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THE ROLE OF TECHNOLOGICAL PROGRESS AND ECONOMIC COMPETENCE IN ECONOMIC GROWTH: A Micro-to-Macro Analysis

by

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The Role of Technological Progress and Economic Competence in Economic Growth: A Micro-to-Macro Analysis

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Abstract

Economic growth requires both technological progress and economic competence. Technological change is often represented as (exogenous) outward shifts in the production possibility frontier (opportunity set) over time. The forces which generate and push out the production possibility frontier may be referred to as a *Technological System*. This paper focuses on *economic competence*, i.e., the ability of firms or other economic agents to take advantage of the business opportunities to which the production possibility frontier gives rise, or to influence the opportunity set itself, and on the importance and implications of interaction between technological systems and economic competence, i.e. the relationship between pushing out and exploiting the opportunity set. The analysis relies on extensive use of the micro-based macroeconomic simulation model of the Swedish economy (MOSES).

In the first part of the paper it is shown that in a ten to fifteen-year perspective, very substantial technological progress is required in order to yield the same macroeconomic results as fairly modest increases in economic competence. In other words, the allocation of resources within the production possibility frontier is at least as important as pushing out the frontier.

In the second part of the paper, a more thorough analysis of certain aspects of economic competence and their role in the macroeconomy is undertaken. An important implication of the results, if borne out in further analysis, is that while it cannot be denied that technological progress is essential for economic growth, the ability of firms to take advantage of the business opportunities generated by new technology is probably just as important. And while there is still a gap in our understanding of the linkages between technological progress and economic growth, the gap is even wider when it comes to understanding the role and nature of economic competence in economic growth. In fact, our study has just begun, and this paper represents only one of the first steps of what is likely to be a long journey.

Another implication is that it might be advisable to shift the focus of economists and public policy makers away from being almost exclusively oriented towards generating technological progress towards being more concerned with the exploitation of business opportunities. It is suggestive that even though the United States outspent its economic rivals in industrial R&D for several decades, other countries, particularly Japan but also other countries such as Sweden, took advantage of new technology created in the United States, sometimes with more success than the American firms.

resources, if they are poorly organized or coordinated, and if they do not adapt easily and costlessly to changes in their environment - differences in the performance of firms (at least within the same industry or line of business) may be explained mainly by differences in economic competence.[2] In addition, it is no longer possible to assume that an outward shift of the production possibility frontier necessarily results in increased economic activity or improved economic performance.

The basic idea of the present paper is to explore the importance and implications of interaction between technological systems and economic competence, i.e. the relationship between pushing out and exploiting the opportunity set. The analysis relies on extensive use of the micro-based macroeconomic simulation model of the Swedish economy (MOSES). Space does not allow a full presentation here, but a brief overview of the model is provided in the Appendix; for a more detailed presentation, see Eliasson (1978, 1985), Albrecht *et al.* (1989), and Taymaz (1991).

2. Technical Progress vs. Economic Competence

In a previous paper (Carlsson 1991), an analysis was made of the relative importance for investment, productivity, and economic growth at the industry and macroeconomic levels of the rate of technical progress on one hand vs. various aspects of economic competence on the other. The rate of technological progress was represented by the (exogenous) rate of growth of best-practice labor productivity in each industry, given that the degree of technical efficiency varies among firms. Economic competence was represented by differences among firms in investment behavior resulting from their having different expectations and varying willingness and ability to finance investment by borrowing.

The impact of changes in the rate of technical progress was explored in one set of simulations. The basic question was, what would be the rate of technical progress required to generate the rate of increase of labor productivity in each sector similar to that actually observed in the early 1980s, assuming that the initial labor productivity in each firm was the same as in a previous base year (1976)? The conclusion was that, *ceteris paribus*, it takes a very large increase indeed in the rate of technical progress in the model in order to generate the kinds of macroeconomic growth rates observed in the real world. (The simulations were generally allowed to run for 25 years.) The main constraint appears to be the slowness of investment activity to react to increased incentives in the form of increased productivity associated with new investment.

These results were compared to those of a second set of experiments in which each of two parameters influencing investment behavior of firms was varied while holding the rate of technological progress constant. The conclusion drawn from this set of simulations was that when firms are made more sensitive to their recent profitability performance and to their current capacity utilization rate, their investment behavior changes in predictable ways -- but the resulting changes in macroeconomic performance

2 Thus, economic competence includes, but is not confined to, the notion of X-efficiency as stated by Leibenstein (1966; see also Carlsson, 1972).

are not easily predicted. What happens at the macro level in terms of investment, output, and productivity growth depends on initial conditions and on the degree of diversity among firms.

The comparison of the results of these simulations showed that the conditions which determine resource allocation among firms and plants within each industry (including technical inefficiency) are more important in determining the labor productivity at the sector level than the rate of technical progress as reflected in the rate of change of best-practice technology. In other words, the distribution of investment and production among plants inside the production frontier is more important than shifts of the frontier, at least over a 10-25-year period.[3] It takes very substantial changes in the productivity rates of best-practice technology to achieve the same results as those obtained through relatively modest changes in the parameters determining investment allocation among firms within industries.

There are several implications of this. One is that a high investment level is not necessarily more desirable than a lower one. This is true particularly if, as is usually the case, "investment" refers to physical capital (plant, machinery, and equipment) only. It has been shown, at least for Sweden, that the amount of resources devoted to research and development in manufacturing is now of the same magnitude as that devoted to physical capital (Carlsson *et al.*, 1981). If other intangible resource accumulation (such as in international marketing) is also considered, physical capital can be seen to play an even less important role. Similar trends are observable in other countries as well. (OECD, 1986, p. 21.)

Another implication is that a high productivity growth rate is not necessarily more desirable than a lower one. Productivity per se is really of limited interest and is not generally viewed as a target by firms; what is more important is the resulting impact on output growth (particularly as reflected in market share growth) and, above all, profitability.

The analysis also demonstrates the well-known but often forgotten fact that productivity growth is at best only a partial indicator of economic performance even at the macroeconomic level. Effectiveness (doing the right thing) is more important than efficiency (minimum resource use for given output) or productivity (maximum output for given input use). The experience of the Swedish shipyards in the 1970s is a perfect illustration: they were highly efficient in making products which no one wanted!

A further implication, of particular importance for the present paper, is that if technological progress by itself is not sufficient and if it needs to be combined with economic competence on the part of various agents in order to generate economic growth, it is necessary to explore further what it is that constitutes economic competence, and how it relates to macroeconomic performance.

