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Bo Carlsson

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Bo Carlsson

Department of Economics

Case Western Reserve University

Cleveland, Ohio 44106

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ABSTRACT

PRODUCTIVITY ANALYSIS: A MICRO-TO-MACRO PERSPECTIVE

by Bo Carlsson
Case Western Reserve University
Cleveland, Ohio 44106

This paper raises several issues concerning productivity analysis. An attempt is made to demonstrate the usefulness of a micro-based approach to productivity analysis which challenges some basic assumptions of conventional analyses based on aggregate production functions. With the help of a micro- (firm-)based macro simulation model it is shown if there are important differences among firms in economic competence, here represented by efficiency and investment behavior, the relationships between investment, productivity, and economic growth are much more complex and unpredictable than commonly assumed. The rate of technological progress as measured by the rate of change in best-practice technology seems to be less important than the elimination of inefficiency by closure of firms and/or by firms moving closer to their respective production frontiers.

It is also shown that the conditions which determine firm borrowing for investment (involving their interpretation of past profitability and expectations based on current capacity utilization) are more important for productivity and economic growth than the total amount invested. In other words, it matters less how much is invested than who does the investing, and under what incentives.

The implication for productivity analysis is that unless diversity among economic units is taken into account, the results are likely to continue to be inconclusive. What is needed is much more of an integration of micro and macro theory than has been accomplished thus far. In particular, economic competence must be included.

The paper also tries to put productivity in the proper perspective, not as an object in and of itself but rather as a partial measure, at best, of economic performance at any level within the economy.

PRODUCTIVITY ANALYSIS: A MICRO-TO-MACRO PERSPECTIVE*

Bo Carlsson

Department of Economics

Case Western Reserve University

Cleveland, OH 44106

Introduction

Ten years ago, having carefully studied the U.S. productivity slowdown in the 1970s, after making numerous adjustments for input quality changes, economies of scale from larger markets, etc., and after considering a large number of hypotheses concerning the causes of the observed slowdown, E.F. Denison concluded that "what happened is, to be blunt, a mystery" (Denison 1979, p. 4). Despite all the studies made by economists on this subject in the intervening years, the productivity slowdown remains a mystery. Summarizing the results of a recent symposium on the subject, Stanley Fischer found that "the overall impression is that economists are as yet unable to pin down the relative contributions of the potential causes of the productivity slowdown" (Fischer 1988, p. 6).

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There is a general consensus on two points only: (1) that there was a considerable slowdown in the observed rate of productivity growth both in the United States and in other industrial countries after 1973 compared to the earlier postwar period; and (2) that the decline was both sharp and sudden. However, the magnitude of the slowdown differs among various studies depending on "differences in data sources, time periods, concepts, sector of the economy studied, research methods, measurement errors in the raw data, and the underlying assumptions and models used." (Wolff 1985, p. 49.)[1] Given this, it is not surprising that the causes of the slowdown pinpointed in various studies vary even more widely.

The existence of such a multitude of explanations without any unifying consensus is troublesome because it really indicates the failure of economics as a discipline to explain productivity change. There are at least three possible interpretations of these failures. One possibility is that the productivity slowdown is such a complex phenomenon that its analysis requires a far more comprehensive approach than has been tried thus far. For example, Olson (1988, p. 67) suggests that any econometric estimates of the causes of the productivity slowdown are likely to be seriously misspecified unless they include a variety of macroeconomic and institutional variables; these variables should be included in the model itself, not added <u>ad hoc</u> as in the growth accounting approach.

Another approach which has gained adherents recently (see for example Gordon and Baily, 1988; Kendrick, 1989) focuses on measurement problems. Its basic premise is that the slowdown is partially or entirely a statistical artifact -- a result of measurement errors -- and that once these measurement errors have been eliminated, there is nothing which conventional productivity analysis cannot explain.

