MODEXC

Release 4.1

A Friendly Computer Model

Impact Assessment and Priorization of Investment Projects in Agricultural Research

CIAT
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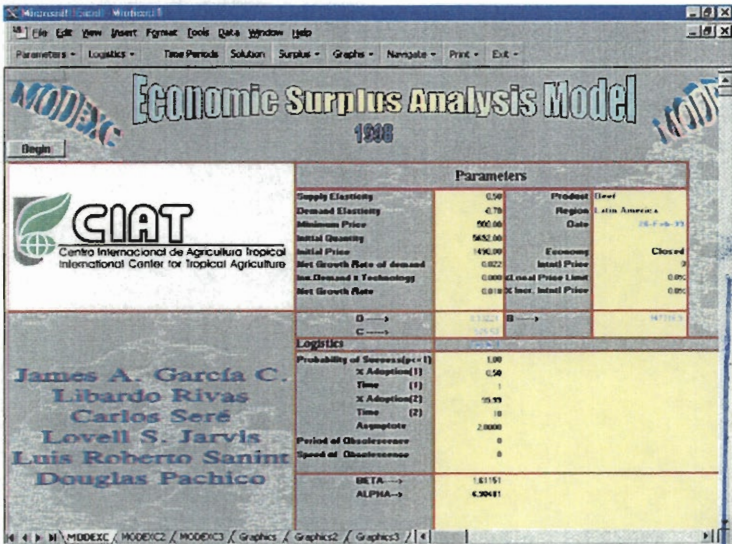

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Impact Assessment and Priorization of Investment Projects in Agricultural Research

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ECONOMIC SURPLUS ANALYSIS MODEL (MODEXC)

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1. INTRODUCTION

Scientific research is crucial in the search for new technological alternatives that are capable of increasing production and productivity in a sustainable manner. More goods are thus made available at lower prices, which is particularly important for low-income groups, especially for food. The lowest income groups are known to spend a very high proportion of their income on food products.

A large amount of public resources is invested in the generation of technology. Because these funds are restricted, their opportunity cost is high. This is especially the case in developing countries, given the many and growing needs of their populations in areas such as education, health, electric power, security, and road infrastructure.

Research design and planning must therefore be rigorously prioritized to ensure that funds are invested in those alternatives that will most benefit society as a whole.

Several non-excluding alternative criteria can be used to assess the potential of these new technologies and to set priorities. For example, the size of benefits in relation to necessary investments, the distribution of benefits among producers and consumers (large and small, rich and poor), and the externalities of the technology regarding its impact on the environment, on natural resources, and on other economic activities. As a result, the assessment of the socioeconomic impact of new technologies is a very broad concept that goes beyond the simple, direct effect of technology on production and prices.

The economic surplus model MODEXC is a useful tool for estimating several indicators that will help prioritize technologies (ex-ante analysis) and then evaluate them after their adoption and dissemination (ex-post analysis).

This manual refers exclusively to the latest version of MODEXC, which runs in Excel. MODEXC can also be used with Lotus 1-2-3 (English versions 3 and 4). For the numerous researchers in Latin America and the Caribbean, Excel and Lotus 1-2-3 are the calculation programs most widely available and easily accessible. The speed with which information is processed will basically depend on the hardware and on the version of software used. Annex 2 lists several precautions that should be taken into account to correctly use the program.

MODEXC can be run in Lotus 1-2-3, versions 1 and 2, using the file MODEXC2.wk1, and with versions 3 and 4 using the file MODEXC3.wk3. The MODEXC version for Excel 97 corresponds to the file MODEXC.xlt.

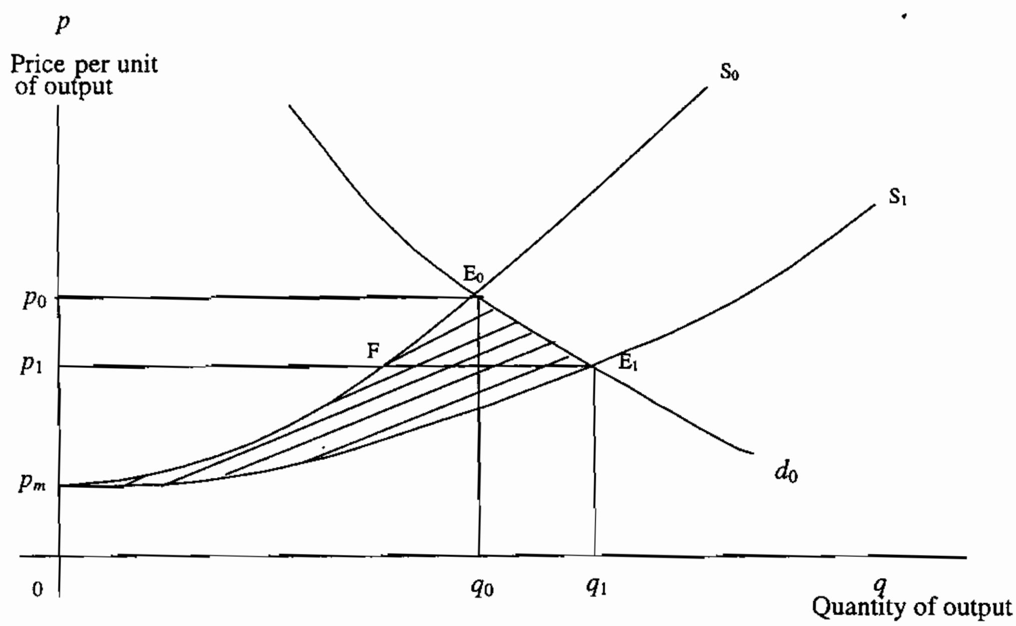
2. THE THEORETICAL MODEL AND THE MATHEMATICAL MODEL

The MODEXC model helps calculate and analyze the benefits derived from technological change, which are measured as the economic surplus of producers and consumers. The model also estimates indicators of social gains from investment in research. By introducing into the model the annual flows of investments in research and development, indicators of social gains can be estimated, for example net present value (NPV), internal rate of return (IRR), and the cost/benefit (C/B) ratio.

2.1. The Theoretical Model

The model is based on the Marshallian theory of economic surplus that stems from shifts over time of the supply and demand curves. In Diagram1, the rightward shift (s_1) of the original supply curve (s_0) generates economic surplus for producers and consumers. Such a shift can stem from changes in production technology.

Diagram 1



Given that the demand function remains constant, the original market equilibrium E_0 (p_0, q_0) is transferred by the effect of technological change to E_1 (p_1,q_1).

Consumers gain because they are able to consume a greater amount (q_1) at a lower price (p_1). The area $p_0p_1E_0E_1$ represents this gain. The new technology affects producers in two ways:

1. Lower marginal costs (according to the theory, the supply curve corresponds to the curve of marginal costs as of the minimum value of the curve of average variable costs).
2. Lower market price (p_0 reduced to p_1).

The $p_m\mathrm{FE}_1$ area represents producers' gains due to lower costs, and the $p_0\mathrm{E}_0\mathrm{F}p_1$ area represents losses caused by price reduction. Therefore, the net producers' surplus (NPS) is defined as $p_m\mathrm{FE}_1 - p_0\mathrm{E}_0\mathrm{F}p_1$.

The area $p_m\mathrm{E}_0\mathrm{E}_1$ represents the net social surplus.

The level and distribution of surplus between producers and consumers are mostly determined by the nature of the shift of the supply and demand curves, by price elasticities, and by the minimum bid price (see Alston et al. 1988).

The absolute value of price elasticity of demand is basic in determining whether producers obtain a positive surplus during technological change. If the absolute value of price elasticity of demand faced by producers is very low, the market price will have to be lowered significantly if additional quantities of output derived from technological change are to be placed in the market. This increases the possibility of $p_0\mathrm{EF}p_1$ being greater than $p_m\mathrm{FE}_1$, in other words, the effect of price reductions will be greater than that of cost reductions (increased productivity).

Whether the economy is closed or open (without or with international trade) has a direct effect on the surplus of producers and consumers. In an open economy, domestic prices are below international prices. Domestic prices therefore tend to be readjusted to match international prices, detaining the fall of domestic prices, and reducing consumer surplus while increasing those of producers.

The model assumes free market conditions. In other words, there are no policy distortions such as subsidies, production or trade quotas, or tariffs. Many markets, particularly those of agricultural products, are affected by policy distortions, which in turn affect the level and distribution of benefits derived from technological change (see Alston et al. 1988).

MODEXC can be used for (a) an independent, one-commodity market or (b) several markets (a maximum of three) simultaneously. Markets should be linked among themselves by relationships of complementarity/substitution in both production and consumption.

Unlike other models, MODEXC explicitly considers demand shifts caused by different factors such as population growth and income. These demand shifts are introduced through the net annual growth rate of demand, which is calculated as:

$$AGRD = \frac{du}{udt} + \varepsilon\frac{dy}{ydt} + \eta\frac{dp_r}{p_r dt} + \lambda\frac{dp_c}{p_c dt} \tag{1}$$

Where:

$AGRD$	=	Annual growth rate of demand,
η	=	Price elasticity of demand,
ε	=	Income elasticity of demand,
λ	=	Elasticity of substitution/complementarity,
$\frac{du}{udt}$	=	Annual population growth rate,
$\frac{dy}{ydt}$	=	Annual growth rate of real income,
$\frac{dp_r}{p_r dt}$	=	Annual growth rate of real own-price, and
$\lambda \frac{dp_c}{p_c dt}$	=	Annual growth rate of price of substitute or complementary goods in consumption

MODEXC is a partial equilibrium model—when working with a single market, one way of introducing the influence of other related markets into the model, whether they are substitute or complementary consumption markets, is through the term $\lambda \frac{dp_c}{p_c dt}$

If no relationship of substitution or complementarity exists, the net growth of demand is reduced to:

$$AGRD = \frac{du}{udt} + \varepsilon \frac{dy}{ydt} \tag{2}$$

The above aspects should be taken into account when evaluating markets that are linked together by relationships of substitution or complementarity explicitly considered within those markets, because it would be redundant to include such effects within the independent growth rate of demand.

The growth of demand should be explicitly considered in long-term analyses because it clearly influences the level of economic surplus.

In open economies, the model works under the assumption of a small market as related to the international market. In other words, surpluses that are marketed abroad do not affect international prices. The local market therefore faces an infinitely elastic external demand ($\eta = \infty$). The partial equilibrium approach assumes that no other adjustments are made in the economy.

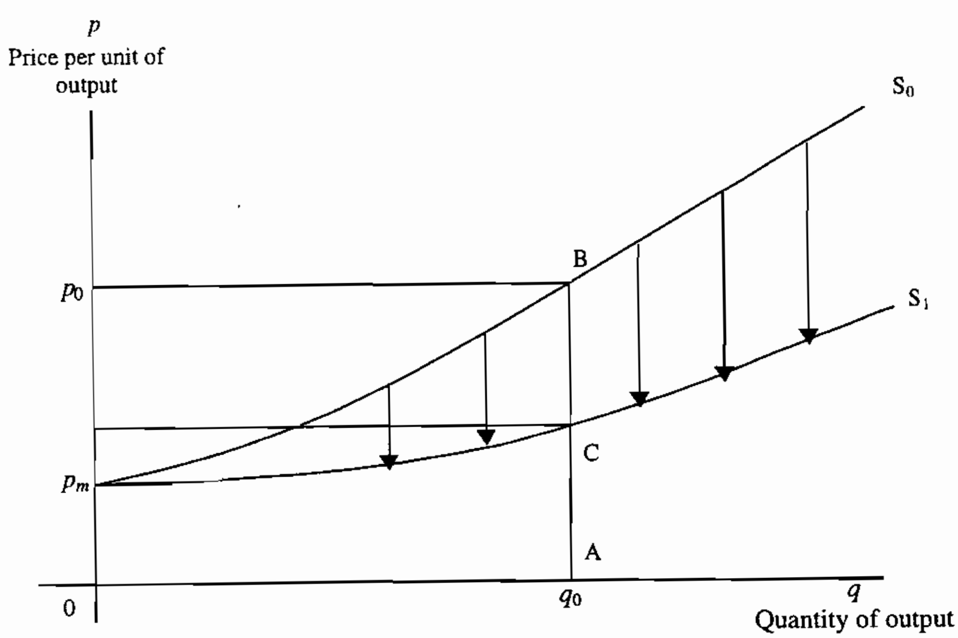
The supply expansion factor (k) can be interpreted as a reduction of absolute costs for each production level, or as an increase in production for each price level. The solution algorithm of MODEXC assumes a horizontal supply shift, which means that it works with a k factor expressed as a percentage increase of production. When k is expressed as a percentage change of production costs (k_c), k must be converted to its equivalent in terms of production expansion (k_p) through supply elasticity.

$$k_p = k_c \, \phi_p \tag{3}$$

Where ϕ_p is the price elasticity of supply.

In Diagram 2, the last unit of output is produced at a cost AB using the old technology at production level q_0. The new technology reduces the cost of the last unit of output to AC, and absolute cost reduction is BC. In this case, k shifted the supply function vertically, explicitly determining a reduction in costs and implicitly determining an increase in production. In an economic surplus model developed by Davis et al. (1987), k represents the direct effect that the cost reduction generated by the use of new technology has on supply.

Diagram 2

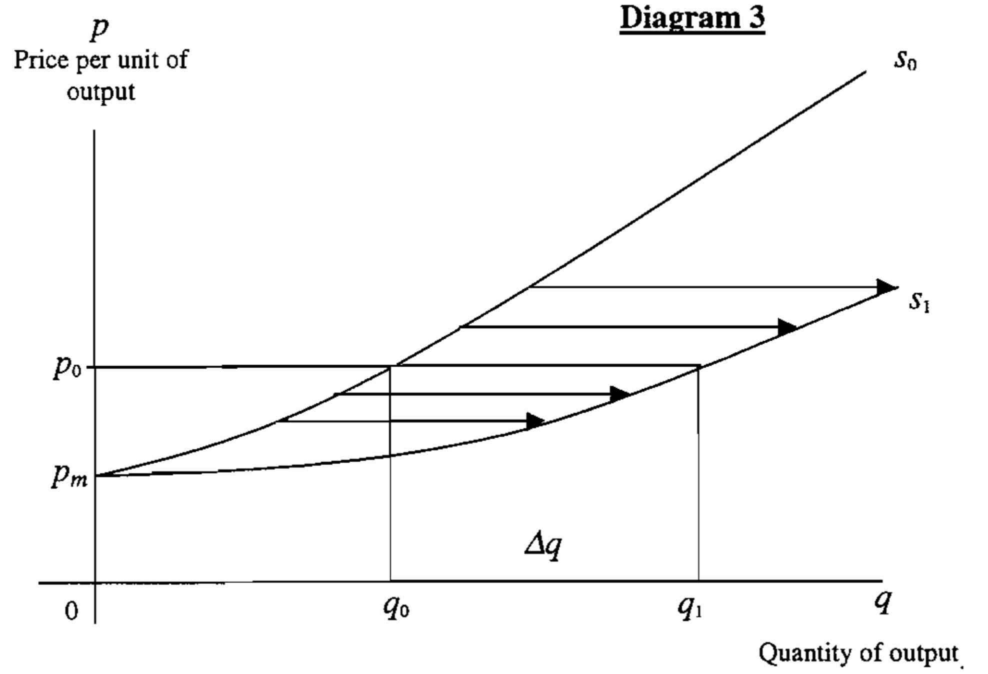


As previously mentioned, in MODEXC, k shifts the supply function horizontally. In other words, it represents an explicit increase in production and an implicit reduction in costs; k is estimated as:

$$k = \frac{q_0 + (q_1 - q_0)}{q_0} = \frac{q_0 + \Delta q}{q_0} \quad \textbf{(4)}$$

Where Δq is the increase in production obtained with improved technology at price p_0.

Diagram 3



2.2. The Mathematical Model

The mathematical model used is based on the scheme proposed by Pachico et al. (1987), in which supply and demand functions are nonlinear with constant elasticity[1]. MODEXC allows the researcher to consider an individual market or miscellaneous markets linked by relationships of complementarity/substitution in both consumption and production.

In the first case, supply and demand are only own-price functions. In the second case, these functions are determined by both the own-price and by prices of certain substitute or complementary goods available in other markets. The prices of substitute or complementary goods correspond to expected prices calculated according to Nerlove (1958).

1 For other types of mathematical models, see Lindner and Jarret (1978), Norton and Davis (1981), Miller et al. (1988), and Seré and Jarvis (1988).

2.3. Supply Functions

When dealing with a single product market, it is assumed that supply curves correspond to the following functional form:

$$s_0 = c(p - p_m)^g \qquad \textbf{(5)}$$

Where:
s_0 = Initial supply before technological change,
c, g = Constants,
p = Price of product, and
p_m = Minimum price that producers are willing to offer.

When dealing with several product markets (a|b, n), the supply function of product "a" is expressed as:

$$s_{0a} = c(p_a - p_{ma})^g \prod_{i=b}^{n} p_i^{\delta_i} \qquad \textbf{(6)}$$

Where in addition:
p_i = Expected price of product "i", and
δ_i = Elasticity of substitution/complementarity in production of product "a " by product "i".

To express the initial supply of each product market in mathematical terms, the following information is needed:

1. The market equilibrium before technological change E_0, in terms of quantity and equilibrium price (q_0, p_0).
2. The value of price elasticity of supply ($\in_p$).
3. Minimum bid price (p_m).

When working with linked product markets, the following are also required:

4. The initial equilibrium conditions in other product markets (p_{0b} ... p_{0n}, q_{0b} ... q_{0n}).
5. The elasticities of substitution/complementarity in production of different products in different target markets (δ_i).

The minimum bid price (p_{mi}) is the price at which production begins. It can be considered the price that covers variable production costs.

Once points 1 to 3 are defined, constants g and c of equation **(5)** for the different product markets are estimated in the following way:

$$g_i = \frac{\phi_{p_i}(p_{0i} - p_{mi})}{p_{0i}} \qquad \textbf{(7)}$$

Where: ϕ_{p_i} = Price elasticity of supply of product "i".

$$c_i = \frac{q_{0i}}{(p_{0i} - p_{mi})^{g_i}} \qquad \textbf{(8)}$$

For more information, see Pachico et al. (1987).

