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Deforestation in Nicaragua**

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Abstract:

This paper investigates the impact of structural adjustment policies on deforestation taking place when the agricultural frontier advances into forest reserves in Nicaragua. A computable general equilibrium model incorporating deforestation by squatters is used for policy simulations. The opportunity cost of migrating to the frontier does not simply depend on wage income opportunity, but also on market prices of basic grain which determine the capacity to consume beyond subsistence food level within a certain real wage. Reducing public expenditures both conserve forests and enhance economic growth, while showing positive distributional effects. On the other hand, a strong conservation trend following a sales tax increase is driven by increasing poverty in rural areas. Noticeably, there are policies which initially intensify deforestation, but turn out to ease the pressure on forests over time. Rapid economic growth does not ensure less pressure on forest reserves.

Keywords: Deforestation, structural adjustment, general equilibrium model, Nicaragua.

JEL classification: C68, O54, Q23, R23

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1. Introduction

Around 1990 Nicaragua entered a period of economic stabilization and adjustments after many years of social and economic turbulence¹. Markets have been deregulated, the domestic currency deflated, public expenditures reduced and the tax system reformed. The reform process implemented various measures crucial to long term development. The transition period, however, has imposed large scale unemployment and increased poverty on a substantial part of the population. Negative long term effects may occur due to increased poverty and deterioration of public education and health services. Also, long term effects on future production capacity and future income generation may be related to deterioration of the natural resource base, for instance if poverty intensifies the pressure on agricultural land and forest reserves.

The focus of this paper is on the impact of structural adjustment policy on deforestation in Nicaragua. Several factors have initiated a migration wave towards the forests for subsistence farming. After several years of war, the forests are again accessible for people. The economic crisis and rising unemployment have set fire to deforestation, literally speaking. A population growth of 3.2 per cent provides an overall pressure on natural resources.

In our approach we highlight the interrelation between poverty, employment opportunities and deforestation caused by migration to the agricultural frontier in Nicaragua. We question how particular policy elements like tax reform, reduced public expenditures and improved external balance affect the pressure on the still significant humid tropical forests of Nicaragua. For this purpose we employ a computable general equilibrium (CGE) model containing an informal food producing frontier sector, advancing into forest land. Forest soil provides land for subsistence farming over a few years, but thereafter deteriorates rapidly, causing deforestation to go on even with a constant population of squatters. In the model, general economic policies affect the flow of new settlers to forest reserves by providing more or less attractive alternative wage income opportunities within the market economy.

In the literature so far the deforestation problem has mainly been dealt with in a partial manner and the actual linkages between general economic policies and the pressure on forests remain diffuse. In a recent theoretical approach, Deacon (1995) discusses the impact of tax policies on deforestation and the social welfare within a general equilibrium framework. Deacon treats land as homogenous input in a single agricultural sector. So do Thiele and Wiebelt (1995) in an empirical model for Cameroon. Thus, it is the general development in supply and demand of an aggregate agricultural good which is driving the demand for input of land in those models. This conceals some important aspects in rural production technology and income generation which might affect the land use and rate of deforestation.

First, the production technology at the agricultural frontier is far more labour and land intensive than the average, stationary cultivation practices. Technology is determined by the lack of infrastructure, making commercial input like fertilizer and pesticides too expensive and production for markets practically beyond reach. This means that various general economic policies might affect the more intensively producing permanent agriculture without penetrating to the agricultural frontier. Second, at the frontier, crops are grown for subsistence. When dealing with the deforestation problem, this has important consequences. The link between deforestation and economic policy in developing countries may primarily be found in the labour market and the off-frontier potential for income generation, and not so much in the changes in the market for agricultural crops in general. Various policies might affect stationary and frontier farming differently and thus generate different deforestation rates, although they have similar impacts on total production in agriculture. Our approach seeks to bring more realism into the policy analysis of deforestation in this respect.

¹ See Gibson (1993) for an economic analysis of this period.

Other empirical and economywide approaches to deforestation frequently deal with the deforestation pressure generated by commercial logging. Thiele and Wiebelt (1995) integrate a forward looking forestry sector in their CGE framework for Cameroon. Persson and Munasinghe (1995) goes one step further and includes deforestation by squatters for either logging or subsistence farming in Costa Rica. An interesting result of this study is that stumpage price increases will reduce deforestation for logging, but total deforestation will nevertheless increase, because general equilibrium effects shift resources towards agriculture. The fact that indirect allocation effects may differ in direction and even dominate over the direct effect identified in partial equilibrium analysis clearly demonstrates the importance of using an economywide approach. To capture these indirect effects of economic reforms on the deforestation rate in Nicaragua, we apply a CGE model. By including land clearing subsistence farming in forest reserves in the model, we look for determinants of migration to forest reserves through income and consumer options facing the labour force.

In section 2 we briefly describe the CGE core model and in more detail present the modelling of technology and income generation at the agricultural frontier. Section 3 outlines the business as usual scenario and describes the policy reforms which we will focus on. Section 4 presents results from model runs while section 5 concludes.

2. The model

2.1. CGE core model

The core model was developed at the Business School of Central America (INCAE) in Managua and further developed for environmental analysis in cooperation with Statistics Norway (see De Franco et al. (1993), Alfsen et al. (1996)). Producers and consumers behave as maximizers of profits and utility respectively. Markets for goods clear, but labour faces the possibility of unemployment, which runs high in Nicaragua. There is no capital market, reflecting the inadequate credit facilities. The model is calibrated to 1991 data.

2.1.1. Producers

There are 27 sectors each producing a single commodity. Among these are 12 agricultural sectors, classified as *rural*, all others are *urban* sectors. Commodities are produced by labour, capital and intermediates. The intermediates are used in fixed proportions to the production levels. Demand for labour is determined by equating the value of the marginal production of labour to the wage rate, and is decreasing in the real wage rate. Each sector receives a fixed share of total nominal investments. Production functions are Cobb Douglas, except in the agricultural frontier sector where the only input factor, labour, is proportional to output, which is a linear composite of basic grains.

2.1.2. Labour market

Total labour supply is growing by a constant rate based on population growth forecasts. There is unemployment in the urban sector, since migration to cities is positive as long as expected urban income, adjusted for the probability of getting a job, is higher than at the countryside. The model is run in two different versions, with constant and flexible real urban wage, respectively, to illustrate two extremes among wage formation rules and unemployment regimes.

2.1.3. Social classes and distribution

The income distribution is the driving force behind migration of labour. To state this force explicitly, the model traces the income of 5 social classes: Campesinos, Frontier farmers, Workers, Petty capitalists and Capitalists. Income consists of profit, wages and transfers from abroad. Campesinos earn rent as agricultural smallholders, while big agricultural producers are counted as Capitalists. Workers earn their wages, in either urban or rural sectors, and frontier farmers earn the imputed income from their production of basic grain. Capitalists receive a share of rural profit and urban profit, while Petty capitalists (informal producers) receive a share of profits in urban sectors. Each of the 5

classes has a consumption pattern formalized as a linear expenditure system. For capitalists, the minimum consumption is 10 per cent, for workers and petty capitalists 15 per cent, and 20 per cent for campesinos. At the agricultural frontier, the total production is used for autoconsumption.

