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A Production Function-Based Policy Simulation Model of Perennial Commodity Markets

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Policy variables greatly influence the growth and development of the coffee sector in Nicaragua. Nicaragua could increase its coffee production and exports substantially by the end of the decade if there were a favorable economic climate, especially in terms of international prices and investment incentives.

This paper — a product of the International Trade Division, International Economics Department — is part of a larger effort in the department to analyze policy impacts on agricultural supply. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Grace Ilogon, room S7-033, extension 33732 (February 1993, 30 pages).

In modeling the supply of perennial crops, many researchers have used the "vintage-capital production approach," most recently formulated by Akiyama and Trivedi.

Implementing this approach requires reliable time-series data on production, total area planted, new planted area, yields, real producer prices, and credit availability. For many producers, these data are not available, and many producers of perennial crops face substantially changed incentive structures in countries undergoing structural adjustment.

So, Akiyama and Coleman developed an alternative method for modeling perennial crop subsectors. It takes into account past investment decisions and other dynamics of supply response, captures all important features of the market, should be consistent with economic theory, should require minimal data, and should not rely on time-series data or econometric estimates.

This production function-based model uses a Cobb-Douglas production function. The model is based on partial equilibrium and does not take into account the impact on individual subsectors on such aggregate variables as wages and interest rates.

The authors apply the model to the coffee sector in Nigeria, which is undergoing major reform, but the model can be applied — with only minor modifications — to other types of crops, in other countries.

The model results show that:

- Policy variables greatly influence the growth and development of the sector. A 10 percent increase in the price of coffee, for example, would increase demand for labor 19 percent and that for fertilizer 29 percent and would expand the area of coffee investment 17 percent.

- The sector would substantially benefit from greater labor efficiency, lower real interest rates, and a reduction in the real value of the cordoba against the U.S. dollar.

- Nicaragua could increase its production and exports substantially by the end of the decade, if there were a favorable economic climate — especially in terms of international prices and investment incentives.

A PRODUCTION FUNCTION BASED POLICY SIMULATION MODEL OF PERENNIAL COMMODITY MARKETS

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1. Introduction

Modeling the supply of perennial crops such as cocoa, coffee, tea, and rubber is considerably more complicated than is the case with annual crops. This is due to the fact that the supply of perennial crops in any given year is influenced not only by decisions made in that particular year, but also by investment decisions in previous years which can be expressed in terms of the existing capital stock of trees. To capture the dynamics of supply response, researchers have used the "vintage- capital production approach", including the recent study by Akiyama and Trivedi (1987). This approach explicitly takes into account past investment in trees.

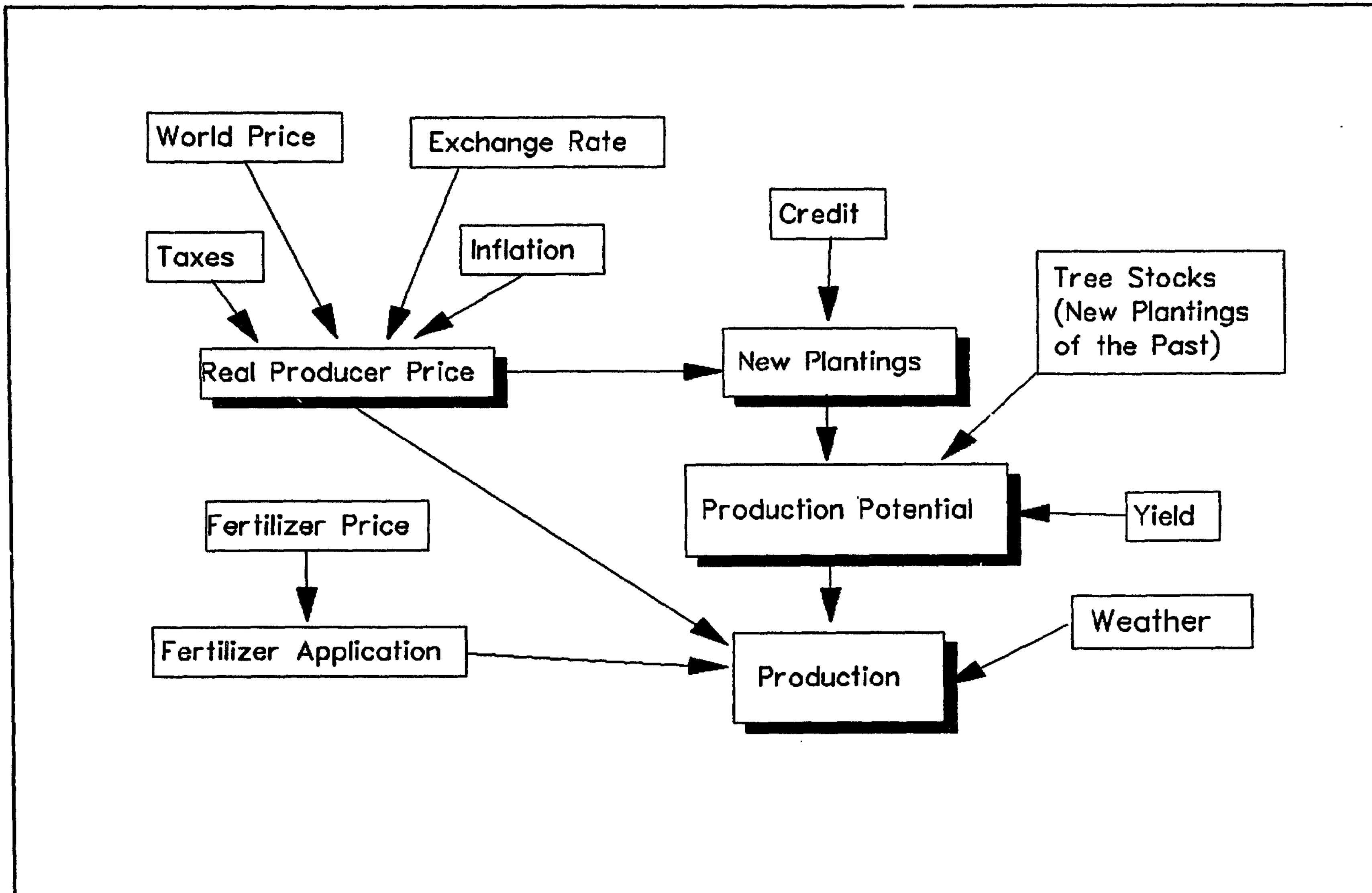
The vintage-capital production approach has three main steps. First, an equation is estimated for the area of new plantings undertaken each year, using economic variables such as real producer prices, interest rates, and credit availability as explanatory variables. Second, by assuming a potential yield for trees of each age cohort, the production potential of the tree stock is calculated for a given year by summing up the production potential of all the trees planted in the past. Third, the actual production realized in a given year is estimated as a function of variables including real producer prices, input prices, and weather, as well as the production potential variable. This approach and the relationship between the various variables which affect the output in a particular year are shown in Figure 1. Once these equations are estimated, future supply can be projected, given assumptions about the values of the key exogenous variables such as world product prices, exchange rates, and fertilizer prices. The set of equations can also be used for policy analysis purposes to simulate the effects of changes in variables such as exchange rates, taxes, credit availability, and output and input prices.

For its implementation, the vintage-capital production approach requires reliable time-series data on production, total area planted, new plantings area, yields, real producer prices, and credit availability[1]. For many developing country producers, the approach cannot be applied due to the lack of these data. In some countries data on these important agricultural variables do not exist, in others the methods of data collection are crude and unsystematic. As well, published data are often inconsistently reported over time due to changes in variable definitions and methods of collection.

Econometric models of commodity markets are valid only when relationships among variables are stable over time; when there have not been any significant "structural changes" which alter substantially the incentive structures facing agents in the market. Many of the important producers of

[1]See, for example, Trivedi and Akiyama (1992)).

Figure 1. Flow Chart of the Vintage-Capital Production Approach.



perennial crops, especially in Africa and Latin America, have recently embarked on structural adjustment programs. Such programs have included exchange rate and trade liberalization, as well as the dismantling of marketing boards and abandonment of commodity price support schemes. In these cases, even if reliable data were available, the usefulness of econometric modeling would be limited in predicting responses to changes in prices and policy variables.

Faced with these problems of insufficient data and structural changes, an alternative method of modeling perennial crop subsectors is needed. Ideally, this approach should be consistent with the vintage-capital production approach in taking into account past investment decisions and other dynamics of supply response; it should capture all the important features of the market; and it should be consistent with economic theory. In addition, the approach should have minimal data requirements and not rely on time-series data and econometric estimation.

In this paper, we present a production function-based model of perennial crop supply as an alternative to the vintage-capital production approach. The model is applied to the coffee sector in Nicaragua. Currently, Nicaragua is undertaking major reforms in its coffee sector, and there is a need to develop a framework to analyze quantitatively the effects of alternative policies on production and exports. Attempts to develop a model using the vintage-capital production approach failed for the reasons mentioned above--insufficient and unreliable data, and recent structural changes. While the model presented in this paper is for coffee in Nicaragua, the approach is general and could be applied, with only minor modifications, to other types of perennial crops and to other producing countries.

Compared with the vintage-captial approach, one drawback of this approach is that the coefficients of the equations in the model (especially those for investment) are determined with a limited amount of data. Hence, sensitivity analyses could be undertaken to evaluate their impact on supply elasticities before deciding on which coefficients to use. The model is based on partial equilibrium and hence does not take impacts of individual subsectors on aggregate variables such as wages and interest rates. However, the model is flexible so that wages and interest rates can be made dependent on the demand for the inputs, either manually or through equations linking these variables.