When dealing with multiple product markets, constant c_i is expressed as:

$$c_i = \frac{q_{0i}}{\prod_{i=b}^{n} p_{0i}^{\delta_i}(p_{0i} - p_{mi})^{g_i}} \qquad \textbf{(9)}$$

Expected prices are defined according to Nerlove (1958) under a scheme of distributed lags that are set forth mathematically as:

$$p_t^* = \alpha_1 p_{t-1} + \alpha_2 p_{t-2} + \alpha_3 p_{t-3} + \alpha_4 p_{t-4} + \alpha_5 p_{t-5} \qquad \textbf{(10)}$$

Where: p_t^* = Expected price in period "t",
$p_{t-1} \dots p_{t-n}$ = Lagged prices from period "t-1" to period "t-n", and
$\alpha_1 \dots \alpha_n$ = Weighted factors of lagged prices.

2.4. Shift of Supply Functions

It is assumed that, once technological change begins, the supply curve shifts gradually over time. Current literature[2] indicates that the supply shift factor due to technological change is known as k. This factor varies in time depending on the dynamics of the adoption and dissemination of new technologies.

[2] Norton and Davis (1981) have prepared an extensive literature review on the topic.

There are different types of supply shift: parallel, pivotal, divergent, or convergent.

Pachico et al. (1987) define three types of supply shift depending on the position k takes within the original function.

1. Pivotal shift: $$s_1 = ck(p - p_m)^g \tag{11}$$

2. Divergent shift: $$s_1 = c(kp - p_m)^g \tag{12}$$

3. Convergent shift: $$s_1 = c(p_0 - \frac{p_m}{k})^g \tag{13}$$

The general form of shifted supply is:

$$s_1 = k_1 c(k_2 p - \frac{p_m}{k_3})^g \tag{14}$$

Where:

Where:	k_1	=	When the shift is pivotal,
	k_2	=	When the shift is divergent, and
	k_3	=	When the shift is convergent.

If k_1 takes a value higher than 1, k_2 and k_3 will take values equal to 1. Only one k at a time can take a changed value.

2.5. Logistic Function

Because technological change is gradual and varies in intensity over time, a logistic function is used to simulate adoption, which is slow in its initial stages. As the technology is adopted and its performance and benefits are better known, the rate of adoption increases, then decreases in advanced stages of the process, and finally becomes stabilized.

The model therefore assumes that the supply shift factor, k, obeys a logistic-type pattern.

To estimate supply functions under conditions of technological change, the maximum value that k will take, once the adoption process has ended, must be known beforehand.

The model also takes into consideration the processes of nonadoption or obsolescence of technologies and the dynamics of both processes.

2.6. Demand Functions

The initial demand function of product market "a" is defined as:

$$d_{0a} = b_a p_a^{\eta_a} \tag{15}$$

Where: d_{0a} = The quantity demanded of product "a",
p_a = The price of product "a",
η_a = The price elasticity of demand of product "a", and
b_a = Constant.

When dealing with several product markets (a|b,......n), the demand function of product market "a" is expressed as:

$$d_{0_a} = b_a p_a^{\eta_a} \prod_{i=b}^{n} p_i^{\lambda_i} \tag{16}$$

Where: p_i = Expected price in product market "i", and
λ_i = Elasticity of substitution/complementarity.

The value of b_a is calculated as:

$$b_a = \frac{q_{0_a}}{p_{0_a}^{\eta_a} \prod_{i=b}^{n} p_{0_i}^{\lambda_i}} \tag{17}$$

Where: p_{0a} = Initial price in product market "a",
p_{0i} = Initial price in product market "i",
η_a = Own-price elasticity of market demand, and
λ_i = Elasticity of substitution/complementarity of consumption of product "i" in the product market "a".

To determine the original demand function when working with a single product, the following are needed:

1. The quantity and initial equilibrium price: p_0, q_0.
2. The own-price elasticity of demand (η).

When working with multiple product markets, the following are also needed:

3. The conditions of initial equilibrium in other product markets (a|b..... n) $(p_b \dots p_n, q_b \dots q_n)$.
4. The price elasticities of other products markets $(\eta_b \dots \eta_n)$.
5. The elasticities of substitution/complementarity in consumption among the different product markets (λ_i).

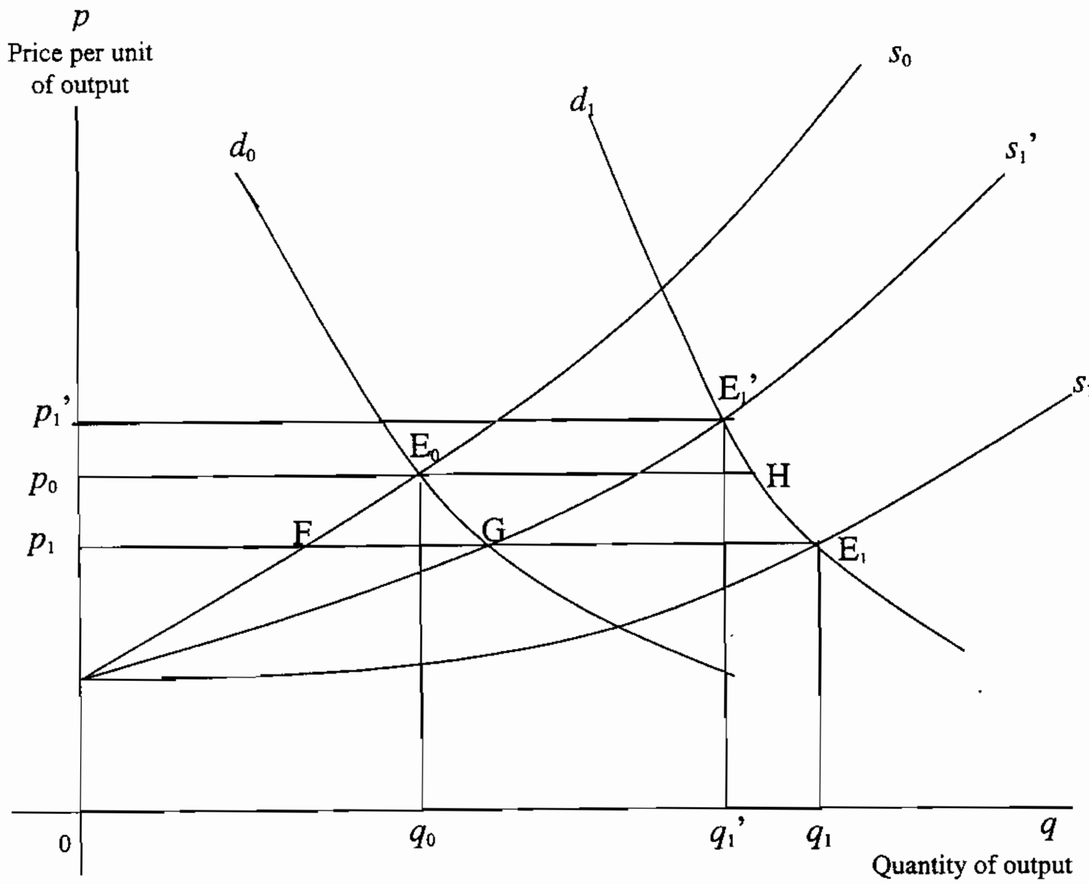
The mathematical formula corresponding to product markets "b" to "n" is similar to that proposed for product market "a".

2.7. Factors other than Technological Change that Alter Market Equilibrium

Even though a technological change of the type we are attempting to analyze does not occur, empirical evidence shows that, over time, supply and demand are shifted by factors other than technical change. Supply may increase because of other technological changes of different nature. MODEXC explicitly involves supply shifts independent of those caused by the technological change in question. Diagram 4 illustrates the situation schematically.

Curves s_0 and d_0 determine the initial equilibrium before technological change. Independent factors, regardless of the technological change in question, shift the initial supply to s_1' and the initial demand to d_1. Subsequently, the technological change shifts the supply from s_1' to s_1 to reach the final equilibrium of period "t" (E_1, Diagram 4).

Diagram 4



Where:

$s_0 = c(p\text{-}p_m)^g$,

$s_1' = c(1+\theta)^t (p\text{-}p_m)^g$,

$s_1 = c(1+\theta)^t k(p\text{-}p_m)^g$,

$d_0 = bp^{N_p}$, and

$d_1 = b(1+AGRD)^t p^{N_p}$.

2.7.1. Demand shift

The model assumes that a demand shift occurs over time, originated by factors such as variations in population, incomes, and prices of substitute or complementary goods. The original demand shift factor is called k_d. It is variable over time and expressed as:

$$k_{d_t} = (1 + AGRD)^t \qquad \textbf{(18)}$$

Where $AGRD$ is the net annual growth rate of demand and "t" the time period (see page 4).

2.7.2. Supply shift

Supply shifts over time, not only because of the technological change in question, but also because of other independent factors, which could be other technological changes. MODEXC incorporates these other factors through a supply expansion factor defined as:

$$k_{0_t} = (1+\theta)^t \tag{19}$$

Where: θ = Expected annual growth rate of supply because of independent factors, and

k_{0t} = Supply expansion factor because of independent factors during period "t".

Within this scheme, the supply and demand functions are defined as:

$$s_0 = c(p - p_m)^g \tag{20}$$

$$s_1^{'} = c(1+\theta)^t (p - p_m)^g \tag{21}$$

$$s_1 = c_1 (1+\theta)^t k_1 (k_2 p - \frac{p_m}{k_3})^g \tag{22}$$

$$d_0 = bp^N \tag{23}$$

$$d_1 = b(1 + AGRD)^t p^N \tag{24}$$

When θ differs from zero, the annual k value is adjusted because θ is applied on a greater base than that used to estimate the final value of k. Annex 1 provides detailed information about this adjustment. When independent supply and demand shifts occur (see Diagram 4), the total economic surplus of society due to technological change and to independent factors is expressed as:

$$p_1 p_0 HE_1 + (p_m E_1 F - p_1 p_0 E_0 F) \tag{25}$$

The economic surplus due to the technological change under study is:

$$p_1 p_1^{'} E_1^{'} E_1 + (p_m E_1 G - p_1 p_1^{'} E_1^{'} G) \tag{26}$$

In mathematical terms, consumer surplus due to technological change and to independent factors is indicated as:

$$\int_{p_{1a}}^{p_{0a}} d_{1a}dp = \int_{p_{1a}}^{p_{0a}} (1+AGRD_a)^t b_a p_a^{\eta_a} \prod_{i=b}^{n} p_i^{\lambda_i} dp = (1+AGRD_a)^t \frac{q_{0a}\prod_{i=b}^{n} p_i^{\lambda_i}}{p_{0a}^{\eta_a}\prod_{i=b}^{n} p_{0i}^{\lambda_i}(\eta_a+1)}\left[p_{0a}^{\eta_a+1} - p_{1a}^{\eta_a+1}\right] \quad (27)$$

Consumer surplus due only to the technological change in question is expressed as:

$$\int_{p_{1a}}^{p'_{1a}} d_{1a}dp = (1+AGRD_a)^t \frac{q_{0a}\prod_{i=b}^{n} p_i^{\lambda_i}}{p_{0a}^{\eta_a}\prod_{i=b}^{n} P_{0i}^{\lambda_i}(\eta_a+1)}\left[p_1'^{\eta_a+1} - p_1^{\eta_a+1}\right] \quad (28)$$

The total producers' surplus due to technological change and to independent factors is calculated as:

$$\int_{pm_a}^{p_{1a}} s_{1a}dp - \int_{pm_a}^{p_{1a}} s_{0a}dp + \int_{p_{0a}}^{p_{1a}} s_{0a}dp =$$

$$\frac{(1+\theta_a)^t\prod_{i=b}^{n} p_i^{\delta_i}(k_{1a}c_a)\left[p_{1a}k_{2a} - \frac{p_{m_a}}{k_{3^a}}\right]^{g_a+1}}{\prod_{i=b}^{n} p_{0i}^{\delta_i}(g_a+1)} - \frac{\prod_{i=b}^{n} p_i^{\delta_i}(c_a)}{\prod_{i=b}^{n} p_{0i}^{\delta_i}(g+1)}\left[p_{0a} - pm_a\right]^{g_a+1} \quad (29)$$

Producer surplus due only to technological change is defined as:

$$\int_{pm_a}^{p_{1a}} s_{1a}dp - p\int_{pm}^{p_1^I} s'_{1a}dp = \frac{c_a\prod_{i=b}^{n} p_i^{\delta_i}(1+\theta_a)^t}{\prod_{i=b}^{n} p_{0i}^{\delta_i}(g_a+1)}\left[\frac{k_{1_a}}{k_{2_a}}(k_{2a}p_{1a} - \frac{p_{m_a}}{k_{3_a}})^{g_a+1} - \left(p'_{1a} - pm_a\right)^{g_a+1}\right] \quad (30)$$

3. USING MODEXC

The MODEXC model runs on Microsoft Excel 5.0 (Microsoft Office 97 for Windows 95) and uses most of its features, such as worksheets, graphing capacity, security, and programming capacity in Visual Basic for Applications (VBA), developed specifically for use with Excel.

The main menu of MODEXC is characteristic of Excel. Its different submenus present several options that activate procedures designed for specific tasks. Some options may require a determined response before a task is performed.

3.1. Installing or Updating MODEXC

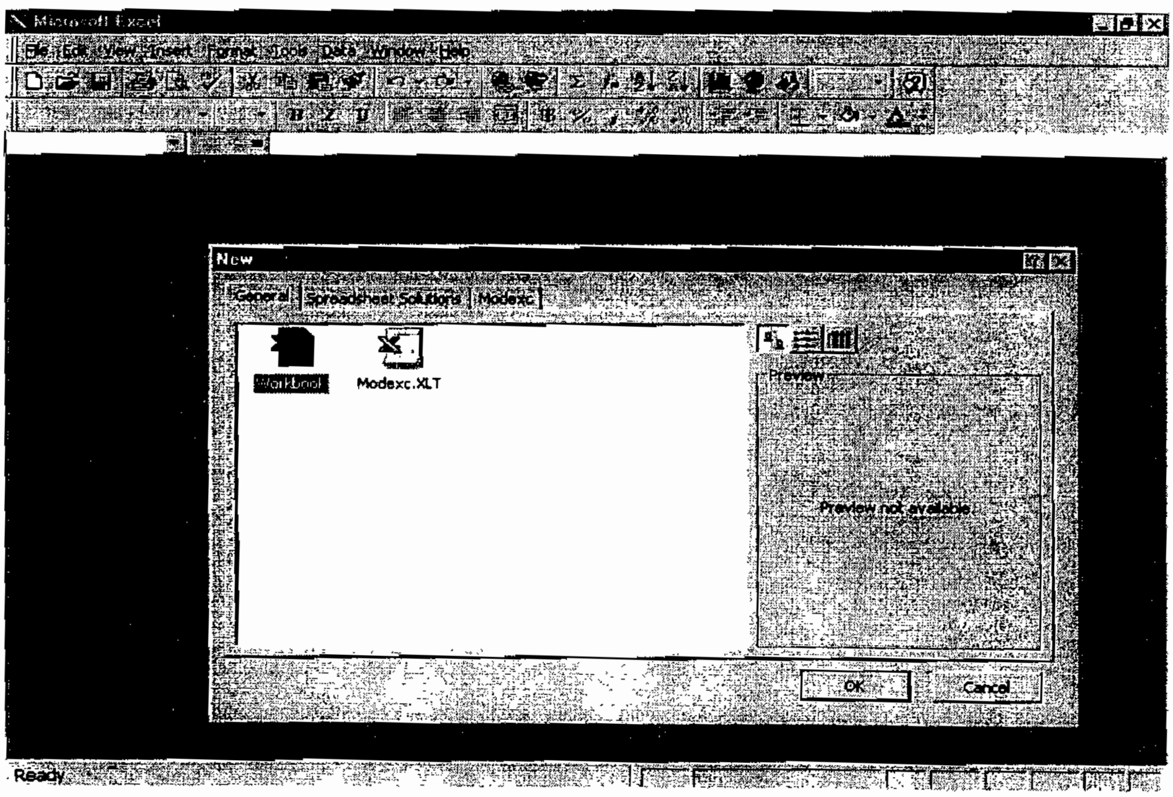
Copy the **Modexc.XLT file** to the **Templates** subdirectory, located in the **Office** or **Microsoft Office** directory at **c:\Program Files\Microsoft Office\Temp.**

When updating the MODEXC version, you must first delete any previous version.

3.2. Getting Started

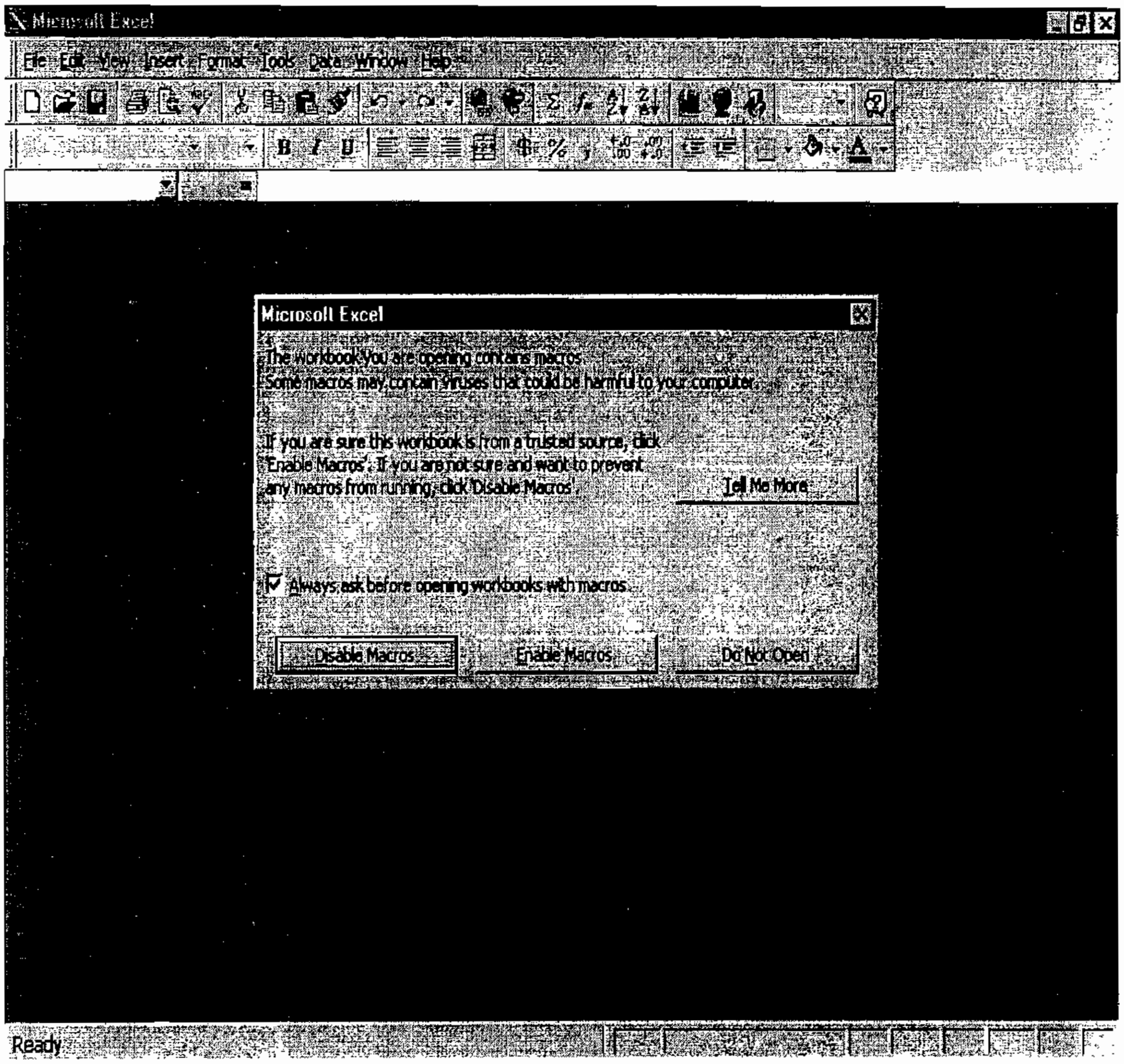
To start, first access Excel 5.0 by double-clicking the **Excel icon**. Once Excel has been activated, choose **File**, then **New**. The window shown below appears.