2.1.4. Saving and investment

Private savings equals total income less taxes and total private expenditure. There are highly different saving rates among classes, hence the income distribution strongly influences the level of total saving. The public sector benefits from foreign transfers, through official development assistance, while workers, capitalists and petty capitalists benefit from private remittances. Public saving is a residual of public revenues less exogenous public expenditure.

Investments in real capital is determined by total savings. Foreign savings are assumed to be constant; so domestic savings are the essential variables for determining the economic growth potential. A dominant share of domestic savings stems from profit, while workers and campesinos contribute insignificantly.

The capital stock in period $t+1$ is equal to the capital stock in period t less depreciation plus investment in period t . Allocation of investment by destination is determined by fixed (base year) coefficients. The sectoral pattern of investment by destination is translated into demand for investment goods by sector of origin.

2.1.5. Foreign trade

Domestically produced goods compete with foreign goods both on the world market and at home. It is assumed that domestically produced commodities and imported goods of the same category are non-perfect substitutes (the Armington assumption). The higher the price of the domestically produced commodity relative to the price of the imported variety, the higher is the import share. The lower the price on exports relative to the world market price, the higher are the exports. World market prices are exogenous, and the nominal exchange rate is set by the government. The prices of imported and exported goods are determined as the world market prices multiplied by the exchange rate and adjusted for tariffs.

Below we discuss in more detail the production system at the agricultural frontier and how we model the links between the frontier and the rest of the economy.

2.2. Production technology at the agricultural frontier

The agricultural land expands in many directions, and the frontier is no clearly defined area. However, in Nicaragua today, there are two distinct areas which are colonial centres, combining the features of rapid expansion of cultivation with the availability of virgin forest. These areas are Bosawas in the north and Indio-Maiz in the south, both forest reserves. The migrators are settling with a cultivation pattern and a technology which is described below, based on surveys of the frontier activity carried out by the Ministry of the Environment (GTZ/MARENA, 1992) and CIPRES (1992). The production system is more thoroughly described by Monge A. (1995).

Table 1 presents the labour and land characteristics of a typical squatter family. The representative family of 8 persons disposes on average 4 man-years of labour, which means that big children and women take part in production (although minors below 12 years are assumed not to contribute). The family clears about 12 manzanas (1 mz = 0.7 ha) to keep aggressive vegetation and shadow on suitable distance from an actually cultivated plot size of 8 mz. The climate allows for 3 seasons per year (24 mz-seasons).

Table 1. Representative family farm at the frontier

Family size	Labour (manyear ¹)	Deforested area(mz)	Plot size (mz)	Seasons	Cultivated area annual basis (mz)
8	4	12	8	3	24

¹ Not including the labour of children below 12 years.

Table 2. Production at representative frontier farm

	Cultivated area (mz)	Yield, (QQ ¹ /mz)	Gross output (QQ)	Per cent loss	Net output (QQ)
Maize	12	20	240	30	168
Beans	8	10	80	30	56
Rice	4	35	140	30	98

Sources: Yields: GTZ/MARENA, CIPRES (man-days per mz)

1) QQ = quintales

Table 2 depicts the typical allocation of labour on the 3 cultivated crops, taken from CIPRES (1992). The crop pattern allocates 12 mz-seasons to maize, 8 mz-seasons to beans and 4 mz-seasons to rice. Representative yields of maize, beans and rice are 20, 10 and 35 quintales (QQ) respectively. The family labour produces 33.6 QQ of maize, 11.2 QQ of beans and 19.6 QQ of rice on average per man-year, when a 30 per cent harvest loss is taken into account.

Table 3. Production and imputed income per man-year

	Production per man- year (QQ)	Output price (C\$/QQ)	Imputed frontier income per average man-year by activity (C\$)
Maize	42.0	38.7	1 625.4
Beans	14.0	48.9	684.6
Rice	24.5	46.8	1 146.6

Prices are taken from Economic indicators from the Central Bank (BCN, 1994a) presenting US\$ prices for important agricultural products in Managua.

The fragile forest soil is degrading rapidly due to current management practice. Consequently, after 3 years a plot is abandoned and new land is cleared. Hence, even a stagnant population at the frontier drives the deforestation process. In addition, the high population growth combined with the widespread poverty and unemployment in Nicaragua further encourage migration to the frontier where income after all is secure and does not fall below a subsistence level due to the practically unrestricted access to forest land.

According to the stylized description above, the frontier labour force (L_F^t) produces $z l_{mz}$, $z l_{fr}$ and $z l_{ar}$ units of maize, beans and rice respectively per man-year. The corresponding frontier production level for a single crop b is

$$(1) \quad XF_b^t = z l_b L_F^t, \quad b \in (mz, fr, ar)$$

where b represents maize (mz), beans (fr) and rice (ar). This production level generates an imputed income WF^t per man-year

$$(2) \quad WF^t = \sum_b P F_b^t z l_b, \quad b \in (mz, fr, ar)$$

at the frontier. This is the level of income which is attracting migrators or not, depending on alternative income opportunities in the economy. The product price obtained at the frontier (PF_b^t) is in the model set equal to the price (P_b^t) facing the market integrated producers of basic grains (maize, beans and rice) in the economy:

$$(3) \quad PF_b^t = P_b^t \quad b \in (mz, fr, ar)$$

Production at the frontier is for autoconsumption and as such, the output of grain has a basic value independent of market prices. However, for accounting purposes it is reasonable to calculate an imputed income based on general market prices. The important assumption for the result is that a change in market prices signalizes a change in the alternative cost of remaining within the market economy and not get access to the frontier diet. If frontier production had been commercialized, farm gate prices would in general be lower than in central agricultural areas with better infrastructure and lower transportation cost. By assuming that all output is for autoconsumption we disregard the fact that a minor share of output is commercialized, for instance as pigs walking their way to some local marketplace.

Alternative occupation and income is available in the established rural economy, and in urban areas with a probability less than one. Equilibrium is obtained when there is equality between the expected income options. The rural wage level WR^t , which is an index for wages in established rural production sectors, is equal to the urban wage level WUO , adjusted for the probability of being employed in urban sectors:

$$(4) \quad WR^t = (1 - UR^t)WUO$$

UR^t is the share of unemployed in the urban economy which is where unemployment exists.

Farming at the frontier is primarily an alternative to rural farming. We assume that landless labourers in rural farming leave for the frontier if income at the frontier is large relative to income in rural farming.

In considering how to model this relationship, an extreme alternative would assume that people leave for the frontier if income at the frontier is larger than income in rural farming, making the income levels equal in equilibrium. A less extreme alternative, which we chose, is to assume a constant elasticity of transformation (CET) macro relationship between working in rural farming and working at the frontier. This relationship means that some landless labourers leave for the frontier immediately when income at the frontier exceeds income in rural agriculture. Other needs a larger income incentive in order to move, for reasons of transport costs, non-pecuniary preferences or risk aversion. In equilibrium, a non-zero income differential is associated with a finite stock of frontier farmers.