In section 2, an overview of the model is given. The main components of the model as presented and the interactions among the model's endogenous and exogenous variables are described. The contribution of this paper is the development of production and investment functions to estimate area, yields and supply. Therefore, in section 3, the production function and associated input demand functions are discussed in detail, along with the method used to obtain parameters in the absence of time-series data. In section 4, the method used to estimate investment needs for rehabilitating the existing coffee area to higher levels of technology is covered. Results from various simulations of the model are reported in section 5. These illustrate further how the model functions and demonstrates the types of analyses possible. Finally, in section 6, conclusions are drawn from the study.

2. An Overview of the Model

The analytical framework is based on the following main assumptions: (i) coffee is produced on land characterized by different levels of technology[2]; (ii) conversion of land from one technology to another requires considerable investment; (iii) investments to improve technology increase with farmers' expected profit from investments; (iv) estimates of the production and rehabilitation costs are available; (v) labor and fertilizer are the main variable inputs required to produce coffee; (vi) the yield of each technology increases with the amount of labor and fertilizer used; and (vii) farmers use labor and fertilizer inputs up to profit-maximizing levels.

The entire model for policy simulation purposes consists of several blocks which are listed and commented on in Table 1. As well, Figures 2 and 3 present flow charts of the model, indicating the relationships among the blocks. As illustrated in Figure 2, the main part of the model contains blocks relating to coffee supply. The model calculates key variables related to exports (export block), labor and fertilizer use (factor demand block), and short- and long-term credit requirements (credit block). The exogenous variables include: (i) world prices of coffee; (ii) world prices of fertilizer; (iii) wages and food costs; (iv) inflation rates; (v) exchange rates; (vi) interest rates on short- and long-term credit; (vii) taxes on coffee and inputs; and (viii) changes in efficiencies of input use. The main outputs include: (i) production, yield, and area by type of technology; (ii) demand for labor and fertilizers;, (iii) the quantity and value of exports; and (iv) the demand for credit.

The blocks dealing with yields, investment, profit, and supply are complex. A flow chart showing the relationships among these variables is presented in Figure 3. As Figure 3 shows, the prices of coffee and inputs determine yields and profitability of coffee growing, and these in turn affect production. A crucial element is the specification of yield equations for each technology using a Cobb-Douglas production function (CDPF), which specifies mathematically the relationships between output and inputs such as labor and fertilizer. Although there are several types of production function which could be used, the CDPF was chosen because of its simplicity and ease with which its parameters can be obtained.

It is assumed that yield of each technology can be specified as a CDPF and that the only inputs

[2]In Nicaragua three technology levels are identified. These are termed T1, T2, and T3, with technology improving from T1 to T3. T0 refers to land not in production.

are labor and fertilizer. Assuming that farmers use inputs in a profit-maximizing way at the levels given by estimated production costs, input-demand equations (more commonly called factor-demand equations) can be derived in terms of the prices of coffee and inputs.

Table 1. Description of Main Blocks in the Model.

Name of Block	Key Variables Calculated	Comments
Assumptions	Exchange Rate, CPI, World Coffee Price, Wages, Food Cost, Interest Rate	Assumptions on impact of key exogenous variables.
Price Linkage	Coffee Producer Price, Fertilizer Price	Using mainly variables from the 'Assumptions' block, calculates coffee and fertilizer prices at the level of coffee producers.
Yield	Expected Yield for each Technology	Calculates yield based on Cobb-Douglas production function and using coffee and input prices.
Profit	Expected Annual and Long-term Profits for each Technology	Calculates expected profits based on outputs from 'yield' block.
Conversion (Investment)	Expected Land to be Converted	Calculates land to be converted based on expected long-term profit and costs of investments.
Supply	Area and Production by Technology	Calculates area under each technology, taking into account the conversions calculated in the 'conversion' block. These areas are multiplied by yields, calculated in the 'yield' block, to produce production.
Factor Demand	Required Labor, and Fertilizer	Calculates factor demand, i.e., labor and fertilizer, for coffee production.
Credit	Required Short- and Long-Term Credits	Calculates credit demand, given factor prices and factor requirements for production conversion.
Export	Export Quantity, Revenues, and Value of Operation	

Figure 2. Flow-Chart of the Model.

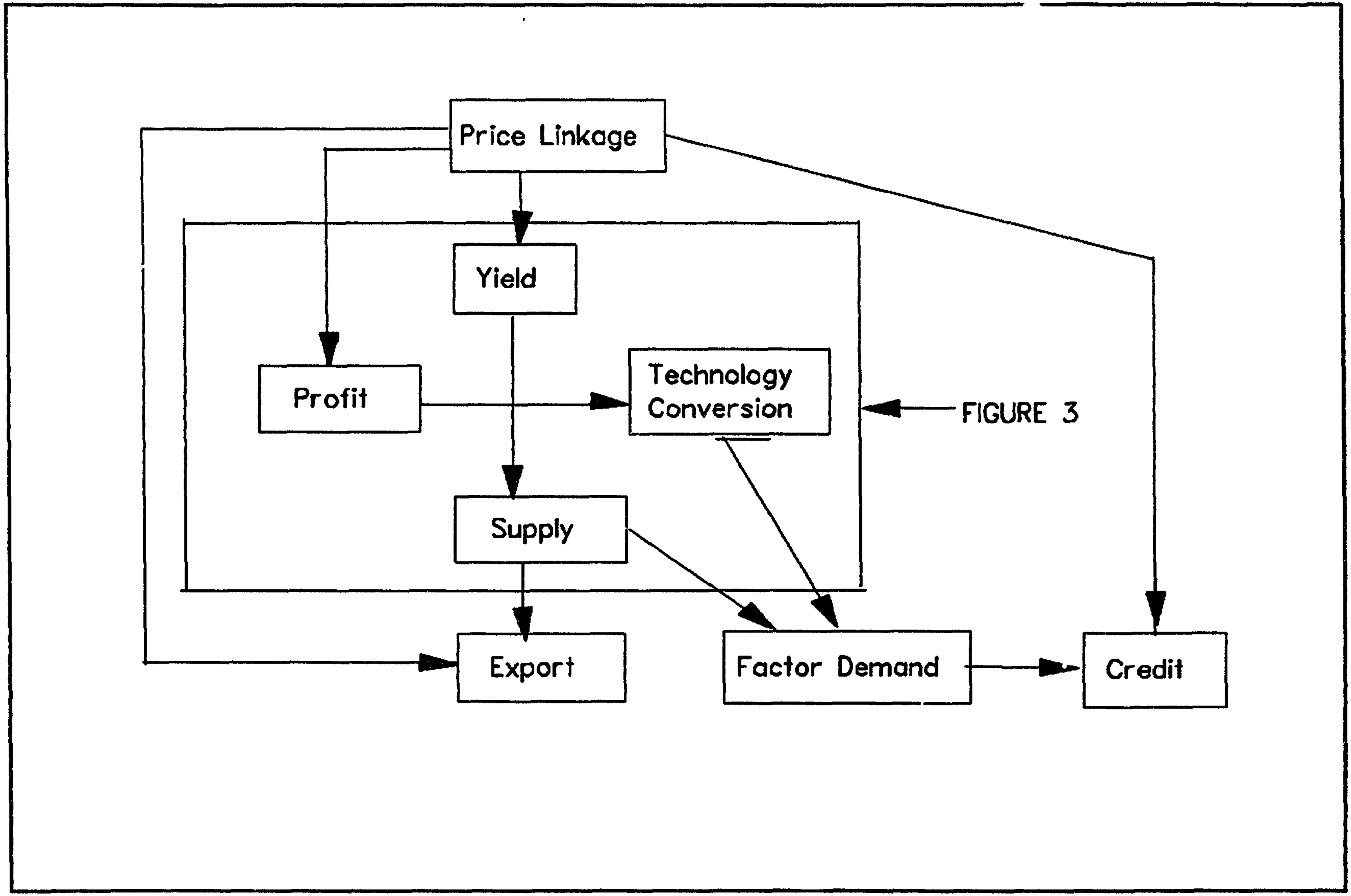
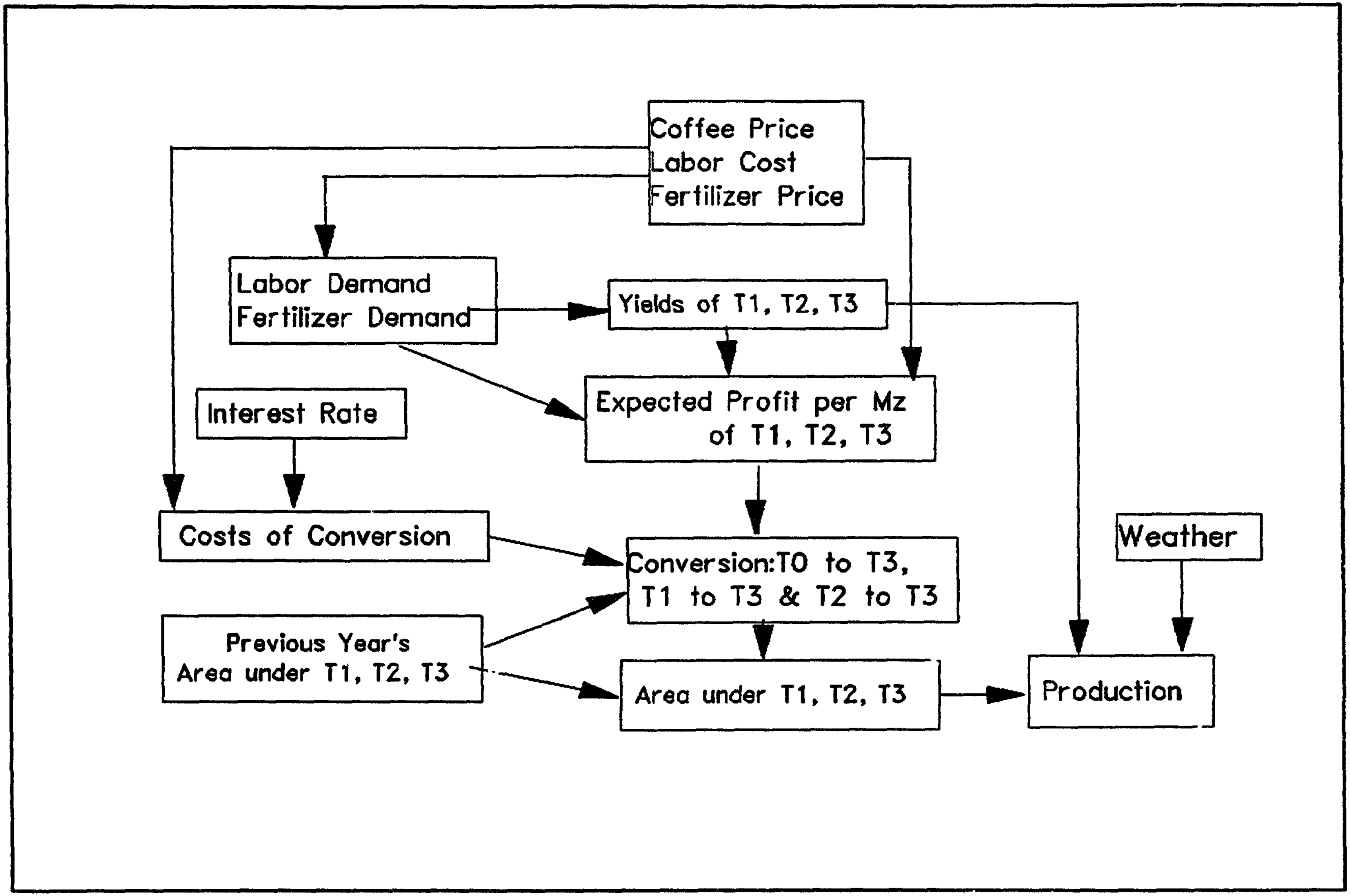