The third possibility which will be explored here is that an entirely different (micro-based) approach is needed in order to explain productivity growth. While the quality of national income statistics gives rise to doubts concerning the magnitude and indeed even the existence of a productivity slowdown, if properly measured, the fact remains that conventional macroeconomic approaches leave a substantial share of productivity growth yet to be explained. The time may have come to try an entirely different approach. Most analyses of productivity growth have been carried out at the macro level,[2] based essentially on an aggregate production function which relates inputs of capital and labor to output; only rarely are other inputs considered. According to numerous studies (following the seminal work by Abramovitz 1956 and Solow 1957), at least one-half, and frequently more, of U.S. aggregate economic growth can be attributed to "total factor productivity" (TFP) growth, the remainder being attributable to increases in inputs of capital and labor. In contrast, in one of the few studies based on sector-level data where allowance is made for intersectoral shifts of output and inputs, Jorgensen, Gollop and Fraumeni (1987) found that increased capital and labor inputs account for more than three-quarters of U.S. economic growth during the period 1947-1979, TFP thus contributing less than one-fourth to output growth. At the very least, such differences in results show that it matters a great deal whether one takes a macro or micro approach to productivity analysis.

The aim of the following analysis is to show not only that a micro perspective is useful and perhaps even necessary in understanding productivity growth but also that the appropriate unit for micro analysis is the firm, not the industry, and that the underlying production function needs to include more factors of production than are usually included. The analysis begins with a rationale for a micro-based approach and an overview of the kinds of variables to be included. This is followed by a presentation of a micro- (firm-) based macro model which will then be used in the analysis. Some illustrative simulations on the model are reported. The interpretation of the results and their main implications for economic theory are summarized in the concluding sections.

Why a Micro Approach?

The superior performance of the Japanese economy in the postwar period in comparison with other countries can certainly not be explained by the country's endowment of natural resources. A highly educated labor force may have played a significant role, although it seems to be only recently that the number of certain highly trained people -- engineers, for instance -- relative to the total labor force has exceeded those in the U.S. and Western Europe. Expenditures on research and development have also been modest until quite recently. Most observers would probably agree that one of the most important factors has been an extraordinarily high investment (and savings) rate, in combination with a high level of what I shall call economic competence -- following Eliasson (1988) and Pelikan (1989).[3] The role of industrial policy, however one wants to define it, and the role of agents such as the Ministry of International Trade and Industry (MITI), are subject to considerable controversy. But it seems beyond question that the ability on the part of the relevant agents within the economy to envision and formulate goals, to carry out strategies to reach those goals, to motivate and educate people, to innovate, and to coordinate activities -- i.e., aspects of economic competence at various levels within the economy -- in combination with a properly functioning market system, explains a large share of the success of the Japanese economy. Of course, the same applies to other economies as well.

That economic competence, broadly defined, is important in explaining success or failure at the level of the firm is clearly beyond question. It is well established in the management literature; indeed it constitutes the main rationale for the existence of the whole discipline of management science. The term "distinctive competence" was first used by Selznick (1957) to describe the character of an organization. It refers to those things than an organization does especially well in comparison with its competitors. The idea that the general level of economic competence within firms has an impact at the national as well as the international level has been recognized for many years. Business historians, such as Alfred Chandler in his pathbreaking work on the history of U.S. corporations (1962 and 1977), have suggested that long-term growth and survival of organizations are profoundly influenced by the strategic choices made by their top executives. Similarly, Servan-Schreiber in his famous book (1968) on the threat of American multinationals becoming dominant in Europe attributes the perceived competitiveness of the American firms to superior management techniques. Similar claims have been made more recently with regard to the competitiveness of Japanese firms in a flood of literature on Japanese management techniques. The study by Peters & Waterman (1982) on excellence in American companies is representative of a multitude of studies in the management literature on what may be broadly referred to as economic competence at the corporate level. More formal analyses of the relationship between competence and performance in organizations have been made by Snow & Hrebiniak (1980) and Reimann (1982).

Economic competence may be analyzed at the individual as well as at the firm level. The seminal work here appears to be the studies by Polanyi on personal knowledge with particular emphasis on its tacit component (1958), further elaborated in The Tacit Dimension (1966). Competence and competence development have been modeled recently by Fredriksson (1989) and Sandberg (1987).[4]

But if it is true that economic competence plays a major role in explaining economic performance not only at the level of the firm but also at the aggregate level, why is it not included in our economic models?

One suspects that the main reason for the neglect of economic competence in macroeconomic models is that it is difficult to conceptualize and therefore to model, and virtually impossible to measure, at the aggregate level. It is, of course, difficult at the microeconomic level as well, although a few attempts have been made, as indicated above. But as is so often the case, the purely firm-level modeling in management science is ignored by micro economists whose Theory of the Firm is really not a theory of the firm at all but rather a theory of groups of firms, usually referred to as industries. Thus, there is often no link at all between truly micro analysis and what economists generally perceive of as micro analysis -- similar to the divorce between microeconomic and macroeconomic analysis.

