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METHOD FOR EVALUATING THE SIGNIFICANCE OF MACRO-ECONOMIC VARIABLES IN THE ANALYSIS OF TECHNOLOGY INCORPORATION DECISIONS

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I. INTRODUCTION

This paper proposes a method for the analysis of entrepreneurial decisions concerning the technology to be adopted. It is based on the assumption that firms behave rationally, with the aim of maximising their advantages in the long term. This rational behavior is constrained by the restrictions imposed by the physical and technical characteristics of production and by the economic conditions - inherent in the overall situation - which firms face; that is, engineering, micro- and macro-economic factors.

The aim of the paper is to achieve an integrated method in which the operation of the three variables - engineering, micro- and macro-economic - can be perceived simultaneously. This method, therefore, provides an analytical basis which will fulfil this paper's objective; that is, the integration of the macro-economic variables into the analysis of technological decisions taken by enterprises.

The usual approach to the technological behavior of enterprises arises from the standard theory of the firm: the analysis is micro-economic in character. This kind of analysis contains an implicit assumption: that of the relative stability of the macro-economic conditions in which the firm operates. This assumption is methodologically valid and conceptually acceptable as long as such stability does in fact exist. In stable economies the further explanatory value to be obtained from the inclusion of macro-economic variables in the study of the firm is probably limited. But this statement cannot be supported in the case of economies like those of Latin America, with varying, but nevertheless considerable, degrees of instability. Thus, this paper proposes a descriptive method of the ways in which macro-economic variables can be incorporated into the micro-economic decisions taken by the firm in connection with the choice of technology.

This method refers to choice in time between technologies. It may help to explain the reason for the rate of expansion of new technologies, the coexistence of technologies of varying vintages, technological gaps, the difference in technological strategies between firms, between sections of one industry, or even between different countries. But its scope is limited. Costs and benefits evaluated in connection with each alternative decision are dissected and each part judged separately, but they are accepted as they are, as the results of the availability of resources whose composition is not in question. In this way the important area covering the accumulation of knowledge and skills, absolutely central to technology, is entirely left out of the analysis. Also left out are the technological choices which do not imply time: to make something or have it made?; to order the finished or semi-finished product? etc. Obviously, macro-economic conditions influence these kinds of question. The method, however, does not cover them.

The paper makes no claim to theoretical originality. The subjects have been extensively analyzed in the literature. But the mode of approaching the problem of technological change which it proposes is not found in the usual literature on the matter. Its main aspiration is to incorporate into the analysis of the phenomenon of technology all matters of a macro-economic nature which significantly affect the behavior of the firm.

II. REPLACEMENT VS. MODERNIZATION OF EQUIPMENT

At its most abstract level this approach is concerned with the choice between alternative strategies in time, in order to achieve a specific aim. A number of problems connected with technological change can be analyzed by this approach; for example: the decision between alternative strategies for maintenance, the financing of research and development programmes; the choice between the development of local or the acquisition of foreign technology; programmes for the substitution of outside advisory services; the calculation of the useful life of a production line, etc.

Throughout the analysis, however, we follow the convention of considering the problem as one of choice between modernization and the replacement of existing machinery. This convention is not arbitrary. There are two reasons for adopting this kind of choice as relevant: in the first place, because to a considerable degree the process of technological change occurs through change of machinery; in the second place, because the investment decisions involved, due to their size and nature, are the most likely to reflect the effects of variations in macro-economic conditions.

It is assumed that the choice between the alternatives of modernizing or replacing machinery is posed for a fully functioning establishment. This assumes that the firm makes its choice starting from a given situation defined by the use of certain equipment and its related technology. This decision involves definite costs, one of them being the foregoing of benefits which would arise if the present machinery continued in use. This is a different situation from that of a choice made between two alternative technologies, prior to the acquisition of the requisite equipment. By approaching the problem in the first way, we apparently ignore the analysis of an important source of technological change, that generated by new production plants, particularly in processing industries, and direct our attention to working plants. There is some evidence to show that this second source of generation of innovations is as, or more, important than the first, for the aggregate and for almost all industrial sectors, at least if the increase in labor productivity is used as a progress indicator. Nevertheless, the analysis carried out is applicable, with minor modifications, to the case of technological choices from zero.

As further justification for the relevance of choice between replacement and modernization of machinery, it must be borne in mind that in Latin American countries enterprises capable of creating frontier technology in the international field are the exception. The normal procedure is for firms to buy and adapt existing technologies. One can visualize them being confronted by a catalogue of alternative technologies, on the basis of which they have to make their decision, but with the special condition that they currently have one of them in use.

III.

III.1. Discount Formula

Since the choice between replacing or modernizing machinery is a problem requiring the comparison of original investment costs with expected future income and costs, the analytical instrument to be employed is the discount formula:

$$\sum_{1}^{n} \frac{Y_j - C_j}{(1+r)^j} = 0 \qquad (1)$$

or, alternatively,

$$V\,P = \sum_{1}^{n} \frac{Y_j - C_j}{(1+i)^j} \qquad (2)$$

where:

Y_j income in the period j $(j=1\ldots n)$

C_j costs in the period j

r rate of return

i interest rate

VP current value of income and costs flow

The formula is a general one and is equally applicable to both replacement and modernization of machinery. It may include the costs of paperwork, machinery acquisition, transportation; assembly, running, maintenance and repair costs, resale value, etc.

For example:

$$VP = -\sum_{1}^{k} \frac{I_j}{(1+i)^j} + \sum_{k+1}^{n} \frac{Y_j - C_j}{(1+i)^j} + \frac{R_n}{(1+i)^n} \qquad (3)$$

$(1\ldots k)$ being the maturity period of the investment I_j; $(k+1)$ the moment at which operation begins; n the planning horizon; Rn the resale value at point n.

III.2. Timing of Machinery Replacement

The problem of machinery replacement or modernization can be posed in terms of pure or mixed strategies. The latter case is the most common one. At time *to* the entrepreneur has under consideration the period (to–tn) and must select the technology to be applied during it. A mixed strategy refers to the using of the old equipment - modernized or not - during a first subperiod $(to - \ell)$ and of the new equipment during a second one $(\ell - tn)$. The choice relates to determining the moment of replacement: if $\ell = to$, the new machinery is adopted at once; if $\ell = tn$, the old machinery remains in use for the whole period. These are both opposite cases of pure strategies.

Let us consider the optimal replacement time ℓ^*. The formula to be applied is:

$$VP = - \sum_{1}^{k_1} \frac{I_j^M}{(1+i)^j} \quad {}_{k_1+1} \frac{Y_j - C_j}{(1+i)^j} \sum_{\ell - s}^{\ell + k_2} \frac{I_j^R}{(1 \ i)^j} + \sum_{\ell + k_2 + 1}^{n} \frac{Y_j - C_j}{(1+i)^j} \qquad (4)$$

In this formula we distinguish four subperiods:

$(1 \ldots k_1)$	maturity period of investment I^M in modernization.
$(k_1 + 1 \ldots \ell)$	additional working period of old machinery.
$(\ell - s \ldots \ell + k_2)$	maturity period of investment I^R in replacement (investment begins $\ell - s$ periods before the old machinery ceases operation).
$(\ell + k_2 + 1 \ldots, n, \ldots m)$	working period of the new machinery up to the planning horizon n, with an additional period $m - n$ for the foreseeable use of the new equipment until it is completely worn out.

To sum up, the basic idea is that firstly the machinery in use is modernized so it may be utilized for a certain period, and then replaced.

To determine the optimal moment ℓ^* for replacement, let us establish a technological plan in the period $(to - tn)$, such that the modernized machinery is used in the subperiod $(to - \ell)$ and the new machinery in the subperiod $(\ell - tn)$. We assume that $(to - tn)$ is the additional period during which the modernized machinery will last physically, so that the machinery must be replaced at point tn at the latest. We recognize, furthermore, that in the valuation of the new machinery are included the income and expenditure deriving from its operation even beyond point tn, say, up to a point tm which is a flexible limit obtained by accounting the foreseeable physical life of the new machinery and the moment at which it was put into operation.

First of all, it is necessary to establish if $\ell^* \neq$ to; that is, if it is feasible to modernize in a first stage or if, on the contrary, the machinery must be replaced from the beginning. To do this, it is necessary to compare current values of both plans at point to. The current value of replacement plan Vo^R, applied at point to is:

$$Vo^R = \sum_{1}^{m-n} \frac{(Y_j - C_j)^R}{(1+i)^j} \qquad (5)$$

The further the commencement of this plan moves from point to its value is reduced by factor $\frac{1}{1 i}$ so that if it occurs at we obtain:

$$V\ell,o^R = \beta^\ell Vo^R = \frac{1}{(1+i)^\ell} Vo^R \qquad (6)$$

which changes as ℓ moves from to to tn.

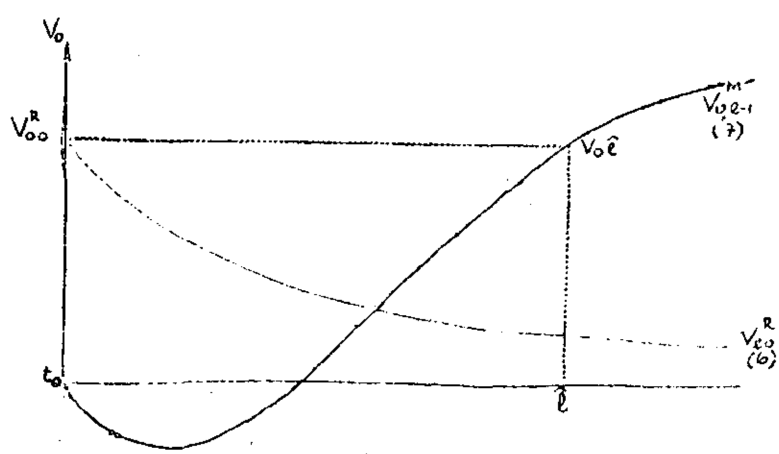
The current value of the modernization plan at point to, Vo^M depends on the number of periods during which the plan lasts. It has no fixed value, but grows with the length of time during which the old equipment continues in use.

$$Vo^M,_{\ell-1} = \sum_{1}^{\ell-1} \frac{(Y_j - C_j)^M}{(1+i)^j} \qquad (7)$$

which changes as ℓ moves from to to tn.