3 This result confirms the findings of previous studies by Nishimizu and Page (1982) and Førsund & Hjalmarsson (1987).

3. The Role of Economic Competence

The aspects of economic competence mentioned so far are fairly limited in scope: they basically involve the ability of firms to finance investments and to take calculated risks. Carlsson & Eliasson (1991) define economic (or business) competence more broadly as the ability of firms to generate and take advantage of business opportunities. More specifically, business competence is viewed as consisting of strategic (selective) capability, organizational (coordinating, integrative) ability, functional (operational) capability, and adaptive (learning) ability.

While work is in progress to model economic competence more fully in MOSES, we report here some early results of these efforts. The idea is to indicate the kinds of analysis that can be performed even without more elaborate re-formulation of the model. We focus here on three sets of experiments or simulations, each set representing one aspect of economic competence. The first experiment simulates what would happen if some firms were to increase their "investment efficiency" (INVEFF), i.e. their incremental output/capital ratio. Such an increase may be the result of a variety of changes including vertical disintegration (e.g. in the form of focusing on certain core businesses while divesting non-core businesses), a shift to more 'downstream' investment, enhancement of efficiency and capacity utilization through elimination of bottlenecks, and generally "tighter" management.

The second experiment involves raising the level of labor productivity associated with new capital in some firms (MTEC). Via more astute management, better luck in drawing from the opportunity set (perhaps as a result of higher yield on internal R&D efforts or better utilization of innovations made by others), and similar factors, firms are in a position to take better advantage of best practice technology.

The third set of simulations focuses on the benefits of increased flexibility as represented by a reduction in the amount of time required to convert inputs into output, as well as the level of work-in-process (WIP) inventories (measured as a percentage of quarterly output).

3.1 *Investment Efficiency (INVEFF)*

Five experiments were run to analyze the effects of the investment competence of the engineering industries on performance. The INVEFF (incremental output/capital ratio) was used to represent the investment competence.

The first experiment (BASE) is the base case. In this run, the quarterly rate of increase in the INVEFF variable was equal to 0.52% for all firms. In the second experiment (EXP2), the INVEFF variable was increased by 2.5% quarterly for five years (1983-1988) for all plants in the engineering industries. (The rate of increase after 1988 was at the "normal" level, i.e., 0.52%.) Given that INVEFF varies as widely as between 0.56 and 3.22 in the engineering industry in the BASE run, a 50 % increase over 5 years does not seem unreasonable. In the third experiment (EXP3), the INVEFF variable was increased by 2.5% quarterly for five years for 18 plants representing about 10% of the labor force in the engineering industries in 1982, the base year. These plants are dispersed throughout the distribution of plants in the engineering industry in terms of all the variables analyzed.[4] In the fourth and fifth experiments (EXP4 and EXP5), the INVEFF variable was *de*creased by 2.5% quarterly for five years for the same 18 plants and for *all* engineering industry plants, respectively.

The results show that over a 15-year period (1982-1997), the output of the engineering industries grows substantially faster in EXP2 and EXP3 than in the BASE case, while EXP4 and EXP5 do not differ significantly from the BASE case. See Figure 1. As far as the rank ordering among the various experiments is concerned, the results are very similar in terms of other variables as well. For example, labor productivity in 1997 is higher in EXP2 than in EXP3 for all plants and much higher in both cases than in the BASE case. Figure 2 shows the level and rank ordering of plants in terms of labor productivity in 1997 in EXP3 and the BASE case. The level of productivity is higher in every plant in EXP3 than in the BASE case, and the rank ordering among plants is also affected. The level of labor productivity as well as relative position of plants are identical in EXP4 and EXP5. Predictably, the level of labor productivity is lower in these experiments than in the BASE case, and the relative position of the affected plants worsens. The results concerning the level and plant distribution of rates of return show the same pattern as the results concerning labor productivity.[5]

See Table 1 for a more detailed summary of the results.

3.2 *Increased Labor Productivity Associated with New Investment (MTEC)*

These experiments are similar in design to the previous set. In EXP6, MTEC is increased by 2.6% each quarter for five years for all plants in engineering industries relative to the BASE case, and for the 18 plants in EXP7. For symmetry, MTEC is *de*creased by 2.6% quarterly for five years for all plants in EXP8 and for 18 plants in EXP9. As indicated earlier, an increase in MTEC may be thought of as resulting from making better choices of new equipment, utilizing its potential more fully, and integrating it better into the overall operations of the firm.

The pattern of results is generally similar to that in the INVEFF experiments concerning both output of engineering industries and rates of return. Labor productivity is slightly higher in all plants in EXP6 than in EXP7 and substantially higher in both experiments than in the BASE case; until the very end of the 15-year simulation there is not much difference between the BASE case, EXP8 and EXP9.

4 These plants are Åkermans Verkstad, one division of ASEA, Atlas Copco Tools AB, Bofors Defense Materials Division, Eldon Industrial Division, 5 Electrolux divisions, 4 Ericsson division, Saab-Scania Automobile Division, and 3 Volvo divisions.

5 An alternative way to model a similar aspect of economic competence is to equip firms with better knowledge of their respective production functions. They can then set production and employment targets *on* the production function (rather than below it), namely where the slope of the production function is equal to the wage/net price ratio. In EXP10, the 18 engineering industry plants were allowed to optimize in this fashion, and in EXP11, all engineering plants. As a result, the economy performed even better than in EXP2 and EXP3, respectively, in terms of all variables analyzed. This may be regarded as further evidence on the importance of exploiting existing resources as one aspect of economic competence.

3.3 *Increased Flexibility*

Flexibility of production systems is a subject which has been touched upon in several disciplines in the last decade, including production engineering and economics. Technological developments in electronics (especially in the area of numerical control) have created possibilities for *flexible automation* and pressures to increase flexibility of production systems as a result of a changing international competitive environment. (See Gustavsson 1984, Taymaz 1989, Carlsson 1989a and b, Carlsson & Taymaz 1990.)

Although flexibility has been shown to be important for competitiveness at the micro, firm-level (American Machinist 1979, Edquist & Jacobsson 1988, Usui 1984, Suresh & Meredith 1985, Hutchinson & Holland 1982), the macroeconomic effects of flexibility have not been fully studied, although steps in that direction have been taken (Carlsson & Taymaz, 1990; 1991). One probable reason is that the tools normally available to economists are not suitable for such an analysis. MOSES offers an exception to this rule.