To model the CET relationship, we use the dual and specify the macro index of income in rural agriculture and the frontier:

$$(5) \quad WX^t = [\eta_1(WF^t)^\rho + \eta_2(WR^t)^\rho]^\frac{1}{\rho}$$

WX is the macro index of income, ρ indicates the elasticity of substitution. We define the stock of frontier farmers as a function of income relative to the wage index (which, since the wage index consists of frontier income and rural income, is equivalent to defining it as a function of frontier income relative to rural income):

$$(6) \quad LF^t = \eta_1 LS^t [WF^t / WX^t]^{\rho-1}$$

to describe the labour market, it remains to determine the stock of landless rural labourers. To do so, the model allocates potential labourers between urban unemployed and rural labour such that the urban unemployed equal the number necessary for the expected urban wage to equal rural income for the landless labourer.

Total labour supply (LS^t) in the economy grows at an annual rate g

$$(7) \quad LS^t = LS0(1+g)^t$$

where $LS0$ is the base year labour supply.

Deforestation consists of two elements. One is land cleared by new colonists, and the other is land cleared by the population which has settled at an earlier time, but have to clear new land due to rapid degradation of soil. The deforested area in year t (DF^t) is:

$$(8) \quad DF^t = A[LF^t - LF^{t-1} + 1/3LF^{t-1}]$$

where A is the average cleared area per man-year. We assume that 1/3 of formerly settled frontier farmers have to clear new land each year. This formulation ignores the fact that frontier population is composed of colonial waves with various strength over the years, but this is a minor omission.

3. Structural adjustment policy and deforestation

To assess the impact of economic reforms on deforestation we have chosen policy scenarios containing some central stabilization and adjustment elements. These are reducing public expenditures, broadening the tax base, and narrowing the foreign trade gap (devaluation). Below we sketch the background for implementing these policy measures and finally some characteristics of the business as usual scenario. The policy simulations represent a mixture of implemented and planned policies which we simulate over a 10-year period.

1) Reducing government expenditures

The Government of Nicaragua faced the challenge to improve fiscal balance in order to ease the inflation pressure in the economy. To reduce the public deficit, the total employment in public sector has been reduced by about 180 thousand employees. Of these, 20 thousand were laid off from the central government's civil staff, while the rest were laid off from defence and public enterprises in roughly equal shares (Government of Nicaragua, 1996). The consequent rise in unemployment can be expected to reduce migration to urban areas by lowering the probability of getting a job and hence the expected income from urban work. The pressure on land might increase. It remains to be seen from model runs to which extent this pressure will affect virgin forests.

2) Increasing government revenues by broadening the tax base while harmonizing tax rates

According to World Bank (1993), around 30 per cent of total tax revenues were still collected from eleven enterprises in an early phase of the reforms. We focus on the impact of broadening the base for a sales tax. Since agricultural sales still are practically beyond reach of tax collection, the administrative system must be developed to deal with this. A significant widening of the tax base to include the rural sectors is a medium or long term policy - not actually an implemented reform so far. By means of a more efficient administration, public revenues have increased from 16 per cent of GDP in 1990 to 26 per cent in 1995 (Government of Nicaragua, 1996). To illustrate a possible impact of broadening the tax base, we study the case of increasing the effective indirect tax on urban sectors by 5 percentage. In rural sectors the tax rates are increased by 3 percentage points after 4 years of reforms, assuming that the government has managed to build up the administrative capacity to widen the rural tax base by then. Since government consumption is exogenous in this simulation, the increased revenue is directly transformed to a similar increase in public saving (and total saving).

3) *Narrowing the trade balance gap*

A macro-devaluation initiated the stabilization efforts in 1991, and was followed by a 20 per cent devaluation in 1993. Thereafter, the government carried out a crawling peg exchange rate policy. During devaluations the economy was supported by a strong inflow of foreign aid. Future developments are supposed to rely considerably less on foreign aid, and foreign borrowing options are limited. Hence we study the impact of a reduction in the foreign deficit, which also is to be interpreted as an effect of devaluation.

The impact of these measures (under the assumption of constant real wages) are presented in section 4. In addition, the cumulative effect of the same policies is studied under a flexible wage regime. The characteristics of the base case or business as usual scenario are given below.

4) *Business as usual*

The Business As Usual - scenario (BAU) portrays the continuation of base year behaviour and policies. The labour force is assumed to grow at an annual rate of 3.4 per cent. The population growth was estimated to be 3.2 per cent in the years 1990-1995 and is expected to fall to an average of about 3.0 per cent for the years 1995-2000. (Comision Nacional de Poblacion, 1994). Considering that the population is very young at present, we assume that the working population will grow somewhat faster than the total population in the simulation period.

Tax revenue is mainly generated from a sales tax of 15 per cent. Industries as defined in our model face different rates according to the various exemptions and inefficiencies in tax collection. The rural sectors practically pay no taxes. This is even so for coffee which is an important export crop.

A few adjustments are made to catch some changes likely to occur. The saving rate of campesinos was negative in 1991, owing to credit supply combined with limited enforcement of debt services. A negative saving rate may, however, be a poor estimate of future saving practice because reforms in the financial sector has restricted credit and also seek to re-enforce payment of debts services. This institutional reform is not explicitly dealt with here. However, we have assumed that the campesino saving rate may turn positive because less producer credit is available, and payback ratios are forced upwards. Also, an implicit taxation of agricultural production is phased out by deregulation of agricultural marketing. This may increase rural income and leave more for saving and investment. To account for these possible effects, the campesino saving rate is set to 2.5 per cent after 1991, which is roughly the same level as for workers and urban petty capitalists.

The BAU assumes a constant real urban wage while the level of urban unemployment is variable. The threat of social conflicts and disorder might possibly unite employers and labour unions on approximately such terms.

Public expenditures are assumed to grow at an annual rate of 1.8 per cent. The Business As Usual scenario is mirroring shrinking investments, increasing unemployment and an annual decline of 3 per cent in GDP. The annually deforested area is increasing by almost 10 per cent per year, making total deforestation in the reserves more than twice the base year level after 10 years.

The BAU is not a sustainable path, but base year behaviour and restrictions offers a reference point for analysis of various economic reforms, and levels of external financing. A main factor behind future sustainability not thoroughly dealt with in this study, is the potential for technological change and increased efficiency following a reorientation of economic policy. The moderate assumption of a 0.5 per cent technological progress is included in the model runs. Urban sector efficiency might be expected to improve above this rate, while technological progress in agricultural sectors might be more uncertain, being contingent upon infrastructure and marketing facilities which are not immediately provided by deregulation.

4. Results from policy simulations

Below we present the results for each scenario by first pointing at the short term effects of the implemented policies, and thereafter commenting the outcome after 10 simulation periods. Table 4 presents the output of model runs by the end of the horizon. Figure 1 presents the effect of single policy measures on GDP, unemployment rate, private consumption and deforestation. Figure 2 displays the development of rural and urban per capita income along with the change in deforestation.