This is where micro-macro modeling comes in. As soon as there arises a possibility to link firms via markets to the macro economy, vast opportunities open up for formalizing knowledge about economic competence at the firm level (as well as within firms) and incorporating it in such a way as to yield insight about its role in the economy as a whole.

The rest of this paper attempts to outline such an approach. It rests on a micro-based macro simulation model of the Swedish economy (MOSES). Although the model in its current form is not designed specifically to analyze the role of economic competence, it incorporates some features which provide insight and are illustrative as far as macroeconomic impact is concerned. But before the model is presented, we focus in the next section on some shortcomings of macro analysis of productivity change, all of which involve aspects of economic competence at the firm level and which can be remedied in a micro-based approach. The specific issues to be examined here, as well as their connection to the analysis of productivity in general, will be given in the next section.

Shortcomings of Macro Analysis

There are three assumptions which are usually incorporated in conventional neoclassical macro models, which are crucial in analyzing the relationships between investment, productivity, and output growth, and which involve various aspects of economic competence. If these assumptions do not hold, various anomalies arise. The first is technical efficiency: all units (firms or industries) are on the production frontier; this is implicit in the aggregate production function. The second is that new investment incorporates best-practice technology. Neoclassical models usually make no assumptions about technical change as such. Instead, technical change is incorporated via exogenous changes in labor productivity. In vintage-type models, improvements in labor productivity are associated with each new vintage; new vintages are assumed to embody best-practice technology. In other models, there is no linkage at all between capital investment and labor productivity. The third assumption is that investment behavior is identical among all units (firms); there is only one marginal efficiency of capital within each aggregate. Therefore, it does not matter which firms within the aggregate make the investments.

Obviously there are many other aspects of economic competence which could be investigated. These have been chosen because they are judged to be important, they challenge some of the conventional assumptions, and they are relatively easy to model. The results are only indicative of the insight which a more full-fledged model of economic competence would yield.

Technical inefficiency

One type of anomaly occurs if the assumption regarding technical efficiency is violated. In the presence of technical inefficiency, capital investment and labor productivity are not always positively correlated. For example, labor productivity in the Swedish textile and apparel industry increased faster than in most other manufacturing industries during the period 1965-1980, even though both investment and output fell (SOU 1980:52, pp. 275-280). The elimination of the least productive firms from the industry reduced employment at a higher rate than output. A similar effect (but in the opposite direction) has been reported by Nelson (1986, p. 149): United States plants shut down by the energy price shocks during the 1970s tended to have higher labor productivity than others in their respective industries (by virtue of being more energy-intensive); therefore, their closure reduced the average labor productivity in the industry. Extensive work based on data for individual plants in several process-type industries in Scandinavia has also shown that structural changes within industries have a considerable impact on measured productivity at the industry level. (Førsund and Hjalmarsson 1987.)

Another aspect of the same phenomenon has to do with the so-called Horndal effect. Horndal was a Swedish steelworks in which labor productivity was observed to increase by almost 2 percent per year for 15 years without any investment other than replacement of worn-out equipment. (Lundberg 1961, pp. 130-1.) A similar case has been reported for another iron works (Carlsson 1981, pp. 346-8). Despite an absence of investment for 26 years, labor productivity increased by 3.7 percent per year. The increase was found to be attributable to the following factors: (1) As sales increased over time, more and more of the plant's capacity was utilized, but without any more labor input being required. (2) The increased production made possible larger batch sizes for each product, thus requiring less idle time in connection with changing from one product to another. (3) This scale effect was further enhanced by a reduction in the number of varieties of the products produced (i.e., increased specialization), partly due to a higher degree of product standardization resulting from international efforts to achieve more uniform standards. (Carlsson, 1981, p. 346.)

There is no reason to believe that this is a unique case. In fact, even though most of the economic literature focuses on the linkage between physical investment and productivity (the "vintage effect"), the everyday improvement, step-by-step learning mechanism just described is probably as important a determinant of productivity as capital investment in major new technology.[5] But these two determinants clearly complement each other. Building a new plant and installing equipment embodying new (hardware) technology opens up possibilities of reaching higher levels of potential output and productivity which are in fact reached only as the company "grows into" its new plant, moves down along its learning curve, and modifies its "software" (organization and management) technology.