One of the best conceivable methods for the analysis of the effects of flexibility would be to incorporate the manufacturing processes explicitly into firms' production functions. However, this requires detailed information on firms' manufacturing characteristics. Since such data are not available, it is currently not meaningful to develop the model in this direction. Instead, we have modified the production specification of the model so that it allows us to analyze two important aspects of flexibility: responsiveness or throughput time (the time required to convert inputs into output) and the level of work-in-process inventories in relation to output.

The new production process specified to analyze flexibility is similar to the investment specification: it is specified by a lag function. More precisely, there are now four "stages" of manufacturing. Firms buy inputs and keep inventories of input goods. Then they transform inputs to WIP3 (work-in-process at the 3rd stage); then WIP3 is transformed into WIP2, WIP2 to WIP1, and WIP1 to output goods. (For a more detailed specification, see the Appendix.) There are now three types of inventories: input, work-in-process (WIP3 + WIP2 + WIP1), and output. Flexible firms are able to convert input inventories in a short time into output inventories. Thus there are three benefits of flexibility:

1) Flexible firms can adjust quickly to changes in the environment since they require shorter response times than others.

2) They keep less work-in-process inventories.

3) They do not need high levels of output inventories to smooth out unexpected changes in demand.

We have run five experiments. The first one is the BASE run; in this case, the flexibility of all engineering plants is equal to 0.75.[6] In the second experiment, we increased the flexibility of the same subset of 18 plants as in the simulations reported

6 The flexibility variable can be interpreted as follows. It refers to both throughput time and the level of WIP inventories. If its value is 0.75, this means that the mean throughput time is 1.75 (0.75 + 1) quarters. (If its value is zero, all inputs can be converted into outputs within one quarter.) It also shows the level of WIP inventories under steady-state conditions. If a firm with flexibility 0.75 produces 100 units every quarter, then the WIP inventories are equal to 75 units (25 units at each stage).

above; this was done by reducing the throughput time from 0.75 to 0.10. In the third experiment, all engineering plants were made more flexible, the flexibility coefficient being reduced from 0.75 to 0.10 for all plants.

The fourth experiment is similar to the second one in that changes are made involving a subset of 18 plants. However, in this case we allow quantity adjustments in the engineering goods market. In the current specification of the model, firms produce the level of output planned at the beginning of each quarter, and prices are allowed to change only if total demand is not equal to total supply. If, after a number of iterations, demand remains higher than supply, firms have to reduce their output inventories below the "desired" level. If the excess demand cannot be satisfied even after the reduction in output inventories, then the difference is supplied by imports. In this run, however, we have changed the specification so that, after a number of iterations in which prices are changed, engineering firms may produce more, depending on their input inventories, to satisfy excess demand. Note that flexible firms have an advantage in this case since they can produce more than other firms, thanks to their shorter throughput time.

The fifth experiment is similar to the previous one except that the flexibility of *all* engineering plants is increased.

Finally, all experiments were re-run under (stochastically) fluctuating changes in foreign prices to examine the impact of uncertainty on the benefits of flexibility.

The experiments can be summarized as follows.

Experiment	**Specification**
FLEX1	Base case
FLEX4	Base + fluctuating foreign prices
FLEX2	Base + increased flexibility of 18 plants
FLEX3	FLEX2 + fluctuating foreign prices
FLEX5	Base + increased flexibility of all engineering plants
FLEX6	FLEX5 + fluctuating foreign prices
FLEX7	FLEX2 + quantity adjustments
FLEX8	FLEX7 + fluctuating foreign prices
FLEX9	FLEX5 + quantity adjustments
FLEX10	FLEX9 + fluctuating foreign prices

The main results of the flexibility experiments are summarized in Table 2. In the "normal price" runs, FLEX7 achieves the highest growth rates in virtually all the variables with the notable exception of the rate of return in both the engineering industry and manufacturing as a whole; as a result, the investment level is also lower in this case (investment being endogenously determined).
In the "fluctuating price" cases, FLEX9 dominates similarly, also with lower rates of return and lower investment than in the other cases.

3.4 *Overall Comparison of the Simulation Results*

In Table 3, a comparison is made of the results for each type of experiment of the cases in which all engineering plants are subject to a favorable change. In each case, the change has a favorable impact relative to the base case (no change), as expected. The rate of growth of output (of engineering goods, manufactured goods, as well as GNP) increases. The rate of growth of labor productivity increases, as does the average annual rate of return, particularly in comparison to the interest rate (determined endogenously in the model).

The results indicate that a 50 % increase over 5 years in the INVEFF of all engineering plants leads to a 24 % increase in the industry growth rate (from 9.5 to 11.8%) and a 29% increase in the labor productivity growth rate over 15 years, compared to the BASE case. A similar 50 % increase for a subset of 18 plants (representing 10 % of industry employment in the base year) leads to a 13% increase in the industry growth rate and a 19% increase in the labor productivity growth rate.

The table also shows that a 50 % increase in INVEFF over 5 years leads to a higher rate of aggregate labor productivity growth (EXP2) over the 15-year experiment than a similar 50 % increase over 5 years in incremental labor productivity (EXP6). The aggregate engineering industry output growth rates show similar differences in these two experiments. The results imply further that such a labor productivity increase has an impact similar to that of a substantial increase in flexibility.

The overall impression one gets from these results is that changes in firm behavior, reflecting changes in their economic competence, may have the same macroeconomic impact as fairly substantial changes external to the firms (or to the economy), e.g. technological progress or foreign prices. At the very least, the results suggest that internal changes within firms may be of such importance that they cannot be ignored at the macroeconomic level.

The question that arises, of course, is whether changes in economic competence of the order of magnitude implied in these experiments make sense. In other words, is it possible to translate the obtained results from the model to the real world?

As indicated earlier, a change in INVEFF may be the result of restructuring at the corporate or lower levels. Given the restructuring constantly going on in industry, particularly in the form of mergers and acquisitions during the last decade, a 50 % change in INVEFF does not seem excessive. A similar increase in labor productivity is certainly not unreasonable. There are numerous examples of productivity increases of that magnitude in less than 5 years. Similarly, there are numerous anecdotes about dramatic reductions in throughput times and inventories of the order of magnitude assumed here. The fact that in none of the experiments does the distribution of plants become "skewed" even though certain plants have been specifically favored or disfavored, is one indication that the assumptions are not too unreasonable. (See e.g. figure 2.) But a more comprehensive and systematic analysis of industry data in this regard should be illuminating and would seem to be a suitable topic for further empirical research.