The formulae (6) and (7) can be illustrated by a graph:

Graph 1



As can be seen, initially $Vo,^{M}\ell-1$ has negative values which correspond to the early periods when there is expenditure on modernizing the machinery. As is shown in the graph, if the program for utilizing the modernized machinery envisages a period less than $\hat{\ell}$ - to, the value of $Vo,^{M}\ell-1 < Voo^{R}$, and it is not worth carrying it out. For values of $\ell > \hat{\ell}$, on the other hand, the technological plan must begin with modernization. Therefore, the initial choice depends on the time foreseen during which the modernized machinery will remain in use.

It is necessary, therefore, to calculate the optimum time ℓ^*, at which machinery is replaced. To do this, it is necessary to compare, for every point of time ℓ, within the period to - tn, the current value of both plans, taking into consideration the expenditure and income flows of each one from that point into the future. Replacement is carried out at the moment at which the current value of the replacement plan exceeds the current value of the modernized machinery in use. Formula (6) for V_{ℓ}^{R}, o gives the current value of the replacement plan at moment ℓ when it is evaluated from to. The current value of the modernized machinery in use, at moment ℓ, when also evaluated from to, is:

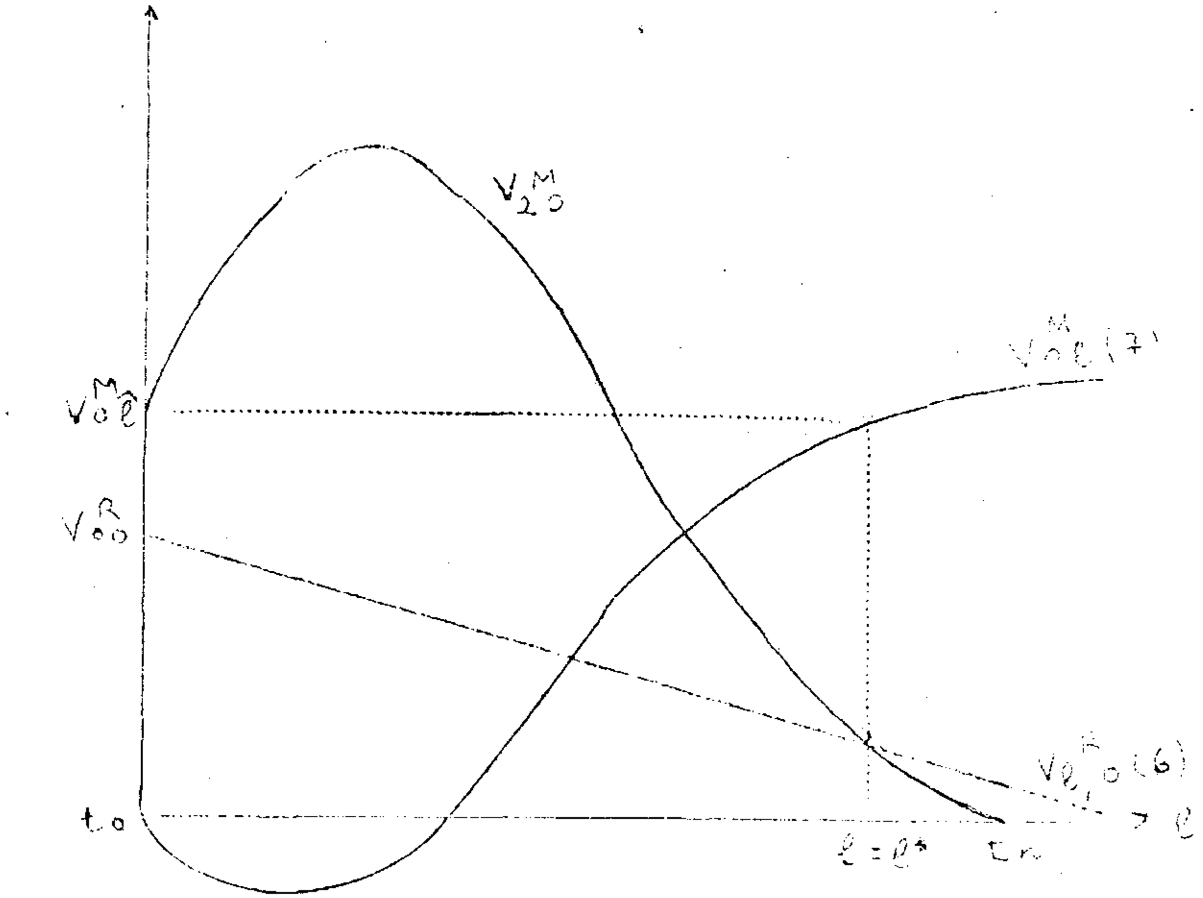
$$V_{\ell}^{M}o = \sum_{\ell}^{n} \frac{(Y_j - C_j)^M}{(1+i)^j} \qquad (8)$$

Equation (8) can be illustrated graphically by a parabola whose values increase during the initial periods in which successive valuations of current value gradually exclude modernization expenditure - this becomes a factor of the past and is no longer accounted for - and then fall as ℓ approaches tn.

The solution to the problem of finding the optimum ℓ^* for machinery replacement is shown in Graph 2.

It can be observed from the graph that the replacement point ℓ^* falls where V_{ℓ}^{R}, o = V_{ℓ}^{M}, o, that is the point from where on the current value of the replacement plan exceeds that of continuing to use the modernized machinery. Note that $\ell^* = \hat{\ell}$, since $Vo^{M}\hat{\ell} > Voo^{R}$; that is, when at point to the value of the modernized machinery in use, if utilized to $\hat{\ell}$, is greater than the value of the new machinery if installed at the said point to. If, on the contrary, the value $Vo^{M}\hat{\ell} < Voo^{R}$, it would be advantageous to replace the machinery at to(ℓ^* = to).

Graph 2



III.3. The Influence of Interest Rates

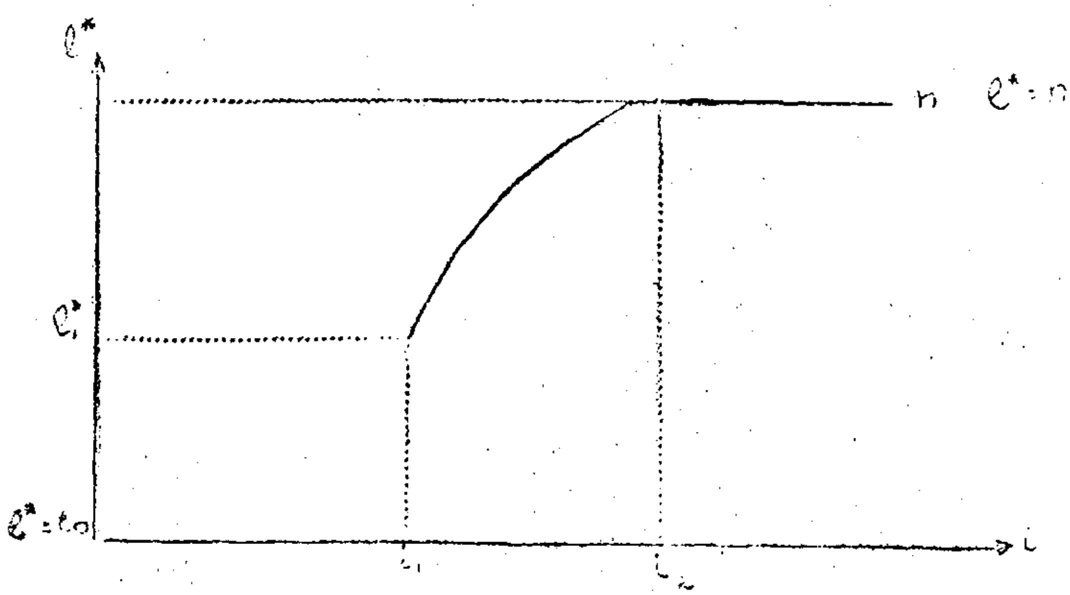
The solution described in Graph 2 depends on the values I_j, Y_j, C_j, i, of the formulae (6), (7) and (8). The variables I_j, Y_j, and C_j refer specifically to the conditions pertaining to the machinery and types of production involved, although they reflect indirectly the operation of macro-economic variables: relative prices and expectations regarding the future. The interest rate i is a direct macro-economic variable. Let us analyze the effects on the technological decision of a change in this variable.

When the interest rate falls we expect a shift of the value $\hat{\ell}$ towards the origin. This is due to the fact that, in general, the upwards shift of the function V^R_{ℓ}, o is greater than that corresponding to the function V^M_{ℓ}, o. The reason for this is that the average period of duration of the function V^R_{ℓ}, o - which is the total life of the new machinery - is greater than the remaining period of life of the old machinery at any point ℓ of the period to - tn. Therefore, the elasticity-interest of V^R_ℓ, o tends to be greater than that of V^M_ℓ, o.

It is also to be expected, for the same reason, that the upwards effect of a lower interest rate is greater for $V^R_{o}o$ than for $V^M_{o}\hat{\ell}$; this would favor taking the decision to replace at the outset. This decision, however, is a certainty if two assumptions are made: 1) $I^R > I^M$ and 2) $(Y_j - C_j)^R > (Y_j - C_j^M)$; that is, that replacing machinery is more capital intensive than modernizing it. This means that the function V^R_ℓ, o is more elastic in relation to changes in the interest rate than the function $V^M_o\ell$.