Figure 3. Flow Chart for Supply Block.



The yield elasticities with respect to labor and fertilizer used in the model are given in Table 2. For example, in T3 it is assumed that a 10% increase in labor increases yield by 2.6%. Because these elasticities also correspond to the shares of total revenues paid to factors of production, they were derived from production cost data for each technology. In this specification, the two inputs used and the yield change with the prices of coffee and inputs. For example, if the fertilizer price declines while other prices remain unchanged, fertilizer use, and hence yield, will increase. Thus, we can analyze the effects of changes in coffee and inputs prices on yield. Once the CDPF and the input-demand equations are specified, profit per unit area per year can be calculated for each technology. Profit is simply revenue minus total costs. Revenue, in turn, is the product of yield and the coffee price; total cost is the product of inputs used and their prices[3] [4].

Table 2. Yield Elasticities For Each Input and Technology.

Technology Type	Labor	Fertilizer
T1	0.25	0.00
T2	0.27	0.16
T3	0.26	0.16

Source: IECIT, World Bank.

In addition to the direct use of the production function, a key element of this approach is the specification of the investment functions. These explain the extent of the conversion, through investment, of land to a higher technology. We assume that the area undergoing technological conversion increases with farmers' expected profit from the investment. Farmers' expected profit from investment, is in turn, the expected increase in profit from the land with the new technology, minus the foregone profit from old technology minus the costs of investment. The cost of conversion depends on the availability and interest rate of credit, and prices of labor and fertilizer inputs. The expected profits and investment costs are expressed in terms of the present values of the sum of discounted future flows of profits and costs.

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[3]A series of sensitivity analyses were undertaken to determine the robustness of model forecasts of production to changes in these parameters. The results of these found the model results are fairly stable across a range of parameter values. For example, doubling the size of the ß coefficients in the equation for T3, led to only a 15% increase in T3 area by 2000/01, while production was less than 10% higher.

[4]Despite similar cost shares and hence elasticities, labor and fertilizer yields for T3 are substantially higher than for T2 (see Table A1.). This is due to substantially more efficient use of inputs in T3.

In other words, farmers are assumed to evaluate the long-term profits of converting land from one technology to another and the costs involved in the conversion.

To estimate the total area converted in a particular year, given the expected profitability of such investment, a simple linear function was specified. The coefficients of this function were determined by the estimated profitability of conversions expected to be undertaken during the base year, and by "guesstimates" of the elasticity of investment with respect to the expected profitability.

It should be noted that we assume that the expected profitability is the national average and that there are farmers who are considerably more efficient than the average. Hence, we allow for investments to occur even if the average expected profitability of the conversions is negative because, even in this case, there will be some efficient farmers whose expected profitability of conversion is positive.

3. The Production Function

As stated above, it is assume that coffee yield in Nicaragua is determined by the level of fertilizer and labor inputs used, according to the estimated Cobb-Douglas production function (see Figure 3 where yields of T1, T2, T3 depend on labor demand and fertilizer demand)[5] [6],

$$Y=\alpha F^{\beta_f} L^{\beta_l} \qquad (1)$$

where:

Y	=	Yield per unit area,
F, L	=	Units of fertilizer and labor, respectively,
β_f, β_l	=	Elasticity of yield with respect to fertilizer and labor,respectively,
α	=	Constant.

This production function has been used widely in empirical studies because it has a number of desirable properties. These are mentioned briefly below.

(i) The β_i represent the percentage change in output for a one percent change in the unit of input i. These technical coefficients can be derived from cost of production data, or can be estimated econometrically.

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[5] For each technology type a different production function was constructed. The form of the production function for T2 and T3 is represented by equation (1). For T1, the only input used is labor and so the fertilizer component of equation (1) was dropped in this case.

[6] A thorough discussion of the Cobb-Douglas production function is provided by Chambers (1988).

(ii) The sum of the β_i gives the degree of homogeneity or returns to scale. $\Sigma\beta_i < 1$ indicates decreasing returns to scale, $\Sigma\beta_i = 1$ indicates constant returns to scale, and $\Sigma\beta_i > 1$ indicates increasing returns to scale.

(iii) The elasticity of substitution between inputs is equal to one.

(iv) The production function implies declining marginal products of the inputs.

(v) The β_is also represent the ratio between the total cost of factor i and total revenue (i.e., factor shares). This assumes that $\Sigma\beta_i \leq 1$. Also, $\Sigma\beta_i < 1$ indicates that one or more factors of production earn economic rents.

For profit maximization, it was assumed that coffee producers apply additional fertilizer and labor inputs up to the point at which the marginal value product of an additional unit of input is equal to its cost.

Formally, these conditions are given by,

$$P_y \alpha \beta_f F^{\beta_f - 1} L^{\beta_l} = P_f \tag{2}$$

$$P_y \alpha \beta_l F^{\beta_f} L^{\beta_l - 1} = P_l \tag{3}$$

where:

P_y = Price of output (coffee),
P_f = Price of fertilizer,
P_l = Price of labor.

Rearranging (2) and (3) gives the input demand functions,

$$F = (RP_f \alpha \beta_f L^{\beta_l})^{-\frac{1}{(1-\beta_f)}} \tag{4}$$

$$L = (RP_l \alpha \beta_l F^{\beta_f})^{-\frac{1}{(1-\beta_l)}} \tag{5}$$

where:

RP_f = Price of coffee relative to the price of fertilizer (P_y/P_f),
RP_l = Price of coffee relative to the price of labor (P_y/P_f).

By substituting equation (5) in (4), labor demand is expressed in terms of product and factor prices and production function parameters. The labor demand equation, using logarithms to simplify the expression, is,

$$LnL=[\frac{1}{(\beta_l-1)}(LnRP_l-Ln\alpha-Ln\beta_l)-\frac{\beta_f}{(\beta_l-1)(\beta_f-1)}(LnRP_f-Ln\alpha-Ln\beta_f)] \\ /(1-\frac{\beta_l\beta_f}{(\beta_l-1)(\beta_f-1)}) \tag{6}$$

Similarly, the demand for fertilizers is given by,

$$LnF=[\frac{1}{(\beta_f-1)}(LnRP_f-Ln\alpha-Ln\beta_f)-\frac{\beta_l}{(\beta_f-1)(\beta_l-1)}(LnRP_l-Ln\alpha-Ln\beta_l)] \\ /(1-\frac{\beta_f\beta_l}{(\beta_f-1)(\beta_l-1)}) \tag{7}$$

Finally, labor and fertilizer demands, derived from equations (6) and (7), were substituted into equation (1) to give the yield level.

Since data on production and labor and fertilizer use were not available on a time-series or cross-sectional basis, it was not possible to estimate the production function parameters econometrically. Instead, the parameters were based on the labor and fertilizer share of total production revenues derived from recent data for Nicaragua. These parameters were consistent with what are believed to be 'reasonable' estimates of the ß's--based on knowledge of coffee production techniques and practices in other countries with similar technologies and production conditions. It was found that use of such parameters and applying recent output and input prices gave rise to labor and fertilizer use and production estimates consistent with current levels of these variables.

4. The Investment Function

The method used to estimate investment demand for converting existing coffee areas to higher levels of technology use and the establishment of new coffee areas is described below. The basic theoretical assumption is that producers rehabilitate existing areas and plant new areas if the discounted profit of doing so is positive. Clearly the decision is complicated by the fact that costs and benefits of such investment accrue over a number of periods into the future and that revenues and costs are uncertain at the time investment decisions are made.