4. Conclusions

It was pointed out in the introduction to this paper that economic growth requires both technological progress and economic competence. In the first part of the paper it was shown that in a ten to fifteen-year perspective, very substantial technological progress is required in order to yield the same macroeconomic results as fairly modest increases in economic competence. In other words, the allocation of resources within the production possibility frontier is at least as important as pushing out the frontier.

In the second part of the paper, a more thorough analysis of certain aspects of economic competence and their role in the macroeconomy was undertaken. An important implication of the results, if borne out in further analysis, is that while it cannot be denied that technological progress is essential for economic growth, the ability of firms to take advantage of the business opportunities generated by new technology is probably just as important. And while there is still a gap in our understanding of the linkages between technological progress and economic growth, the gap is even wider when it comes to understanding the role and nature of economic competence in economic growth. In fact, our study has just begun, and this paper represents only one of the first steps of what is likely to be a long journey.

Another implication is that it might be advisable to shift the focus of economists and public policy makers away from being almost exclusively oriented towards generating technological progress towards being more concerned with the exploitation of business opportunities. It is suggestive that even though the United States outspent its economic rivals in industrial R&D for several decades, other countries, particularly Japan but also other countries such as Sweden, took advantage of new technology created in the United States, sometimes with more success than the American firms.

Appendix

The Swedish Micro-to-Macro Model[7]

Overview of the Model

The micro-to-macro model is a simulation model of the Swedish economy. It has been constructed primarily to analyze industrial development. Therefore, manufacturing is modeled in greater detail than other sectors. The manufacturing sector is divided into four industries (raw material processing, intermediate goods, investment goods, and consumer non-durables). Each industry consists of a number of firms, some of which are real (with data supplied mainly through an annual survey), and some of which are synthetic. Together, the synthetic firms in each industry make up the difference between real firms and the industry totals in the national accounts. There are approximately 150 real decision-making units covering about 30 % of industrial employment and output, and about 50 synthetic units.[8]

Firms in the model constitute short and long-run planning systems for production and investment. Each quarter, each firm begins by forming price, wage, and sales expectations and a profit margin target. These expectations and targets are then used as inputs into the production planning process in which each firm sets a preliminary production/employment plan. The basic inputs to this planning process are (1) the firm's initial position (level of employment, inventories, etc.), (2) a specification of the feasible production/employment combinations (determined by past investments), i.e. the firm's production function, and (3) a set of satisfactory production/employment combinations.

The firm's initial (*ex ante*) production and employment plans need not be consistent with those of other firms in the model. If, for example, the aggregated employment plans for all the firms exceed the number of workers available at the wage levels the firms intend to offer, an adjustment mechanism is invoked to ensure *ex post* consistency. In case of labor, the adjustment takes place in a stylized labor market, where the firms' employment plans confront those of other firms as well as labor supply. The labor supply is treated as homogeneous in the model, i.e., labor is recruited from a common "pool" but can also be recruited from other firms. However, the productivity of labor depends on where it is employed. This process determines the wage level, which is thus endogenous in the model. In a similar manner, firms' production plans are revised after a market confrontation in the domestic product market, and domestic prices are set.[9]

There is also a capital market where firms compete each quarter for investment resources and where the rate of interest is determined. (However, in the simulations reported in Section 2 in the main text, the rate of interest was determined exogenously.)

7 This presentation draws on Eliasson (1989) and Albrecht & Lindberg (1989) in Albrecht *et al.* (1989).

8 The 150 real decision-making units represent divisions within the 40 largest manufacturing companies plus several medium-sized firms.

9 There is also an export market whose specification need not concern us here.

Given this interest rate, firms invest as much as they find it profitable to invest, in view of their profit targets.

Other sectors in the model are a government sector, a household sector, and a foreign trade sector. There are also sectors for agriculture/forestry/fishing, construction, oil, electricity, services, and finance, although these are not explicitly modeled.

The exogenous variables which determine the potentials attainable in the model are the rate of technical change (which is specific to each sector and raises the labor productivity associated with new, best-practice investment -- see further below) and the rate of change of prices in export markets. The rates of change of these variables are held identical in all the simulations reported here. What drives the model is the incentive system implicit in the feedback mechanisms (particularly in the labor and product markets).

It should be noted further that firms which are unable to reach their profit targets or whose net worth becomes negative, exit from the industry.

The parts of the model most pertinent for our present purposes are presented below.

The Objective Function

Based on market requirements and its own past experience, the firm i sets a target for its rate of return on equity during time period t:

$$R_{it}^{E} = M_{it}\sigma_{it} - \rho_j + \overset{\circ}{p}^{K} + \epsilon_{it}\Phi_{it} \quad (1)$$

$$= R_{it}^{N} + \epsilon_{it}\Phi_{it} \quad (2)$$

where

R_{it}^{E} = rate of return on equity (nominal)

M_{it} = profit margin on sales

σ_{it} = sales/total asset ratio

ρ_j = rate of depreciation of capital in sector j (exogenous)

$\overset{\circ}{p}^{K}$ = rate of price change of capital goods (exogenous)

ϵ_{it} = $R_{it}^{N} - r$

R_{it}^{N} = rate of return on total capital

r = firm's borrowing rate (determined exogenously in the simulations reported here and set equal for all firms)

Φ_{it} = debt/equity ratio

Expectations/Targets

Expectations are generated on an annual basis with quarterly modifications concerning percentage changes in sales, prices, and wages for each firm according to the formula

$$EXP_{it}(V_{it}) = R * EXPI_{it}(V_{it}) + (1-R) * EXPX_{it}(V_{it}); \quad (3)$$

where $EXPI_{it}$ and $EXPX_{it}$ stand for "internally" and "externally" generated expectations, respectively, and V_{it} is the variable about which expectations are being generated. The externally generated expectations and the weighting factor ($0 \leq R \leq 1$) are treated as exogenous parameters, whereas the internally generated expectations are determined by the firm's previous experience with respect to each variable.

In a similar manner, targets are set for the firm's profit margin:

$$TARGM_{it} = MHIST_{it} * (1+EPS_i), \tag{4}$$

where $MHIST_{it}$ is determined by the firm's "profit margin history" as well as the actually realized profit margin in the previous period, and where EPS_i is a constant forcing the firm to increase its profit-margin target as compared with its historical performance.