An illustration of this is provided by the introduction of automatic lathes in a Swedish firm. Within one year after the new machines were installed, the initial labor saving due to the automation had doubled as the new machines were better integrated with existing equipment and the whole work process was re-organized. This required input of production engineering knowhow but little or no further capital investment. (Carlsson 1981, p. 345.)

The vintage effect is relatively easy to measure because it requires only fairly easily observable ("blueprint") data. The everyday learning effect, on the other hand, requires a wealth of detailed information over a more extended period. But studying one without the other is likely to yield incomplete results, as far as understanding productivity growth is concerned.

There is a similar learning effect not necessarily associated with capital investment, namely organizational change. It has been demonstrated that even at the firm level, half of measured productivity change is attributable to organizational change. Major re-organization resulting from mergers, take-overs, and internal restructuring often involves elimination of products and plants, consolidation of production in more specialized plants affording greater scale economies, opportunities to automate, etc. In other words, the productivity effects resulting from changes in the composition of output do not stop at the macro or sector level. This means, of course, that estimates of the macroeconomic impact of re-allocation of resources at a certain sector level are likely to be highly arbitrary. (Carlsson 1981, pp. 324-8.)

For the reasons outlined above, it is clear that the majority of firms are not on the production frontier. In the first attempt ever to measure technical efficiency across a broad spectrum of manufacturing industries, it was shown for each of 26 4-digit manufacturing industries in Sweden that the actual output was between 10 and 40 percent less than that which could have been obtained if all firms had been on their respective industry production function rather than below it (Carlsson 1972, p. 483). Similar results have been reported by Førsund & Hjalmarsson (1987) for the Swedish dairy, cement, pulp, and pig iron industries and for the Norwegian aluminum industry, and by Caves & Barton (1990) for a cross-section of more than 200 U.S. manufacturing industries in 1977.

The implication of this is that a micro-based model has to allow for substantial differences in technical efficiency among firms and other micro units.

Embodiment of Best-Practice Technology

As mentioned earlier, the assumption that new capital equipment embodies best-practice technology is usually implicit, except in vintage models. The question, to which extent best-practice technology is actually embodied in new plant and equipment, does not seem to have been subjected to much empirical analysis. One exception is a study by Gregory & James (1973) which showed that in 25 Australian industry groups for which a productivity range could be calculated, the value added per worker of the most productive new factory exceeded three times that of the least productive new factory (p. 1146). They also found that the number of industries in which the ratio of value added per worker of new factories to the average value added per worker in the industry as a whole exceeded unity in about as many cases as it did not (p. 1148). They concluded that "if new factories incorporate the latest equipment, then in most industries either new equipment is relatively unimportant as a determinant of productivity dispersion, or there are systematic factors which . . . bias the labor productivity of new factories downwards" (p. 1153).

In another interesting study, Nishimizu & Page (1982) have shown that changes in technical efficiency (as represented by a narrowing of the gap between average and "best" practice) dominated technological progress (i.e., improvement in best-practice technology) in relative importance in explaining sectoral total factor productivity growth in Yugoslavia during the period 1965-1978. (Nishimizu and Page 1982.)

These results suggest that in a micro-based model, the micro units should not all be assumed to be equally efficient in taking advantage of best-practice technology.

Differences in Investment Behavior Among Firms

In addition to differences among firms in technical efficiency and in the extent to which they reap benefits from new capital investment, there are also differences in the way firms respond to various incentives. Of more specific interest in the present context is the notion that the output and/or productivity "yield" of investment varies because of differences among firms in their expectations and in their evaluation of present circumstances. This feature is virtually impossible to incorporate without a micro-based model.

Implications for Modeling

For all these reasons, then, the linkages between capital investment and (total factor) productivity growth are much more complex and less transparent than is commonly assumed. Unless productivity analyses are carried out at the firm or plant level as well as at the industry level, the policy conclusions that follow are likely to be wrong.

The difficulty of obtaining the necessary micro data is certainly one reason why the analysis of productivity change remains as elusive as it is. Another reason is that most models used in productivity analysis, while designed for micro-level analysis, are actually used on industry- or macro-level data. If the observation unit is the industry rather than the firm or plant, it is not possible to study micro behavior.

The object of the exercises that follow is to analyze the implications for investment, productivity, and economic growth at the industry and macro levels (1) of different rates of technological progress as represented by best-practice labor productivity, given that the degree of technical efficiency varies among firms, and (2) of differences among firms in investment behavior resulting from their having different expectations and varying willingness and ability to finance investment by borrowing.

