1.13 and A1.14, respectively. Since regional production data for beef and milk were not available, supply response models could only be estimated for the national level. However, even at the national level data availability for milk and (particularly) beef is such that only a limited number of observations could be obtained.

Table A1.13 Supply response model for beef[1]

		Explanatory variables		Performance indicators		
Region	N	Q_{t-1}	P_{t-1}	R^2	LM	White
	(# of obs.)	beef	beef	(adj.)	(prob.)	(prob.)
Costa Rica	12	0.53	28588	0.25	0.10	0.66
t-value		*3.60*	*3.19*			

[1] Dependent variable is beef production in 10^3 MT per year

Both the lagged beef price variable and the lagged beef production variable have positive and highly significant coefficients, being about equally important in the determination of current production. Thus, current beef production is to a significant extent determined by the herd size that remains after last years' slaughter. In addition, the nature of livestock fattening activities allows for a flexible adjustment of the number of animals to be slaughtered in accordance with prevailing beef prices. While the adjusted R^2 value is relatively low, problems of autocorrelation and heteroskedasticty are largely absent.

Table A1.14 Supply response model for milk[1]

		Explanatory variables			Performance indicators		
Region	N (# of obs.)	P_{t-1} milk	P_{t-1} cows	AR(1)	R^2 (adj.)	LM (prob.)	White (prob.)
Costa Rica	15	195.65	145007	0.51	0.69	0.04	0.34
t-value		*4.45*	*3.60*	*3.40*			

[1] Dependent variable is milk production in MT per year

Estimation results for milk indicate that current milk production is influenced by both lagged milk prices as well as lagged cow prices. Both price coefficients are positive and significant at the 5% level. Lagged cow prices are positively correlated with milk production as female animals reflect an intrinsic value over and above the value they generate through milk production. Serial correlation problems required the inclusion of an *AR(1)* term which suggests a missing variable problem. Even though the exact nature of this variable is unknown, it may be related to the large influence of the Costa Rican government on milk production and national milk prices.

Appendix 2 Conversion factors applied to consumption, export and import data

Conversion factors were applied in order to ensure consistency between consumption, export and import data on the one hand, and gross production data on the other hand.

Commodity	Production	Consumption	Exports	Imports
Rice	humid & dirty	*2.8 for humid & dirty and indirect consumption	*1.3 for humid & dirty	*1.3 for humid & dirty
Maize	humid & dirty	*1.8 for humid & dirty and indirect consumption	*1.2 for humid & dirty	*1.2 for humid & dirty
Beans	humid & dirty	-	*1.2 for humid & dirty	*1.2 for humid & dirty
Coffee	ripe beans	*1.4 for green to ripe beans	*2.8 for export quality to ripe beans	-
Banana	fresh fruit	-	-	-
Sugar	cane	*9.9 for sugar to cane	*9.9 for sugar to cane	-
Plantain	fresh fruit	*1.6 for indirect consumption	-	-
Palm heart	heart plus peel	*1.6 for peel	*1.6 for peel	-
Mango	fresh fruit	*2.4 for indirect consumption	*2.4 for indirect consumption	-
Melon	fresh fruit	*1.1 for indirect consumption	*1.1 for indirect consumption	-
Pineapple	fresh fruit	-	-	-
Cassava	root	*1.4 for indirect consumption	*1.5 for indirect consumption	-
Onion	fruit	*1.6 for indirect consumption	-	-
Orange	fresh fruit	*1.3 for indirect consumption	-	-
Potato	root	*1.3 for indirect consumption	*1.3 for indirect consumption	-
Beef	carcass weight	*2.9 for carcass weight and derived consumption	*1.9 for beef to carcass weight	-
Milk	milk	*5.3 for indirect consumption	*8.0 for powder to milk	*8.0 for powder to milk