Therefore, $\ell^*(i)$ is an increasing function: the greater i is, the longer is the time ℓ^* which must pass before the optimum moment to replace the machinery is reached. The function, nevertheless, is discontinuous: while i falls, $\hat{\ell} = \ell^*$ moves towards the origin, but at a specific moment it becomes $\hat{V^R_o o}$ $V^M_o\ell$, so that ℓ^* jumps to the value to(ℓ^* = to) even when $\hat{\ell} >$ to. The reason behind this jump is that the modernization program for the used machinery must have a minimum number of periods of positive net income to justify the negative income of the initial periods when investment expenditure is dominant. This is shown in the negative values of the function $V^M_o\ell$ in the early periods. The shape of the function $\ell^*(i)$ is shown in the graph.

Graph 3



for $o < i \leqslant i$ — the optimum is $\ell^* = o$ (replace the machinery at the outset)

for $i_1 \leqslant i \leqslant i_2$ — the optimum lies between o and n $o \leqslant \ell^* \leqslant n$

for $i \geqslant i_2$ — the optimum is $\ell^* = n$ (do not replace: retain the modernized machinery)

Note that at interest rate i_1 it makes no difference if the machinery is replaced at $\ell^* =$ to or at ℓ_1^*. The situation may arise where $i_1 = i_2$, for $i < i$ it is advantageous to replace the machinery at the outset; for $i = i_1 = i_2$ both alternatives are equally valid; for $i > i_2$ it is advantageous not to replace during the period and wait till n when the old machinery must be replaced anyway because of its physical deterioration.

III.4. Uncertainty and the Planning Period

There are several reasons for uncertainty which affect the values of formula (4): it may vary the Y_j's or the C_j's or the I_j's, or the maturity periods k and k_2. This may arise from changes in relative prices - wages included - or from changes in demand, or different rates of progress in investment, etc.

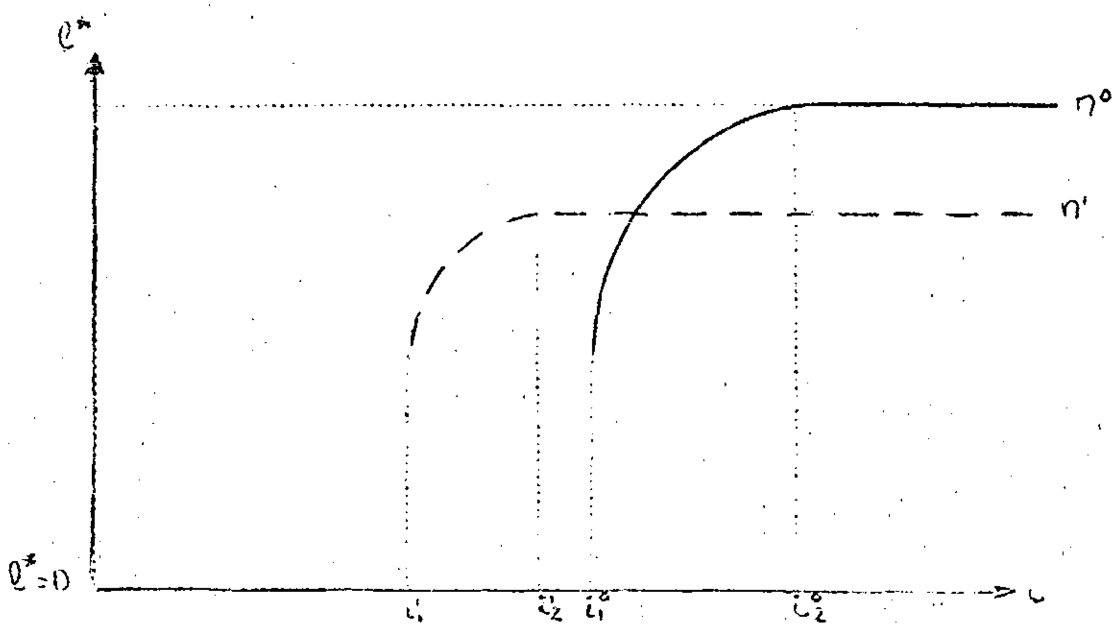
The average values expected for each of these variables - expected at point O when the plan is drawn up - have a random distribution. The greater the uncertainty the greater the variance in the distribution. One may further assume that the longer the future period, the greater the uncertainty; that is, the expected values have distributions of greater variance, the further they are in the future. As Hicks says in Value and Capital, if it is assumed that economic agents are averse to taking risks, the buyers add to the average value expected in a future period the value of the standard deviation of the distribution, while the sellers deduct it. Then in formula (4) the I_j's and C_j's increase and the Y_j's decrease, the greater the uncertainty and the greater the distance from the future. The current values of both alternatives and, therefore, of the overall plan, fall.

Let us suppose that for a period j the value $(Y_j - C_j)$ is positive. A sufficiently high increase in uncertainty makes this value zero or negative. From that point on the period j contributes nothing to the current value of the alternative studied, or if it does, it does so in a negative sense. As the distributions have an increasing variance according to the remoteness of the future, as uncertainty increases, successive periods starting from the future and working towards the present are gradually eliminated. The planning period is shortened when there is uncertainty. This is the justification for the procedure by firms which fix a shorter "pay-off period", the greater the uncertainty.

In its effects, in relation to the choice between technical alternatives, the increase in uncertainty operates in the same way as an increase in the interest rate: it tends to enhance the weight of the near future over that of the distant future. Since replacing machinery is more capital intensive than modernizing it, this greater prevalence of immediateness is antagonic to it; it loses priority over the other alternative. Therefore, the increase in uncertainty not only reduces the planning horizon n, but also extends the period ℓ^* (that is, the optimum moment to change the machinery recedes).

In relation to the interest rate, the uncertainty effect can be shown in the following graph:

Graph 4



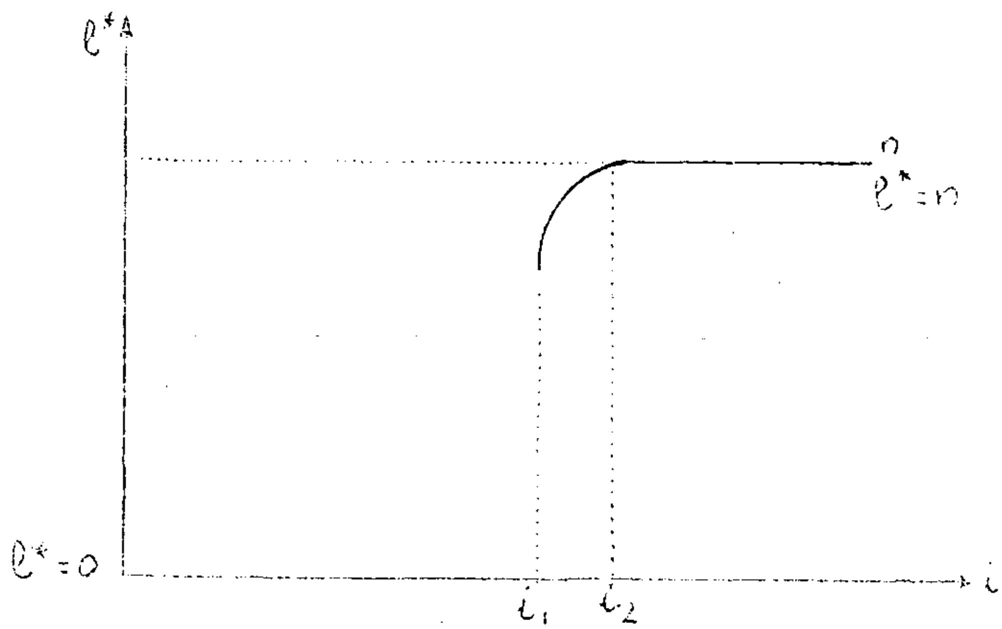
The increase in uncertainty reduces n, i_1 and i_2. This means that machinery replacement projects, for any date at which they have been planned, need a lower interest rate - because of the increase in uncertainty - if they are to be profitable.

III.5. The Relevance of a Pure Strategy

The choice of the moment ℓ^* - at which the machinery is changed - when $0 < \ell < n$, implies a mixed strategy: first modernization and then replacement. The usual practice is to choose, from the moment 0 one or other alternative for the whole planning period ($\ell^* = 0$ or $\ell^* \geq n$). We call these pure strategies. A justification of this procedure can now be attempted.

If it is assumed that ℓ^* (the optimum moment for change) is very sensitive to the varying degrees of uncertainty - or to the inclinations of the entrepreneurs to take risks - then the range $i_2 - i_1$, of interest rates between which mixed strategies are adopted, is very limited. In the graph

Graph 5



it can be seen that the choice is in all probability made between $i < i_1$ and $i \geq i_2$. The example considered previously in which $i_j = i_2$ is only an extreme case.

III.6. The No-Innovation Alternative

So far two alternatives have been considered: to modernize or to replace the machinery. There is always a third: to do nothing, leave everything as it is. As this is the least investment intensive alternative, it could be incorporated into the analysis by adding an initial period of inaction prior to the modernization investments, so to define a second optimum date ℓ' at which any investment commences. The study would be similar to the one already considered, but more complex. It is not certain, on the other hand, that this greater complexity makes for greater clarity. For this reason, an alternative treatment is preferable.

The method is to deduct from current values of each alternative the loss in profits which would have been obtained if neither alternative had been adopted. The choice between alternatives makes sense to the extent that both have at least a positive current value - once the deduction has been made - for all the values of ℓ within the planning horizon. If only one alternative reaches a positive value, there is no choice to be made: this is the only possible alternative. If neither reaches a positive value - no positive value - it is better not to innovate.

The negative weight of both uncertainty and the increase in interest rates on the two alternatives favors the solution of no innovation.