4.1. Reduced public expenditures

During the period 1990 - 95, fiscal policy has been a key element in the stabilization process. The non-financial public sector balance improved from an 18 per cent deficit in 1990 to a surplus from 1992 on. In this scenario, the annual growth in public expenditures is lowered from 1.8 per cent in BAU to 1 per cent.

The direct effect of reducing public expenditures is an increase in public savings and the level of investments. Initially - before additional investments has expanded the productive capacity - the impact of improved fiscal balance is a reallocation of resources towards production of investment goods within the same resource constraints as in the BAU.

Investment demand is directed towards construction and private services, mainly met by domestic supply. The same applies to public demand. What happens when public sector lowers demand is that additional demand for investment goods is taking over for public expenditures. Consequently, no significant structural changes take place in domestic and foreign markets, conserving the terms of trade. However, second order price effects tend to favour agricultural sectors. These price effects, together with an increase in urban unemployment of 0.4 per cent make the outcome of frontier farming improve slightly in relative terms, and the annual deforestation increases by 0.3 per cent after 2 years. However, it is an important conclusion that tightening of the budget does not imply mass unemployment and exodus to the agricultural frontier in the short term.

The short term increase in investment is not taking place at the expense of private consumption, and demand for agricultural products is maintained. The average rural income level is positively affected. Average income for the urban working population (employed or self employed) is also increasing (0.4 per cent), reflecting that profit in informal sector is rising. There is an increase in urban unemployment, though. Still, including the unemployed, the average income for the urban population as a whole, is constant. The rural population has a considerably lower income level than the urban population. Consequently, there are some immediate positive distributional elements of this policy, but they are conditional upon increased consumption of natural resource capital, and an increase in urban unemployment. The social impact of increased unemployment is clearly negative, but empirical evidence indicates that family income in the dominant urban region Managua-Masaya is a composite of wage income and profit in self employed production of goods and services (IHC, 1986). A broad segment of the urban population might then share benefits as well as disadvantages of this policy, which keeps the average urban income stable in the short term.

The reduction in government spending launches a process of capital accumulation. Over time, increased investments expands the production capacity and income is increasing. By year 2000, GDP is 4.7 per cent above BAU as shown in table 4. Private consumption is also increasing, although slightly less (3.1 per cent).

The investments raise labour productivity and allow for an overall long term increase in profits and real rural wages. The higher rural wages attract workers more than being an unemployed urban poor, and the unemployment rate is reduced by 2.3 per cent compared with BAU by the end of the simulation period. The rural per capita income level (consisting of real wage income plus campesino share of profit) is increasing by 0.5 per cent. The average urban income level is increased by as much

as 3.3 per cent since the number of unemployed urban workers falls and profit increases for small urban producers.

The frontier farmers do not invest in capital equipment, but compensate declining soil productivity with fresh natural land capital. Hence, productivity is stagnant at frontier farms, which are lagging behind in comparison with the rural wage earners who are the social basis for migration to the frontier. Less people than in the BAU are so poor that remote subsistence farming feels like a better option, and the clearing of forests is reduced. The annual rate of deforestation is reduced by 4.8 per cent compared with BAU. Taking into account that the initial effect of this policy was an increase in migration to the frontier, this indicates a more significant positive long term effect on deforestation beyond our time horizon. Total deforested area over the simulation period is reduced by 1.8 per cent.

Overall, the policy implies less deforestation. The level of private consumption is conserved in the process of accumulation and growth, which in the early phase of reform is beneficial to the rural population. However, over time the urban population gains more from this policy than the rural. Both unemployed and frontier farmers merge into the stationary agricultural sectors where real wages increase by about 2.5 per cent, but profit in agricultural sectors is not increasing much and rural per capita income is lagging behind the urban income level growth.

4.2. Sales tax reform

To mobilize resources for public services and investments, economic reform programs aim at broadening the tax base. Nicaragua has recently increased the government's current income from 16.5 per cent of GDP in 1990 to 26.8 per cent in 1995 (Government of Nicaragua, 1996). In this scenario we study the effect of increasing the sales tax in urban sectors by 5 percentage points. In the less formal rural sectors, a sales tax of 3 per cent is introduced by year 5. Scenario 2 in Table 4 represents the combined effect of both reduced public expenditures and the sales tax reform by the end of the simulation period.

Initially, only urban sectors face increasing tax rates. The tax increase lowers net producer prices and profits, and the short term response of urban companies is to lay off workers, since urban real wages are rigid. The increase in investments enhances labour productivity, but in an early phase this is small and incapable to compensate fully for the contractive effect of lower urban net producer prices, even though investments mainly are allocated to urban production sectors.

The loss of private income through rising unemployment and the decline in profits makes private consumption fall by 9 per cent after 2 years. Food is a significant element in consumer demand and prices on food crops fall considerably. Due to the decline in food prices, the terms of trade between basic grains and other consumer goods change markedly. This leaves frontier farmers in a different position. In their remote settlements they do not have the option to substitute general consumer goods for basic grains. When food becomes cheaper relative to other consumer goods, it is perceived as increasingly beneficial to get access to and choose from a wider basket of goods and services available to rural and urban labourers. Hence, people tend to leave the frontier. This effect dominates over the impact of increasing urban unemployment, which lowers the expected urban wage income and makes people less inclined to stay at the frontier. The annual rate of deforestation falls to 8 per cent below BAU as a short term effect.

Although the urban sector is the one being levied an additional tax at this stage, the rural sector is carrying the main burden. Real rural wages are reduced by about 5 per cent. Still, the number of rural workers is falling almost 6 per cent and rural labourers are turned into urban unemployed poor.

In the short term, the urban sales tax generates an economic contraction and engrave the distributional differences between cities and the countryside. But forest land is preserved even during this crisis due

to the increasing relative disadvantage of generating income through basic grain production for subsistence.

Rural sectors are taxed from 1995, contributing to a further increase in public saving and investments. The higher level of investments eventually gives an additional value added. In year 2000, GDP is 1.6 per cent above the previous scenario and 6.3 per cent above BAU. However, this long term benefit is obtained at a high cost in the sense that the level of private consumption is reduced almost 6 percentage points compared with the reduced public expenditure scenarios (to a level of 3 per cent below BAU).

The long term benefits in forest conservation are significant, though. The annual rate of deforestation is reduced by 9 per cent (to 14 per cent below annual deforestation in BAU) after 9 years. The migration from the countryside to the cities is dampened, but unemployment remains almost 5 per cent above BAU.

The urban population (including the unemployed) has got its per capita income reduced by 6 per cent compared with the previous scenario (to 3 per cent below BAU). The elements included in the average per capita urban income are urban wages and profits in informal sector. For those who are employed or (informally) self employed in the cities, the per capita income level is slightly reduced, because profit in the informal sector is negatively affected. The main change in the urban real income level is due to increased unemployment. The rural sector suffers from the considerable fall in rural real wages.