First, the expected annual profit per manzana[7] was calculated for each technology type for the forecast period using the formula (see Figure 3 box captioned 'Expected Profit per Mz of T1, T2, T3),

$$E\Pi_{Ai} = P_y Y - P_l L - P_f F - OC \tag{8}$$

where:

$E\pi_{Ai}$ = annual profit,
OC = Other Costs.

Next, the sum of annual profit per manzana, discounted over the productive life of newly developed T3 area (i.e., 12 years) was calculated for each year using[8],

$$E\Pi_{Dit} = \sum_{t=1}^{12} E\Pi_{Ait}\, \Gamma_t \tag{9}$$

where:

$E\pi_{Dit}$ = discounted profit,
Γ_t = discount factor.

Then, the annual investment cost of converting land from T0 to T3, T1 to T3, and from T2 to T3 were calculated for each year of the conversion period using,

$$ICC_{Ai} = P_l L_c + P_f F_c + OCC \tag{10}$$

where:

ICC_{Ai} = annual investment cost of conversion,
L_c = units of labor used for conversion,
F_c = units of fertilizer used for conversion,
OCC = other costs used in conversion.

Since it takes four years to transform land from T0 and T1 to T3, and three years to convert from T2 to T3, the investment cost per manzana, discounted over the period of conversion, was calculated using (see Figure 3 box 'Cost of Conversion' which depends on interest rates, coffee price, labor cost, and fertilizer price),

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[7] A manzana, the unit of area used in Nicaragua, is equivalent to about 0.7 hectares.

[8] It is assumed that rehabilitation only from T0, T1, and T2 to T3 will occur, which is in accordance with Nicaragua authorities' plan.

$$ICC_{Dit} = \sum_{t=1}^{4} ICC_{Ait}\ \Phi_t \tag{11}$$

where:

ICC_{Di}	=	discounted investment costs of conversion,
Φ	=	discount factor.

Then, the expected profit from conversion was calculated as the expected discounted profit per manzana in T3, less the discounted expected profit foregone from production using a lower technology type (i.e., T0, T1 or T2), less the discounted investment cost of conversion[9]. That is,

$$E\,\Omega_i = E\,\Pi_{D3} - E\,\Pi_{Di} - ICC_{Di} \tag{12}$$

where:

$E\Omega_i$	=	expected profit from conversion to T3 from T1 or T2,
$E\pi_{D3}$	=	discounted profit in technology 3,
$E\pi_{Di}$	=	discounted profit in technology i (with i = 0, 1 or 2).

The expected profit from conversion was then used to estimate the amount of land converted from either T0, T1 or T2 to T3 (see Figure 3 box 'Conversion:T0 to T3, T1 to T3 & T2 to T3). For this, a linear equation was used:

$$A_i = a_i + b_i * E\,\Omega_i \tag{13}$$

where:

A_i	=	area converted from Ti to T3.
a_i	=	intercept term in the relationship between the area converted and the expected profit from conversion from Ti to T3.
b_i	=	slope term in the relationship between the area converted and the expected profit from conversion from Ti to T3.
$E\Omega_i$	=	expected profit from converting from Ti to T3.
i	=	0, 1 or 2.

The parameters of the linear function (a and b) were estimated for each technology type. The assumption of a linear function made it possible to estimate the parameters of the function provided that

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[9]Other conversions (i.e., to T2 from T0 and T1, and to T1 from T0) are not policy option under the five-year program. Also, cost data are available only for conversions to T3.

any two points on the line were known. In Figure 4 the relationship between land converted and expected profit from conversion is displayed. Using recent data on land converted and expected profit, an observation on the line (such as C and D in the Figure) was identified. Next, an assumption was made about point B in Figure 4, which represents the level of expected profit from conversion that would result in no land being converted. Estimates of these levels for each technology type were derived from sensitivity analysis such that the overall long-run elasticity of supply would be about 1.5[10]. With estimates of points B and C in Figure 4, it was possible to derive intercept and slope coefficients for the curve.

Using these equations, the land area converted each year from T0 to T3, T1 to T3 and from T2 to T3 was estimated. Next, the area converted was adjusted to the previous year's area under T1, T2, and T3 (see Figure 3 box 'Previous Year's Area Under T1, T2, T3') to give the current year's area in each technology (see Figure 3 'Area under T1, T2, T3'). Finally, the production for each year was determined using yields for each stage of technology improvement and at each year of maturity.

5. Simulation Results

5.1. Assumptions for the Base Run

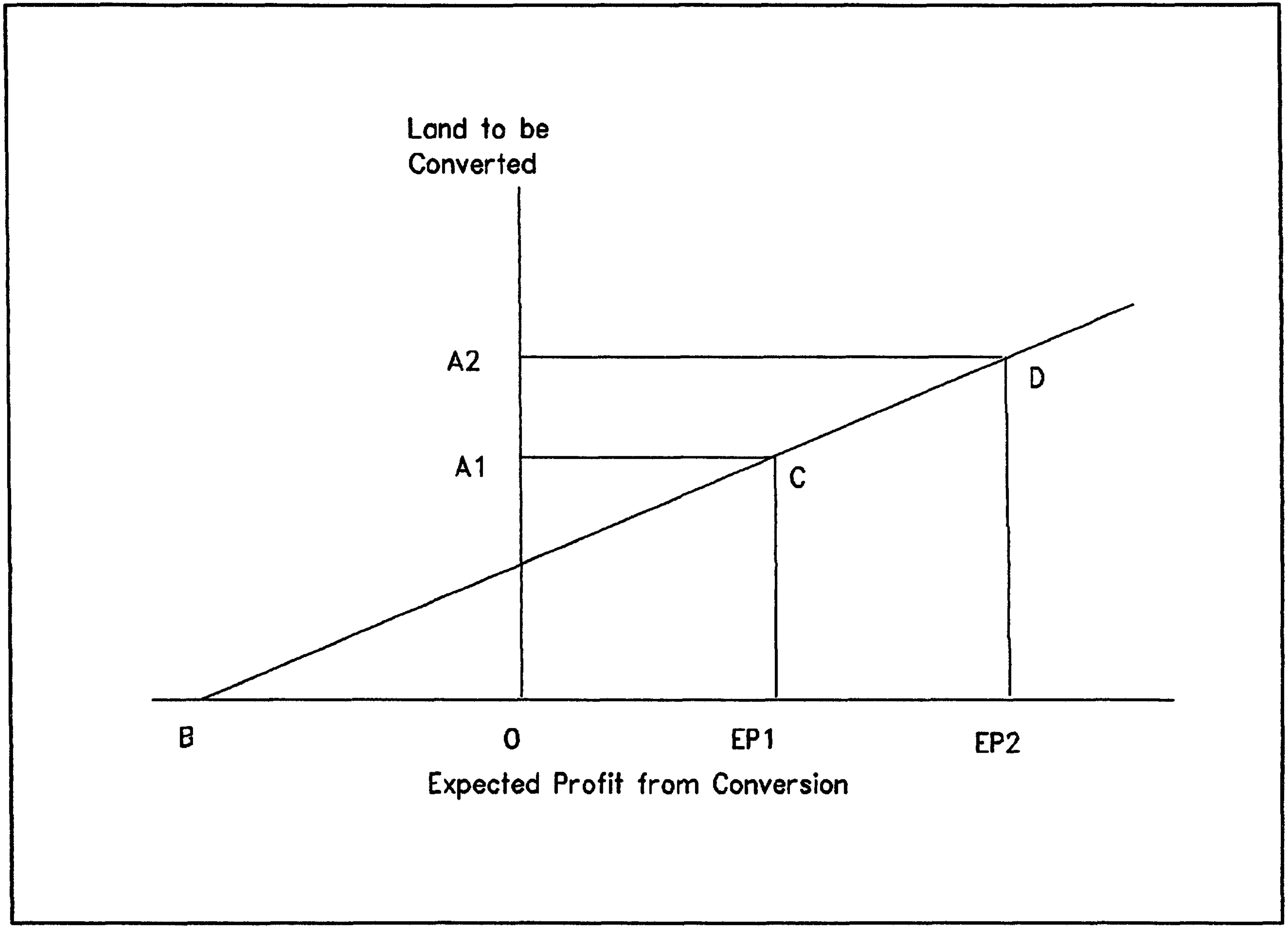
The model was run to provide projections over the 1991/92 to 2000/1 period. Assumptions for the model's exogenous variables for the Base Run are given in Table 3. Nicaragua's inflation rate was assumed to be the same as the world inflation rate. Labor and food costs were assumed to increase with the inflation rate. Efficiency indices for labor and fertilizer use were assumed to remain the same as in the base year. Taxes in terms of percentage and marketing costs were assumed to be constant in real terms at the 1991/92 level. Short- and long-term interest rates were assumed to remain at their 1991/92 levels.

An assumption difficult to make was the extent of land conversions in the future. Under the "5-year Agricultural Rehabilitation Program", the expected conversions were:

	T1 to T3	T2 to T3
1991/92	20,000 mz.	5,000 mz.
1992/93	20,000 mz.	5,000 mz.
1993/94	10,000 mz.	

[10]It should be noted that we are assuming that the expected profitability is the national average and that there are many farmers who are considerably more efficient than the average. Hence, we allow for investment to occur even if the average expected profitability from conversion is negative because, even in this case, there will be some efficient farmers whose expected profitability of the conversion is positive and who want to undertake the investments.

Figure 4. Estimation of Area Converted.



The converted area estimated by the National Commission for Coffee (CONCAFE) as of June 1992 for 1991/92 were:

T0 to T3	None
T1 to T3	8,980 mz.
T2 to T3	2,500 mz.