IV. COMPARISON BETWEEN PURE STRATEGIES

In order to complete this exposition, we shall discuss the most common example of choice between pure strategies.

Let there be two alternative projects $P_A \{I_A, C_A\}$ and $P_B \{I_B, C_B\}$, such that in each period j $I_{Aj} > I_{Bj}$ and $C_{Bj} > C_{Aj}$ (there may be exceptional periods when this condition is not fulfilled). In short, project A is more investment intensive.

The same income is assumed for both projects: only expenditures are compared. If, in addition, we consider I_A and I_B fully made at a given point of time (for the sake of simplicity), the formula

$$I_A - I_B = \sum_{1}^{n} \frac{C_{Bj} - C_{Aj}}{(1+r^*)^j} \qquad (9)$$

gives values for the rate of return r^* for which both alternatives have the same current value at point 0.

IV.1. Changes in i

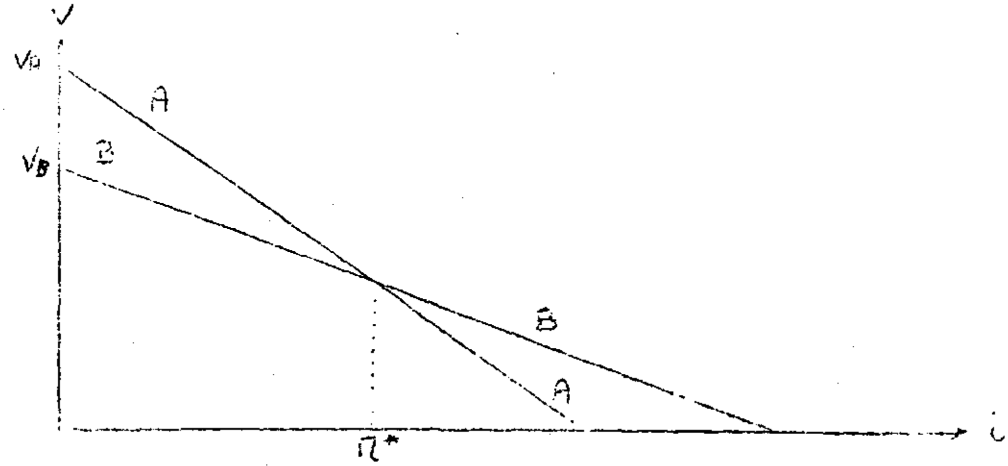
For $i < r^*$:

$$I_A - I_B < \sum_{1}^{n} \frac{C_{Bj} - C_{Aj}}{(1+i)^j}$$

that is, the additional costs deducted, implied by project B, are higher than the initial difference in investment. For $i > r^*$ the opposite is the case.

Thus, for $i < r^*$ project A (most intensive) is the most advantageous and for $i > r^*$ project B.

Graph 6



Therefore: the higher the interest rate, the more favorable the least intensive projects (the future counts less).

IV.2. Changes in the Planning Horizon n. (Uncertainty)

If $$I_A - I_B = \sum_{1}^{n} \frac{C_{Bj} - C_{Aj}}{(1 + r)^j}$$

for $n_1 < n$ the result is:

$$I_A - I_B \quad \sum_{1}^{n_1} \frac{C_{Bj} - C_{Aj}}{(1 + r^*)^j}$$

the shortening of the period from n to n_1 favors project B (less intensive). To find the new indifference rate of return r^{**} such that:

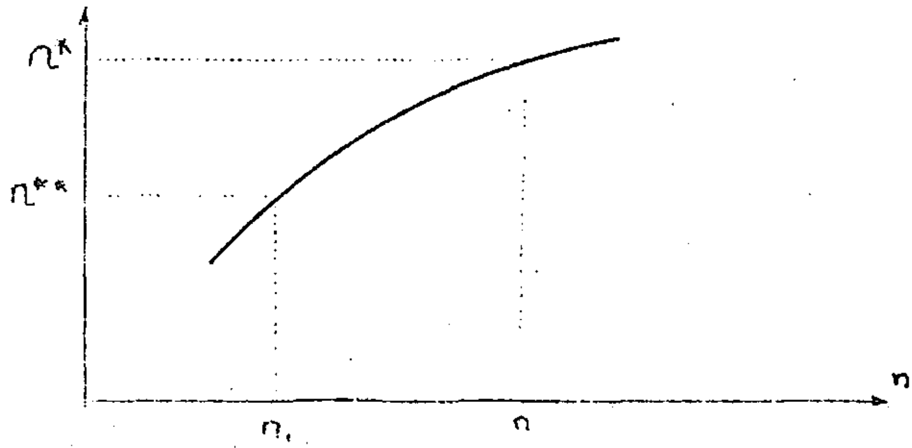
$$I_A - I_B = \sum_{1}^{n_1} \frac{C_{Bj} - C_{Aj}}{(1 + r^{**})^j}$$

it is necessary for $r^{**} < r^*$. Then the indifference return rate r changes in the same direction as the planning horizon n. If n increases, so does r^* and vice versa.

The drop from r^* to r^{**} when n falls to n_1 makes the order of preference between projects A and B change for the interest rates which lie between r^* and r^{**}.

For $r^{**} < i < r^{*}$ in the case of the horizon n, project A (more intensive) is preferred; conversely, in the case of the horizon n', project B is preferred. That is, the shortening of the planning horizon favors less intensive projects. The graph shows function $r^{*}(n)$.

Graph 7



IV.3. The Case of Positive Maturity Periods

For the sake of simplicity, we assume that the maturity period (1....k) for both alternative investments is the same. Then

$$\sum_{1}^{k} \frac{I_{Aj}-I_{Bj}}{(1+r^{*})^{j}} = \sum_{k+1}^{n} \frac{C_{Bj}-C_{Aj}}{(1+r^{*})^{j}} \qquad (10)$$

Let us call the first term I and the second C. Since in C, r is raised to values of j greater than those related to I, variations of C when r changes are greater than variations of I. That is:

$$\left|\frac{dI}{dr^{*}}\right| < \left|\frac{dC}{dr^{*}}\right| \quad \text{(both derivatives are negative)}$$

Then, if we take a period $n_1 < n$ (leaving k constant) the result is

$$\sum_{1}^{k} \frac{I_{Aj}-I_{Bj}}{(1+r^*)^j} > \sum_{k+1}^{n_1} \frac{C_{Bj}-C_{Aj}}{(1+r^*)^j}$$

for both terms to be equal r^* must be reduced to r^{**} ($r^{**} < r^*$). The result is similar to that obtained previously: the shortening of n gives higher priority to the less investment intensive projects.

Now let us suppose that the maturity period of the investments is k_1 and that the return rate r^* is such that

$$\sum_{1}^{k_1} \frac{I_{Aj}-I_{Bj}}{(1=r^*)^j}$$

and consider the example of a shortening of the maturity period from k_1 to k_2 such that $k_2 < k_1$. Then

$$\sum_{1}^{k_1} \frac{I_{Aj}-I_{Bj}}{(1+r^*)^j} < \sum_{k2+1}^{n} \frac{C_{Bj}-C_{Aj}}{(1+r^*)^j}$$

To make both terms equal it is necessary to raise r^* to r^{***}; this gives proportionately higher priority to the more intensive investment projects.

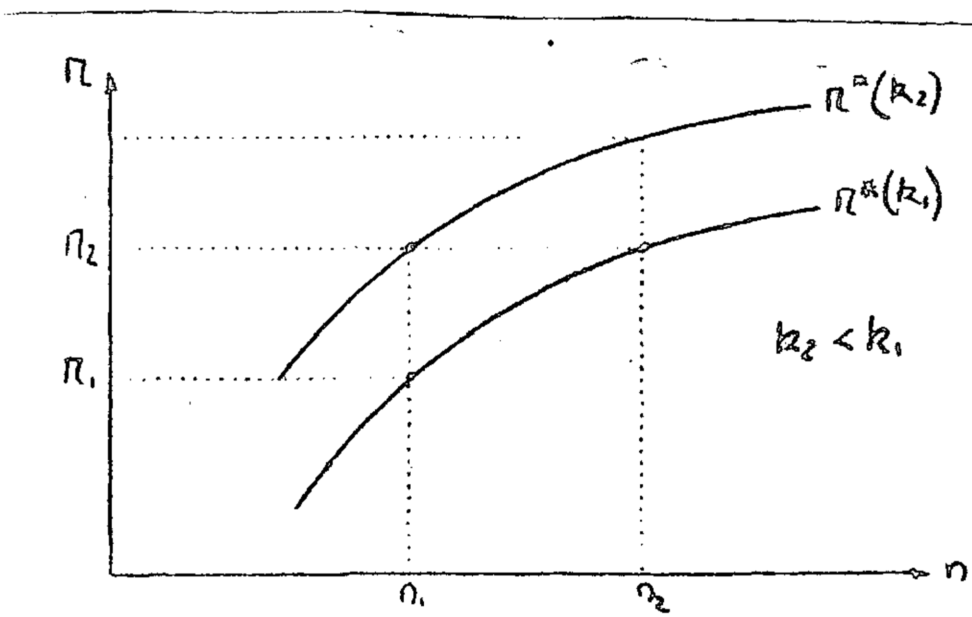
In Graph 8, the simultaneous effects of changes in the maturity period k and in the planning horizon n are summarized.

As can be observed, a reduction in the maturity period from k_1 to k_2 is equivalent, in terms of the value of the indifference return rate, to an expansion of the planning horizon from n_1 to n_2.

IV.4. Changes in Relative Prices

In order to evaluate the influence of changes in relative prices on the technological decision, it is necessary to weigh

Graph 8



their effect on the variables I_j, Y_j and C_j. This requires the incorporation of the analysis into an overall framework of relationships which may allow the form of the functions providing the values of those variables to be defined. It is also necessary to know the structure of relations between prices, in order to know which of them are independent and which are endogenous. In short, to evaluate the effect of changes in relative prices requires a detailed model of the overall economy.