Except for the beneficial impact on natural resources, there seems to be little to gain from the tax reform within the first decade. But the high investment level which has turned the result from a sharp decline in activity level early on to some positive medium term results might embed a potential for even higher growth and lower unemployment in the longer term, in particular if the technological improvements associated with the higher investment rates are taken into account. However, if a significant contribution to economic growth and increased welfare will come after 15 years or so, the younger half of the population at that time would have been waiting all their childhood for improvements in nutrition, health and education so crucial and conditional for long term development. The long term structural impact of the tax reform might still be beneficial, but the tax reform as a means of stabilization should be complemented by measures which increase productivity and compensate the rural population where the incidence of poverty is high.

The investments are increased by roughly the same magnitude in this tax reform scenario as in the previous scenario. In the case of reducing public expenditure, growth is stimulated from the outset and over the whole decade, rising GDP 4.7 per cent above BAU in year 2000. Financing the same amount of investments by indirect taxes only adds 1.6 per cent to GDP within our time horizon. Why does it make such a difference whether investments are financed by cutting expenditures or raising the tax rate? The reason for sluggish performance under the tax reform may be that raising the urban sales tax eats up the initial growth impulse created by the investments generated by the tax revenue. Urban sectors dominate the investment activity, so the potential to enhance growth through investments in the current regime lies within the urban economy. When urban sales taxes are increased, the investment induced increase in labour productivity and profits is withdrawn. Actually, the urban economy is contracting, and through lay offs and lower levels of income and consumption this strongly affects the rural income level. Over time, increased growth is showing up, but the rural income is lagging behind the urban income growth. Rural growth and welfare depend upon the level of private consumption and the associated demand for food crops, since (credit and) investments do not reach far out in the fields. More direct gains from increased productivity through investments are not easily available to the countryside.

When cutting public expenditures, this self-defeating mechanism involving urban investments and urban taxes does not show up. Additional investments are allowed to generate increased urban income

which keeps up demand for food and generates rural income as well. Also, the composition of domestic demand is hardly disturbed when increased investment demand is substituted for public demand. The sectoral structure remains stable, ensuring that no income loss occurs due to structural changes, since sectors differ somewhat with respect to profitability.

4.3. Reducing foreign transfers

Stabilization and structural reforms are implemented to stimulate growth and investments and thus reduce dependency on foreign development assistance. In this scenario we trace the impact of reducing the external deficit by US\$ 50 millions per year from 1995, a 15 per cent annual reduction compared to the BAU deficit level. The policy is implemented late in the simulation period, so the time horizon is short anyway. The results effect short or medium term effects (5 simulation periods) only.

As a first order effect, the reduction in foreign savings is to lower total investments equally much. However, although economic growth is hampered to the extent that nearly all GDP gains from the sales tax is neutralized, the investment level is not reduced proportionally due to relative price effects.

When the inflow of foreign currency is reduced, the stricter trade balance forces the real exchange rate upwards, protecting exports, while imports nearly falls to BAU level, in spite of an activity level 5 per cent above the reference scenario. The domestic price level is falling, and investment demand, which mainly consists of domestic goods and services, is encouraged by the relative change between domestic and world market price levels.

The decline in activity level increases the level of urban unemployment. The increase in the unemployment rate lowers the expected wage income in the cities, and the equilibrium rural wage is reduced more than the urban nominal wage level. The rural population is getting poorer. Per capita real income is reduced by 1 per cent to 10 per cent below BAU. Behind this change lies a reduction in real rural wages (0.5 per cent) and a decline in rural profits (2 per cent). Fewer opportunities for earning rural wage income will generally encourage migration to the frontier and to the cities. However, urban demand for labour is hardly increasing and the migrators are adding to the number of unemployed. The urban average income is reduced by 1.5 per cent at the end of the simulation period.

Average incomes for both the urban and rural population are reduced. Still, deforestation is only slightly increased. The migration flow is held back because food items (basic grains) are becoming relatively cheaper in the markets, and partly compensates for the effect of the fall in income levels. Hence, the income level and not deforestation is of concern when the external deficit is being reduced.

4.4. Flexible wages

So far, the policies introduced in the scenarios have moved GDP in year 2000 a few per cent above BAU. Such gains are significant if combined with beneficial distributional effect and less pressure on natural capital, but do not qualify as a take off in a development context. A common feature of these scenarios is that they hinge upon the assumption that rigidities in the labour market are sustained during the simulation period of 10 years. If they do not, and real wages in urban sectors start to respond to the level of unemployment, the outcome might turn out differently. In the following scenario, it is assumed that the real urban wage is flexible, and that the market is successful in stabilizing the unemployment at 9 per cent, assumed to be a structurally determined minimum level. All policies introduced in earlier scenarios are retained.

By removing the assumption of rigid urban real wages, the profitability is increasing and GDP jumps to a level of 9 per cent above BAU after year 2 of the simulation period.

The production costs level is falling 2.3 per cent, owing to the urban real wage decline of about 1 per cent. However, the agricultural sectors benefit from increased food demand and a substantial rise in output prices, and compete for labour by rising real rural wages by 5 per cent.

With such immediate improvements in rural workers' income level, one might expect the subsistence production at the agricultural frontier to dwindle. However, the prices of basic grains are increasing significantly, reducing the value of access to the broader consumer goods basket in comparison to frontier basic grain production. Within the market economy and for a certain real wage, less goods and services are now available in addition to basic food consumption, which has become significantly more costly. Even though employed work in the countryside is being rewarded higher than before, and expected urban real wage is increasing, this price effect is strong enough to encourage the migration to the frontier. Hence, in the short run, the rate of deforestation is actually increasing.

The deflationary effect associated with less rigid urban real wages encourages exports to increase, in particular exports from urban sectors. The increase in profits stimulates investments, since saving rates are higher among capitalists than workers.

Unemployment is reduced by assumption and the average income for the urban citizen increases by 4.5 per cent in the short term. It actually turns out that urban real wage is reduced by less than 1 per cent. Rural per capita income level is increasing 5 per cent. The beneficiaries of the flexible real wage in the short term are thus the former unemployed and people at the countryside, which regain their income level from BAU after the unfavourable impact of the previous policies.

The consumption level is kept relatively low and real investments high due to the considerable increase in profits. In the longer term this initiates a take off in terms of economic growth, with GDP almost 50 per cent above BAU after a decade.

The flexible urban wage initiates rapid growth through an (essentially urban) profit driven accumulation and growth process. Employment is increasing, and urban real wages are only moderately lowered by 1 per cent by the end of the simulation period. High investments causes a significant positive shift in labour productivity, which contributes to keep up the urban wage level. Consumer demand is increasing (although less than GDP) and the price of basic food items goes up as well. Basic grain prices rise considerably relative to other goods and services in the consumer basket available outside the remote frontier and inside the market economy. The intense urban investment activity assures that a wide variety of consumer goods are supplied at moderate prices due to the continuous rise in urban productivity. But still it is so that the price effect through increasingly expensive food in the markets dominates over the incentives to leave the frontier related to the positive income shift in stationary agriculture and in the cities. Consequently colonists stick to subsistence farming at the frontier, limiting the reserve of labour available for the growth sectors, which also helps keep up the general wage level.