These figures are considerably lower than those originally expected with the "5-year program". The reasons for lower figures are shortage of credit and reduced farmers' demand for conversion due to low coffee prices. The model incorporates the latest estimates of conversion for 1991/92. These area conversion estimates and estimates of expected profitability from conversion at which conversion is zero were used to define the linear function between expected profitability from conversions and area converted.

Table 3. Assumptions for the Key Variables for the Base Run.

Variables	Assumptions
World inflation rate	4% p.a.
World coffee prices	Increasing in real terms at 4% p.a. for the period 1991/92 - 1995/96 and at 3% p.a. for the period 1995/96 -2000/01.
World fertilizer prices	Constant in real US dollar terms
Nicaragua's inflation and exchange rates.	Purchasing power parity was assumed
Wages, food prices, and marketing costs	Constant in real cordoba terms
Taxes	Same in percentage terms as in 1991/92
Interest rate on long-term credit	18%
Interest rate on short-term credit	17%

5.2 Results of the Base Run

The results of the Base Run for key variables are shown in Table A1 in the Annex. They show large growth in most of the key variables including production (from 974 thousand qq. in 1991/92 to 2,531 thousand qq. in 2000/01), yields (average of 9.7 qq./mz. in 1991/92 to 21.1 qq./mz. in 2000/01), and export revenues (from 1991 US$ 52 million in 1991/92 to 1991 US$ 185 million in 2000/01). Area is expected to reach almost 120 thousand mz. by 2000/01, an increase of about 20% from the 1991/92 level. Also, labor requirements are projected to increase about three-fold. Generally, the Base Run results indicate the substantial growth potential of Nicaragua's coffee subsector. However, it should be emphasized that the main cause of this spectacular growth is the large investment projected under the "5-year Agricultural Rehabilitation Program" in years up to and including 1993/94, and the expected real increase in world coffee prices in the mid- to late-1990s.

5.3. Policy Simulation Runs

Four other model runs were carried out to evaluate the effects of changes in exogenous variables on the subsector. These were: (i) world coffee prices 10% lower; (ii) labor efficiency 10% higher; (iii) a real devaluation of 10%; and (iv) doubling of short- and long-term interest rates. The results of these simulation runs are given in Tables A2-A5 in the Annex. As well, graphs for production and area for each simulation are shown in Figures 5-8.

The impact on the sector of world coffee prices being 10% lower than in the base scenario are reported in Table A2. With lower prices, coffee production becomes less profitable and causes producers to demand less labor and fertilizer. The demand for labor is 19% lower and the demand for fertilizer is 29% lower by 2000/01 compared to the base scenario. Less labor and fertilizer use means lower yields which decline by 4%-7% by 2000/01 depending on the type of technology employed. As well as impacting on yields, lower coffee prices make investments to improve technology less attractive, so that more land remains under T1 and T2 technology (higher by 4,559 mz. and 1,644 mz., respectively in 2000/01) and less land is converted to T3 (down by 10% in 2000/01). The combined effect of lower yields and less investment is for production to be 17% lower. This implies a long-run supply elasticity of about 1.7[11]. Less production means lower export volumes (lower by 17% by 2000/01), and with lower world prices, the real value of exports falls 26% below the base level. Finally, the demand for

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[11]This is considerably higher than given by Akiyama and Varangis (1990) for a number of countries. However, an elasticity of this magnitude is possible when a subsector is recovering from long-term neglect.

short-term credit falls because of falling production. The demand for long-term credit falls initially because of the decline in the profitability of conversion, but decisions to convert are delayed so that by 2000/01 the demand for long-term credit is 12% higher than in the Base Run.

Another simulation of the model was designed to assess the impact of higher labor efficiency in the coffee sector as a result say of farm extension or some other form of human resource development. In Nicaragua there is substantial scope for increasing labor efficiency and a 10% increase should not be difficult to achieve. Higher labor efficiency means that the same amount of work can be completed by fewer man-days and therefore has the effect of reducing the effective wage rate. This feature is built into the model, so that increasing the labor efficiency index has the effect of lowering the price of labor in the model under the assumption that the increase in labor efficiency and higher demand for labor by the coffee subsector do not increase wages. The model was simulated with the labor efficiency index 10% higher than in the base scenario and the results are reported in Table A3. Given the labor demand function embodied in the model, lower wages increase the demand for labor and by 2000/01 employment is 8% higher than in the base case. This is an important result since it says that improving labor efficiency does not lead to displacement of labor in the long-run. The improved labor efficiency causes yields to increase for all technologies, and this, in turn, increases the demand for fertilizer. As well, the more efficient work force encourages producers to convert coffee area to T3 from T0, T1 and T2. The combined effect of all these factors is for production and export volume and value to be 9% above their Base Case levels by 2000/01[12].

Another policy issue of interest is the impact of changes in the exchange rate on coffee production, exports, and investments. To make a quantitative assessment of exchange rate effects, the model was simulated assuming a 10% real devaluation of the cordoba (i.e., the model was run with an exchange rate of 5.5 cordobas/US$ instead of 5.0 cordobas/US$). The change in the exchange rate has two impacts in the model. First, it is used to convert the world price of coffee into a domestic price facing producers in cordoba terms and therefore a devaluation leads to an increase in the producer price. However, producers use imported fertilizers so that the devaluation makes these inputs more expensive. Therefore, this simulation measures the net impact of both higher output and input prices on production. Note that this simulation is for a 'real' devaluation, so it is assumed that prices of non-tradables such as wages do not change. The results are reported in Table A4. We observe that the devaluation has a

[12]It should be made clear that this simulation is not equivalent to a devaluation of the real exchange rate. In the model, increasing labor efficiency has the effect of lowering the wage rate, while a devaluation of the real exchange rate increases the prices of tradeables (i.e., coffee and fertilizer) but not prices of non-tradeables (i.e., labor).

positive effect on the coffee sector. By 2000/01 coffee production is 10% higher than in the Base Run, indicating an elasticity of unity between production and the exchange rate. Export volume and value also are 10% higher as a result of the 10% devaluation.

The final policy simulation was designed to assess the impact of changes in short- and long-term interest rates. Higher short-term interest rates have the effect of increasing the price of labor and fertilizer because farmers usually use short-term credit to hire labor and purchase fertilizer, and the consumption of these inputs is 13% and 16% lower, respectively, by 2000/01 when the short-term interest rates are doubled (Table A5)[13]. Higher short-term interest rates have a fairly small effect on coffee yields, which range between 2% to 4% lower than in the Base Run. In contrast, the increase in the long-term interest rate has a major adverse impact on investment and land conversion. As shown in Table A5, the area of T1 is 5,087 mz. higher than in the Base Run, while the area of T2 is 1,766 mz. higher. The area of T3 and total area decline by 10% and 4%, respectively. The combined effect of lower area and yields leads to production, export volume and value being 10% lower in 2000/01 compared to the Base Run. The reason for the limited impact of the short-term interest rates is that short-term interest costs represent a small share of total input costs since farmers usually get short-term credits for only three to four months.

6. Concluding Remarks

In this paper, a production-function based model for use in analysis for perennial crops has been presented. The approach contains the essential elements of the vintage-capital production approach in basing supply on past investment decisions as well as on current production decisions. This analytical framework should prove to be useful for policy analysis in countries where perennial crops are an important part of the economy because: (i) the data requirements are relatively small compared to other modeling approaches and the framework can be used even when structural changes in the industry have taken place; (ii) it incorporates all the important variables affecting the perennials sector and can therefore be used to evaluate the impacts of a large number of policy scenarios; and (iii) the model is very easy to operate in terms of computer requirements and modeling expertise.

The results from the model indicate that these policy variables are very important in determining the future growth and development of the sector. For example, higher coffee prices would lead to higher input demand and improved yields, as well as expanded coffee area through investment. Substantial

[13]Given the partial equilibrium nature of the analysis we assume that the decline in the demand for labor does not effect the nominal wage rate.

benefits to the sector would also be achieved by greater labor efficiency, lower real interest rates, and a reduction in the real value of the cordoba vis-à-vis the US dollar. Finally, the analysis shows that Nicaragua has the potential to increase its production and exports substantially by the end of the decade, provided there exists a favorable economic climate, especially in terms of international prices and investment incentives.

Figure 5: Simulation with 10% Lower World Price of Coffee.