The Long-Run Production Function

There are two production functions in MOSES, one short-run and one long-run. The short-run production function is used in quarterly production planning in the firm and will be presented below.

The long-run production function for each firm in MOSES is of the following form:

$$Q_{it} = QTOP_{it} * [1 - e^{\frac{-TEC_{it} * L_{it}}{QTOP_{it}}}] \tag{5}$$

where
- Q_{it} = potential output (in physical units)
- $QTOP_{it}$ = the maximum level of output which is approached asymptotically when infinite amounts of labor are used, given a certain level of capital stock.
- TEC_{it} = state of technology
- L_{it} = firm employment, and
- t refers to the time period.

The only factor of production which is explicit in this function is labor. However, the potential output, and hence the productivity of labor, is determined by the state of technology TEC_{it} and $QTOP_{it}$. The exponential term in equation (5) represents the degree of technical inefficiency in the firm. The state of technology at time t in each firm is determined by the previous period's state of technology, the amount of capital, and the level of productivity of new capital:

$$TEC_{it} = \frac{TEC_{it-1} * QTOP_{it-1} + MTEC_{jt} * \Delta QTOP_{it}}{QTOP_{it-1} + \Delta QTOP_{it}} \tag{6}$$

where

$$MTEC_{jt} = MTEC_{jt-1} * (1 + \delta_j); \tag{7}$$

$$QTOP_{it} = QTOP_{it-1} * [1 - \rho_j] + \Delta QTOP_{it}; \tag{8}$$

$$\Delta QTOP_{it} = INV_{it} * INVEFF_{it}; \tag{9}$$

- INV_{it} = investment made in previous periods and which comes on stream in period t; this is determined endogenously in the model (see eqns. (12)-(17) below);
- $INVEFF_{it}$ = the efficiency of newly installed capital (see eqns. (16) and (17) below);
- $MTEC_{jt}$ = the level of labor productivity associated with new capital in

sector j;

δ_j = the (constant) rate of change of $MTEC_{jt}$ in sector j; exogenous; this parameter is allowed to vary in the first set of simulations below.

j = 1, . . , 4;
1 = raw material processing sector
2 = intermediate goods manufacturing sector
3 = investment goods manufacturing sector
4 = consumer goods manufacturing sector.

Several things should be noted about this production function. First of all, capital enters indirectly via its effects on labor productivity. Each quarter, firms decide on their level of investment (see below). This investment incorporates best-practice technology which is available to all firms in each industry; the best-practice technology improves at an exogenously determined rate (δ_j) which varies from industry to industry. However, since the efficiency of newly installed capital ($INVEFF_{it}$) varies among firms, the increase in labor productivity resulting from each investment dollar varies from firm to firm. Technological change can therefore be regarded as embodied in new capital, but with the benefits varying individually among firms. The differences in labor productivity that exist initially may increase or decrease over time depending on how the firms fare in the markets, how much they invest, etc.

Secondly, note that $QTOP_{it}$, the maximum output attained asymptotically when infinite amounts of labor are used, is not affected by TEC_{it}. (The production function is illustrated in Figure 3.) However, with a better state of technology, the curvature of the production function is increased so that the asymptote is approached more quickly (cf. broken curve in Figure 3).

Thirdly, by hiring more labor, firms can raise their output (although at a diminishing rate): this is represented by movement along Q_{it}. $QTOP_{it}$ is lowered due to the depreciation of capital and raised due to gross investment.[10]

Thus, there are three factors which determine the growth of potential output, namely the level of investment INV_{it}, the efficiency of newly installed capital ($INVEFF_{it}$), and the rate of depreciation of capital ρ_j.

Short-Run Production Planning

The quarterly production planning in the firm starts with the profit target $TARGM_{it}$ which has to satisfy the minimum criterion

$$TARGM_{it} \leq 1 - (EXPW_{it} * L_{it}^e)/(EXPP_{it} * S_{it}^e), \tag{10}$$

where

$EXPW_{it}$ = the wage rate the firm expects to pay for the current quarter;

L_{it}^e = expected employment in the firm;

10 For further information on capacity utilization in Swedish industry as represented in MOSES, see Albrecht (1979).

$EXPP_{it}$ = the net price the firm expects to obtain for its product (net of input goods)

S_{it}^{e} = expected sales volume.

The feasible output, given the firm's labor force at the beginning of the period, is determined by the short-run production function

$$Q_{it}^{S} = (1-RES_{it}) * QTOP_{it} * \left(1 - e^{-\frac{TEC_{it}}{QTOP_{it}} * L_{it}}\right) \quad (11)$$

where

Q_{it}^{S} = feasible output volume during the quarter;

RES_{it} = "Residual slack fraction", or the ratio between potential and actual output. This is updated quarterly.

The short-run production function is the same as the long-run production function, except that the slack variable now also enters in. For various reasons, firms operate below their potential in the short run (via RES_{it}), just as they do in the long run (via $INVEFF_{it}$).

It should be noted that $QTOP_{it} * (1 - RES_{it})$ corresponds to a standard measure of capacity, i.e., the potential output from existing facilities. There is normally some degree of slack (or X-inefficiency -- cf. Leibenstein 1966). If the firm comes under pressure to fulfill its targets, it reduces the slack. Conversely, lack of pressure may lead to increased slack.

The short-run production planning is illustrated in Figure 4, where the set of simultaneously satisfactory and feasible combinations of output and employment is given by the shaded area. Suppose that, given its initial employment, the firm expects to sell a certain volume of output and that, after adjustment for desired inventory change, this results in the quarterly output plan Q_{it}^{e}. Then the point (Q_{it}^{e}, L_{it}^{e}) becomes the trial output/employment combination. If this point is inside the feasible and satisfactory set, then that point is adopted as the production/employment plan. If, on the other hand, it does not lie within that area, adjustment mechanisms of the sort indicated above for the determination of the employment level are called into play.

Determination of Investment

[NOTE: THIS SECTION DESCRIBES THE VERSION OF THE MODEL USED IN THE SIMULATIONS REPORTED IN SECTION 2 IN THE MAIN TEXT. IT WILL BE REVISED TO INCORPORATE THE CHANGES MADE FOR THE SIMULATIONS REPORTED IN SECTION 3 ABOVE.]