As this lies outside the conceptual limits of this paper, we are going to take as an example a few simplified hypotheses to observe how changes in relative prices affect the technological decision. Let us consider three prices: the price of capital goods (Pk), the price of unskilled labor (Wn) and the price of skilled labor (We). Let us suppose that I^R, equipment replacement investment, depends basically on the price of capital goods, and that these are imported. In this way the investment I^R is relatively independent of the values Wn and We; let us also suppose that I^M, the modernization investment, is dependent on the price of skilled labor We, thus reflecting the effect of domestic learning; finally, let us suppose that the current operating costs C_j are dependent on the price of unskilled labor Wn.

Even in its extremely simplified form, the analysis may serve to obtain a preliminary idea of the possible effect on the technological decision of exchange rate and tariff protection policies, wage policy and the whole range of policies which affect the rate of domestic technological learning.

For the analysis we use the simplified version of formula (9), with instant maturity investments.

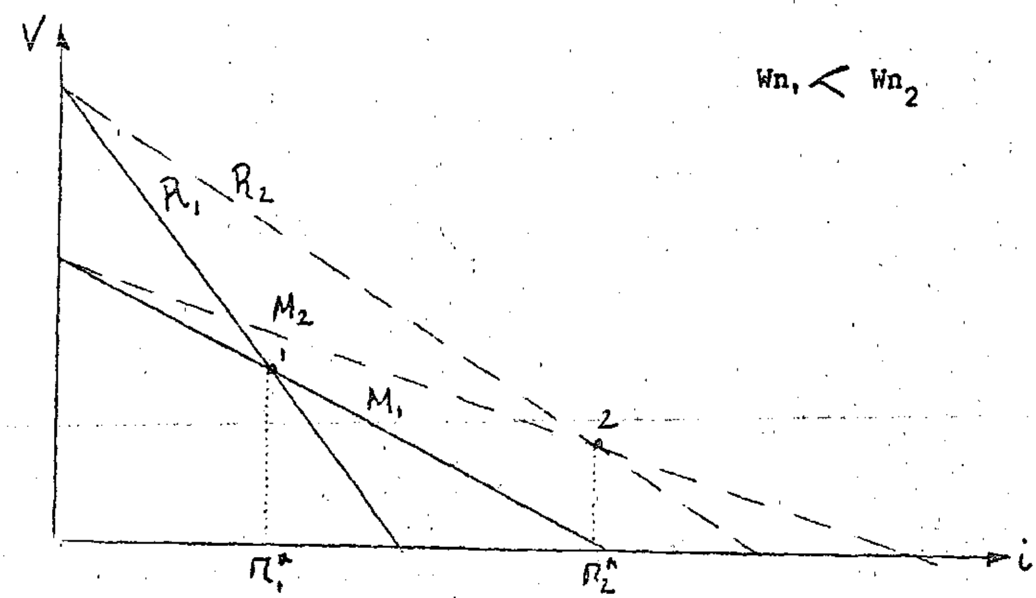
a) Increase in the relative price of unskilled labor Wc.

In formula (9)

$$I^R - I^M = \sum_{1}^{n} \frac{C_j^{M} - C_j^{R}}{(1+r^*)^j}$$

the increase in Wn leads to an increase in the term $C_j^M - C_j^R)$ since $C_j^M > C_j^R$.

Graph 9



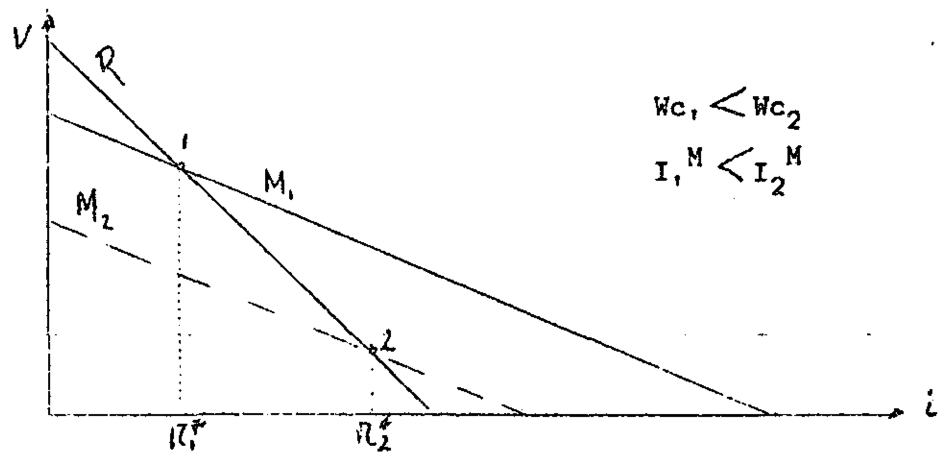
When Wn increases towards Wn_2

$$I^R - I^M < \sum_{1}^{n} \frac{(C_j^M - C_j^R)_2}{(1+r^*)^j}$$

so that to obtain equality r_1^* must increase towards r_2^*. This favors the replacement projects relative to the modernization ones.

b) Increase in the price of skilled labor Wc. Given the assumptions made, the increase in Wc increases the value of I^M.

Graph 10



As a result of the increase in I^M:

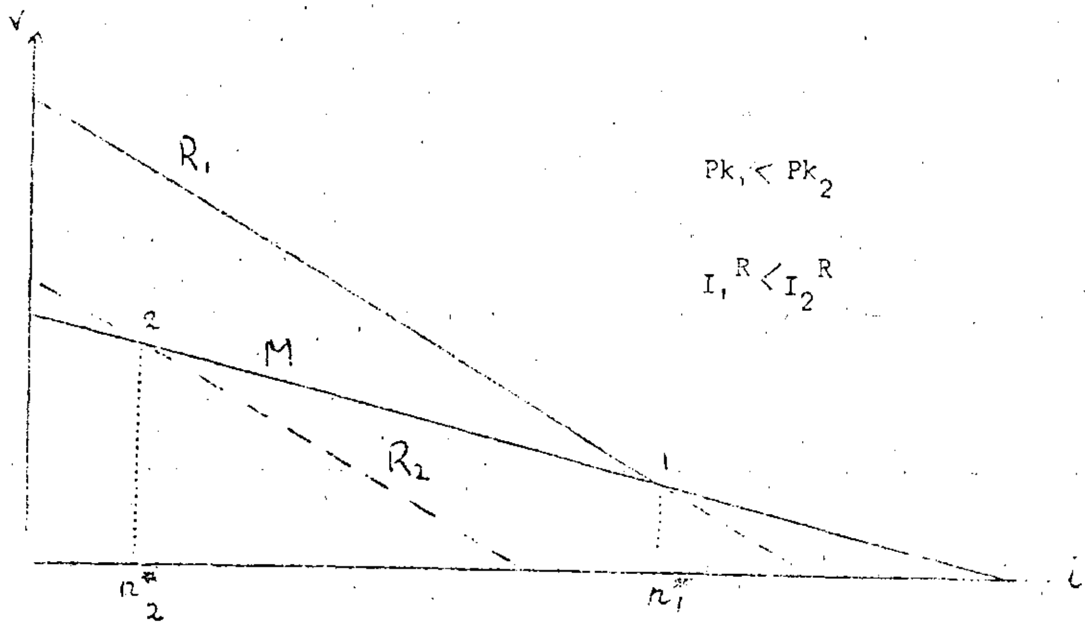
$$I^R - I_2^M < \sum_{1}^{n} \frac{C_j^M - C_j^R}{(1+r_1^*)^j}$$

then, in order to be equal, r_1^* must increase towards r_2^*. The increase in the price of skilled labor tends to favour replacement projects over modernization ones.

c) An increase in the price of capital goods Pk (as a result, for example, of a relative increase in the foreign exchange rate).

Given the assumptions made, the increase in Pk increases the value of I^R.

Graph 11



As a result of the increase of I^R:

$$I_2^R - I_M > \sum_1^n \frac{C_j^M - C_j^R}{(1+r_1*)^j}$$

then, to be equal, r_1* must fall to r_2*. The increase in the price of capital goods favors modernization projects over replacement ones.

V. THE INFLUENCE OF MACRO-ECONOMIC VARIABLES

In the foregoing argument three macro-economic variables were taken into consideration: 1) the degree of uncertainty; 2) the interest rate; and 3) relative prices. Each one of them covers in turn a number of variables linked to decisions connected with economic policy and with the general conditions of economic behavior. The degree of uncertainty refers to the expectations of the economic agents with respect to the future, and to the economic and political conditions which may affect the technological decision. The interest rate reflects the influence of the financial market. The relative prices take into account the wage and prices policies, the exchange rate, and the tax structure.

There remain, however, some macro-economic variables not taken into account in the analysis. Of these, the main one is the rate of growth of the economy, whose principal effect on technological change is through the incorporation of new productive units.

The virtue of the model is that it presents the operation of the whole range of variables in a single compact formula, as shown in the graphs. The decision is summarized in the calculation of one variable: the equilibrium rate of return of the interest rate. It is conceivable - if there were an underlying economic model - that an alternative graph could be worked out in which the definition variable might be a particular relative price. But it is more straightforward to subsume under the return rate r^* the whole range of variables which affect the technological decision.

Theoretically, it is sufficient to find out whether r^* is greater or smaller than i in order to know whether to opt for replacing or modernizing the machinery. This conclusion depends strictly on the assumption that the total influence of uncertainty is fully absorbed via changes in the planning horizon. Although this is the most convenient procedure - to adjust the repayment period - it is not universal. An alternative procedure is to demand a higher r^*, keeping the repayment period the same, which implies adding an extra amount to the effective interest rate to cover the risk.