In spite of the significant increase in economic growth, the impact on deforestation is still negative after 10 years. In this case, there is a clear contradiction between urban economic growth and the conservation of natural resources.

Whether real wages are flexible or not strongly affects the distribution between profit and wage income. Flexible wages rise profits which in turn are invested and generate growth particularly in the urban sectors, favoured by the investments. This stimulation of the urban economy is not capable of counter-weighting the negative impact on rural income opportunities, since private consumption and demand for food is rising more slowly than GDP. Consequently, the contribution from flexible wages is to increase deforestation.

Table 4. Impact of economic reforms on deforestation and main economic variables in Nicaragua. Deviation from Business As Usual scenario. Year 2000. Per cent

	(1) Reduced public expenditures	(2) Sales tax reform	(3) Reduced trade deficit	(4) Flexible real wages
	(1)	(1)+(2)	(1)+(2)+(3)	(1)+(2)+(3)+(4)
Gross domestic product	4.7	6.3	4.9	47.4
Private consumption	3.1	-2.8	-4.2	29.5
Export	4.2	3.0	2.8	50.4
Import	3.7	2.7	0.5	42.3
Urban real wage	-	-	-	-1.0
Rural real wage	2.5	-1.0	-1.6	3.3
Per capita rural income	0.5	-8.9	-9.9	5.0
Per capita urban income	3.3	-3.2	-4.7	40.7
Urban unemployment	-2.3	4.6	6.0	-78.7
Annual deforestation	-4.8	-13.9	-13.5	-12.2
Total deforested area	-1.8	-7.8	-7.9	-3.4

Figure 1. Economic indicators and deforestation. Changes from previous scenario in year 2000

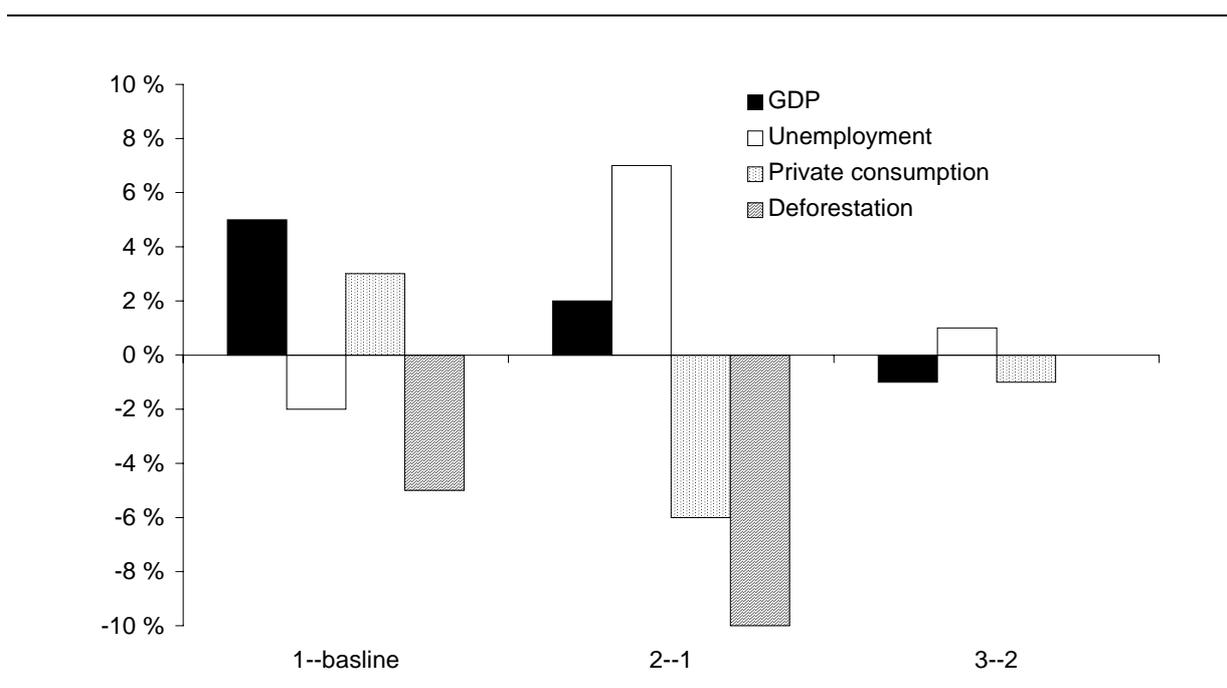
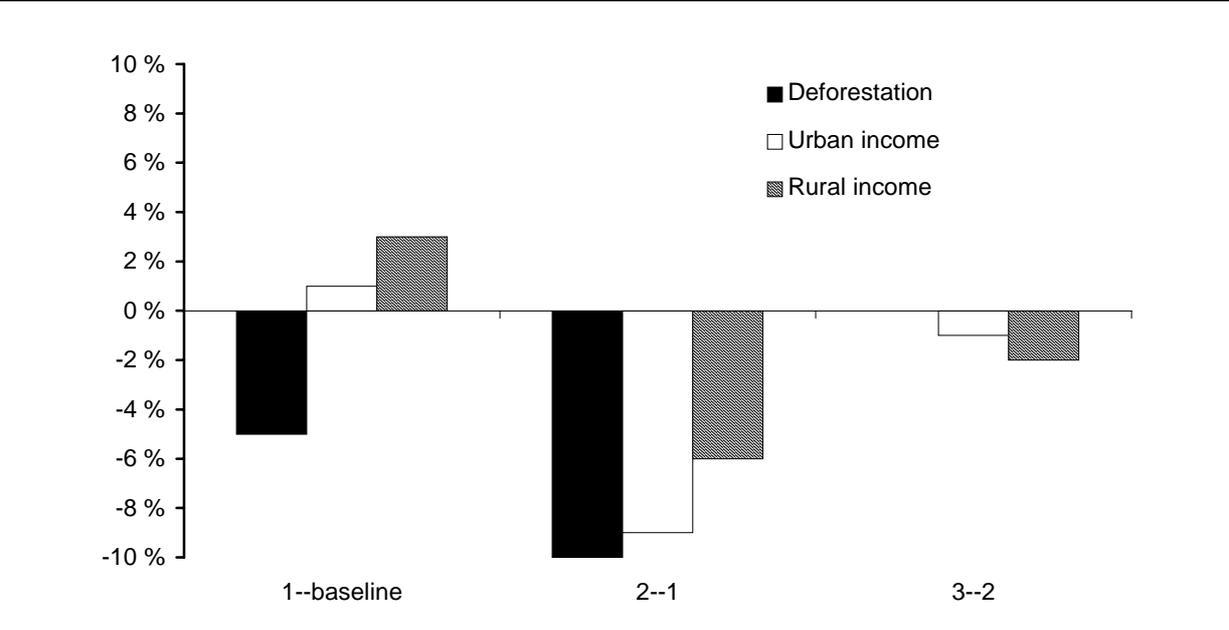


Figure 2. Per capita income and deforestation. Changes from previous scenario in year 2000



5. Conclusion

In this paper we have studied the impacts of various economic policies on economic growth and deforestation in Nicaragua by means of a computable general equilibrium model. A key feature of this model is that the income level at the agricultural frontier is determined by the price of basic grains, and not directly linked to the alternative cost of labour within the market economy. This means that deforestation by squatters is particularly sensitive to distributional aspects which affect the level of private consumption, the demand for food and food prices.