There are three kinds of assets in MOSES : fixed assets (K1), liquid and other current assets (K2), and inventories (K3). The funds available for investment are calculated in the following way:

$$FUNDS_{it} = CASH_{it} + DESCHBW_{it} - DESCHK2_{it}, \quad (12)$$

where

$CASH_{it}$ = the quarter's cash flow (determined elsewhere in the model)

$DESCHBW_{it}$ = the desired change in debt (or borrowing)

$DESCHK2_{it}$ = the desired change in liquid assets; these assets are kept as a buffer against temporary fluctuations in sales and hence are directly related to the value of sales.

$DESCHBW_{it}$ is determined in the following way. The desired change in the firm's total borrowing is proportional to existing debt with the factor of proportionality dependent on the "internal-external interest margin:"

$$DESCHBW_{it} = BW_{it} * [\alpha + \beta * [(QRR_{it}/4) + \mathring{p}^K - (r/4)] \qquad (13)$$

where

BW_{it} = the firm's total borrowing;

α = a constant (here set equal to 0.077);

β = a constant (exogenous); it is one of the parameters whose value is allowed to vary in one set of simulations below.

QRR_{it} = the firm's rate of return before taxes (a fraction on a yearly basis);

$\mathring{p}^K$ = quarterly relative price increase for investment goods;

r = rate of interest on firms' borrowing.

If $DESCHBW_{it}$ should exceed a certain (exogenous) fraction of BW_{it}, it is capped at that level. If the desired level is less than that, the firm goes on to determine whether or not its capacity utilization rate is such that it wants to borrow for investment during the current quarter. The criterion is

$$1 - \eta * \{UTREF - Q_{it}/[QTOP_{it} * (1 - RES_{it})]\} \geq 0, \qquad (14)$$

where

η = a constant elasticity (exogenous); this parameter is allowed to vary in the third simulation set below.

UTREF = a "reference" level of capacity utilization; a constant whose value is set equal to 0.85 in these simulations.

Q_{it} = (actual) quarterly production of the firm.

The quarter's investment expenditures are then determined by

$$INVEST_{it} = \max [0, (CASH_{it} + CHBW_{it} - DESCHK2_{it})] \qquad (15)$$

where $CHBW_{it}$ is the actual change in borrowing of the firm in the current quarter. Should $CASH_{it} + CHBW_{it} - DESCHK2_{it}$ be negative, the firm foregoes investment, and the liquid assets bear the adjustment.

The investments in the current quarter do not affect output until at least three quarters later, as determined by the exogenous parameters of a delay function. Thus, INV_{it} coming on stream in the current quarter are the result of $INVEST_{it-3}$.

Having thus determined current investment, the investment efficiency parameter $INVEFF_{it}$ is determined:

$$INVEFF_{it} = (QTOP_{it} * QP_{it})/K1_{it}, \tag{16}$$

where QP_{it} is the firm's sales price during the quarter (comprising an average of foreign and domestic sales), and where $K1_{it}$ has been updated according to

$$K1_{it} = INV_{it} + (1 - \rho_j) * (K1_{it} * (1 + \mathring{p}^K)). \tag{17}$$

Thus, $INVEFF_{it}$ is essentially the firm's incremental output/fixed capital ratio. It may vary over time and among firms for a variety of reasons, including "structural" differences such as differences in type of production, production processes, and degrees of vertical integration. It may also vary because of differences in management techniques and approaches, the amounts of resources devoted to "soft" capital formation in the form of R&D, marketing, etc. Thus, it captures several of the elements of economic competence at the firm level.

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Table 1. Results of INVEFF and MTEC Experiments

	BASE	EXP2	EXP3	EXP4	EXP5	EXP6	EXP7	EXP8	EXP9	EXP10	EXP11
Annual growth of											
GNP	7.3	8.0	7.8	7.0	7.2	7.6	7.3	7.2	7.2	7.6	8.4
Manufacturing	9.0	10.1	9.7	8.4	9.0	9.4	9.1	8.8	8.9	9.7	10.5
Raw matrls	5.9	6.5	6.4	5.9	6.1	6.3	6.2	6.3	6.0	6.4	7.3
Intermediate	8.9	9.2	9.0	8.8	9.0	9.1	8.8	8.8	9.0	9.3	9.4
Capital goods	9.5	11.8	10.7	8.3	9.2	10.1	10.0	9.3	9.1	10.8	12.5
Consumer goods	9.1	9.1	9.5	8.8	9.3	9.6	8.8	8.7	9.1	9.2	9.0
Productivity growth of											
Manufacturing	7.3	8.6	8.2	6.9	7.2	7.8	7.6	7.0	7.3	8.0	8.8
Raw matrls	9.5	10.5	10.4	10.2	9.7	10.1	9.3	10.0	10.0	10.0	10.4
Intermediate	4.3	4.6	4.7	4.7	4.3	4.4	4.5	4.6	4.4	4.5	5.1
Capital goods	7.8	10.1	9.3	6.6	7.2	9.1	8.7	6.9	7.7	9.6	10.9
Consumer goods	7.3	7.9	7.6	7.1	7.6	7.1	7.1	7.0	7.4	7.1	7.2
Investment											
Manufacturing	41.8	45.5	44.8	41.5	44.4	45.6	40.0	43.1	41.3	43.4	55.4
Capital goods	8.3	9.2	9.7	9.3	9.7	9.8	8.6	9.8	8.6	10.8	17.3
Rate of return											
Manufacturing	12.6	13.3	12.8	12.2	12.6	12.9	12.8	12.3	12.4	13.1	13.9
Capital goods	13.9	14.7	14.0	12.9	13.4	14.7	14.2	13.4	13.6	15.6	17.5
Interest rate	12.4	11.8	12.2	12.8	12.5	12.1	12.4	12.5	12.4	12.1	11.3

Notes
INIT: Initial data at 1983 (other data for 1997)
1: Base
2: INVEFF ↑ all eng plants
3: INVEFF ↑ 18 eng plants
4: INVEFF ↓ all
5: INVEFF ↓ 18