Having made that qualification, the proposed formula provides an immediate pragmatic criterion to decide which technological decisions are likely to be affected by changes in macro-economic variables and which are not. Let us suppose that the historical range of variation in the interest rate in a particular economy is $(i_{min} \dots i_{max})$. This variation reflects the change in macro-economic conditions as far as monetary and financial performance, and the relations between saving and investment are concerned. We shall now consider the value of r^*. This value is determined by the characteristics inherent in innovation, by those specific to the firm in which such innovation is to be carried out and by the macro-economic conditions connected with relative prices and expectations. All of them are susceptible to variations and are affected, therefore, by some degree of uncertainty. Note that even uncertainty with regard to the strictly technical return of the innovation is included. All this produces a range of variation for the values of r^* which can be identified by the period $(r^*_{min} \dots r^*_{max})$. In which case can it be said that the decision to make technological innovations is sensitive to the changes in macro-economic variables? When both variation periods $(i_{min} \dots i_{max})$ and $(r^*_{min} \dots r^*_{max})$ overlap. In that situation, whether it be a modification in price relations or in interest rates or in expectations with regard to the future, it is liable to change the technological decision to replace instead of modernizing the machinery or vice versa. In the opposite case, that is, when the values of r^* in the period $(r^*_{min} \dots r^*_{max})$ lie completely below or above the values of the period $(i_{min} \dots i_{max})$, the decision to innovate is completely immune from the influence of changes in the macro-economic variables.

What precisely does this immunity mean? It means that there is a dominant technological alternative throughout the whole spectrum of foreseeable values of the interest rate. For example: investment in equipment of low cost relative to the total investment, but whose function is complementary to that of the totality of the plant machinery, or to the functioning of labor - as in the case of a tool - has very high returns - as it allows the whole to function - and as a result it has a very high r^* in comparison with the expenditure and returns which would be required by its repair and modernization. In that case the purchase of new machinery is definitely profitable; that is, whatever the situation regarding the macro-economic variables. In the contrary case of immunity we can cite the example - usual in processing industries - of very high replacement costs, arising not only from investment in the equipment itself, but also from the interruption to the manufacturing process, so that r^* is very small - or negative - and the clearly dominant alternative is to modernize the machinery in use. In both situations it is very unlikely that any modification in the macro-economic variables may change the choice between alternative technological routes.

It is possible to ask to what extent this criterion of decision which, in the final analysis, reduces the criteria of choice to determining if r^* is greater or smaller than i, the interest rate, is realistic. A long post-Keynesian pragmatic tradition tends to undervalue the importance of the interest rate in its effects on entrepreneurial decisions. A first line of defence of the criterion presented is to assert that this tradition bases its argument fundamentally on the uncertainty involved in the determination of r^*. But uncertainty - arising as much from technical as from micro- or macro-economic causes is taken into account in the variation period of r^*. So that for the purposes of the analysis, the entrepreneur acts as if he were implicitly taking into account the relation between r^* and i, even when the problem is not set out explicitly in that way. But, secondly, the value of r^* is an expression of the profit requirements of the technological decision and, therefore, is directly connected with the dominant consideration in entrepreneurs' behavior.

V.1. Influence of Long Run Variables

In long run analysis the predominant effect on technological decisions is that of relative prices. The typical long run analysis is that which relates to comparisons between countries or between different periods in the same country. A pure analysis is that which eliminates the possible effect of other variables, selecting for the comparison the same innovation in the same industry.

Let us take up again the analysis of the simple three prices model studied in IV.4. Let us consider the price of capital goods (Pk), the price of unskilled labor (Wn) and the price of skilled labor (Wc).

In countries which produce new technology machinery the relationship between these prices tends to be stable. This is due to the fact that in the production of capital goods the cost of both kinds of labor represents both directly and indirectly, through inputs, important components of the total cost. The proportion is stable to the extent that profits do not undergo significant variations, which is infrequent. In the same way, the costs of modernizing machinery in use also include the costs of both kinds of labor. Hence the relationship between replacement, modernization and working costs tends to be stable. Over time they gradually alter because of changes in the degree of market imperfection and due to technical progress in the capital goods producing industries.

The stability of this relationship allows a sort of pattern of behavior relating to technological decisions. The size of the range of variation for the values of r^*, $(r^*_{min}...r^*_{max})$ is minimal and so is that for the values of i, $(i_{min}...i_{max})$, exept in extremely recessive or inflationary conditions. This is the reason why the attention given to the macro-economic variables in the literature on technological innovation decisions, written in the industrialized countries, is slight and the analysis concentrates on the micro-economic and engineering variables.

The situation is different in technology-importing countries, because the price of capital goods is, to a large extent, independent of the cost of labor. There is domestically manufactured production machinery and also expenditure on domestic labor (transport, installation, testing, etc.), even for foreign machinery, but the main portion of the cost of investment depends on the international price of the machinery, on the exchange rate and on the tariffs levied on its importation, and this is most marked in the case of machinery of recent technology.

In the absence of a micro-economic relationship between the prices of capital goods and of labor, the fundamental relationship which operates is of a macro-economic nature. But this relationship lacks the inherent condition of stability which characterizes the other one. In fact, this relationship is usually highly unstable; to prove this it is sufficient to observe the historical fluctuations in the relationship between the exchange rate and the nominal wage in most Latin American countries. Periods can also be distinguished in which high tariffs are levied on imported capital goods, and others in which these goods are imported freely, or even subsidized. Neither should the existence of many specific situations in which ad-hoc policies are applied be ignored. In short, this disparity of policies and the instability resulting from the price of capital goods makes the level of these prices very difficult to define conceptually. A theory of their definition necessarily demands a step back to look at the problem of the factors determining economic policy. In this way - given that the price of capital goods is "chosen" in the context of a specific economic policy - a whole group of elements of a more general order, including those of a social and political nature, are incorporated into the decision analysis.

The determination of the price of both skilled Wc and unskilled Wn labor, is, on the other hand, of a more structural nature. The relationship between these prices basically reflects the relative abundance of each kind of labor. It is to be expected, therefore, that, except in periods of great expansion, those countries with a wider and more complex industrial experience will be those where skilled labor is relatively cheaper. The relationship W_c/W_n - price of skilled to unskilled labor - should decrease with the degree of development of each economy. In those conditions, those operations should be favored - in the more industrialized countries - which require a relatively greater use of skilled labor; that is, a priori, in these countries a greater tendency to the modernization alternative is to be expected. There are many examples of it. The modernization option - in the same way as the option to build the necessary machinery locally, or to carry out Research and Development activities - arises and becomes stronger in countries where skilled labor is available. This was clear in the analysis in section IV.4 b): a reduction in the price of skilled labor tends, ceteris paribus, to reduce the value of r^*, and therefore to favor modernization projects.

This general statement, however, deserves qualification. This qualification refers to the definition of skilled and unskilled labor. The degree of skill is directly related to the task to be performed; essentially to the degree of novelty and complexity of the particular task. So that the concept of skill is usually of a very specific nature. This does not imply ignoring the fact that the productive system is permeable with regard to the diffusion of skills and abilities of universal application generated in an industrial society as a whole. However, in many industrial activities, there are areas of production, and related innovations, requiring specific skills which can only be achieved through past experience in the area itself. In many instances, these skills arise from abilities developed in situ by a technical team during a particular period and are, so to speak, inherent in relation to the rest of the industrial activities, even those in the same branch of production. In other cases, there are skills highly developed in traditional craft and pre-industrial activities, consideration of which forces us to be careful when utilizing overall concepts of abundance or scarcity of qualified labor.

These qualifications having been made, the general consideration still remains. In technology-importing countries where a relatively long industrial experience exists, the ratio between the price of capital goods and the cost of skilled labor is usually relatively high. This may be due as much to protectionist tariff policies which cause a higher price for capital goods, as to the relative abundance of skilled labor, or to both effects combined. This higher relative price leads to lower values for r^*, and then favors the alternatives of utilization and modernization of the old machinery. In this way it is possible to explain the continuing profitable use of technologies which have been discarded in other more industrialized countries. Paradoxically, in countries of very recent industrial development, a greater absorption of the latest technologies is often observed. In terms of the analysis carried out in section IV.4, this is the result of a relatively low Pk/Wc ratio - similar to that observed in highly developed countries - caused both by non-protectionist capital goods importation policies - since there is no-one to protect - and by the high price of skilled industrial labor. The effect is to give r^* high values and, therefore, to favor the purchase of new machinery.

This apparently paradoxical behavior can be observed when the use of technologies in certain areas of economic activity is compared between the countries of the southern triangle of Latin America, with an industrial tradition going back to before the First World War, and those of the Caribbean area, more recently industrialized. One example is the continued use of the first Siemens-Martin electric furnaces in the steel industry, furnaces which are obsolete in the rest of the industrial world and which are not installed in the new plants in less developed countries. Another is the almost universal use of traditional building techniques instead of the more recent technology of modular units which are adopted in the Caribbean countries. Many examples are provided by the service sector, where the early urbanization process has given rise to the development of a wide spectrum of qualifications. A very clear case is that of the different technological strategy adopted by the same tobacco companies - American or English in origin - in each kind of country: while in the companies located in the Caribbean countries the latest existing technology was adopted, in those in the Southern Triangle, machinery two or three decades old continued to be used after several remakings done by domestic engineering teams.

V.2. The Influence of Short Term Variables

In countries which have begun the industrialization process in the last half century, backed up by the expansion of their own internal market, an almost universal characteristic is the unstable behavior of the economy. Relative prices, the level of activity, the direction of economic policy all suffer fluctuations of a magnitude not to be seen in older industrialized countries. This is clear in the examples of Argentina, Chile, Brazil and, to a lesser extent, in most Latin American countries.