- Click **Modexc.XLT**
- Click **OK**.



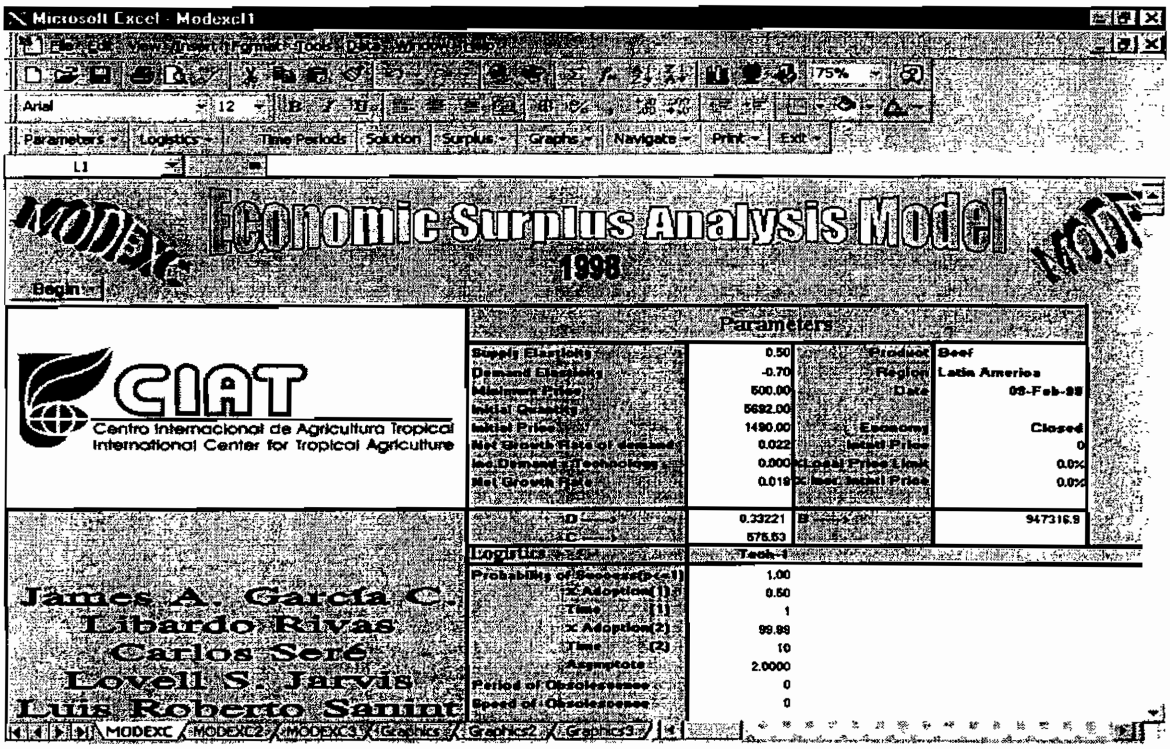
The window shown below appears.

- Click Enable Macros.



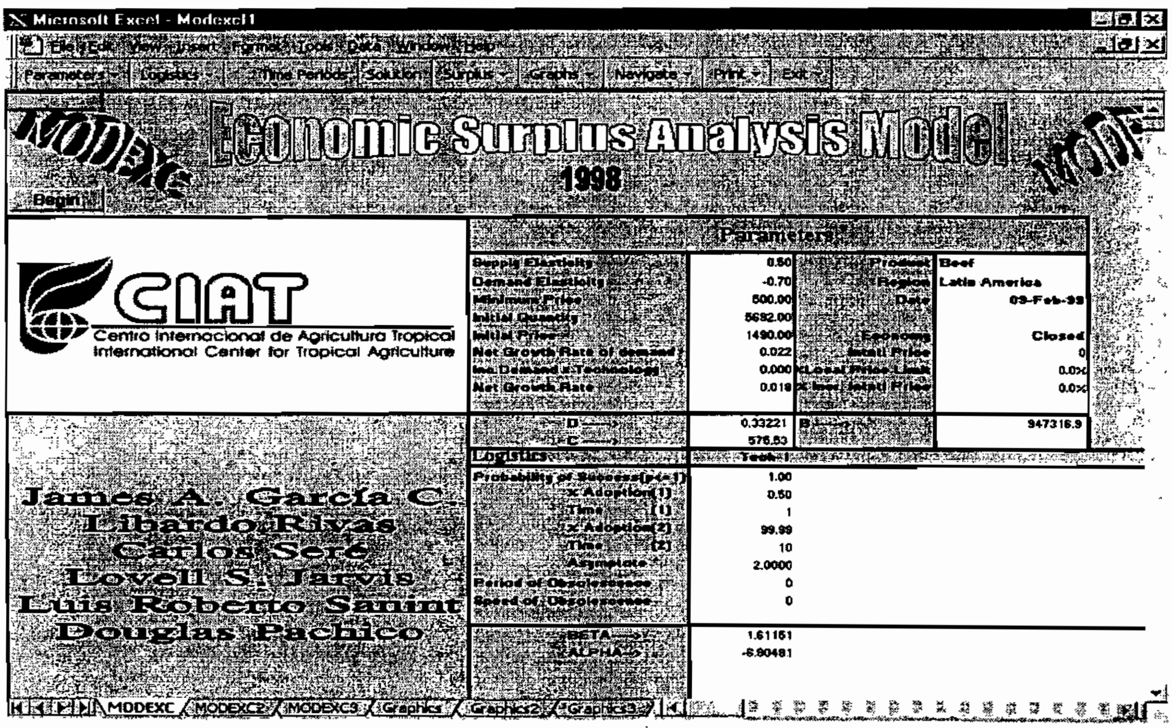
If you want to eliminate the alert box, disable the option **Always ask before opening workbooks with macros** by clicking on the box located to the left of the text. (The check mark in the box indicates that the option is activated.)

- Access MODEXC, as shown in the next window, under a **Standard Excel Environment**.
- Click **Begin**.



MODEXC's own environment will appear on screen (window below).

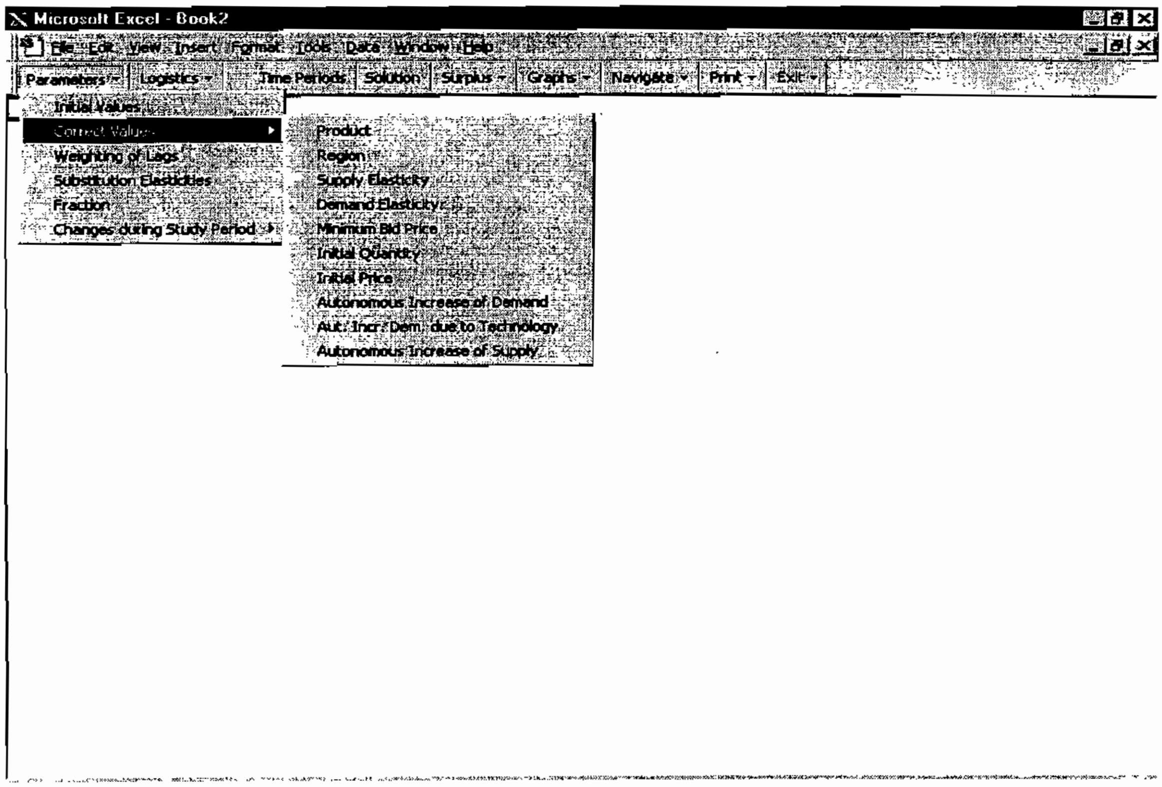
3.3. The Main Menu



If this does not remain under Excel's main menu, drag into place with a sustained click. The main menu (above) has nine options, seven of which open submenus.

3.3.1. Parameters

This submenu (below) is the first step in using the model. It has six options.



1. **Initial Values** asks you to define the different values the model needs to operate.

   You must define the number of markets. The model then asks you to define the following parameters for each market:

   (a) Name of the product.
   (b) Name of the country or region.
   (c) Price elasticity of demand (η).
   (d) Price elasticity of supply (ε).
   (e) Minimum bid price (pm_0)
   (f) Initial quantity in equilibrium before technological change (q_0).
   (g) Initial price in equilibrium before technological change (p_0).
   (h) Net growth rate of demand (Ω, %).
   (i) Net growth rate of demand due to technology (w, %).
   (j) Net growth rate of supply (θ, %).

- Enter each value for the corresponding parameter
- Press **Enter** or click **OK**.

2. **Correct Values** allows you to modify or correct any of the parameters. Click the option and select as required.

3. **Weighting of Lags** allows you to define the weighting coefficients (or weight, α_i) that you can assign to each price prior to base period *t*. These coefficients are used to calculate the expected market price, which is defined as the weighted average of the five prices prior to base period *t*:

$$Expected\ price = p_{(t-1)}{*}\alpha_1 + p_{(t-2)}{*}\alpha_2 + p_{(t-3)}{*}\alpha_3 + p_{(t-4)}{*}\alpha_4 + p_{(t-5)}{*}\alpha_5 \qquad \textbf{(31)}$$

Where: $p_{(t-n)}$ = Lag price for *n* periods with respect to base period.
α_t = Weight factor for lag price during period *t*.

If you want to work with the lagged value of only 1 year, you must assign a weight of 100% to the weighted value corresponding to that lag (α_1) and a weight of zero (0%) to the remaining weight coefficients (α_2, ... α_5).

If you work with two lagged values, you must distribute the total weighted value (100%) among the weighted factors (α_1, α_2) and assign zero (0) values to the remaining weighted factors (α_3, ... α_5). If you use three or four lagged values, proceed in the same way.

Distributed lags	Weighting (%)
t-1	50.00
t-2	26.00
t-3	13.00
t-4	7.00
t-5	4.00
Substitution elasticity	
Consumption	0.000
Production	0.000

4. **Substitution Elasticities** define substitution or complementarity elasticities in consumption and production of product "a" respective to product "b".

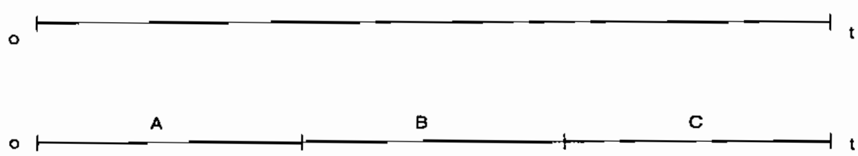
5. **Fraction** allows you to define a parameter that MODEXC uses in its process of finding, through successive approximations, equilibrium points in time. The model iteratively assesses the supply and demand functions of different production levels, calculating for each equilibrium point the prices corresponding to supply and demand until their difference is equal to or less than a unit of output.

   To carry out successive approximations, the model first calculates the initial value of increase (or decrease) to be used by dividing the initial equilibrium quantity by the value provided by the **Fraction** parameter. Once the first approximation is made, the following value of increase (or decrease) will be one-tenth of the previous increase (or decrease) and so on successively until the minimum difference sought is reached (<=1). The value of the **Fraction** parameter should be a multiple of 10 (e.g., 10, 100, 1000). The default value is 100.

6. **Changes during Study Period** allows you to evaluate the entire period during which a new technology is being disseminated. The study period has subperiods differentiated by having different autonomous growth parameters of supply (θ), demand (Ω), or both simultaneously.

   You can introduce up to six subperiods or time intervals when evaluating a given alternative.

   For example, you can evaluate the entire period 0-t, but if you expect changes in parameters Ω and θ over time, you can divide the entire study period into subperiods and thus take into account expected changes in the indicated parameters. The diagram and table below illustrate these points. The table illustrates a situation in which three time intervals are used.

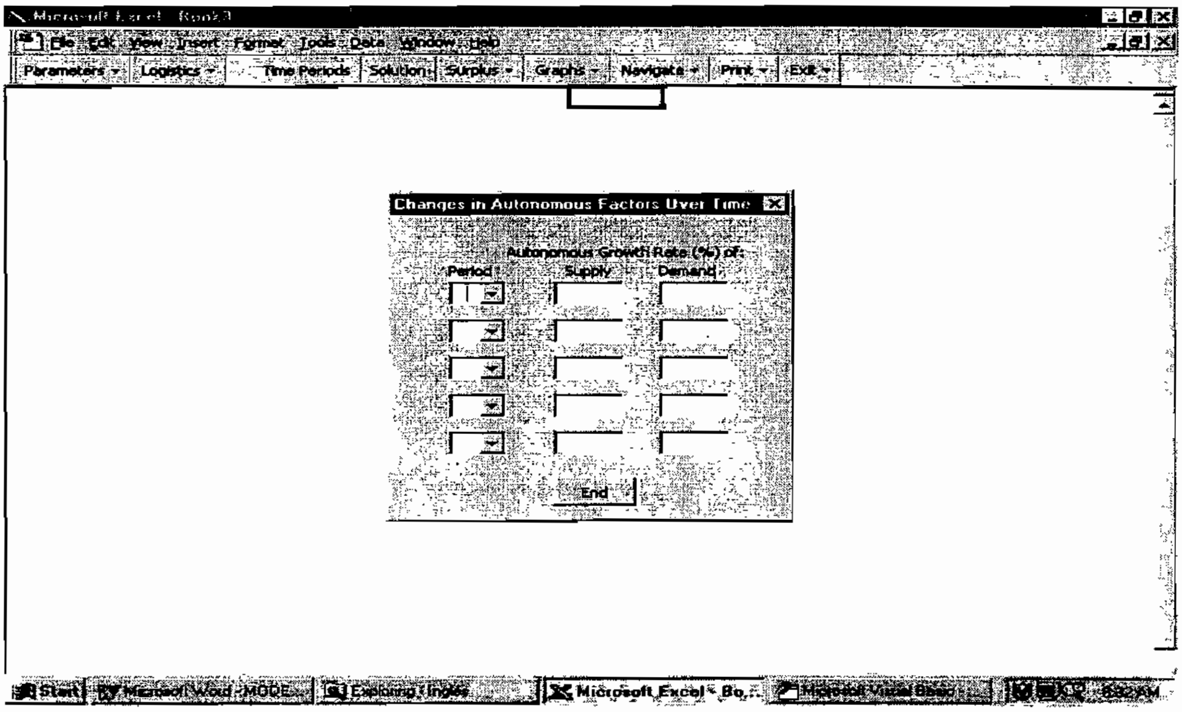


Interval (Segment)	Period	Autonomous growth rate	
		Supply (θ)	Demand (Ω)
a	$0\text{-}t_1$	θ_a	Ω_a
b	$t_{(1+1)}\text{-}t_2$	θ_b	Ω_b
c	$t_{(2+1)}\text{-}t_3$	θ_c	Ω_c

Where: $\theta_a \neq \theta_b \neq \theta_c$ and $\Omega_a \neq \Omega_b \neq \Omega_c$

- Click **Changes during Study Period.**

The following format appears. You can indicate up to 5 changes.



Accessing **Parameters** feeds the model with the initial θ and Ω values. If no changes in these values are expected over time, then they will remain constant throughout the entire study period 0-t.

However, if changes are foreseen, the format above allows you to introduce time variations in the parameters mentioned.

Let us assume that the complete study period covers 20 years (from year 0 to year 20) and that the initial parameters were $\theta = 1.5$ and $\Omega = 2.2$.

The expected changes in these parameters during the study period are:

Year 5	$\theta = 2.0$ and $\Omega = 2.5$
Year 7	$\theta = 1.8$ and $\Omega = 1.3$
Year 11	$\theta = 1.8$ and $\Omega = 2.0$
Year 15	$\theta = 2.0$ and $\Omega = 2.5$
Year 18	$\theta = 1.0$ and $\Omega = 1.0$.

As you can see, changes will occur in the indicated parameters five times during the study period (20 years). The following table summarizes these changes in time and their effect.