6: QDMTEC ↑ all
7: QDMTEC ↑ 18
8: QDMTEC ↓ all
9: QDMTEC ↓ 18

10: 18 eng plants optimize
11: all eng plants optimize

Table 2. Results of Flexibility Experiments

	FLEX1	FLEX2	FLEX7	FLEX4	FLEX3	FLEX8	FLEX5	FLEX6	FLEX9	FLEX10
Annual growth of										
GNP	7.2	7.4	7.9	6.7	7.2	7.6	7.3	7.2	7.5	7.5
Manufacturing	8.9	9.1	9.6	8.3	9.0	9.3	8.9	9.0	9.4	9.3
Raw matrls	5.9	6.6	6.9	4.5	5.6	4.9	6.2	5.6	6.2	5.5
Intermediate	9.1	9.2	9.1	7.6	7.8	7.5	8.7	7.8	9.0	7.8
Capital goods	9.3	10.0	10.7	8.8	9.8	10.6	9.5	9.9	10.7	10.7
Consumer goods	8.8	8.2	9.1	9.3	9.7	10.0	9.2	9.7	8.7	9.8
Productivity growth of										
Manufacturing	7.2	7.3	8.0	6.7	7.2	7.5	7.3	7.3	7.7	7.7
Raw matrls	9.8	10.2	10.7	8.2	9.4	9.4	9.4	8.5	9.3	11.0
Intermediate	4.6	4.4	5.2	5.3	5.9	6.7	4.5	6.0	4.6	5.8
Capital goods	7.2	8.0	8.1	6.4	6.8	7.0	8.0	7.1	8.4	7.5
Consumer goods	7.1	6.9	7.7	6.6	7.0	7.2	6.9	7.1	7.4	7.2
Investment										
Manufacturing	45.1	43.9	46.6	44.0	48.0	44.1	41.8	45.7	45.7	50.0
Capital goods	9.9	10.8	10.9	10.4	11.7	10.1	9.2	10.1	11.3	12.6
Rate of return										
Manufacturing	12.0	11.8	12.2	12.4	12.9	12.3	12.8	13.3	12.9	13.8
Capital goods	10.6	11.8	10.6	11.1	12.2	9.9	14.1	13.7	13.9	14.4
Interest rate	12.5	12.5	11.9	12.2	12.0	11.9	12.4	12.0	12.4	12.0

Notes
Normal foreign prices
- FLEX1: Base
- FLEX2: 18 eng plants flexible
- FLEX5: all eng plants flexible
- FLEX7: 18 + quantity adjustments
- FLEX9: all + quantity adjustments

Fluctuating foreign prices
- FLEX4: Base
- FLEX3: 18 eng plants flexible
- FLEX6: all eng plants flexible
- FLEX8: 18 + quantity adjustments
- FLEX10: all + quantity adjustments

Table 3. Comparison of Simulation Results

Variable	BASE	INVEFF	MTEC	FLEX
Average annual growth rate				
GNP	7.3	8.0	7.6	7.5
Manufacturing output	9.0	10.1	9.4	9.4
Engineering output	9.5	11.8	10.1	10.7
Manufacturing productivity	7.3	8.6	7.8	7.7
Engineering productivity	7.8	10.1	9.1	8.4
Average annual investment				
Manufacturing	41.8	45.5	45.6	45.7
Engineering	8.3	9.2	9.8	11.3
Average annual rate of return				
Manufacturing	12.6	13.3	12.9	12.9
Engineering	13.9	14.7	14.7	13.9
Average annual interest rate	12.4	11.8	12.1	12.4

Figure 1. Engineering Goods Production in the INVEFF Experiments

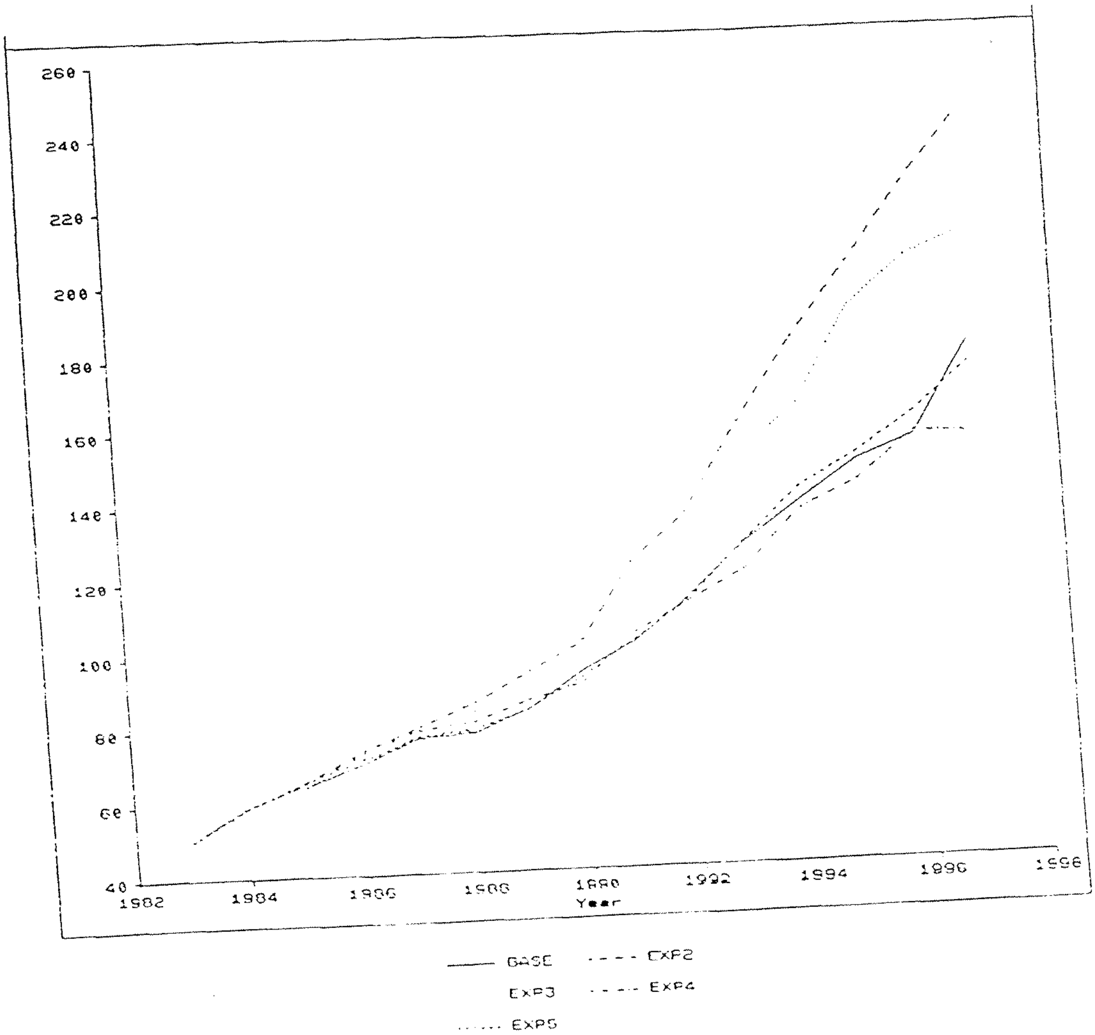

Figure 2. Rank Ordering of Engineering Industry Plants in Terms of Labor Productivity in the BASE and EXP3 Cases