The ultimate reason for this instability lies in the difficulties of the process of capital accumulation. Growth, for countries undergoing industrialization, is unbalanced, not by design, but as a consequence of the scarcity of resources. There are investment indivisibilities which make it necessary to select a few priority sectors and direct savings towards these. Thus, a sequence of different stages of industrialization can be recognized, each one being identified by the prominence of a particular sector of production: food processing, textiles, light durables, transportation, capital goods, chemicals and steel, communications, etc. At each stage a double problem has to be solved: first to transfer income via changes in relative prices, and fiscal and monetary policy - from the economy as a whole to the priority sectors; second, the creation of a market for these sectors, expansive enough to guarantee the profitability of the operation. To this economic problem, difficult in itself, is added that arising from the resistance of the groups which have been pushed aside, and the workers, to those income transfers which damage many and benefit only a few. This resistance shows up, economically, in the phenomenon of inflation, and, politically, in the building up of a powerful - although transient - coalition of groups opposed to the strategy in force. Hence, the relative brevity of each pattern. In the next step, under a different political arrangement, a new strategy is devised: income transfers change direction. Since resources are still too limited to satisfy everybody, some privileged groups emerge. The new coalition breaks down and the story recommences.

Within this context, in each short-term situation, not only the policies designed to solve the problems of the short run - inflation, balance of payments deficit, recession, etc. - appear, but also those policies which propose a definitive solution for the long-term project. There is a long-term component incorporated into the short-term policies, which is expressed in the measures designed to encourage certain productive activities and discourage others.

In these conditions, firms'expectations are essentially confined to the short term. What they are interesting in evaluating is the orientation and the probable duration of the economic policy in force. An increase in the rate of inflation is an indication of its weakness and a precursor of its substitution. The information provided by the economic indicators fulfils less the function of indicating what the probable development of the economy will be in the more or less immediate future - which is its accepted function - than of giving information on the state of the political health of the economic management and the likelihood of its lasting.

These considerations, taken together, are grouped under the evaluation of the uncertainty variable of which we made use in the formal analysis of the decision problem. As was shown in III.4, the effect of an increase in the degree of uncertainty is to postpone the decisions to incorporate new machinery and with it the introduction of the most up-to-date technology. In turn, as was seen in IV.2, this same increase favors the less capital intensive alternatives: machinery modernization projects over those for replacement with new machinery, and the use of own resources and skills rather than outside contracts.

These are the reasons which favor the apparition of supplementary technological developments, so characteristic of the industrialized countries of Latin America. Forewarned by the uncertainty of economic programs against the high risk of investments which depend on long-term returns, firms create a number of technological skills designed as substitutions: adaptations, changes, improvements, tricks and even sorcery */. Consequently, there is a whole indigenous industrial culture, based more on ingenuity and skill rather than on science, designed to provide this supplementary technology. This visible phenomenon, which borders on craftsmanship, and the technical reasons which justify it, are the result of the same basic conditions which affect all economic behavior: the weakness of the agents and the precarious nature of the capital accumulation instruments.

The dependence of technological decisions which imply high investment expenditure with respect to the orientation and anticipated duration of the economic policy in force, can be very clearly shown by the behavior of the Argentine cement factories. Technology in these plants is on the world frontier. However, the technological replacement process is not continuous; it takes place in stops and starts. These forward jerks take place at the start of periods of application of stabilization policies by right-wing authoritarian governments. These same investments were postponed throughout the previous period of populist orientation and occur

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*/ A remarkable example is that of Acindar's iron and steel plant in Rosario, studied by Philip Maxwell.

suddenly at a time when, paradoxically, a recessionary period in economic activity begins.

But dependence with respect to economic policy appears in a more concrete and real way than the ideological or psychological manner suggested by this example. Since instability is a short-term phenomenon, one might think that long-term projects will face a considerably smaller degree of uncertainty. It is apparently easier to predict what the economic situation in one of these countries will be in the year 2000 than to forecast what will happen next year. It is less risky, for example, to estimate the volume of demand for steel in 10 or 15 years and even the likely price, than to do the same thing with regard to the policy on steel to be imposed by the State, not only in 10 years' time, but in the intervening period and even in the following year. For this reason, the immediate profit - two or three years at the most - of any project is the decisive factor. For such restricted planning horizons the return rate can only be positive if huge subsidies can be counted on. Projects are particularly impracticable if they are carried out with loans at positive interest rates. The dependent nature of any decision in relation to economic policy thus takes on a very concrete character: the project is carried out or not according to the amount of subsidies obtained. This is basically for long-term projects and large-scale investments, but applies to a lesser degree to all others.

V.3. Interest Rate

By considering the interest rate as a variable, we synthesize all the financial conditions faced by firms. There is not a single interest rate for each company. They may draw on their own funds and obtain credit both within and outside the institutional market.

The capital market, in economies like those dealt with here, is neither unique nor transparent. As in each accumulation "model" price relations are strained to favor the priority sectors; in the same way, the institutionalized financial market is also orientated in their favor. Usually it applies relatively low interest rates on its operations in order to borrow and lend. However, this gives rise to secondary financial markets, with higher interest rates.

In these conditions, the interest rate facing firms is an increasing function of their need for funds. In the first place, firms call on the institutionalized market, where they pay the lowest rates, then on their own funds, whose opportunity cost is derived from the rate determined in the free market, and finally on non-institutional credit - suppliers, for exampel - on which an additional risk premium is charged (this premium increases according to the increase of the firm's indebtedness.

The institutionalized market is a rationed market suffering from excess demand. It discriminates in granting credit according to its destination, line of activity and the qualifications of applicants, on the basis of criteria arising from the orientation of economic policy and the practices of financial institutions. These criteria are not always the same. Furthermore, it is a market with a variable supply, this latter characteristic deriving from its limited capacity to attract private funds, which makes it dependent on the Central Bank's will to supply it with funds by means of the rediscount mechanism.

These characteristics of the behavior of the official financial market have their effect on the technological decision of the firms by establishing differential situations. In the cases in which the decision to replace the machinery is backed by credit from the official market, it is much more likely to be adopted than when such backing does not exist; the lower interest rate favors the alternative of replacement over that of modernization. The criterion applied to the rationing out of credit thus affects the technological decision directly and differentially. The extension of the rediscount policy in turn determines periods of easy or difficult credit and it is one of the important variables which regulate the spasmodic pace of technological innovation.

The process of indexation of the value of debts, which has taken place recently in Latin America, has to a great extent moderated the difference between the official and unofficial markets. Firms now move in a context of positive interest rates, although uncertainty with respect to the level of such rates still exists. For non-indexed credits at rates high enough to exceed the expected inflation rate, as is the normal practice in unofficial markets, the entrepreneur's risk lies in tha chance of his having to pay very high real interest rates; for indexed credit the risk arises from the negative disparity between the level of price increases which the firm receives and the indexes according to which its debts are adjusted. In such cases the expected real interest rate, as it is perceived by the entrepreneur is higher than that resulting from a simple subtraction of the average value of the expected price rises from the nominal rate. In these conditions a reduction in the rate at which new machinery is incorporated is to be expected. Naturally, this conclusion is valid as long as the profit expectations of the firms do not rise.

In any case the interest rate is only one among the set of possible economic policy instruments. Those investments in machinery which, for reasons of low reliability of profit expectations, require negative interest rates, will claim, as a compensation for the credit indexation policy, other additional subsidies to make these rates possible. From the analytical point of view, the compensatory measures can be included in the model as having an effect on the values of r and of i alternatively.

VI. DIFFERENTIAL BEHAVIORS IN PRODUCTIVE ACTIVITY

Studying the state of technology in the overall productive structure, particularly in the industrial sector, reveals different behaviors between areas of activity and between firms in the same area. For example, it is obvious that the proximity to the international frontier of the technology used in a given country differs according to activities. There are some in which the world's most advanced techniques are applied (for example, in the cement industry); whilst in others, firms continue to function profitably with machinery belonging to technologies developed several decades ago and which, in highly industrialized countries, have long since disappeared. Another example of differential behaviors is that of the greater or lesser technological heterogeneity between firms in the same area of production, according to the area. There are sectors in which all firms have the same technology, while in others samples of technologies of different vintages can be observed.

In principle it is obvious that firms are not equal and it is normal for them to exhibit different behaviors. The whole area of studies of industrial organization is designed to investigate the technical reasons for, and the micro- and macro-economic factors which determine, these differences. In that sense technological behavior is simply a part of the whole picture. But without ignoring the complexity of the matter and the inevitable bias of an analysis carried out within the limits of this paper, we try to set out some hypotheses of a generic nature based on the variables used here: type of production, nature of the market, degree of concentration, qualifications of labor, rate of growth etc.

The first topic is that of relative prices. This is the variable traditionally used in static analysis, to explain the simultaneous use of different techniques. Its applicability is clear when it is a matter of comparing firms of the same industry in different countries. But as has already been shown when the topic was studied earlier, relative prices are calculated in the context of economic policies which obey a particular operating and expansion model for the economy as a whole. For example, if we examine the spectrum of different technologies used in the Latin American steel industry, it is necessary in the final analysis to make reference to variables such as the nature of the ownership of firms, income distribution, the degree of openness of the economy and that of the particular area, the growth rate etc. This analysis will show that, independently of reasons of a micro-economic nature that have affected each technological decision, the final result, which shows different distributions of techniques in use across countries, responds finally to the way in which those macro-economic variables have been arranged. This is chiefly valid for the steel industry due to its central role in any process of economic development.