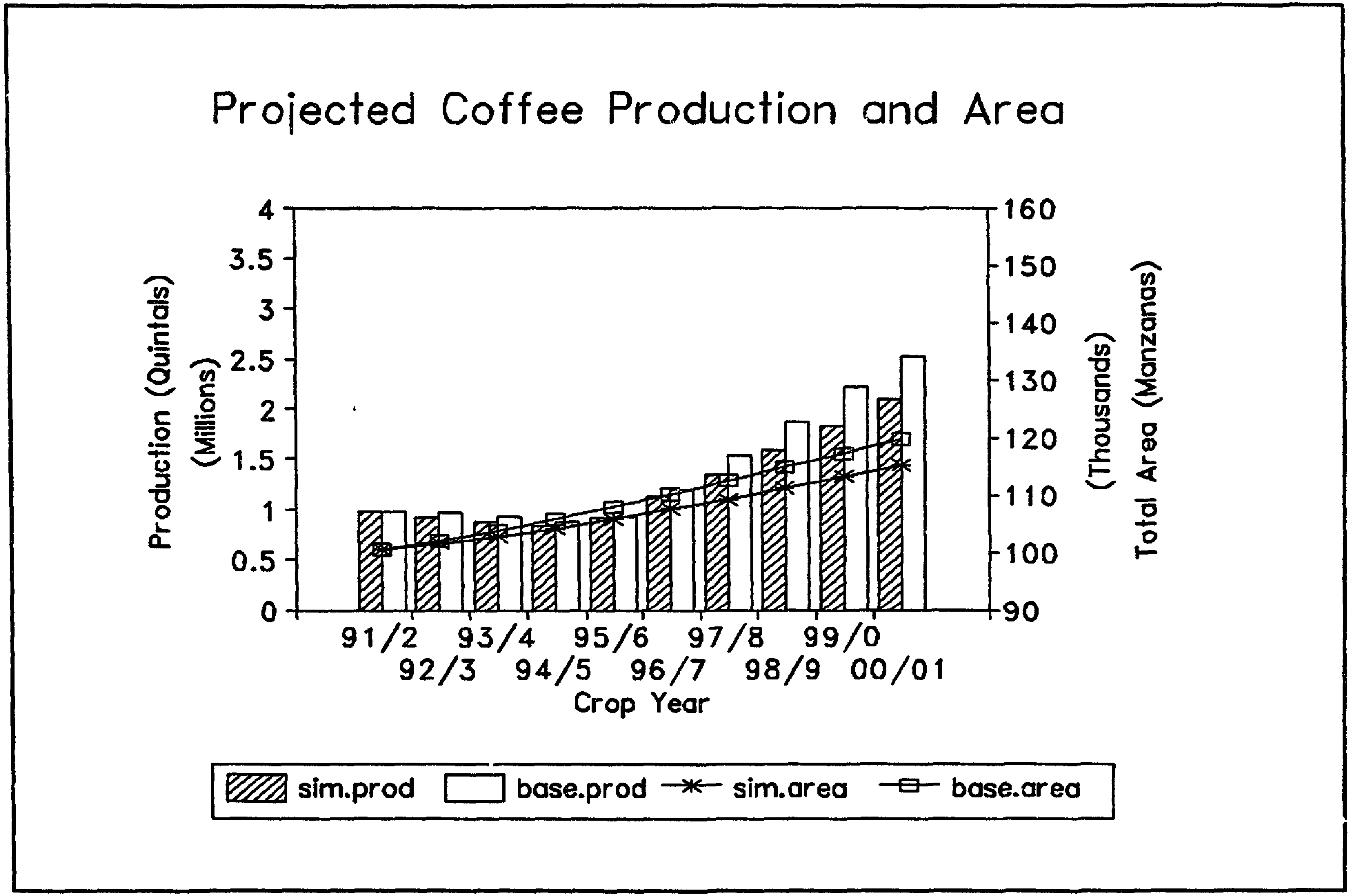


Figure 6: Simulation with 10% Higher Labor Efficiency.

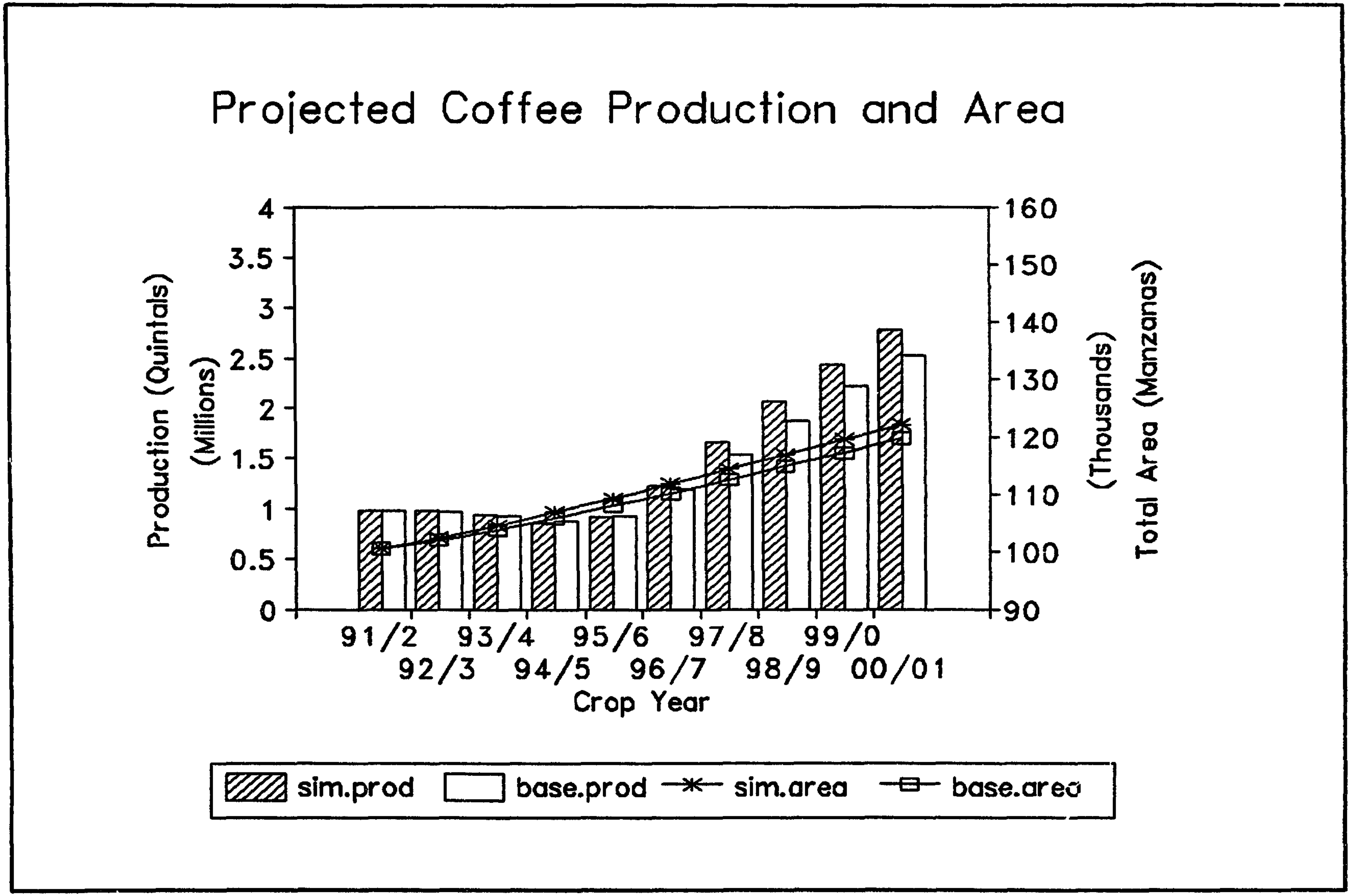


Figure 7: Simulation with 10% Real Devaluation.