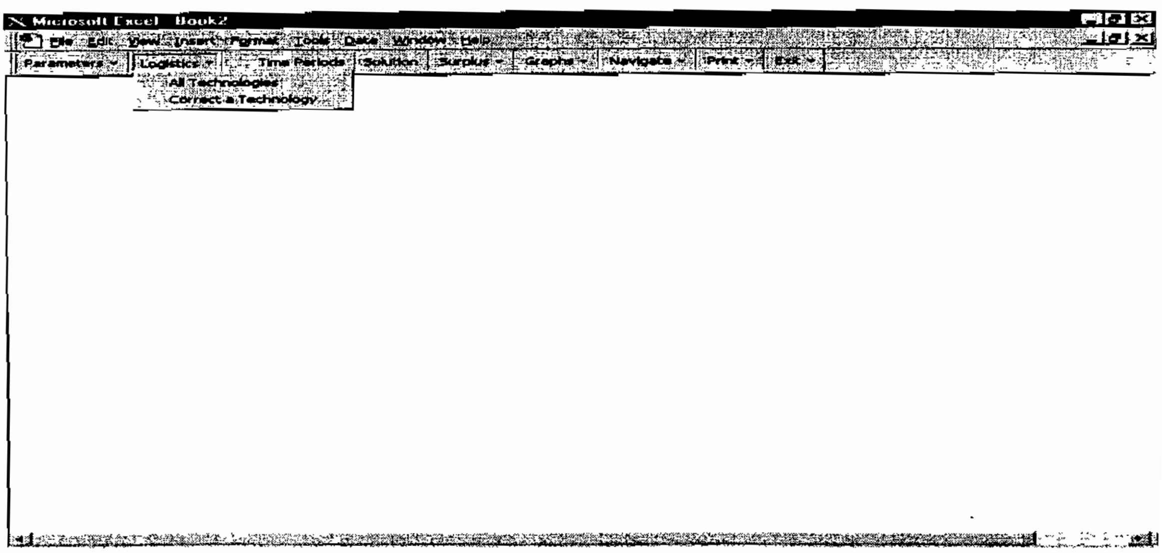
Year of change	Value		Effect of parameters (years)
	θ	Ω	
0 (initial parameters)	1.5	2.2	0 - 4
5	2.0	2.5	5 - 6
7	1.8	1.3	7-10
11	1.8	2.0	11-14
15	2.0	2.5	15-17
18	1.0	1.0	18-20

You must provide the model both with the value of the time period from which the changing parameter will prevail and with the value it assumes. The example here includes the maximum number of parameter changes allowed (5). In this case, you would include in **Format 1** the data from when the first change occurs (shaded area).

To indicate the year or period from which the parameters change, click on the arrow to the right of the **Period** field. A drop-down list of values, ranging from zero to the total number of periods or years under study, is displayed. Select the period from which the parameters in question change. Enter the new Ω and θ values. Repeat this procedure as often as the parameters change their value.

In a given year, one parameter can be changed alternatively or both can be changed simultaneously.

3.3.2. Logistics



The **Logistics** submenu (see above) has two options.

1. **All Technologies** allows you to enter (1) the parameters for estimating the adoption function (logistic or sigmoid function) of each new technology, and (2) those parameters affecting technology performance over time. For example, the point at which the adoption of a technology begins to decline and the speed at which this process can occur.

When defining the logistic function of each technology, you must know two points located anywhere on the adoption curve and know the value of the k asymptote. These two points are defined in terms of coordinates, time, and percentage of adoption: point 1 *corresponds to* (d) *and* (e), *and point* 2 *to* (f) *and* (g) *in the following list.*

When you select **All Technologies**, the model asks you to provide the following parameters for each of the defined markets.

(a) Number of technologies (minimum 1, maximum 30).
(b) Type of adoption post time _2 (1: Yes, 0: No). If you assign a value of 1, the k value will take the value generated by the function, as of the time defined in (g). On the other hand, if you assign a value of 0 (zero), k will remain constant and equal to the value defined in (f). This parameter applies for all defined technologies.
(c) Probability of the technology's success ($0 < pr <= 1$).
(d) Percentage adoption during initial period.
(e) Duration of initial period (1, 2, 3, ..., n).
(f) Percentage adoption during final period.
(g) Duration of final period (2, 3, 4,..., n).
(h) Asymptote value of the k function. Corresponds to the maximum value that the function can reach during the period of the technology's dissemination.
(i) Obsolescence period (2, 3, 4,..., n). This parameter indicates the time (period) in which a technology reaches its maximum value of adoption, after which disadoption begins. If you assign a value of zero, the model assumes that the technology in question will not become obsolete or undergo disadoption.
(j) Speed of obsolescence (1, 2, 3,..., n). This parameter indicates how fast a technology can begin disadoption.

If you assign a value of 1, you will be indicating that disadoption is symmetrical to adoption, which means that the two processes occur at the same rate. In this case, disadoption will last exactly the same time as adoption.

If you assign a value of 2, the model assumes that disadoption occurs twice as fast as adoption and, accordingly, the time of disadoption will be half that of adoption. A value of 3 indicates a disadoption rate three times faster than that of adoption, and so forth.

You must indicate the parameters (c) through (j) for each technology you define in (a), for each market. For more information, see Annex 1.

Correct a Technology allows you to correct the parameters of a technology previously specified in a given market. Once you indicate the market and the number of the technology you wish to correct, the model will ask you to input their parameters again. These parameters will correspond to (c) through (j) of the previous option.

3.3.3. Time Periods

This option of the main menu (see page 19) defines (1) the duration of the entire study period and (2) the time or initial period when the evaluation begins. In MODEXC, "time period" refers to 1-year time units.

Initial period is defined, by convention, as the starting or initial point of market equilibrium at which you want to simulate the adoption of one or more technologies. Under normal conditions for any given time interval under study, the initial period will always have a value of zero because it is the starting point of the process in question.

The model allows you to conduct evaluations for a minimum of six time periods up to a maximum of 50. You must indicate the value corresponding to the number of time periods desired.

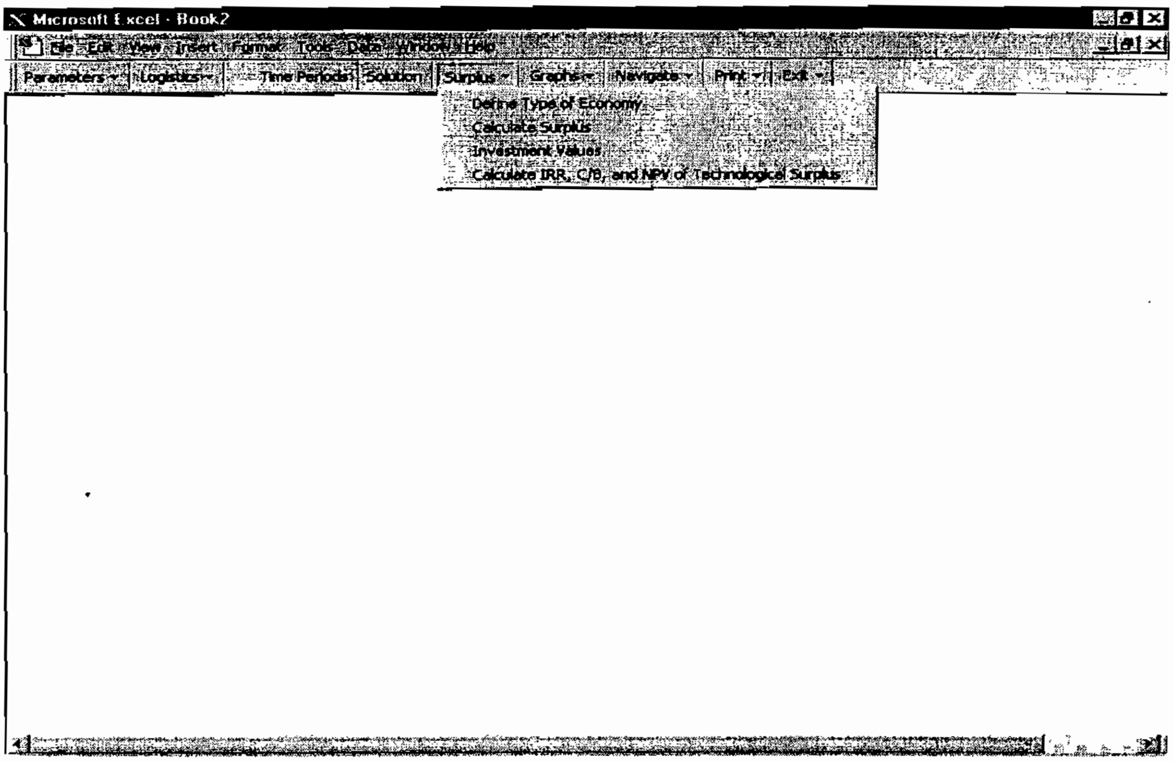
3.3.4. Solution

This option of the main menu accesses the search procedure for market equilibrium points for every year covered by the study.

Before beginning calculation, the model asks you to define the type of shift of the supply function. This could be, alternatively, **Pivotal** (k_1) if you assign a value of 1, **Nonpivotal divergent** (k_2) if you assign a value of 2, or **Nonpivotal convergent** (k_3) if you assign a value of 3.

3.3.5. Surplus

Once the market equilibrium points have been calculated, the next step is to estimate economic surplus, using the different options of the submenu shown below.



Define Type of Economy is the first step for calculating economic surplus. For each one of the markets you defined you can choose, alternatively, two types of economy or market opening. If you assume that the economy is closed (no international trade), enter a value of zero (0). If it is open (with international trade), enter a value of one (1). If you do not activate this option, the model assumes a closed economy.

When you select an open economy scheme, the model will ask you to provide:

(a) International price value.
(b) Expected growth rate of the international price, expressed as a percentage.
(c) Threshold percentage of domestic price, expressed as a percentage of the international price.

The model accepts both exports and imports. Exports occur when the domestic price is lower than the international reference price.

The parameter of (c) makes imports feasible. First, you must define the maximum percentage above the international reference price that the price policymakers will allow the domestic price to reach. When the domestic price exceeds the previously established threshold, imports are allowed.

For example, if the international price is US$1500 per ton and constant in time (growth rate = 0%), and if the threshold established for the domestic price is 20%, then the country or region can begin to import when the domestic price exceeds US$1800 per ton (1500*1.2).

If we assume that the international price shows a trend, the model makes comparisons between the pertinent domestic price and the international price adjusted by the trend factor, to determine whether the region or country can begin to import or export.

If imports are undesirable, you must assign a very high value to the threshold percentage of the international price, for example 100%, 200%, or more. This case would be that of a partially open market, which allows exports but not imports. If you want a completely open market, with no restrictions regarding imports and exports, then establish a threshold value of zero so that at any time when the domestic price is more than the international reference price, imports are allowed and vice versa.

Calculate Surplus calculates the annual surplus flow, as well as present values and their annuities. The model asks you to provide the annual discount rate of monetary values.

Investment Values asks for information on investments and expenditures carried out each year during research and development of the technological options under study.

The monetary units used to express the investment and the economic surplus should be consistent. For example, if the initial quantity (q_0) is expressed in thousands of tons and the initial price (p_0) in US$ per ton, surplus value will be expressed in thousands of US$. Therefore, when entering investment data, these must be expressed in thousands of US$. For example, if the investment in year t is US$3 million, then that value is expressed as 3000.

The model allows you to include investment expenditures for time periods before and after the initial equilibrium period or period zero. The maximum number of time periods before initial equilibrium is ten and the maximum number of time periods after initial equilibrium is equal to the number of periods that the study will last.

For example, if you are evaluating the dissemination of a technology over a 20-year period, the costs and investments can be included up to a maximum of 30 periods, 10 before the initial equilibrium point and 20 after.

Calculate IRR, C/B, and NPV of Technological Surplus allows you to calculate the IRR. The model asks you to supply the initial rate of return assumed (or seed), after which the IRR is calculated. This seed should be expressed as a percentage, and entered as 5, 10, 30, et cetera.

The model conducts a sensitivity analysis of the IRR proportionally related to research benefits attributed to a given entity that participated in the research and development of the technologies under study. Because the generation and dissemination of a new technology often result from the joint effort of different institutions, it would be inappropriate to attribute all the expected technological benefits to one alone. Sometimes one entity develops the technology and others are responsible for technology transfer.

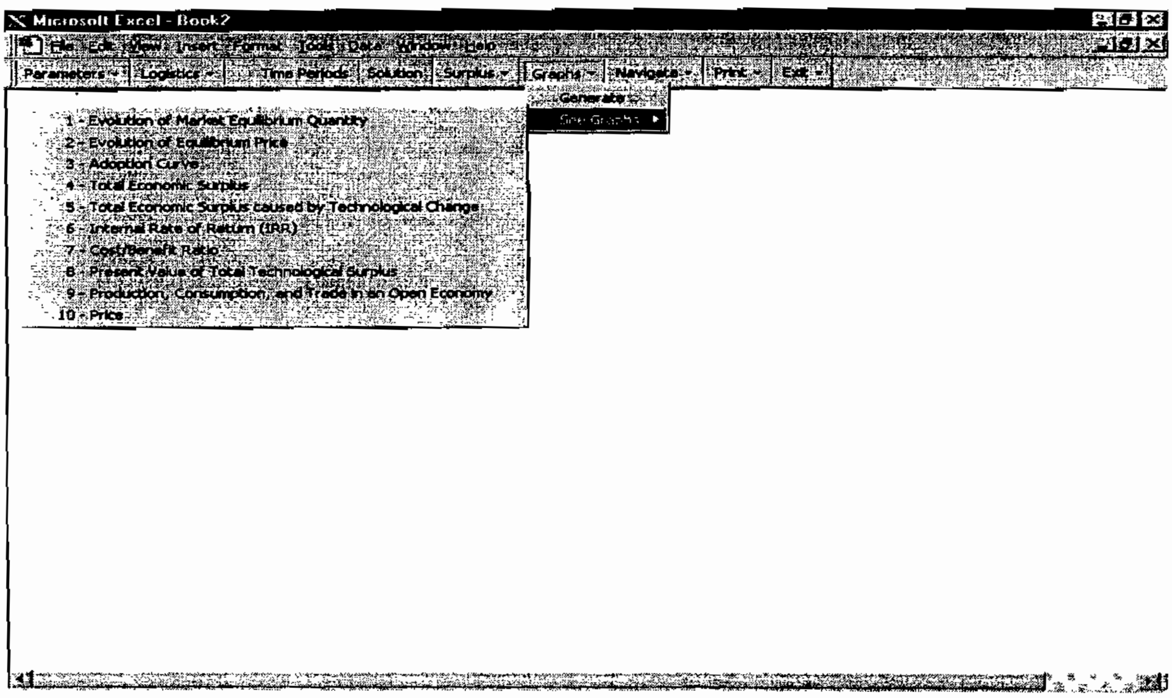
MODEXC conducts a sensitivity analysis for the IRR regarding the percentage of benefits attributable to an institution participating in the process, which could range from 5% to 100% (see Evolution of k values for each technology, page 39).

Therefore you must verify that the value of the seed provided is appropriate to calculate the IRR for all the levels of participation of the benefits (from 5% to 100%). The IRR value for the 5% level of participation appearing as **#DIV/0!** indicates that the seed is not satisfactory. Other values must be provided until the IRR can be correctly calculated for the complete range of levels of participation.

It may happen that no single seed occurs with which to calculate the IRR for the entire range. In this case, you should work with several seeds and calculate the different segments of the IRR spectrum separately. For example, for IRRs ranging from 5% to 40% of the technological benefits, seed valued at 30% is adequate, but for benefits between 45% and 100% it is not. This means that those IRRs will appear as errors, and another seed value will have to be used.

In addition to the IRR, the model calculates the cost/benefit (C/B) ratio and the present value of benefits (PV), for each level of participation in technological benefits.

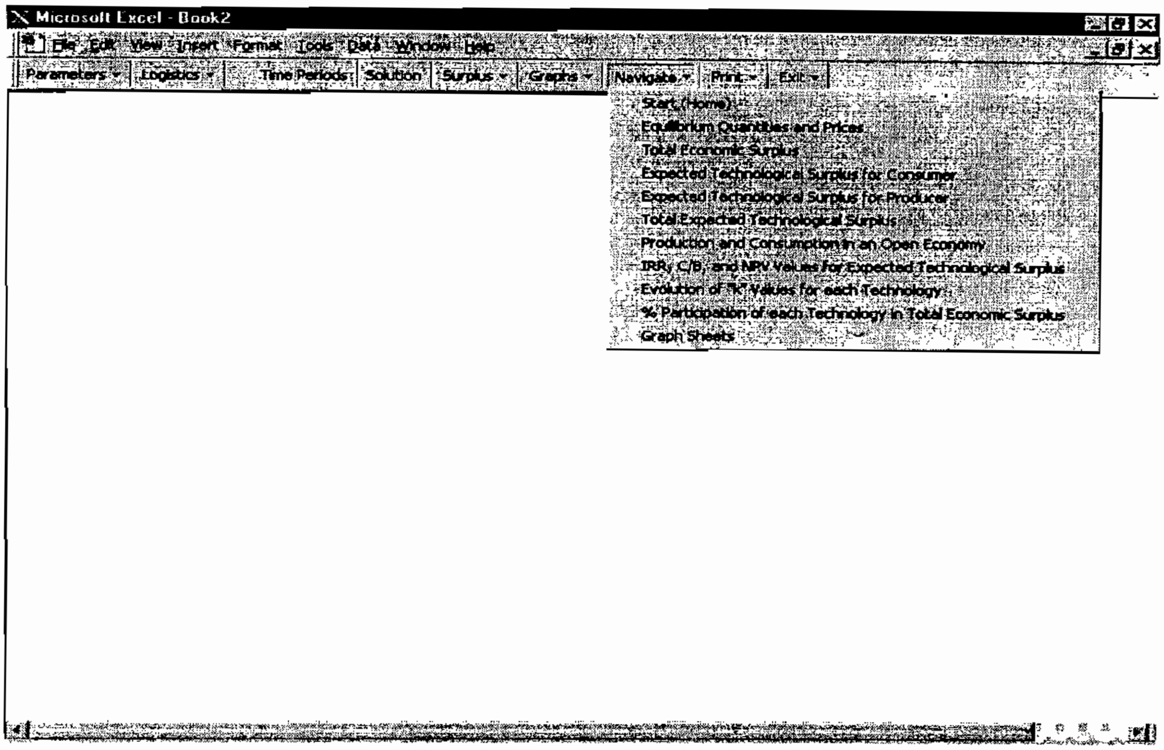
3.3.6. Graphs



This submenu allows you to automatically graph data for each one of the markets you defined.