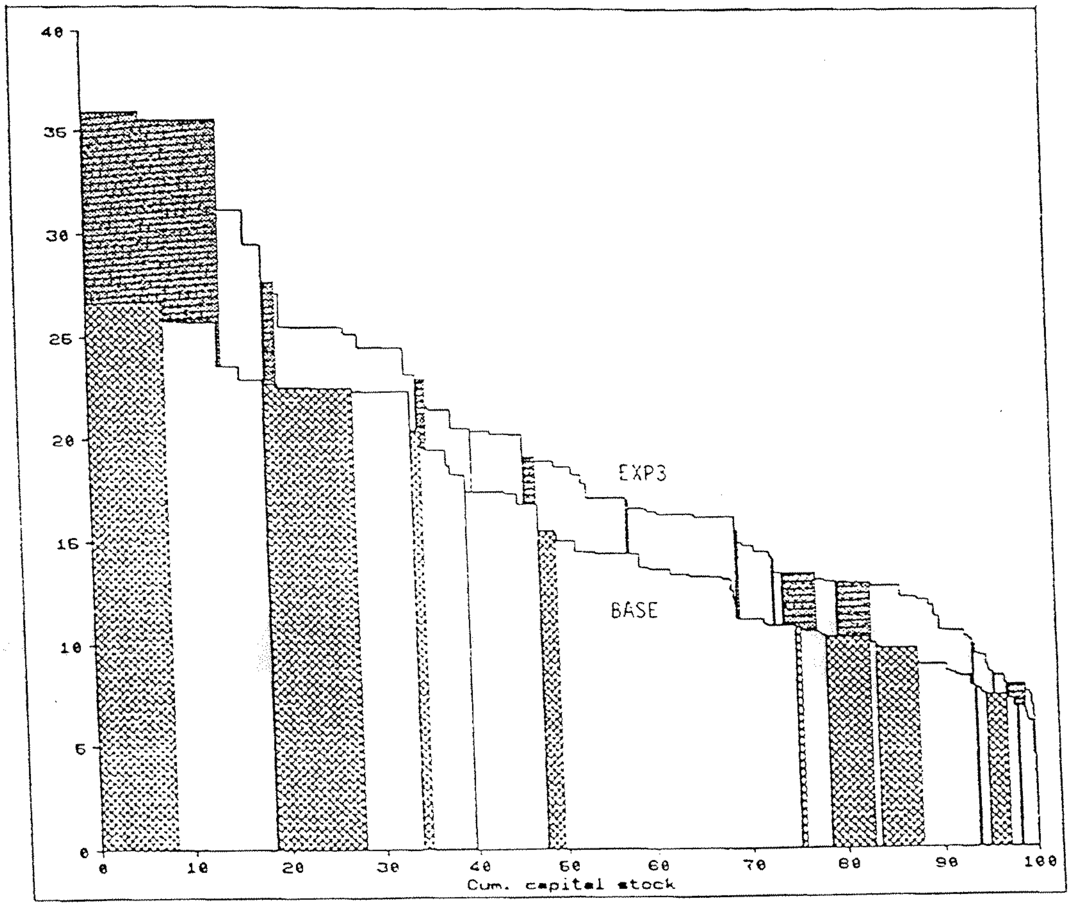

Figure 3. The Long-Run Production Function

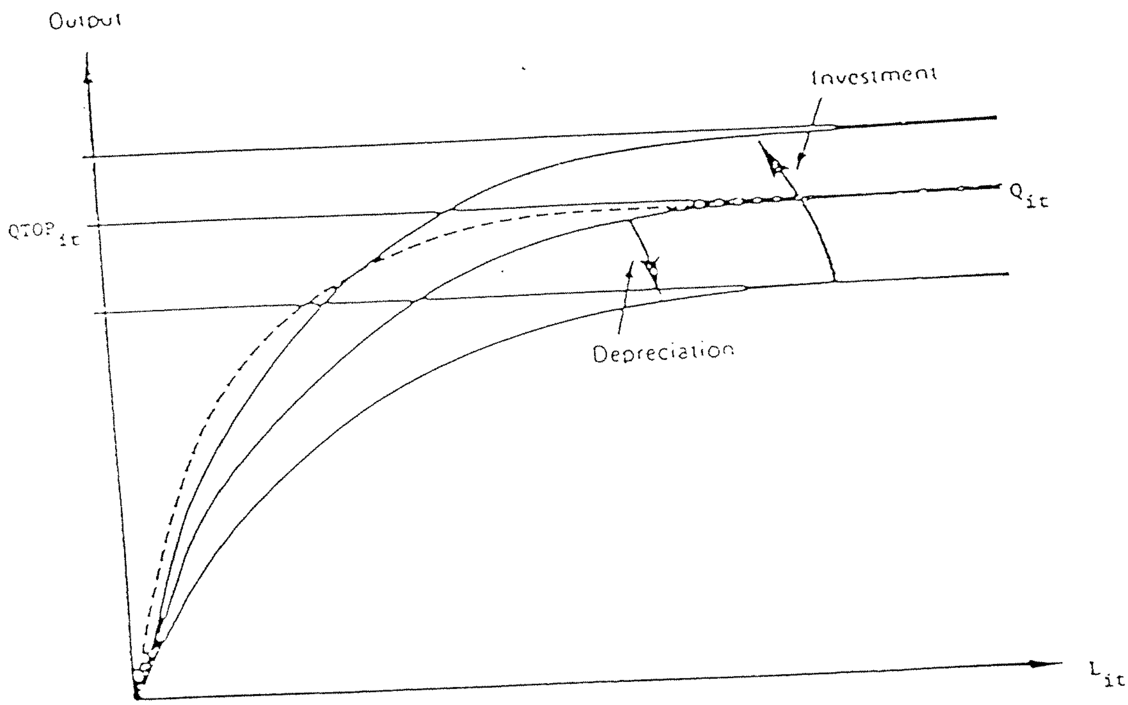

Figure 4. Short-Run Production Planning