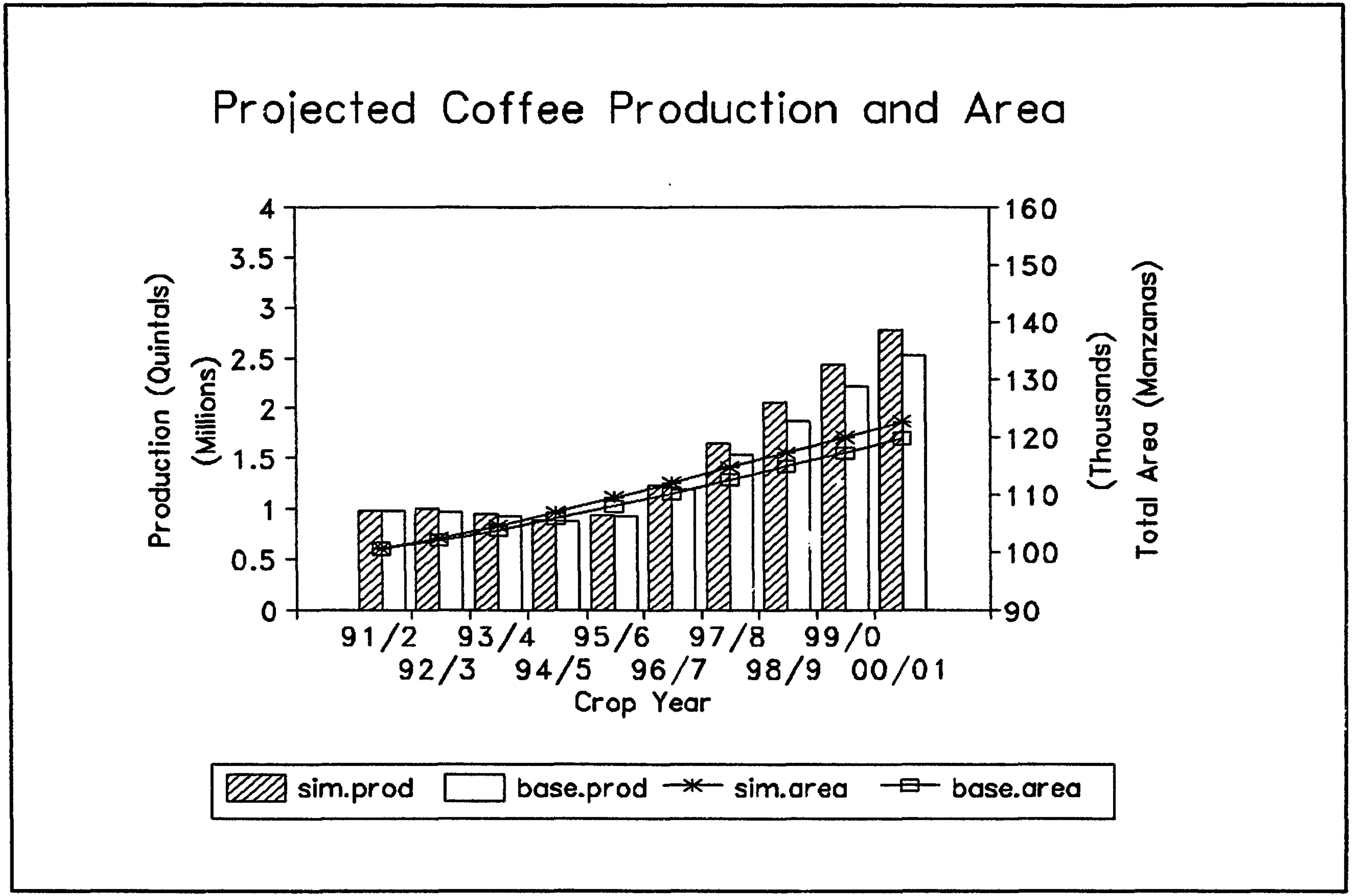
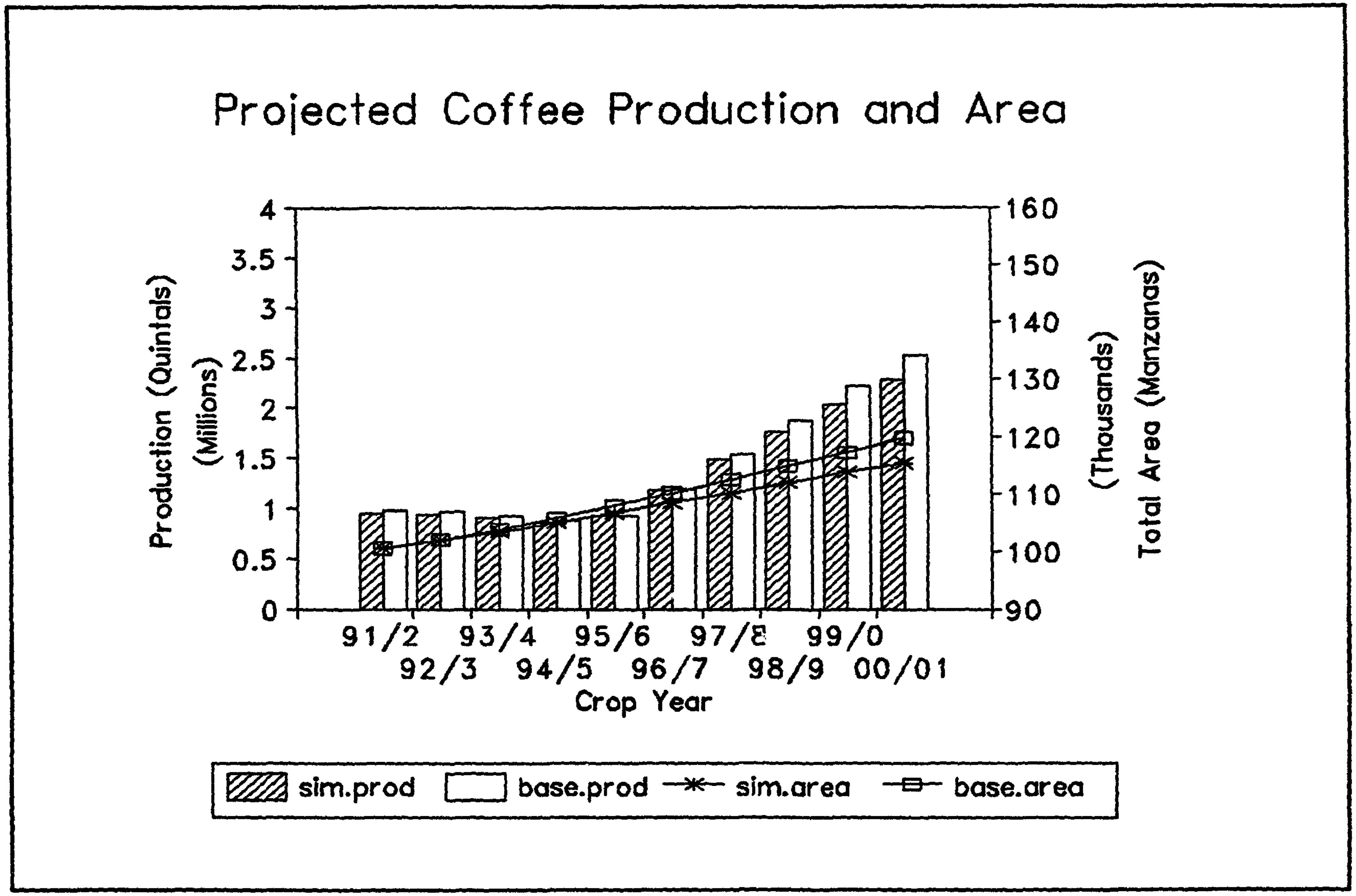


Figure 8: Doubling of Short- and Long-Term Interest Rates.



Annex

Simulation Results

Table A1. Base Simulation Results.

Variable	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00	2000/01
Production (million qq.)	974,332	966,969	924,843	871,350	928,372	1,196,558	1,535,046	1,878,024	2,214,323	2,531,070
Export Volume (qq.)	847,669	841,263	804,613	758,075	807,684	1,041,006	1,335,490	1,633,881	1,926,461	2,202,031
Export Revenue (million US $)										
Nominal	52	56	58	60	69	95	131	171	215	263
Real (1991/92 US$)	52	54	54	53	59	78	103	130	157	185
Area (Mz.)										
T1	59,005	48,624	38,829	29,955	22,249	16,097	11,326	7,737	5,122	3,279
T2	22,180	19,407	16,775	14,312	12,041	10,036	8,284	6,768	5,472	4,376
T3	19,315	34,072	48,286	61,592	73,713	84,094	92,913	100,375	106,695	112,084
Total	100,500	102,103	103,890	105,858	108,003	110,227	112,523	114,880	117,289	119,738
Yield (qq./Mz.)										
T1	5.00	5.10	5.19	5.29	5.38	5.44	5.50	5.56	5.62	5.67
T2	11.65	12.11	12.56	13.01	13.45	13.73	14.00	14.27	14.54	14.80
T3	21.78	22.58	23.36	74.13	24.88	25.35	25.81	26.27	26.72	27.15
National Average	9.69	9.47	8.90	8.23	8.60	10.86	13.64	16.35	18.88	21.14
Credit (million 1991/92 Cordobas)										
Short-Term	166	172	170	166	185	250	332	415	498	578
Long-Term	72	135	173	176	163	146	126	107	90	77
Labor Demand (Man Yrs)	55,285	56,409	55,164	53,110	58,530	78,198	102,650	127,487	152,036	175,484
Fertilizer Demand (qq.)	346,303	390,686	417,558	436,723	525,999	751,129	1,035,943	1,338,029	1,650,105	1,962,542

Source: IECIT, World Bank.

Table A2. Simulation with 10% Lower World Price of Coffee.

Variable	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00	2000/01
Production (million qq.)	974,332	910,136	875,890	844,712	910,282	1,130,030	1,346,139	1,584,757	1,838,934	2,097,519
Index with Base Run = 100	100	94	95	97	98	94	88	84	83	83
Export Volume (qq.)	847,669	791,819	762,024	734,899	791,945	983,126	1,171,141	1,378,738	1,599,873	1,824,841
Index with Base Run = 100	100	94	95	97	98	94	88	84	83	83
Export Revenue (million US $)										
Nominal	52	47	49	51	60	80	102	128	159	194
Index with Base Run = 100	100	83	84	86	87	84	78	75	74	74
Real (1991/92 US$)	52	45	45	46	51	66	80	97	116	136
Index with Base Run = 100	100	83	84	86	87	84	7[illegible]	75	74	74
Area (Mz.)										
T1	59,005	52,072	44,842	37,591	30,595	24,397	19,038	14,519	10,807	7,838
Index with Base Run = 100	100	107	115	125	138	152	168	188	211	239
T2	22,180	19,953	17,769	15,653	13,630	11,775	10,089	8,571	7,217	6,020
Index with Base Run = 100	100	103	106	109	113	117	122	127	132	138
T3	19,315	29,557	40,224	51,018	61,639	71,388	80,222	88,133	95,153	101,343
Index with Base Run = 100	100	87	83	83	84	85	86	88	89	90
Total	100,500	101,582	102,835	104,262	105,863	107,560	109,349	111,223	113,176	115,202
Index with Base Run = 100	100	99	99	98	98	98	97	97	96	96
Yield (qq./Mz.)										
T1	5.00	4.[illegible]	4.94	5.04	5.14	5.20	5.26	5.32	5.38	5.44
Index with Base Run = 100	100	95	95	95	95	96	96	96	96	96
T2	11.65	10.93	11.39	11.84	12.29	12.58	12.87	13.15	13.43	13.70
Index with Base Run = 100	100	90	91	91	91	92	92	92	92	93
T3	21.78	20.51	21.32	22.11	22.90	23.39	23.88	24.36	24.84	25.31
Index with Base Run = 100	100	91	91	92	92	92	93	93	93	93
National Average	9.69	8.96	8.52	8.10	8.60	10.51	12.31	14.25	16.25	18.21
Index with Base Run = 100	100	95	96	98	100	97	90	87	86	86
Credit (million 1991/92 Cordobas)										
Short-Term	166	157	154	153	172	224	275	332	393	455
Index with Base Run = 100	100	92	91	92	93	89	83	80	79	79
Long-Term	72	106	134	133	134	129	120	108	97	86
Index with Base Run = 100	100	79	77	76	82	89	95	101	107	112
Labor Demand (Man Yrs)	55,285	52,910	51,418	50,287	55,866	71,949	87,661	104,840	123,070	141,651
Index with Base Run = 100	100	94	93	95	95	92	85	82	81	81
Fertilizer Demand (qq.)	346,303	305,282	323,522	344,814	422,122	586,531	757,774	952,193	1,166,852	1,395,486
Index with Base Run = 100	100	78	77	79	80	78	73	71	71	71

Source: IECIT, World Bank.