- Click **Generate**. You have access to ten graphs.
- Click **See Graphs** and you can move to a specific graph within the indicated market.

3.3.7. Navigate



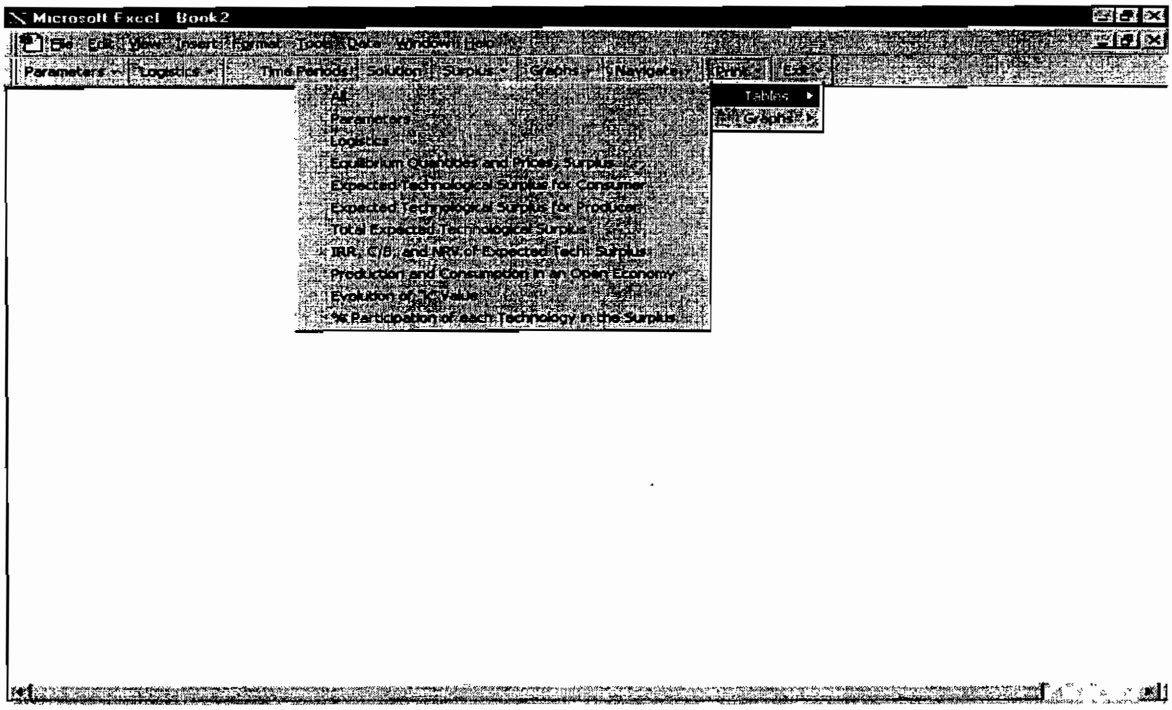
This submenu allows you to move between different areas of results offered by MODEXC, within a previously specified market:

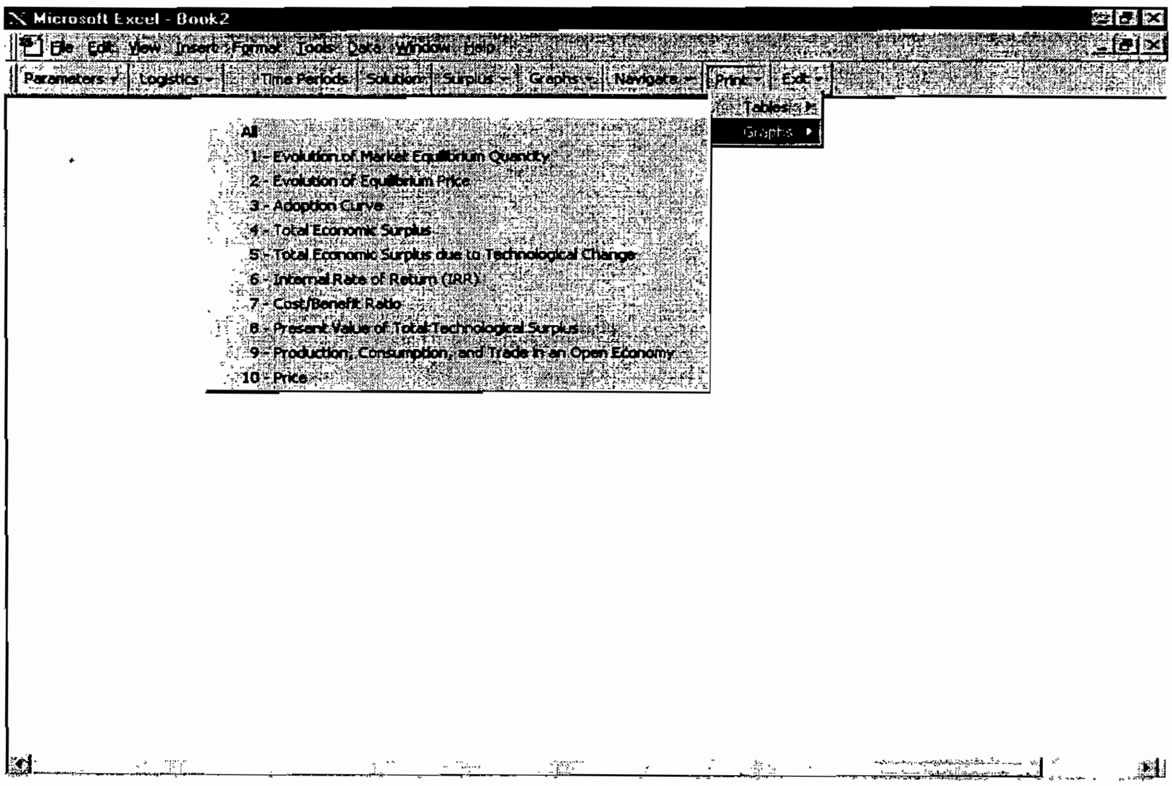
(a) Equilibrium quantities and prices.
(b) Total economic surplus.
(c) Expected technological surplus for the consumer.
(d) Expected technological surplus for the producer.
(e) Total expected technological surplus.
(f) Production, consumption, trade, and self-sufficiency indexes in an open economy.
(g) IRR, C/B, and NPV values for expected technological surplus.
(h) Evolution of *k* values for each technology.
(i) Percentage participation of each technology in the total economic surplus.
(j) Graphs.

You can also move between these areas using **Page Up** and **Page Down**, and the **horizontal scroll bar**.

3.3.8. <u>Print</u>

Under this option of the main menu, the submenus **Tables** and **Graphs** appear. They allow you to print separately the tables of results and the graphs generated.





- Go to the **Excel menu**
- Click **File**
- Click **Print Area**
- Click **Set Print Area** to define the print range
- Click **Print**

Initial values (see table below) contains the initial or base values provided to the model such as date; name of the product analyzed; region, country or locality; supply and demand parameters; and type of economy assumed to calculate the surplus.

Parameters			
Elasticity of supply	0.50	Product	Beef
Elasticity of demand	-0.70	Region	Latin America
Minimum price	500.00	Date	02-March-98
Initial quantity	5692.00		
Initial price	1490.00	Economy	Open
Autonomous increase of demand	0.022	Domestic price	1000
Increase demand x technology	0.000	% Threshold local price	5.0%
Increase of supply	0.018	% Growth international price	5.0%

If, during the study period, changes occur in the autonomous growth rate of supply and/or the autonomous growth rate of demand, the following table will also be printed.

Period	Growth rate	
	Supply	Demand
0	0.018	0.022
4	0.010	
8		0.015
12	-0.002	0.010
3	<------ Total changes	

In this hypothetical example of 15 time periods or years, the growth rate of supply is 1.8% between periods zero and 3, 1.0% between periods 4 and 11, and -0.2% between periods 12 and 15. The growth rate of demand assumes a value of 2.2% between periods zero and 7, 1.5% between periods 8 and 11, and 1.0% between periods 12 and 15.

Within a given period, one or both parameters can change.

If the situation analyzed considers more than one market, the substitution elasticities and the lag values for weighting factors needed to calculate expected prices are printed.

Distributed lags	Weighting of lagged values (%)	
t-1	50.00	
t-2	26.00	
t-3	13.00	
t-4	7.00	
t-5	4.00	100.00
Substitution elasticity of Product 1		
By --->	Product 2	Product 3
Consumption	0.500	0.000
Production	0.400	0.000

The table below presents the parameters of the logistic function for each technology.

Logistics	Technology 1	Technology 2	Technology 3	Technology 4
Probability of success	1.00	1.00	1.00	1.00
% Adoption (1)	0.50	0.50	0.50	0.50
Time (1)	1	1	1	1
% Adoption (2)	99.99	99.99	99.99	99.99
Time (2)	10	10	10	10
Asymptote	2.000	2.000	2.000	2.000
Period of obsolescence	0	5	7	8
Rate of obsolescence	0	2	1	1

The equilibrium points (next table), with and without technological change, is organized as follows:

Column No.	Contents
1	**Years**
2	**Quantity** (q_1') - Equilibrium quantity in each time period, after autonomous changes, but before technological change.
3, 4	**Price Demand** and **Price Supply** - at the "partial equilibrium" point of each period, after autonomous changes, but before technological change.
5	**Quantity** (q_1) - Final equilibrium quantity in each period, after technological change.
6, 7	**Price Demand 1 and Price Supply 1** - at the final equilibrium point of each period (these prices are assumed equal because their difference is <=1).
8, 9, 10	Value of supply shift factor throughout the equilibrium period ($k = k_1$, k_2, k_3).
11,12,13	Flow of annual **Surplus for Consumer** according to origin (technological change or autonomous factors).
14, 15,16	Flow of annual **Surplus for Producer** according to origin (technological change or autonomous factors).
17,18,19	Flow of **Total** annual **Surplus** according to origin: technological change or other factors.
20	Flow of annual **Net Expected Technological Surplus** (economic surplus minus investments in research). The probabilities of success of generating and developing the evaluated technologies are used to estimate expected values.
21	**Year.**
22	**Investment** - Flow of investments in research.
23	Flow of **Net Technological Surplus** (in this example, the probability of success of each technology is equal to 1.).

At the bottom of the window appear the present values of surplus flows, calculated using the discount rate previously provided. The table also presents flow values expressed as annuities. These values are estimated using the same discount rate and a time period equal to the number of years of the study, from period zero onwards. In the hypothetical example, the study period covers 15 years.

The three windows of tables that follow after that of **Equilibrium points** also show the present values and annuities at the bottom. For more information see Annex 3.

Two other results tables follow these (total six in all).

Equilibrium points.

MODEXC

TABLE OF RESULTS IN : Closed Economy

Years	Quantity (q1')	Price Dem.1'	Price Supp.1'	Quantity (q1)	Price Dem.1	Price Supp.1	A1	A2	A3	Surplus for Consumer Total	Surplus for Consumer Technological	Surplus for Consumer Others	Surplus for Producer Total	Surplus for Producer Technological	Surplus for Producer Others	Total Surplus Total	Total Surplus Technological	Total Surplus Others
0	5692.0	1490.0	1490.0	5692.0	1490.0	1490.0	1.0000	1.0000	1.0000	0	0	0	0	0	0	0	0	0
1	5804.1	1494.8	1495.0	5857.1	1475.5	1473.7	1.0157	1.0000	1.0000	64594	112329	-37911	38890	-45103	103993	143280	67208	76082
2	5917.9	1499.8	1499.7	6239.6	1393.8	1392.6	1.0926	1.0000	1.0000	585400	643722	-58322	-50410	-862130	311740	534990	381571	153419
3	6034.5	1504.7	1504.7	7400.7	1124.1	1124.6	1.4392	1.0000	1.0000	2449024	2534840	-85813	-785532	-1084375	320843	1663492	1450464	330028
4	6152.8	1509.7	1509.5	9917.0	763.4	763.7	2.5178	1.0000	1.0000	5605547	5728530	-123958	-2269985	-4728803	458879	3336622	3024696	311926
5	6234.0	1514.6	1514.6	11880.6	608.4	608.3	3.9823	1.0000	1.0000	7437639	7582844	-155206	-3263223	-3811561	548337	4164416	3771284	393132
6	6397.6	1519.5	1519.7	12035.0	646.1	615.5	3.8783	1.0000	1.0000	7497591	7687424	-189833	-3179312	-3844868	665556	4318219	3842556	475663
7	6522.9	1524.6	1524.5	12325.4	614.4	614.6	3.9115	1.0000	1.0000	7683632	7911088	-227476	-3172520	-3959513	786993	4511113	3951575	559536
8	6651.5	1529.5	1529.7	12345.7	617.8	617.4	3.8408	1.0000	1.0000	7809245	8074473	-265108	-3118727	-4028686	909959	4690518	4045787	644771
9	6781.8	1534.7	1534.6	12633.5	631.0	631.6	3.6976	1.0000	1.0000	7812232	8119193	322961	-3089197	-4126543	1037346	4824035	4082650	751385
10	6915.4	1539.6	1539.8	12406.1	666.1	666.5	3.2836	1.0000	1.0000	7516428	7863373	-346944	-2666232	-3832572	1166340	4850196	4030801	819396
11	7051.0	1544.8	1544.7	11984.3	724.1	723.7	2.8380	1.0000	1.0000	6991394	7382736	-391142	-2513271	-3513236	1299965	4778323	3869502	908623
12	7189.9	1549.8	1550.0	11373.1	804.9	805.5	2.3839	1.0000	1.0000	6191459	6623053	-433594	-1628297	-3063574	1435278	4563179	3563489	999684
13	7330.6	1555.0	1554.9	10709.5	876.9	879.3	2.0943	1.0000	1.0000	5494194	5977638	-483444	-1122453	-2697894	1575442	4371741	3279744	1091997
14	7475.2	1560.0	1560.2	10418.6	907.9	908.9	2.0045	1.0000	1.0000	5294276	5825871	-531595	-889107	-2606464	1717377	4405170	3219367	1185783
15	7621.7	1565.2	1565.3	11082.4	916.9	917.2	1.9853	1.0000	1.0000	5311128	5694495	-383338	-766673	2627066	1854396	4544456	3267394	1341037

Net Tech. Surplus Expected	Year	Investment	Net Tech. Surplus
-2340	-10	2340	-2340
-2340	-9	2340	-2340
-2340	-8	2340	-2340
-2340	-7	2340	-2340
-2340	-6	2340	-2340
-2340	-5	2340	-2340
-2000	-4	2000	-2000
-2000	-3	2000	2000
-2000	-2	2000	-2000
-2000	-1	2000	-2000
-2000	0	2000	-2000
65208	1	2000	67208
381571	2	0	381571
1450464	3	0	1450464
3024696	4	0	3024696
3771284	5	0	3771284
3842556	6	0	3842556
3951575	7	0	3951575
4045787	8	0	4045787
4082650	9	0	4082650
4030801	10	0	4030801
3869502	11	0	3869502
3563489	12	0	3563489
3279744	13	0	3279744
3219367	14	0	3219367
3267394	15	0	3267394

Discount Rate (%) 10.0

	Surplus for Consumer Total	Surplus for Consumer Technological	Surplus for Consumer Others	Surplus for Producer Total	Surplus for Producer Technological	Surplus for Producer Others	Total Surplus Total	Total Surplus Technological	Total Surplus Others	Net Tech. Surplus	Investment	Expected Net Tech. Surplus
Present Value ———>	34138733	35614793	-1475787	-12134584	-17140645	5006111	22001470	18472146	3529324	20276333	43103	20276077
Annuity ———>	4447969	4682411	-194423	-1575373	-2238838	658435	2892616	2428003	464314	2665796	5667	2666085

Expected technological surplus for the consumer.

Year	Total Exp. Tech. Surp. for Cons.	Expected Technological Surplus for Consumer Tech-1	Tech-2	Tech-3	Tech-4											
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	112309	28077	28077	28077	28077											
2	643722	160930	160930	160930	160930											
3	2534840	633710	633710	633710	633710											
4	5728500	1432125	1432125	1432125	1432125											
5	7582844	1895711	1895711	1895711	1895711											
6	7667424	2465389	291257	2465389	2465389											
7	7911088	2633472	10572	2633472	2633472											
8	8074475	2743605	0	2587263	2743605											
9	8119193	2954360	0	2245748	2919085											
10	7863373	3378545	0	1306474	3178354											
11	7382735	3946066	0	438524	2998146											
12	6627063	4699242	0	110813	1817009											
13	5977638	5360489	0	21453	595696											
14	5825871	5691636	0	0	134215											
15	5894466	5870970	0	0	23496											
NPV------->	33614790	15187038	8890702	7024402	30108648											
Annuity-->	4542411	1996097	333757	1002953	1329022											

Expected technological surplus for the producer.

Year	Total Exp. Tech. Surp. for Prod.	Expected Technological Surplus for Producer Tech-1	Tech-2	Tech-3	Tech-4											
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	-45102	-11275	-11275	-11275	-11275											
2	-262150	-65538	-65538	-65538	-65538											
3	-1084375	-271094	-271094	-271094	-271094											
4	-2703803	-675951	-675951	-675951	-675951											
5	3811561	952890	-952890	952890	-952890											
6	-3844858	-1233065	-145872	-1233065	-1233065											
7	-3959512	-1318057	-5341	-1318057	-1318057											
8	-4028686	-1358897	0	-1290892	-1358897											
9	-4026543	-1465153	0	-1113731	-1447659											
10	-3832572	-1646688	0	-636769	-1549115											
11	-3513236	-1877822	0	-208681	-1426733											
12	-3063574	-2172377	0	-51227	-839971											
13	-2697894	-2419356	0	-9582	-268456											
14	-2606484	-2546436	0	0	-60047											
15	-2627068	-2616396	0	0	-10472											
NPV--->	-17142445	-7213261	-1278557	-3732873	-4915933											
Annuity-->	-2253804	-948618	-168097	-490775	-646319											

Total expected technological surplus.