It is shown that some policies initially intensify the clearing of forest land, but turn out to ease the pressure on forest capital over time. This trade-off between short and long term effects should be taken into account under policy formation. An argument for accepting short term increase in deforestation could be positive distributional effects, like experienced in the case with reduced public expenditures.

Noticeably, improving the fiscal balance by cutting public expenditures or by means of a sales tax reform both enhance economic growth and conservation of forest. The former policy is efficient in stimulating growth, while the latter is efficient in conservation. While the rural income level is conserved under reduced public expenditures, it is being eroded by the sales tax increase, through a demand induced decline in prices of basic grains. With low prices on basic grain, the migration to urban surroundings is seen as more beneficial because cheaper grain makes it less hard to make financial room for a subsistence food consumption level in the cities within a given real wage; i.e. the alternative cost of staying at the frontier is rising. Thus, the forest conservation associated with a rising sales tax is driven by a general rural poverty increase.

A flexible urban wage setting would generate more rapid deforestation. The economy would grow at a considerably higher rate, but the rural wage level would not be much higher than in the reference scenario. A significant increase in food prices would cancel out the potential benefit from improved and less uncertain income opportunities within the market economy. Subsistence would be increasingly attractive under the new price regime. A conclusion is that rapid growth does not guarantee more forest conservation, as illustrated under the flexible urban wage regime.

However, there are policies which both stimulate growth and conservation, like reducing the public expenditures and broadening the tax base. While the former generates no clearly negative distributional effects, the rural income level is strongly reduced under the sales tax reform. In the latter case then, conservation is obtained at the cost of increasing poverty in rural areas.

Monitoring and enforcement problems of remote forests in Nicaragua may exclude market based measures against deforestation by squatters, and also a Pigouvian approach may seem inappropriate as a corrective measure among the poorest groups of the population. Our study has shown that the general equilibrium effects of economic policies on the deforestation rate are considerable, and may be used to identify indirect measures to control deforestation.

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An Applied General Equilibrium (AGE) model for Nicaragua

Model equations

1	Composite price:	$PC_i \cdot XC_i = PD_i \cdot XD_i + pm_i \cdot M_i$	$i \in IM$
2	Composite price in non-importing sectors:	$PC_i = PD_i$	$i \in I-IM$
3	Value of sale (gross revenue):	$P_i \cdot X_i = PD_i \cdot XD_i + pe_i \cdot E_i$	$i \in EX$
4	Unit value of sale in non-exporting sectors:	$P_i = PD_i$	$i \in I-EX$
5	Price on capital:	$PK_i = \sum_j PC_j \cdot imat_{ji}$	$i, j \in I$
6	Activity level, exporting sectors CET (note: $\rho_{ei} \geq +1$):	$X_i = at_i \cdot \left[\gamma_i \cdot E_i^{\rho_{ei}} + (1 - \gamma_i) \cdot XD_i^{\rho_{ei}} \right]^{\frac{1}{\rho_{ei}}}$	$i \in EX$
7	Activity level, non-exporting sectors:	$X_i = XD_i$	$i \in I-EX$
8	Commodity composition of output:	$\frac{E_i}{XD_i} = \left\langle \frac{pe_i}{PD_i} \cdot \frac{1 - \gamma_i}{\gamma_i} \right\rangle^{\frac{1}{\rho_{ei} - 1}}$	$i \in EX$
9	Composite commodities CES:	$XC_i = ac_i \cdot \left[\delta_i \cdot M_i^{-\rho_{mi}} + (1 - \delta_i) \cdot XD_i^{-\rho_{mi}} \right]^{\frac{-1}{\rho_{mi}}}$	$i \in IM$
10	Output in non-importing sectors:	$XC_i = XD_i$	$i \in I-IM$
11	Demand for imports:	$\frac{M_i}{XD_i} = \left\langle \frac{PD_i}{pm_i} \cdot \frac{\delta_i}{1 - \delta_i} \right\rangle^{\frac{1}{1 + \rho_{mi}}}$	$i \in IM$
12	Unit cost:	$COST_i = \sum_j PC_j \cdot a_{ji} + W_i \cdot LC_i$	$i, j \in I$
13	Profit:	$GAN_i = [P_i \cdot (1 - tv_i) - COST_i] \cdot X_i$	$i \in I$
<i>Income and consumption</i>			
14	Income working class:	$Y_{wk} = \sum_i W_i \cdot LC_i \cdot X_i + er \cdot trxk_{wk}$	$i \in I$
15	Income camposino class:	$Y_{cp} = \sum_i dgc_i \cdot GAN_i$	$i \in R$

16	Income producers class:	$Y_{pr} = \sum_i dgs_i \cdot GAN_i + er \cdot trxk_{pr}$	$i \in U$
17	Income capitalist class:	$Y_{kp} = \sum_i (1 - dgc_i) \cdot GAN_i + \sum_j (1 - dgs_j) \cdot GAN_j + er \cdot trxk_{kp}$	$i \in R, j \in U$
18	Expenditure:	$EXPEND_k = (1 - s_k) \cdot (1 - td_k) \cdot Y_k$	$k \in K$
19	Basic consumption:	$SUB_k = \sum_i csub_{ik} \cdot PC_i$	$i \in I, k \in K$
20	Private consumption (LES):	$PC_i \cdot CD_{ik} = PC_i \cdot csub_{ik} + q_{ik} \cdot (EXPEND_k - SUB_k)$	$i \in I, k \in K$
Wage formation			
21	Rural sector wage:	$W_i = relw_i WR$	$i \in R$
22	Urban sector wage:	$W_i = relw_i W_{i0} IPC_{wk,t-1}$	$i \in U$
Labour market			
23	Labour supply:	$LS = ls_0 (1 + g)^t$	
24	Frontier labour:	$LF = \frac{\eta_1}{WF_0} LS \left(\frac{WF}{WX} \right)^{\rho-1}$	
25	Rural wage index:	$WX = (\eta_1 WF^\rho + \eta_2 WR^\rho)^{\frac{1}{\rho}}$	
26	Frontier labour:	$LF = (1 - U) LS - \sum_i LC_i X_i$	$i \in I$
27	Unemployment:	$WR = wu_0 (1 - U) IPC_{wk,t-1} \frac{1 - u_{r0}}{1 - u_0}$	
Frontier production and income			
28	Frontier prices:	$PF_i = P_i$	$i \in B$
29	Production function:	$XF_i = z l_i LF$	$i \in B$
30	Income per man-year:	$WF = \sum_i PF_i z l_i$	$i \in B$
31	Frontier income:	$Y_{fa} = WF \cdot LF$	
Investment and saving			
32	Capital in period $t+1$:	$KF_{i,t+1} = KF_{i,t} \cdot (1 - depre) + DK_{it}$	$i \in I$