There is no way to analyze relationships of this sort in a traditional macro model where each industry -- or even the economy as a whole -- is treated as a single entity. Instead, what is needed is a micro-(firm-)based macro model which affords the possibility of analyzing the macro implications of differences in micro behavior. MOSES (Model of the Swedish Economic System), constructed at the Industrial Institute for Economic and Social Research, is such a model.[6] Given the size of the model, it is not possible to give a full presentation here. A general overview is presented in the following section, followed by a more detailed specification of those parts of the model most pertinent here, notably the production function. (For a more complete description, see Eliasson (1978, 1985) and Albrecht et al. (1989) and references therein.) The final part of the paper consists of a description and analysis of two sets of simulation runs on the model. The paper is concluded with an interpretation of the results and implications for future research.

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 75 % 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. I.e., firms are not price takers in this model.[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 analysis below, the rate of interest has been determined exogenously. At this given interest rate firms invest as much as they find it profitable to invest, given their profit targets.

Other sectors in the model are a government sector, a household sector, and a foreign trade sector. 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 in abbreviated form 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:

$$R_{it}^{E} = M_{it}\sigma_{it} - \rho_{j} + \mathring{p}^{K} + \epsilon_{it}\Phi_{it} \tag{1}$$

$$= R_{it}^{N} + \epsilon_{it}\Phi_{it} \tag{2}$$

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)

$\mathring{p}^{K}$ = 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

<u>Expectations/Targets</u>

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

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

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:

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

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:

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

where Q_{it} = potential output (value added)

$QTOP_{it}$ = 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}. 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:

$$TEC_{it} = \frac{TEC_{it-1}*QTOP_{it-1} + MTEC_{jt}*\blacktriangle QTOP_{it}}{QTOP_{it-1} + \blacktriangle QTOP_{it}} \qquad (6)$$

where

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

$$QTOP_{it} = QTOP_{it-1}*[1 - \rho_j]+\blacktriangle QTOP_{it}; \qquad (8)$$

$$\blacktriangle QTOP_{it} = INV_{it}*INVEFF_{it}; \qquad (9)$$

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.[10] 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 1.) 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 1).

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. It is also raised (lowered) if the technical efficiency ($INVEFF_{it}$) in the firm increases (decreases).[11]

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

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

where

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

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

$EXPP_{it}$ = the price the firm expects to obtain for its product

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

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

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 2, 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

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:

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

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 changed 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

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

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

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

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:

$$INVEFF_{it} = (QTOP_{it} * QP_{it})/K1_{it}, \qquad (17)$$

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

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

Thus, $INVEFF_{it}$ is essentially the firm's 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.

Simulations

First Set of Simulations: Varying the Rate of Technical Progress

Two sets of simulations are carried out. The object of the first set is to study the impact of different rates of technological progress (δ_j) on simulated labor productivity. The basic procedure is to vary the specification of δ_j in such a way as to obtain a simulated labor productivity rate of increase in each sector similar to the actual rate during the period 1980-1984. A sample of the assumptions made is listed in Table 1. The initial assumption is that δ_j should be identical to the observed trend in labor productivity (assumption 1). However, as shown in the table (Simulation 1), the resulting productivity turns out to be far too low in sectors 2 and 4. We then alter the assumptions as indicated. It is noteworthy that the productivity in sector 1 is not materially affected even when δ_1 is reduced to one-quarter of its initial value. In sector 2, a fourfold increase in δ_2 is required to bring the resulting productivity trend into the desired range. Sector 3 turns out to be similar to sector 1 in that it does not seem to matter much what assumption is made about δ_3. Sector 4 (the consumer goods sector) proves to be the most sensitive to the δ_j assumption. It is the only sector where there is a direct and positive correlation between δ_j and productivity. This suggests that it is only when technological progress affects final consumption that its impact is dramatic in terms of measured output and productivity.

Under the δ_j assumptions made in Simulation 4, the simulated productivity during the first ten years of the experiment comes very close to the rates actually observed for the period 1980-84 in each sector. However, the assumptions required to achieve this result seem unreasonable: annual improvements of labor productivity associated with new (best-practice) technology of 15 %, 15 %, and 13 %, respectively, in sectors 2, 3, and 4. As shown in Table 2, maintaining the same assumptions while running the experiment for 25 years results in extremely high growth rates for all the variables reported in the table. In particular, the average annual investment level jumps ten- to twenty-fold in sectors 2, 3, and 4 between the first ten and the last fifteen years of the simulation. A further examination of the simulation results shows that despite large differences among the various runs in the assumptions concerning δ_j, the differences in the level of investment and growth of output over the first five years of the simulations are negligible.