Year	Total Exp. Tech. Surplus	Total Expected Technological Surplus Tech-1	Tech-2	Tech-3	Tech-4											
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	67208	16802	16802	16802	16802											
2	381571	95393	95393	95393	95393											
3	1450464	362616	362616	362616	362616											
4	3024696	756174	756174	756174	756174											
5	3771284	942821	942821	942821	942821											
6	3842556	1232324	145583	1232324	1232324											
7	3951575	1315415	5331	1315415	1315415											
8	4045787	1374708	0	1296371	1374708											
9	4092650	1489207	0	1132016	1471426											
10	4030801	1731858	0	669704	1629238											
11	3869500	2068245	0	229843	1571413											
12	3563489	2526865	0	59586	977038											
13	3279744	2941133	0	11771	326840											
14	3219387	3145220	0	0	74167											
15	3267398	3254374	0	0	13024											
NPV---->	16472146	7971776	1418143	3893329	3199893											
Annuity-->	2425603	1048080	185560	512160	682708											

Evolution of *k* values for each technology.

Evolution of "k" Values for each Technology

Year	Tech-1	Tech-2	Tech-3	Tech-4
0	1.0000	1.0000	1.0000	1.0000
1	1.0039	1.0039	1.0039	1.0039
2	1.0231	1.0231	1.0231	1.0231
3	1.1091	1.1091	1.1091	1.1091
4	1.3794	1.3794	1.3794	1.3794
5	1.7456	1.7456	1.7456	1.7456
6	1.9231	1.1091	1.9231	1.9231
7	1.9691	1.0039	1.9691	1.9691
8	1.9789	1.0000	1.9231	1.9789
9	1.9808	1.0000	1.7456	1.9691
10	1.9812	1.0000	1.3794	1.9231
11	1.9813	1.0000	1.1091	1.7456
12	1.9813	1.0000	1.0231	1.3794
13	1.9813	1.0000	1.0039	1.1091
14	1.9813	1.0000	1.0000	1.0231
15	1.9813	1.0000	1.0000	1.0039

Percentage participation of each technology in total technological surplus.

Percentage Participation of each Technology in Total Technological Surplus				
Year	Tech-1	Tech-2	Tech-3	Tech-4
0				
1	0.2500	0.2500	0.2500	0.2500
2	0.2500	0.2500	0.2500	0.2500
3	0.2500	0.2500	0.2500	0.2500
4	0.2500	0.2500	0.2500	0.2500
5	0.2500	0.2500	0.2500	0.2500
6	0.3207	0.0379	0.3207	0.3207
7	0.3329	0.0013	0.3329	0.3329
8	0.3398	0.0000	0.3204	0.3398
9	0.3639	0.0000	0.2766	0.3595
10	0.4297	0.0000	0.1661	0.4042
11	0.5345	0.0000	0.0594	0.4061
12	0.7091	0.0000	0.0167	0.2742
13	0.8968	0.0000	0.0036	0.0997
14	0.9770	0.0000	0.0000	0.0230
15	0.9960	0.0000	0.0000	0.0040

Domestic production and consumption in an open economy.

Domestic Production and Consumption in an Open Economy											
Year	Price Dem.1	Price Supp.1	k1	k2	k3	Total Supply	Internal Consumption	Net Exports	Share of Imp. Exp.	Self-suff. Index	International Price
0	1490.0	1490.0	1.0000	1.0000	1.0000	3692.0	3692.0	0.0	0.00	100.0	1000.0
1	1102.5	1475.7	1.0157	1.0000	1.0000	4990.3	7182.6	-2192.2	0.31	69.5	1050.0
2	1157.6	1393.8	1.0926	1.0000	1.0000	5625.8	7094.1	-1468.3	0.21	79.3	1102.5
3	1157.6	1124.6	1.4362	1.0000	1.0000	7524.5	7250.2	274.3	0.04	103.8	1157.6
4	1215.5	765.7	2.3178	1.0000	1.0000	13817.2	7160.9	6656.3	0.48	193.0	1215.5
5	1276.3	608.3	3.9823	1.0000	1.0000	22858.9	7072.7	15786.1	0.69	323.2	1276.3
6	1340.1	615.5	3.8785	1.0000	1.0000	23265.3	6985.6	16279.6	0.70	333.0	1340.1
7	1407.1	614.6	3.9113	1.0000	1.0000	24502.2	6899.6	17602.6	0.72	355.1	1407.1
8	1477.5	617.4	3.8806	1.0000	1.0000	25370.7	6814.6	18556.1	0.73	372.3	1477.5
9	1551.3	631.6	3.6956	1.0000	1.0000	25196.9	6730.7	18466.2	0.73	374.4	1551.3
10	1628.9	664.5	3.2838	1.0000	1.0000	23337.7	6647.8	16689.9	0.72	351.1	1628.9
11	1710.3	723.7	2.8360	1.0000	1.0000	20998.2	6565.9	14432.3	0.69	319.8	1710.3
12	1795.9	805.5	2.3859	1.0000	1.0000	18381.1	6485.1	11896.0	0.65	283.4	1795.9
13	1885.6	679.3	2.0943	1.0000	1.0000	16808.8	6405.2	10403.6	0.62	262.4	1885.6
14	1979.9	908.9	2.0045	1.0000	1.0000	16739.5	6326.3	10413.1	0.62	264.6	1979.9
15	2078.9	917.2	1.9853	1.0000	1.0000	17244.4	6248.4	10996.0	0.64	276.0	2078.9

The table above is only calculated and printed when working with an open economy. In this case, the domestic supply and demand values that appear in the **Equilibrium Points** table are recalculated at new, pertinent market prices in the years that have trade.

The difference between domestic production and demand represents the annual volume of imports or exports. Column 9 of the table indicates net exports (exports minus imports).

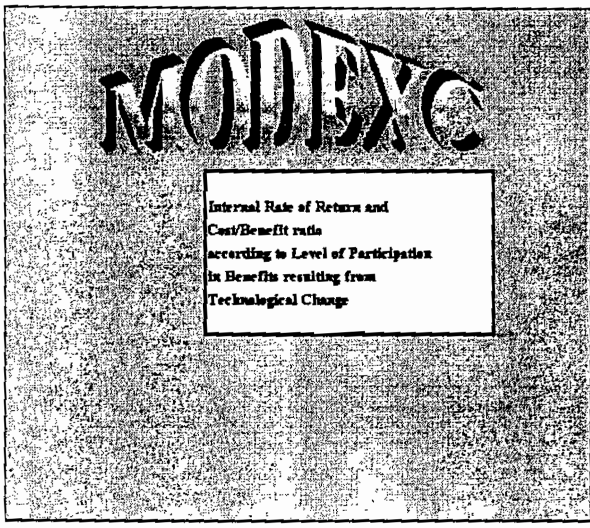
Column 10 alternatively presents two situations:

1. If net exports are negative (imports > exports), the proportion of imports regarding domestic consumption appear in this column.

2. If net exports are positive (exports > imports), then the proportion of exports regarding total domestic production appear.

Column 11 shows the **Self-Sufficiency Index**, defined as the ratio between total production and domestic consumption. Column 12 indicates the evolution of the **International Price** adjusted by its trend factor, if it exists. It is expressed as an annual growth rate, previously provided when defining the economic scheme to be used, in this case an open economy.

IRR, C/B, and NPV of total expected technological surplus.

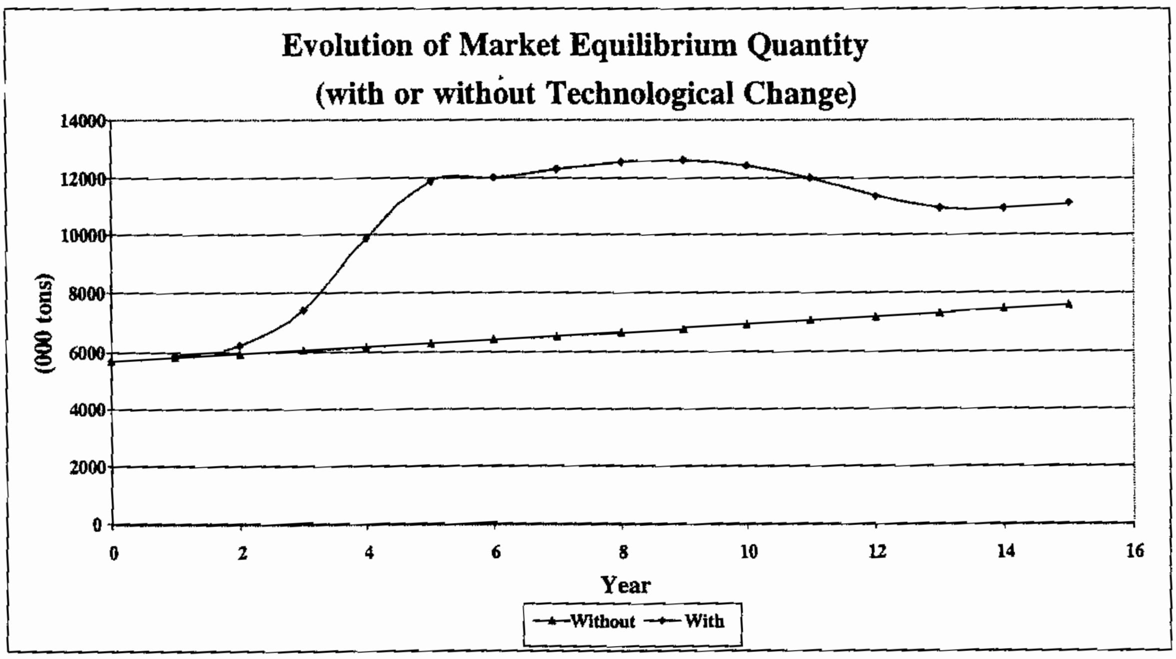


% Participation		Cost/Benefit	NPV Exp.Tech.Surp.
5	47.74%	60.7	2615891
10	55.25%	121.4	5231781
15	59.85%	182.1	7847672
20	63.21%	242.7	10463562
25	65.87%	303.4	13079453
30	68.09%	364.1	15695343
35	69.99%	424.8	18311234
40	71.66%	485.5	20927124
45	73.14%	546.2	23543015
50	74.49%	606.9	26158905
55	75.71%	667.5	28774796
60	76.84%	728.2	31390687
65	77.88%	788.9	34006577
70	78.86%	849.6	36622468
75	79.77%	910.3	39238358
80	80.63%	971.0	41854249
85	81.44%	1031.7	44470139
90	82.21%	1092.3	47086030
95	82.94%	1153.0	49701920
100	83.64%	1213.7	52317811

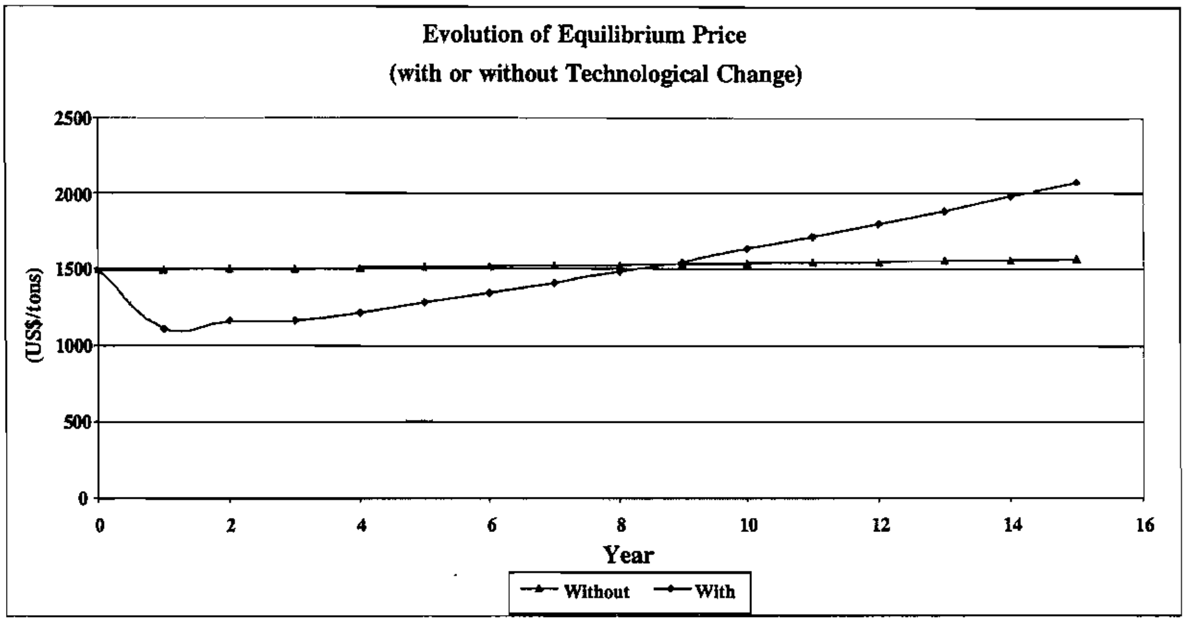
The table above presents the calculations of the IRR, the cost/benefit ratio, and the present value of expected technological surplus for different levels of participation in total benefits, as already mentioned, on a scale ranging from 5% to 100%.

Under the **Print** option of the **Main Menu** appears the submenu for **Graphs**, which allows you to print the graphs generated together or separately. Ten different graphs are available as follow.

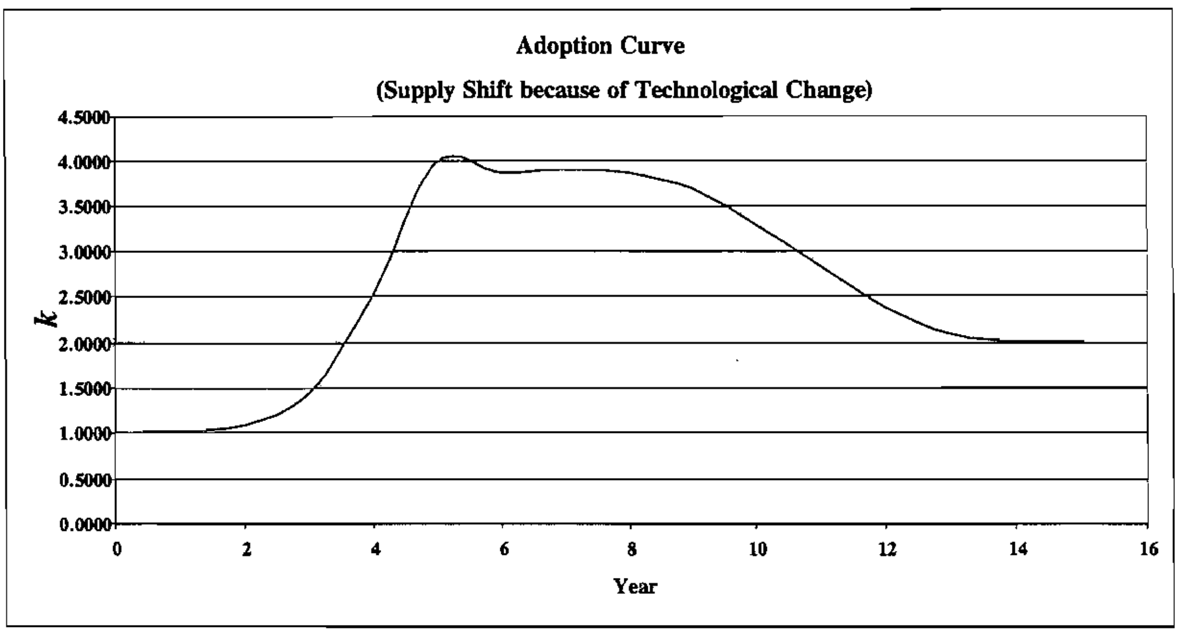
Graph 1.



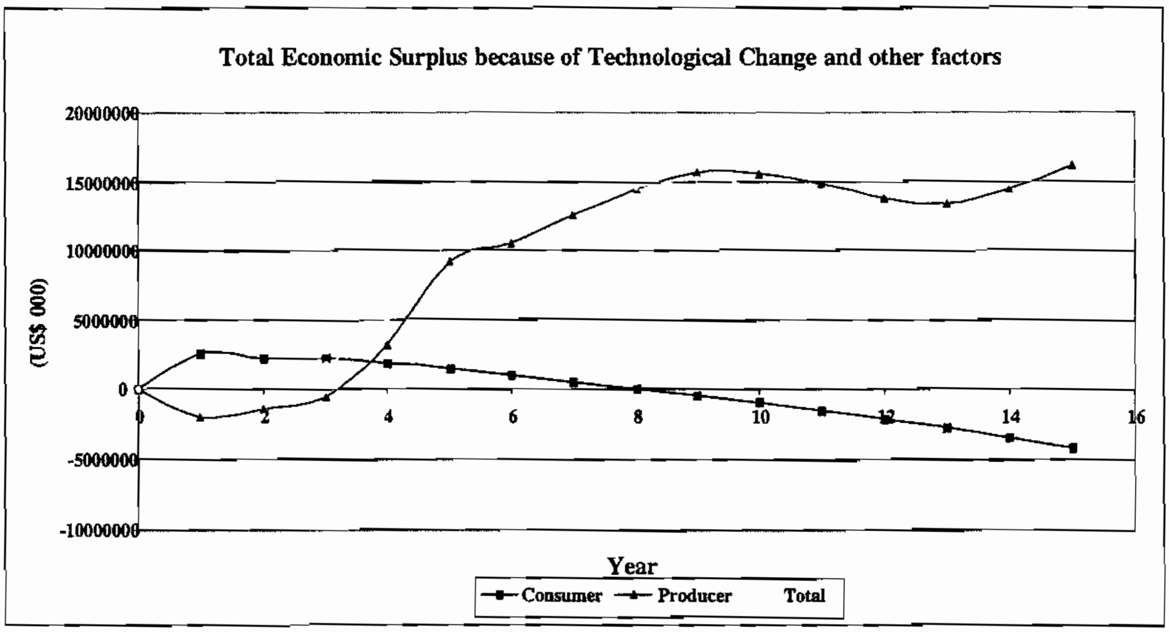
Graph 2.