33	Total investments equal savings: $INV = \sum_k s_k \cdot (1 - td_k) \cdot Y_k + SGOB + er \cdot sfor$ K	$k \in K$
34	Investment by destination: $INV = \sum_i PK_i \cdot DK_i$	$i \in I$
35	Sectoral investment: $DK_i = kshare_i \cdot DKTOT$	$i \in I$
Government		
36	Government revenue: $GR = \sum_i \left[tv_i \cdot P_i \cdot X_i + \frac{tm_i}{1+tm_i} \cdot pm_i \cdot M_i + te_i \cdot pe_i \cdot E_i \right] + \sum_k td_k \cdot Y_k$	$i \in I, k \in K$
37	Government expenditure: $GD_i = gshare_i \cdot gdtot0$	$i \in I$
38	Government consumption: $GR = \sum_i PC_i \cdot GD_i + SGOB$	$i \in I$
Equilibrium of demand and supply		
39	$XC_i = \sum_j a_{ij} \cdot X_j + \sum_k CD_{ik} + GD_i + \sum_j imat_{ij} \cdot DK_j + csub_{i,fa}$	$i \in I, k \in K$
Production		
40	Production: $X_i = ad_i \cdot b_i \cdot [LC_i \cdot X_i]^{\alpha_i} \cdot KF_i^{1-\alpha_i}$	$i \in I$
41	Consumer price index: $IPC_k = \frac{\sum_i PC_i \cdot CD_{ik}}{\sum_i CD_{ik}}$ K	$i \in I, k \in K$
42	Demand for labour: $W_i \cdot LC_i = \frac{\alpha_i}{1 - \alpha_i} \cdot \frac{GAN_i}{X_i}$	$i \in I$

List of variables

Endogenous variables:

CD_{ik}	=	Demand for commodity i by class k
$COST_i$	=	Unit cost of production
DK_i	=	Investment by sector of destination
$DKTOT$	=	Total real investments
E_i	=	Exports of commodity i in local currency
$EXPEND_k$	=	Expenditure on consumption by class k
GAN_i	=	Total profit in sector i
GD_i	=	Government expenditure on commodity i

GR	=	Total income to the government
INV	=	Total nominal investment
IPC _k	=	Consumer price index for class k
KF _i	=	Capital by sector
LC _i	=	Labour per activity unit in sector i
LS	=	Labour supply
LF	=	Labour at the frontier
M _i	=	Imports of commodity i in local currency
P _i	=	Output price
PC _i	=	Composite price of domestic and imported commodities
PD _i	=	Price of domestic commodity i
PF _i	=	Prices at the frontier
PK _i	=	Price of capital
SGOB	=	Government saving
SUB _k	=	Basic consumption by social class
U	=	Unemployment rate
W _i	=	Wage rate
WF	=	Imputed income per man-year at the agricultural frontier
WR	=	Rural wage rate
WX	=	Rural wage index
X _i	=	Activity in sector i
XF _i	=	Production at the agricultural frontier
XC _i	=	Composite commodity of domestic and imported products
XD _i	=	National production for the domestic market
Y _k	=	Nominal income by class k

Exogenous variables and parameters:

α_i	=	Cost share of labour
γ_i	=	Share parameter in export equation
δ_i	=	Share parameter in creation of composite commodity
η_1	=	Allocation parameter
η_2	=	Allocation parameter
ρ	=	Transformation parameter in rural wage index
ρ_{ei}	=	Transformation parameter in export equation
ρ_{mi}	=	Transformation parameter in import equation
a_{ij}	=	Input-Output coefficient

ac_i	=	Shift parameter in creation of composite commodity
ad_i	=	Shift parameter in Cobb-Douglas production function
at_i	=	Shift parameter in activity equation
b_i	=	Shift parameter due to erosion
$csub_{ik}$	=	Basic consumption
$depre$	=	Depreciation rate of capital
dgc_i	=	Distributional coefficient of profits - farmers
dgs_i	=	Distributional coefficient of profits - producers
er	=	Exchange rate
g	=	Growth rate of population
$gdtot0$	=	Total real government consumption in base year
$gshare_i$	=	Government expenditure coefficient
$imat_{ij}$	=	Conversion matrix from destination to origin in investment
$index_i$	=	Wage indexation rule
$kshare_i$	=	Share coefficient on total investment
ls_0	=	Total labour supply in base year
q_{ik}	=	Budget share of consumption by class
$pe0_i$	=	Price of exports in local currency
$pm0_i$	=	Price of competitive imports in local currency
pwe_i	=	World price on exports in \$
pwm_i	=	World price on competitive imports in \$
s_k	=	Marginal propensity to consume by class
$sfor$	=	Foreign savings
td_k	=	Direct taxes on income
te_i	=	Tariff rate on exports
tm_i	=	Tax on competitive goods imports
$trxk_k$	=	Transfers from abroad to class k in \$
tv_i	=	Tax on value added
u_{r0}	=	Urban unemployment rate in base year
u_0	=	Unemployment rate in base year
wu_0	=	Urban nominal wage rate in the base year
z_l	=	Production per man-year at the frontier

List of sectors (I)

No.	Abbrivation	Name	Agr. frontier	Agri- culture	Rural/ Urban	Import	Export
1.	CF	Production of Coffee		AGR	R		EX
2.	AG	Production of Cotton		AGR	R		EX
3.	BA	Production of Bananas		AGR	R		EX
4.	AJ	Production of Sesame		AGR	R	IM	EX
5.	AZ	Production of Sugar		AGR	R		
6.	MZ	Production of Maize	B	AGR	R	IM	
7.	FR	Production of Beans	B	AGR	R	IM	
8.	AR	Production of Rice	B	AGR	R	IM	
9.	SG	Production of Sorghum		AGR	R	IM	
10.	OA	Other agriculture		AGR	R	IM	EX
11.	PC	Production of Cattle		AGR	R	IM	
12.	SV	Forestry			R	IM	EX
13.	PS	Fishery			R		EX
14.	MN	Mining			R	IM	EX
15.	AL	Production of Food and Beverages			U	IM	EX
16.	VT	Production of Textiles			U	IM	EX
17.	QM	Production of Chemicals			U	IM	EX
18.	PT	Oil production			U	IM	EX
19.	OV	Other industries			U	IM	EX
20.	EL	Production of Electricity			U	IM	EX
21.	AP	Water services			U		
22.	CT	Construction			U		
23.	SC	Other Services			U	IM	EX
24.	TR	Production of Transport and Communication Services			U	IM	EX
25.	ES	Education and health			U		
26.	CM	Trade			U		

Social classes (K)

1.	CP	Campeños (farmers)
2.	WK	Urban workers
3.	PR	Urban small proprietors (small producers)
4.	KP	Capitalists
5.	FA	Frontier farmers

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