The effect of relative prices on the technique chosen in some cases acts, not directly, but rather by meas of its influence on the scale of production. The appropriate example here is that of the building industry. This is an interesting sector for many reasons. In the first place, it is a sector in which the technological decision is practically unaffected by the short-term fluctuations of economic variables, but has a clear structural dependence with respect to the long-term level of some of them. Building is, furthermore, a common example of the persistence of traditional techniques in competition with new ones. A significant indicator in several countries is that of the constancy over time of the productivity value per man employed. In this case the decisive relation is that between the price of urban land and the price of labor. It is not a question of substitution between capital and labor, because the most modern techniques not only save labor, but also capital - and the latter in even greater proportion - in so far as they allow building to be carried out more quickly and thus reduce the time during which capital accumulated in the building itself is inactive; The increase in the price of urban land, relative to labor, increasingly inhibits the use of intensive techniques in the utilization of machinery which is only profitable on sufficiently high scales of production. Here the economy of the plot appears, which determines the technological choice and which allows the continued profitable existence of traditional techniques, and in the same way the sector's opennes to new entries and the high elasticity of supply at constant prices. Now, overcoming the limitations imposed by the plot on the scale of production depends, on the one hand, on the price of urban land, and on the other, on the economy's capacity to channel the necessary funds to pay for finance adequate for such a scale; it is at this point that the effect of the structural macro-economic variables becomes evident. Because, although the plot phenomenon is universal, in highly developed societies it is not unusual to observe that even with high land prices, finance can be obtained to allow extensive programs of urban renewal to be carried out, whereas in early industrial societies, with relatively small cities, this is also possible because the price of urban land - perhaps not in downtown itself, but a short distance away - is sufficiently low for it to be financed. Different is the case of medium economies with longstanding urban settlements and property distribution and limited capacity for finance. These are typically the countries where "technical backwardness in building" is found.

The relative price variable is not the only one. The formal analysis of the first part of this paper has shown how that variable interacts with others normally excluded from a static analysis. The expectations variable has been considered. It is associated with uncertainty because in economies like those studied here, uncertainty is a chief component in the expectations function.*/ It is for that reason that this function has been analyzed in the short-term context. Nevertheless, if economic instability is a persistent, or simply a recurrent phenomenon and the expectations function therefore always reflects a relatively high degree of uncertainty in relation to the future, it is to be expected that instability be incorporated as a long-term structural variable. What differences in technological response occur in countries with a different degree of economic instability?

One answer to this question arises from the comparison of the behavior of a particular industry in different countries. The uncertainty variable operates together with the variables considered previously and its evaluation must be subject to empirical proof. But both for the choice of industry and for a better comprehension of the phenomenon it is appropriate first of all to set out the conditions which make the above-mentioned variable more or less relevant according to the industrial area analyzed.

The question raised is to determine what degree of protection is offered by the economic conditions themselves or by institutional arrangements against unpredictable variations in price relations or changes in the level of activity. A first condition is connected with the market: there are areas of industry with a highly elastic demand which undergo severe fluctuations in their level of activity because of modifications in relative prices; State suppliers suffer the instability characteristic of a public sector with an inherent tendency to increase its deficit; sectors such as agriculture and livestock, or exportables, whose prices are regulated according to variables - such as income distribution, for example - which they cannot control, find it difficult to absorb cost increases. These

*/ In other words: the variance of the expectations function is as, or more, important than its mean value.

are all situations in which instability is a permanent component of entrepreneurial decisions. The resulting policy is conservative as far as investment and technology are concerned, unless by means of institutional arrangements some protection mechanism is set up (weighted prices to State suppliers, credit to encourage agriculture and livestock producers, export subsidies, etc.).

One example of the adoption of technologically conservative policies related to experience of instability is provided by the frozen meat industry. The meatpackers are sandwiched between export prices, which depend on export markets and the foreign exchange rate, on the one hand, and the price of cattle, determined by domestic prices, on the other. Since these two markets are to a large extent independent, the industry faces chronic uncertainty with regard to the relation between its prices and costs. Supply traditionally had an oligopolic structure made up of a small number of English and American owned establishments. To this fact has been attributed the extremely conservative policy of firms, particularly in relation to finished products and technology. When the world meat market underwent a sharp change in the mid-sixties, with the large scale incorporation of the continental European markets, replacing the sale of frozen joints with separate cuts, these meatpackers were unable to adapt to the new conditions and went out of business. They were replaced by a number of smaller meatpackers with varying degrees of specialization. The fact is that these new meatpackers, within a short time, suffered the same unstable conditions faced by the former ones and responded in a similarly conservative fashion with regard to technology, despite the fact that the strong oligopolistic nature of supply had disappeared.

The automotive industry, although facing a flexible demand with respect to income, and therefore experiencing markedly cyclical activity, has in its favor the inelasticity of its supply price, which, together with its oligopolistic structure, allows it to safeguard itself with profits higher than the uncertainty derived from fluctuations. The relatively moderate pace of progress in technological development is less a local characteristic than a universal phenomenon in industry. This case throws light on an aspect which, although inherent in every area of production, has been excluded from the preceding analysis: the speed of expansion of the international technological frontier. The fact that attention is concentrated on those sectors where a significant process of technological change is taking place must not make us forget that these situations are the exception and that in a considerable proportion of production the technology is relatively stable.

The textile undustry is one of the most interesting cases in connection with the effects of economic stability on the technological structure of industry. Demand is elastic with respect to price and income and, therefore, the area tends to behave unstably. Part of the fluctuation is absorbed through the industry's control over the main raw material, cotton; in this way, the industry transfers the price fluctuations of the final market to the producer of the raw material. This compensation is only partial in that it does not safeguard firms against variations in the level of activity; there is also a minimum price for cotton determined either by government control, or by the export price. In such conditions, firms' profits are extremely vulnerable to changes in macro-economic conditions. But the picture is not uniform throughout this industry. The textile area is characterised by the presence of a central nucleus of large integrated*/ companies and a large number of medium and small establishments. There is a tendency to greater specialization the smaller the company. During the depressed phases of the cycle, the larger firms make inroads into the market of the peripheral ones, thus offsetting the fluctuations in demand for their own products, but increasing the severity of the fluctuations affecting the others. Instability increases the smaller the size. Technological behavior is therefore different: the planning period for investment tends to be reduced along with size; the larger firms, ceteris paribus, favor machinery replacement while the smaller ones tend towards modernization, or even to maintenance of the machinery in use. Similar situations can be found in the sugar and paper industries. The result is the existence of a heterogeneous technological structure with machinery of different vintages operating simultaneously within the industry.

Furthermore, this phenomenon of technological heterogeneity is favored by the existence of a second-hand market for production machinery. The functioning of this market is not guaranteed for every type of machinery, but rather is an exception. The necessary - although not sufficient - condition, for the existence of such a market is the technical possibility of using the machinery for different purposes. These purposes can be either different products or qualities or markets. In general the machinery follows a degradation process with regard to the purpose for which it is used, going from tasks with more rigid specifications and a lesser degree

*/ Integration covers spinning and weaving. In the case of larger firms it includes dyeing and, very exceptionally, ginning (cotton).

of tolerance, to others with fewer requirements. The effect of this market is to favor machinery replacement, moving towards more modern technologies in the first line companies, transferring used machinery to the dmaller ones. This process is clearly visible in the metalworking and textile industries. The result is a pattern of technological heterogeneity which, in the final analysis, is no more than the reflection of the heterogeneity of supply, synthesized in the simultaneous existence of the central nucleus and the peripheral companies in the area.

In the tobacco industry the instability of demand, determined both by the fluctuations in level and by the price policies imposed periodically by the government, also contributes to a conservative technological strategy. The periods of machinery replacement have coincided with times of expansion of demand - which are not frequent - but the predominant phenomenon is that of fluctuation. As the industry's supply is a closed oligopoly, it is characterised technologically on the one hand by its homogeneity, and on the other, by its distance from the technological frontier.

As a contrast, the cement industry, which is also a closed oligopoly, has a homogeneous technological structure, but lies close to the international frontier. There are two variables whose different behavior explains this difference; the first is the rate of growth of production; the second is the degree of market information being dealt with. The demand for cement also fluctuates fairly sharply, but the fluctuations occur in a context of rapid long-term growth, so that there is a requirement for increased capacity to allow the incorporation of new techniques. But, furthermore, the buyers of cement, whether they be construction companies or, indirectly, the public sector, are informed buyers who demand products incorporating the most advances technology. Thus, there comes into play a technological variable not yet referred to: the replacement of production machinery as a consequence of the replacement of the product launched on the market. In this kind of decision - which can be analyzed by extension with the theoretical instruments set out previously - the short term is relevant. It is not a question of deciding for replacement or not, but the most opportune moment to carry it out. In the cement industry this moment follows almost immediately on the discovery of the existence of an innovation, given the fact that clients are very well informed. On the other hand, in the tobacco industry, the decision can be postponed for a long time. The introduction of the filter cigarette, which only required adaptation of the machinery, was carried out rapidly after its appearance in the United States; cigarettes with low tar and nicotine content, which require its replacement, are being postponed until the public is somehow fully informed or the government demands it.

The availability of skilled labor is, as has been shown, a basic variable in technological choice. But it is difficult to apply this variable to the analysis of the differential behavior of firms without a detailed study of each specific case. The concept of skill has a specific and ad-hoc component in every activity and technique, which allows little possibility of generalization. The availability of more highly skilled personnel in principle favors the retention of existing technology because it allows the adaptation and maintenance of the machinery in use at a more profitable level. It is not clear, on the other hand, if this greater skill encourages the incorporation of new techniques or not. That depends on the degree to which the specialist knowledge is peculiar to the pre-existing technique or may be transferred to the new one. In order to know this, it is necessary to consider each case separately.

Finally, the most important variable: the direction and bias of general economic policy. This policy defines which sectors are to be given priority and which not. The total amount of tax and subsidies, of riskless markets and guarantees of profit levels above a minimum, allow those sectors defined as of high priority to overcome all the limitations and unfavorable circumstances which might delay the incorporation of new technology. In the case of large projects, these subsidies, assurances and guarantees become indispensable requirements for the introduction of the new technology. The size of these privileges is conditioned, as has been said, by the length of the foreseeable period they will be in force. The priority sectors rotate. But if there is a long-term bias, it favors new industries, those so-called dynamic industries, which substitute imports. For a time these industries show the fastest rate of technological change. But this pace does not always go on. Neither is there any reason to associate this condition of priority with efficient technical management of the technology incorporated.

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