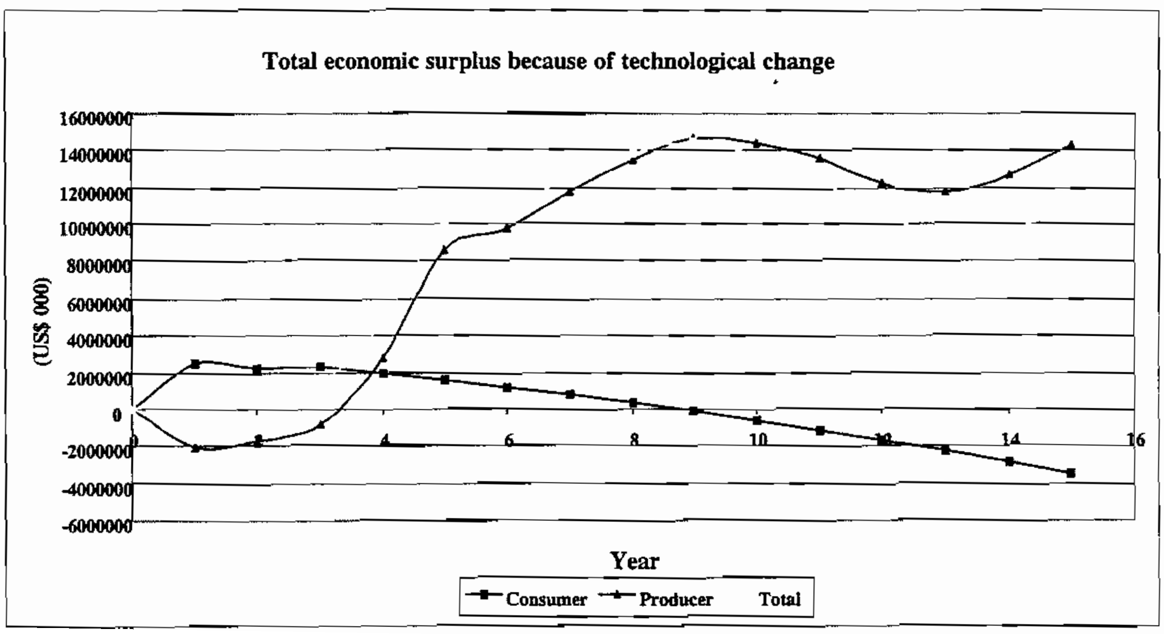
Graph 3.



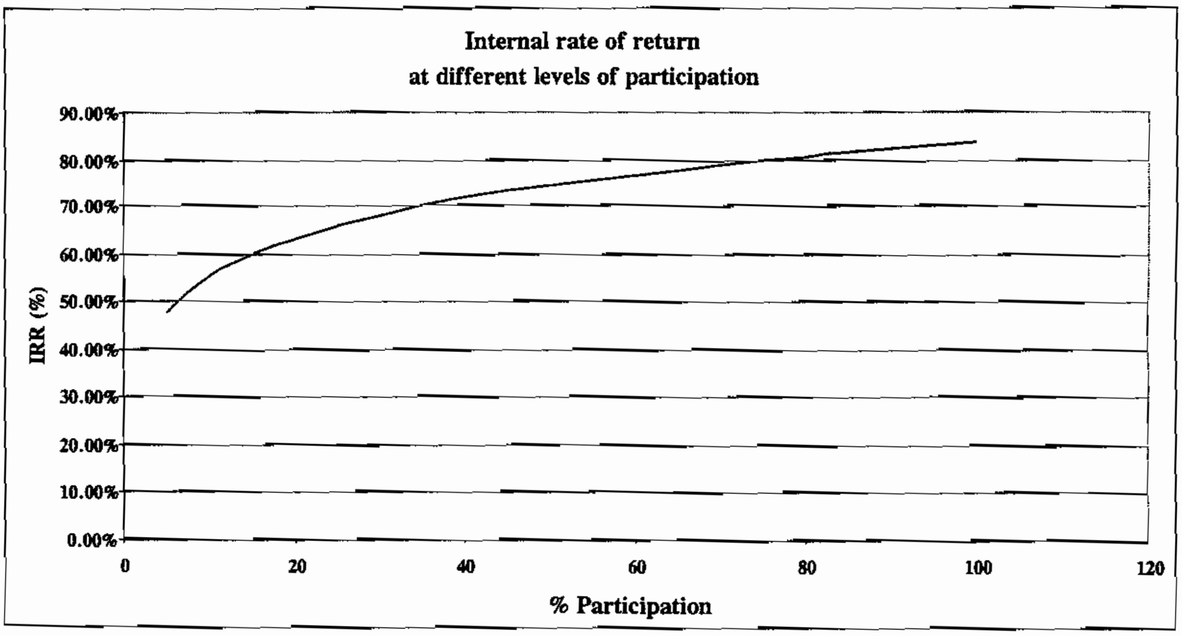
Graph 4.



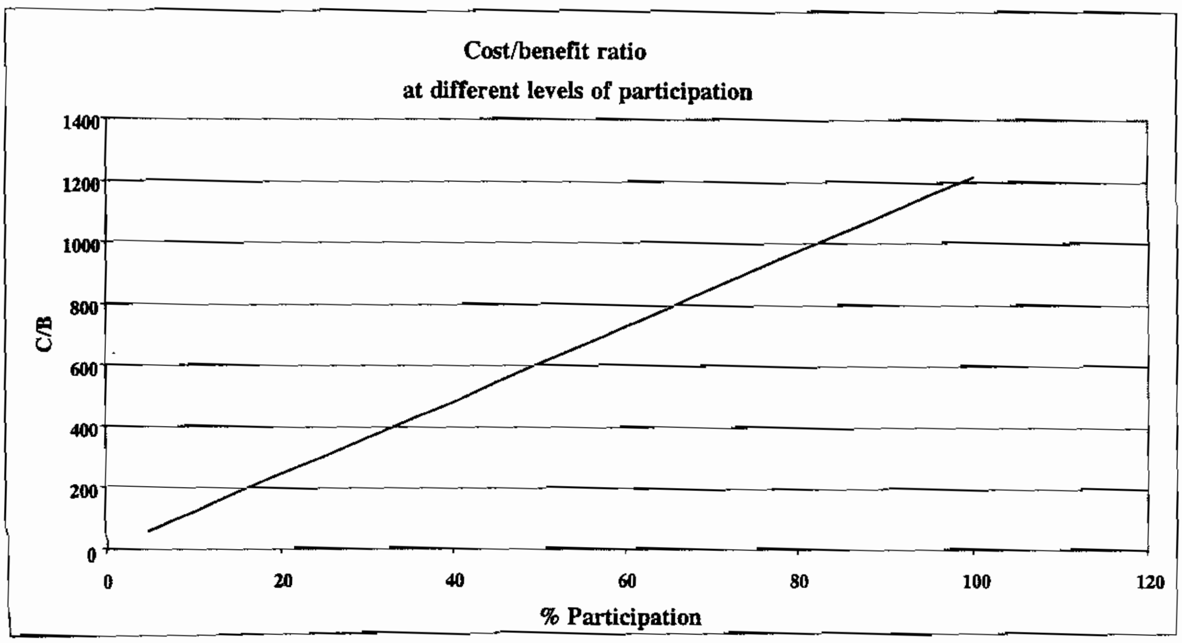
Graph 5.



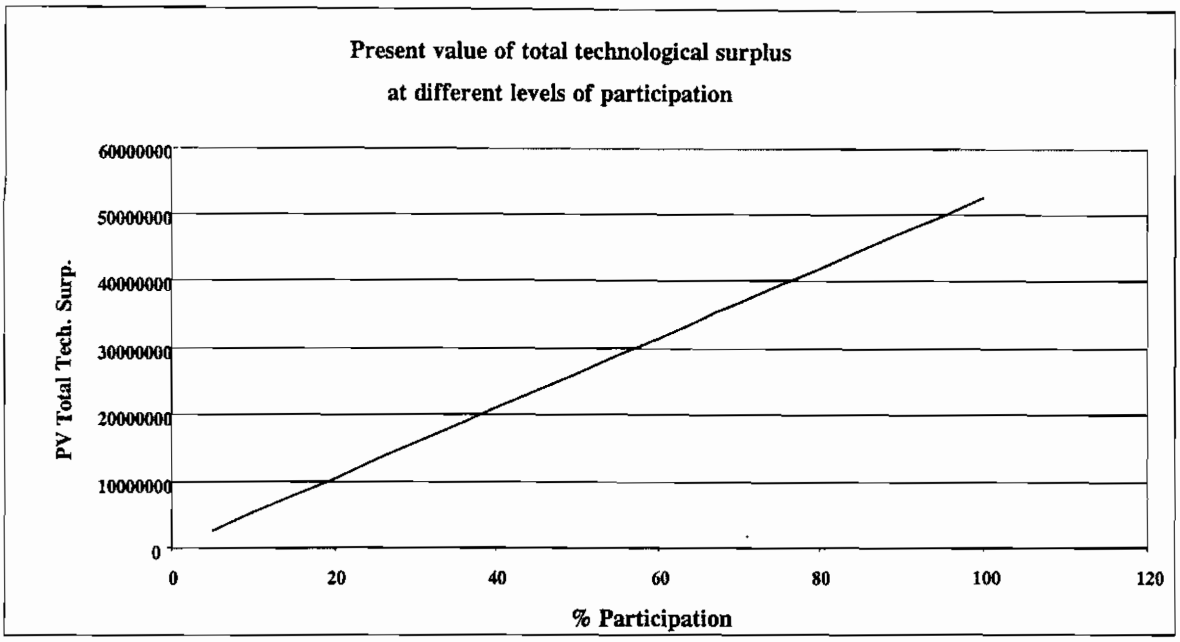
Graph 6.



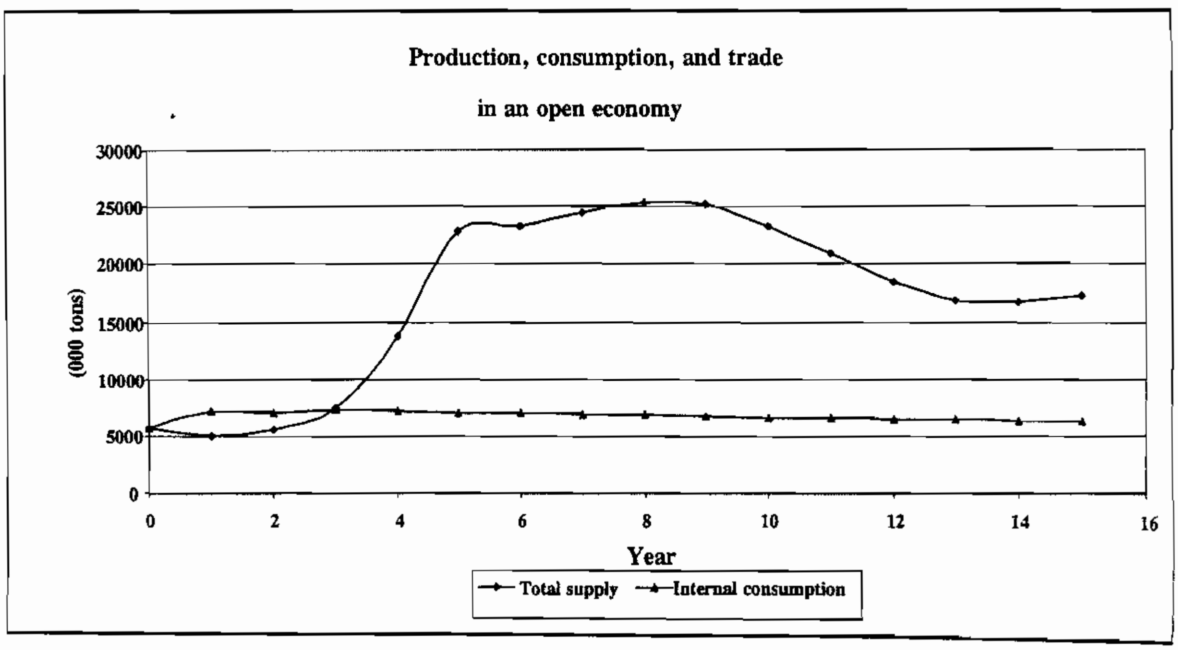
Graph 7.



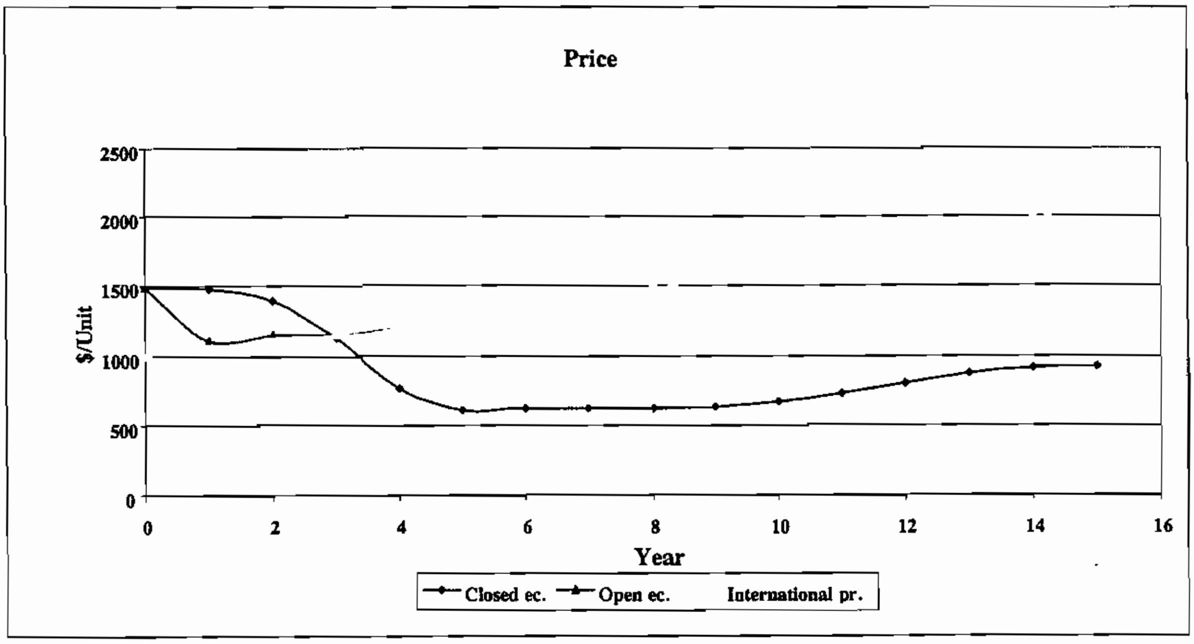
Graph 8.



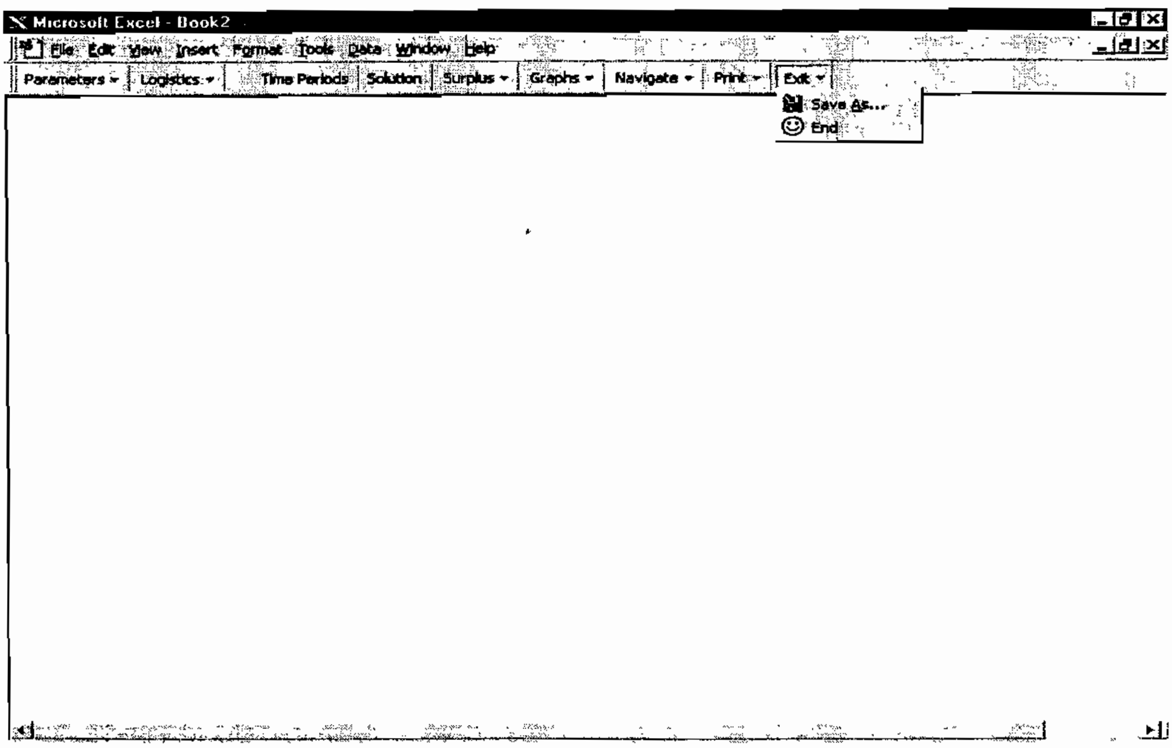
Graph 9.



Graph 10.



3.3.9. Exit



Exit allows you to:

1. **Save as** - You can record the file with any <u>name</u> you want and in the directory of your choice.

2. **End** executes the converse of **Begin**, by which the model displays its own environment. **End** restores the initial Excel environment (see page 19). After executing this option, and because the file with the results has already been saved, click **Close** on the main menu to close the file or **Exit** to leave Excel.

The **End** option is highly important because:

It influences how MODEXC will start up the next time you use the model.

If you forget to execute the **End** *option, the main menu of Excel will be displayed when you reenter Excel. To correct this failure, follow the procedure indicated below to* **Delete the Modexc menu.**

- Click **Tools** on the **Excel menu.**
- Click **Customize.** A tools list is displayed.
- Click **Modexc.**
- Click **Delete.**
- Click **OK.**
- Click **Close.**

If you click the **Start** *button after having selected the* **End** *option, the following message appears:* **Run-time error '5' Invalid procedure call or argument.** *This occurs because the model assumes that you had already ended the work session using the* **Save As ...** *option to save the results and then called the* **End** *option that eliminates the MODEXC menu.*

To run the application again, you must use the options of the Excel menu: **File, Close** and then **File, New** to select **Template MODEXC.xlt** that begins a new session. You can also begin a new session from the Excel files containing the results generated in previous sessions.

If in any doubt as to how the model operates, proceed to **<u>Reinstall</u>**. *Delete the* **MODEXC.XLT** *file from the* **Templates** *directory where it was initially installed and replace it with the original version.*

4. OTHER USES OF MODEXC

Market evolution. MODEXC can be used in market analyses, even in situations where technological change ($k_1 = k_2 = k_3 = 1$) is absent. In these cases, the model can project market equilibrium quantities and prices if the values of expected autonomous growth rates of supply (θ) and demand (Ω) are known.

Equity. An important criteria for decision-making in research is **equity**, or how the benefits of technological change are distributed among the different social groups—poor and rich consumers, small- and large-scale producers. A practical, simple method is to distribute the present value of technological surplus to producers and consumers according to the distribution of consumption among income groups or strata and according to the distribution of production among farm-size strata.