Table A3. Simulation with 10% Higher Labor Efficiency.

Variable	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00	2000/01
Production (million qq.)	974,332	978,426	934,985	867,247	918,737	1,222,781	1,653,749	2,060,946	2,435,777	2,770,285
% Diff. From Base	100	101	101	100	99	102	108	110	110	109
Export Volume (qq.)	847,669	851,230	813,437	754,504	799,302	1,063,820	1,438,762	1,793,023	2,119,126	2,410,148
% Diff. From Base	100	101	101	100	99	102	108	110	110	109
Export Revenue (million US $)										
Nominal	52	57	59	59	68	97	141	187	237	288
Index with Base Run = 100	100	101	101	100	99	102	108	110	110	109
Real (1991/92 US$)	52	54	54	53	58	80	111	142	173	202
Index with Base Run = 100	100	101	101	100	99	102	108	110	110	109
Area (Mz.)										
T1	59,005	45,932	34,565	25,062	17,444	11,803	7,750	4,930	3,031	1,798
Index with Base Run = 100	100	94	89	84	78	73	68	64	59	55
T2	22,180	18,942	15,974	13,289	10,897	8,850	7,115	5,660	4,454	3,466
Index with Base Run = 100	100	98	95	93	90	88	86	84	81	79
T3	19,315	37,578	54,035	68,507	80,955	91,139	99,467	106,319	112,025	116,860
Index with Base Run = 100	100	110	112	111	110	108	107	106	105	104
Total	100,500	102,452	104,573	106,858	109,297	111,791	114,332	116,909	119,510	122,124
Index with Base Run = 100	100	100	101	101	101	101	102	102	102	102
Yield (qq./Mz.)										
T1	5.00	5.25	5.35	5.44	5.54	5.60	5.66	5.72	5.78	5.83
Index with Base Run = 100	100	103	103	103	103	103	103	103	103	103
T2	11.65	12.54	13.00	13.44	13.88	14.16	14.43	14.70	14.96	15.22
Index with Base Run = 100	100	104	103	103	103	103	103	103	103	103
T3	21.78	23.31	24.09	24.86	25.60	26.07	26.53	26.97	27.41	27.84
Index with Base Run = 100	100	103	103	103	103	103	103	103	103	103
National Average	9.69	9.55	8.94	8.12	8.41	10.94	14.46	17.63	20.38	22.68
Index with Base Run = 100	100	101	100	99	98	101	106	108	108	107
Credit (million 1991/92 Cordobas)										
Short-Term	166	158	158	152	170	237	330	420	505	583
Index with Base Run = 100	100	92	93	92	92	94	99	101	101	101
Long-Term	72	152	195	196	171	145	119	98	80	67
Index with Base Run = 100	100	113	112	112	105	99	95	91	89	88
Labor Demand (Man Yrs)	55,285	56,186	55,255	52,511	57,577	79,363	109,711	138,609	165,568	190,108
Index with Base Run = 100	100	100	100	99	98	101	107	109	109	108
Fertilizer Demand (qq.)	346,303	400,715	433,600	448,231	535,426	784,391	1,133,694	1,483,568	1,827,116	2,156,974
Index with Base Run = 100	100	103	104	103	102	104	109	111	111	110

Source: IECIT, World Bank.

Table A4. Simulation with 10% Real Devaluation.

Variable	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00	2000/01
Production (million qq.)	974,332	993,503	948,019	881,357	933,275	1,231,765	1,648,888	2,053,054	2,432,017	2,774,066
Index with Base Run = 100	100	103	103	101	101	103	107	109	110	110
Export Volume (qq.)	847,669	864,347	824,777	766,780	811,949	1,071,635	1,434,533	1,786,157	2,115,855	2,413,438
Index with Base Run = 100	100	103	103	101	101	103	107	109	110	110
Export Revenue (million US $)										
Nominal	52	58	60	60	69	98	140	187	236	288
Index with Base Run = 100	100	103	103	101	101	103	107	109	110	110
Real (1991/92 US$)	52	55	55	54	59	81	111	142	173	202
Index with Base Run = 100	100	103	103	101	101	103	107	109	110	110
Area (Mz.)										
T1	59,005	46,518	35,337	25,770	17,965	12,140	7,935	5,007	3,042	1,775
Index with Base Run = 100	100	96	91	86	81	75	70	65	59	54
T2	22,180	19,100	16,221	13,573	11,179	9,109	7,340	5,848	4,603	3,579
Index with Base Run = 100	100	98	97	95	93	91	89	86	84	82
T3	19,315	36,833	53,038	67,585	80,290	90,758	99,358	106,448	112,355	117,358
Index with Base Run = 100	100	108	110	110	109	108	107	106	105	105
Total	100,500	102,452	104,597	106,928	109,434	112,007	114,634	117,302	120,000	122,712
Index with Base Run = 100	100	100	101	101	101	102	102	102	102	102
Yield (qq./Mz.)										
T1	5.00	5.28	5.38	5.47	5.57	5.63	5.68	5.74	5.80	5.86
Index with Base Run = 100	100	104	104	103	103	103	103	103	103	103
T2	11.65	12.69	13.14	13.58	14.01	14.28	14.55	14.81	15.07	15.32
Index with Base Run = 100	100	105	105	104	104	104	104	104	104	104
T3	21.78	23.57	24.34	25.09	25.82	26.28	26.73	27.17	27.59	28.01
Index with Base Run = 100	100	104	104	104	104	104	104	103	103	103
National Average	9.69	9.70	9.06	8.24	8.53	11.00	14.38	17.50	20.27	22.61
Index with Base Run = 100	100	102	102	100	99	101	105	107	107	107
Credit (million 1991/92 Cordobas)										
Short-Term	166	183	182	176	197	272	375	478	576	668
Index with Base Run = 100	100	107	107	106	106	109	113	115	116	116
Long-Term	72	155	200	203	181	155	129	106	87	73
Index with Base Run = 100	100	115	115	116	111	106	102	99	97	95
Labor Demand (Man Yrs)	55,285	59,208	58,175	55,516	60,941	83,331	114,140	144,288	173,005	199,515
Index with Base Run = 100	100	105	105	105	104	107	111	113	114	114
Fertilizer Demand (qq.)	346,303	414,377	446,111	461,855	551,491	801,347	1,146,508	1,499,096	1,850,120	2,189,733
Index with Base Run = 100	100	106	107	106	105	107	111	112	112	112

Source: IICTT, World Bank.

Table A5. Doubling of Short- and Long-Term Interest Rates.

Variable	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00	2000/01
Production (million qq.)	942,004	940,313	904,845	861,674	926,051	1,182,136	1,479,160	1,762,367	2,030,782	2,282,319
Index with Base Run = 100	97	97	98	99	100	99	96	94	92	90
Export Volume (qq.)	819,543	818,073	787,215	749,657	805,664	1,028,459	1,286,869	1,533,260	1,766,781	1,985,617
Index with Base Run = 100	97	97	98	99	100	99	96	94	92	90
Export Revenue (million US $)										
Nominal	50	54	57	59	69	94	126	160	197	237
Index with Base Run = 100	97	97	98	99	100	99	96	94	92	90
Real (1991/92 US$)	50	52	53	52	59	77	99	122	144	167
Index with Base Run = 100	97	97	98	99	100	99	96	94	92	90
Area (Mz.)										
T1	59,005	49,534	41,134	33,761	27,364	21,992	17,519	13,827	10,809	8,366
Index with Base Run = 100	100	102	106	113	123	137	155	179	211	255
T2	22,180	19,549	17,156	14,986	13,027	11,287	9,746	8,386	7,190	6,142
Index with Base Run = 100	100	101	102	105	108	112	118	124	131	140
T3	19,315	32,899	45,238	56,390	66,418	75,227	82,959	89,748	95,716	100,976
Index with Base Run = 100	100	97	94	92	90	89	89	89	90	90
Total	100,500	101,982	103,527	105,137	106,810	108,506	110,224	111,961	113,715	115,484
Index with Base Run = 100	100	100	100	99	99	98	98	97	97	96
Yield (qq./Mz.)										
T1	4.91	5.01	5.10	5.19	5.29	5.34	5.40	5.46	5.52	5.57
Index with Base Run = 100	98	98	98	98	98	98	98	98	98	98
T2	11.18	11.62	12.06	12.49	12.91	13.18	13.45	13.71	13.96	14.22
Index with Base Run = 100	96	96	96	96	96	96	96	96	96	96
T3	20.93	21.70	22.45	23.20	23.92	24.38	24.83	25.27	25.70	26.13
Index with Base Run = 100	96	96	96	96	96	96	96	96	96	96
National Average	9.37	9.22	8.74	8.20	8.67	10.89	13.42	15.74	17.86	19.76
Index with Base Run = 100	97	97	98	100	101	100	98	96	95	93
Credit (million 1991/92 Cordobas)										
Short-Term	164	170	168	165	186	248	321	392	460	526
Index with Base Run = 100	98	99	99	100	100	99	97	94	92	91
Long-Term	74	131	161	156	141	125	111	97	85	75
Index with Base Run = 100	103	97	93	89	86	86	88	91	94	98
Labor Demand (Man Yrs)	51,712	52,997	51,964	50,371	55,861	73,956	94,770	114,740	133,863	152,048
Index with Base Run = 100	94	94	94	95	95	95	92	90	88	87
Fertilizer Demand (qq.)	314,749	355,974	379,635	397,541	480,474	681,561	920,442	1,162,497	1,406,579	1,650,614
Index with Base Run = 100	91	91	91	91	91	91	89	87	85	84

Source: IECIT, World Bank.

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