Technological components. A new technology is usually represented by a new variety, new inputs, different management practices, and so forth. When evaluating a new technology, the k value used represents the total overall effect of these factors or components. If you want to know the value of the benefits attributable to each factor separately, this is possible if a tentative estimate of the individual contribution of each factor to the total benefit is known. The criteria of technicians and experts working with the technologies under study should support this estimate.

Spillovers. An important topic in the economic assessment of new agricultural technologies relates to the indirect or **spillover** effects. These occur when technical change is adopted or produces benefits in other regions or production systems for which it was not designed or its use was not foreseen. Under these circumstances, unexpected benefits occur, attributable to the technology under study.

When working with MODEXC, you can estimate spillovers by considering them as additional technologies that affect the study market.

The case of Colombia and new forage technologies is an example. The research efforts of CIAT and collaborating institutions focus on the development of high-yielding forage materials adapted to conditions of low fertility and high acidity. The target region consists of extensive marginal areas of Colombia's Amazon and Orinoquia regions. However, forage materials released for the target region can be successfully used in other parts of the country such as the North Coast and the Middle Magdalena. Therefore, when evaluating the benefits of these technologies regarding the Colombian beef market, both direct and indirect benefits have to be considered.

Direct benefits will be generated by the adoption of new technologies in the target area. Indirect benefits will result from the adoption of these technologies in other regions of the country. All these technologies enter the model separately and can be easily identified in terms of k value and diffusion pattern; therefore both direct and indirect benefits can be estimated and identified.

5. REFERENCES

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Sere C. and Jarvis LS. (1988). The betting line of beef: ex-ante estimates of improved pasture: research benefits for the Latin American tropics. Presented at ISNAR/RUTGERS Agricultural Technology Management Workshop", Rutgers University, New Brunswick, New Jersey, July 6-8, 1988.

6. ANNEXES

Annex 1. Adjusting the Logistic Function

A1.1. Adjustment

The supply shift factor, caused by the technological change under study, is called k and is assumed to obey a logistic function of the type:

$$k_t = \frac{A}{1+e^{\alpha+\beta_t}} \quad (32)$$

Where:	k_t	=	Supply shift factor in the period t,
	A	=	Asymptote of the logistic function,
	e	=	Constant,
	α and β	=	Parameters, and
	t	=	Time.

To estimate the logistic function, you must first determine the maximum k value (asymptote of the function, in this case A) and two points located on the curve. These points are defined in terms of percentage of adoption in a given year. Once such points are defined, you can estimate the α and β parameters of the logistic function.

If you define Point 1 as the percentage adoption in period t (initial year of adoption) and Point 2 as the percentage adoption in year $t+n$ (final year of adoption), then:

	% Adoption	Period
Point 1	W_t	t
Point 2	W_{t+n}	$t+n$

$$\beta = \frac{\log itW_{t+n} - \log itW_t}{t+n-t} \quad (33)$$

$$\beta = \frac{\log itW_{t+n} - \log itW_t}{n} \quad (34)$$

$$\alpha = \log itW_t - \beta \quad (35)$$

$$\log it W_t = \ln\left[\frac{W_t / 100}{1 - W_t / 100}\right] \tag{36}$$

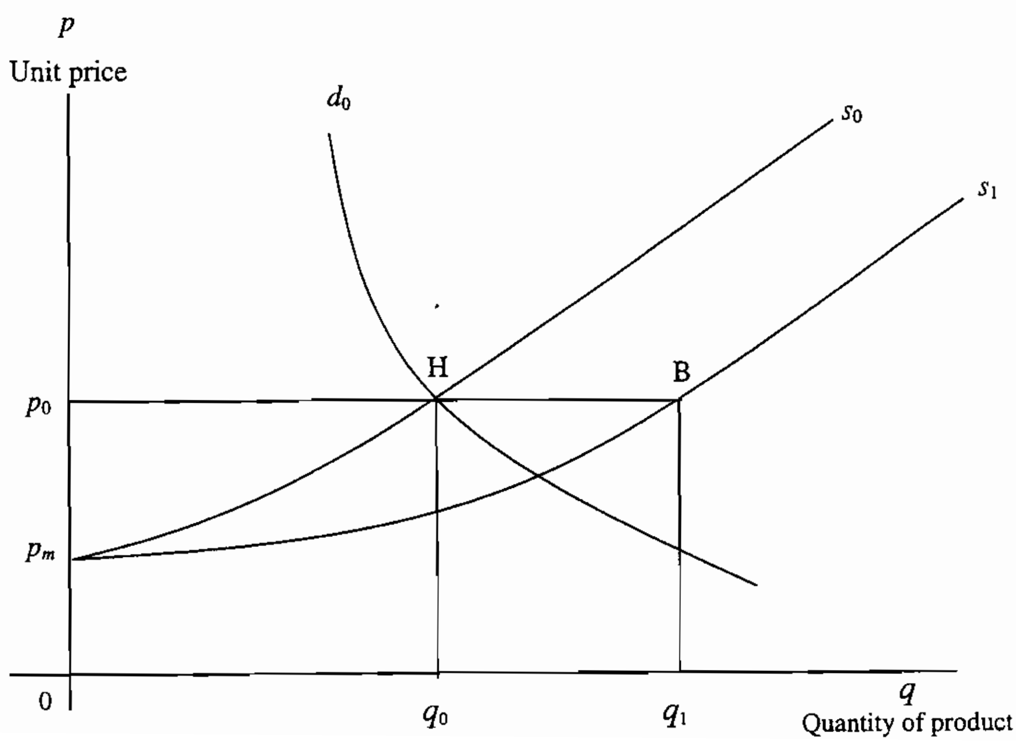
$$\log it W_{t+n} = \ln\left[\frac{W_{t+n} / 100}{1 - W_{t+n} / 100}\right] \tag{37}$$

The logistic function is defined once A, α, and β are known.

A1.2. Correcting the *k* factor with autonomous supply shift

In MODEXC, two situations can be simulated regarding future market evolution. In the first situation, which is the simplest, we assume that the market is only affected by the technological change in question. Accordingly, this becomes the only force that displaces supply and is expressed in the *k* factor.

Diagram A1.1.



The demand function (d_0) is assumed to remain constant throughout the study period. In this case:

$$s_0 = c\,(p\text{-}p_m)^g \tag{38}$$

$$d_0 = bp^{Np} \tag{39}$$

$$s_1 = ck\,(p\text{-}p_m)^g = s_0 k \tag{40}$$

Where:	s_0	=	Supply function before technological change,
	c,b	=	Constants
	s_1	=	Supply function after adoption has ended, and
	d_0	=	Demand function.

Because of technological change, the quantity offered on the market at initial price p_0 is increased from q_0 to q_1 ($\delta q = q_1\text{-}q_0$), that is, segment HB. In this case, the supply expansion factor because of the technology is defined as:

$$k = \frac{q_0 + \delta q}{q_0} \tag{41}$$

Note that k is defined as a shift factor of the initial supply s_0.

A second, more complex, situation can be simulated in MODEXC regarding market performance. Factors other than the technological change under study affect supply and demand and are independent of the technological change in question. The demand changes because of variations in income, relative prices, consumer preferences, et cetera. The annual shift factor of demand is defined as Ω and represents the annual growth rate of demand. The supply also grows because of other factors independent of the technology under study, for example, increase in the resources used and technical changes of another nature. The effect of these factors is defined as θ.

MODEXC assumes that the market equilibrium of each year during adoption is produced by an initial shift of supply and demand caused by the factors Ω and θ, that would lead to final market equilibrium if technological change does not occur. But the k factor again shifts the supply to achieve final market equilibrium during the given time period.

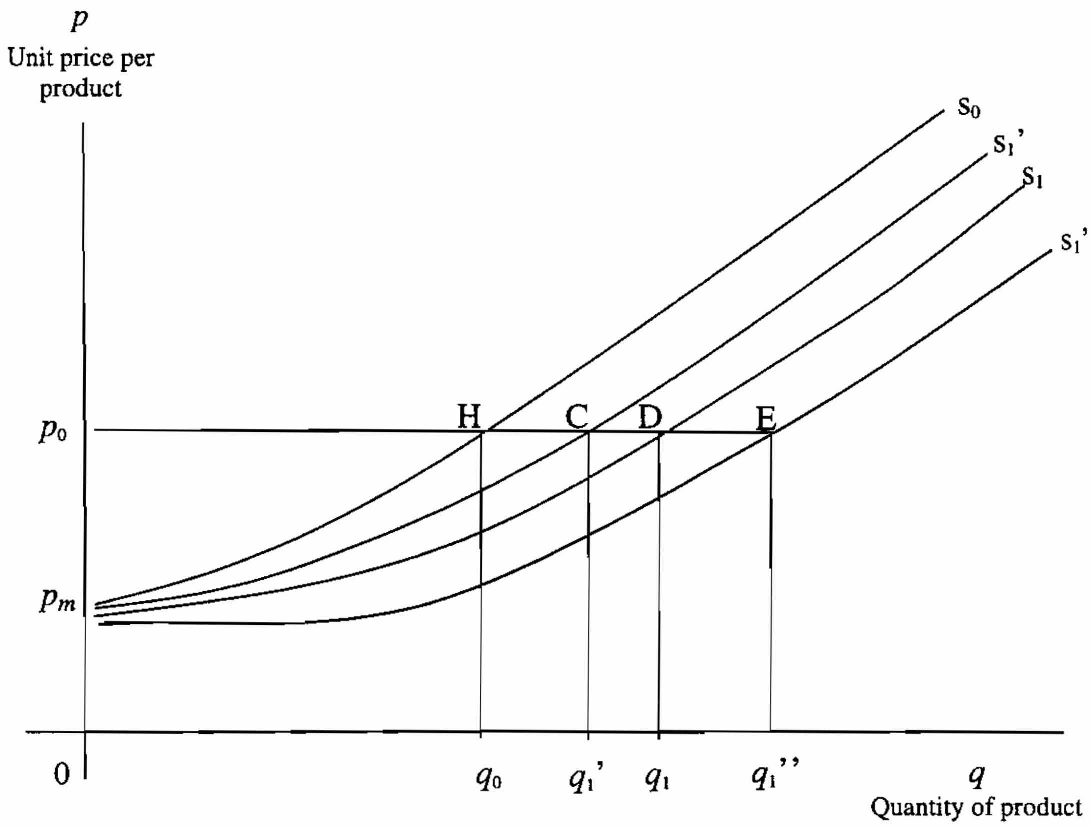
Diagram A1.2. illustrates this situation. The shift of s_0 to S_1' occurs because of exogenous factors (θ), and the shift from s_1' to s_1'' occurs because of technological factors (k). The model gives rise to the following equations:

$$s_0 = c(p-p_m)^g \tag{42}$$

$$s_1' = c(1+\theta)^t (p-p_m)^g = (1+\theta)^t s_0 \tag{43}$$

$$s_1'' = ck(1+\theta)^t (p-p_m)^g = (1+\theta)^t k s_0 \tag{44}$$

<u>**Diagram A1.2.**</u>



Because the technological change factor (k) was initially define as the shift factor of the initial supply, s_0, by applying this factor to the s_1' function already shifted on the HC segment, the effect of technological change is overestimated because k was defined as the shift factor of s_0. The overestimate is the distance DE in Diagram A1.2., because the increase of supply resulting from technological factors at the initial price (p_0) should be the distance CD in Diagram A1.2., equal to the distance HB in Diagram A1.1.

To solve this problem, and for practical purposes, MODEXC adjusts the k value to eliminate this overestimate. The supply function after technological change is therefore stated as:

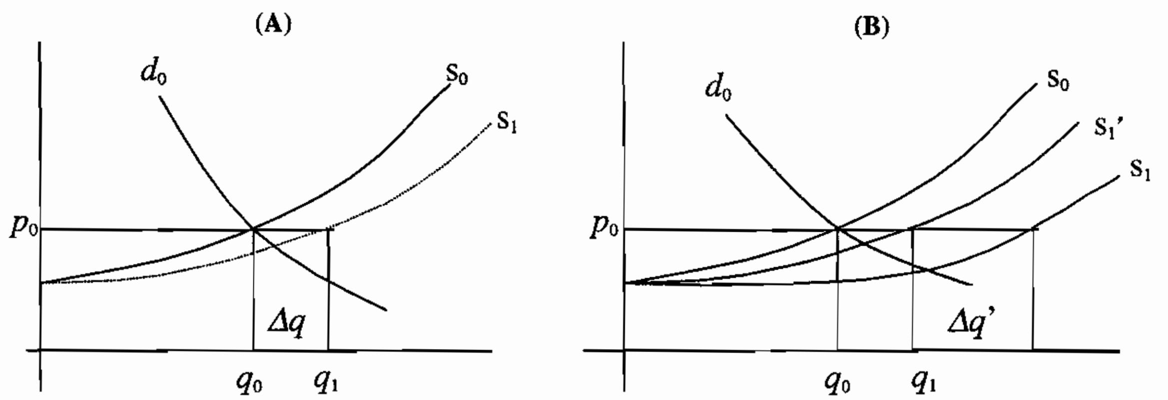
$$s_1 = c(1+\theta)^t \hat{k}(p - p_m)_g \quad (45)$$

$$s_1 = s_1' \hat{k} \quad (46)$$

Where $\hat{k}$ is the adjusted supply shift factor that is applied to the s_1' function.

The mathematical justification of adjusting k is presented below.

Diagram A1.3.



In situation (A), Diagram A1.3., there is no autonomous supply shift (θ = 0), as follows:

$$k = \frac{q_0 + \Delta q}{q_0} \quad (47)$$

In situation (B), an autonomous supply shift ($\theta > 0$) shifts the initial supply (s_0) to s_1'. Later, technological change, through the k factor, moves the initial supply to s_1. Because the k factor is defined to operate on the initial supply (s_0), in situation (B) the Δq value is overestimated, referred to in Diagram A1.3 (B) as Δq'. The Δq of Diagram A1.3 (A) is defined as:

$$\begin{aligned}\Delta q = q_1 - q_0 &= ck\,(p\text{-}p_m)^g - c(p\text{-}p_m)^g \\ &= c(p\text{-}p_m)^g\,(k-1) \\ &= s_0\,(k-1)\end{aligned} \tag{48}$$

$\Delta q'$ is defined as:

$$\begin{aligned}\Delta q' &= ck\,(1+\theta)\,(p\text{-}p_m)^g - c(1+\theta)\,(p\text{-}p_m)^g \\ \Delta q' &= c(1+\theta)\,(p\text{-}p_m)^g\,(k\text{-}1) \\ \Delta q' &= s_0\,(k\text{-}1)\,(1+\theta)\end{aligned} \tag{49}$$

That is, $\Delta q'$ with respect to Δq is overestimated by the factor $(1 + \theta)$. As a result, the k factor should be corrected.

The original k factor acting in situation (A) is:

$$k = \frac{q_0 + q_0(k-1)}{q_0} \tag{50}$$

Note that the function s_0 evaluated at price p_0 is equal to q_0.

The implicit k acting in the second situation, referred to as k', is expressed as:

$$k' = \frac{q_0 + q_0(k-1)(1+\theta)}{q_0} \tag{51}$$

When expressions (50) and (51) are compared, we find that in the second, the $(k\text{-}1)$ factor is overestimated by $(1+\theta)$.

The k factor is adjusted in terms of the magnitude of θ—the higher the θ, the higher the adjustment of k because it will be applied at an increasingly larger scale. When $\theta = 0$, then $k = k'$. The adjusted k is defined as:

$$\hat{k} = \left[\frac{k_t - 1}{1+\theta}\right] + 1 \tag{52}$$

$$\hat{k}_{t+1} = \hat{k}_t + \left(\frac{k_{t+1} - k_t}{1+\theta}\right) \tag{53}$$

You do not have to make this adjustment. The model is programmed to do so when indicated. Enter the asymptote value to MODEXC without any type of adjustment.

Two runs of MODEXC are presented below to illustrate how k evolves when $\theta > 0$ and when $\theta = 0$.

The assumptions used are:

Item	**Case A**	**Case B**
Price elasticity of:		
Supply	0.60	0.60
Demand	-0.50	-0.50
Minimum price	150	150
Initial equilibrium quantity	4240	4240
Initial equilibrium price	580	580
Annual autonomous increase of:		
Supply	0	2.5
Demand	0	3.0
Percentage of adoption in the year:		
4	0.5	0.5
35	99.9	99.9
k value (asymptote)	1.80	1.80
Type of economy	Closed	Closed

The difference between case (A) and (B) is that in case (A) no autonomous shifts of supply and demand occur, while in case (B) they do. In case (B), because $\theta > 0$, MODEXC adjusts the k value.

The table below shows the total economic surplus of both situations. Despite using an adjusted k value in case (B), the present value of total economic surplus is greater than that of case (A), in which the k value is not adjusted.

Case	**PVTES† (US$ million)**	**Final k value**
A	927	1.7992
B	1398	1.7789

† Present value of total economic surplus (PVTES), rate of discount = 10%.

Annex 2. Precautions to Take When Using MODEXC

1. NEVER FORGET THE **END** OPTION.

2. Always keep the original version of the MODEXC *template.*

3. Do not shut off the printer when printing results.

4. If unforeseen failures occur in any circumstances, restart the program by recalling the original version from the main menu of Excel, using the options **File**, then **New**.

5. When working with price and/or production figures that have many digits, we recommend you convert them to a different scale. For example, if figures are expressed in kilograms, change them to thousands of tons; prices should be expressed accordingly in monetary units per ton. If the numbers are very large, they can easily surpass the predefined width of the columns and you will not be able to see the values.

6. When you want to reproduce previously obtained MODEXC results, be careful when introducing the parameters. If the values of the parameters differ at all from those previously used, the results of the new run will differ from results obtained in the previous runs you want to reproduce.

7. The values of the parameters used should be consistent with the economic theory, for example, the price elasticity of demand should always be negative and the minimum price must be lower than the initial equilibrium price.

Annex 3. Distributing Technological Surplus According to Technology

This last version of MODEXC not only calculates the total surplus attributable to the series of technologies under study, but also estimates individual technological benefits attributable to a given technology and distributes them between producers and consumers.

To do so, the model generates, over time, *k* values for each technology evaluated in a given market. This information allows you to estimate the participation of each technology in the overall *k* value (sum of individual *k*s). Assuming that the participation of *k* of a given technology in the overall *k* value corresponds to its participation in total technological benefits, the total benefits are disaggregated among the individual technologies.

This breakdown of information is useful. You can both evaluate the overall economic efficiency of a series of technologies constituting a research program and identify the individual contribution of each technology to program benefits, thus establishing priorities.