The implication of this is that other factors, including differences among firms in technical efficiency, are more important in explaining productivity and output growth than the rate of technological progress. Even with very substantial increases in technological progress, the resulting increases in productivity and economic growth are fairly modest during the first decade. But the impact is quite dramatic in the longer run, as demonstrated in the last 15 years of the simulation.

Since we are dealing only with process innovation here, i.e., the part most directly reflected in measured output, this suggests that it takes quite a long time for new processes to replace old ones. It would be interesting to investigate whether similar time lags apply to new products.

Second Set of Simulations: Varying Attitudes to Borrowing

These observations lead to a second set of experiments in which parameters other than δ_j are changed in order to influence the investment behavior and therefore also the rate of growth of output. The object of this set of simulations is to analyze investment behavior, productivity, and output growth while varying two parameters influencing firms' investment behavior, holding δ_j constant at the same rate as in Simulation 1 above.

The first of these parameters is ß. This is a constant used in the investment financing module to determine firms' desired change in borrowing.

A large value for ß expresses greater willingness on the part of profitable firms to borrow for investment and greater reluctance to borrow on the part of less profitable firms than does a small value for ß. In other words, when ß is large, firms are quite sensitive to their recent profitability as compared to the current rate of interest for borrowing. Conversely, when ß is small, firms are not heavily influenced in their borrowing by their recent profit performance.

The simulation results are shown in Table 3. When ß is increased from 1 to 2 (comparing Simulations 5 and 6), the output growth rate rises in each sector (except Sector 1) during the first ten years. The GNP growth rate also increases. The productivity growth rate rises in all sectors, except Sector 1. The investment level rises in Sectors 2 and 4 and is unchanged in Sectors 1 and 3. However, during the next 15 years, the higher value for ß leads to a shift of industrial output from Sectors 3 and 4 to Sectors 1 and 2, while the productivity growth rates fall. The investment level nearly doubles in Sector 2 and is cut in half in Sector 3. The overall investment level is higher during the last 15 years while the output and productivity growth rates are lower. The results are similar when β is raised even more. See Simulation 7. Comparing the results in Simulation 6 (in Table 3) with those in Simulation 4 (in Table 2) reveals that the targeted rate of productivity increase in each sector can be reached by varying other parameters than δ_j. The interpretation which firms place on their profitability performance can influence their investment behavior via their expectations for the future. This may or may not change investment at the macro level, however. Comparing Simulation 7 with Simulation 5 reveals that in some cases there may well be a perverse relationship between investment and productivity. In Simulation 7, during the last 15 years, the investment level is higher in sectors 1 and 2 while the productivity increase is smaller than in Simulation 5; in sectors 3 and 4, the investment level is higher in Simulation 7 than in Simulation 5 while the productivity growth rate is lower. The total investment in manufacturing is higher and the growth rates of productivity and output are also higher when more profitable firms invest more and less profitable firms invest less. As one would expect, the profitability in manufacturing also rises.

Third Set of Simulations: Varying Sensitivity to Capacity Utilization

Finally, the impact of the parameter η was examined. See equation (14). η is an elasticity parameter which reduces firms' desired new borrowing (and hence investments) whenever capacity utilization is low. A higher value of η makes firms with low capacity utilization rates less investment prone, while those with higher than normal utilization rates invest more.

The results of varying η are shown in Table 4. When η is changed from 3 to 4 (comparing Simulations 5 and 8), the output growth rate rises in each manufacturing sector except Sector 1. The rate of productivity growth also rises in each sector except Sector 2. The GNP growth rate increases as well. It is interesting to note, however, that this is achieved while the amount invested falls somewhat in all sectors (except Sector 4). Thus, when investment is diverted from firms with high utilization rates to those with lower rates, less total investment is needed to achieve an improvement in overall performance.

Conversely, when η is reduced (i.e., excess capacity holds investment back less and firms with higher than normal utilization rates are more cautious in expanding), the total investment level rises, while productivity in manufacturing and GNP fall.

The implication of these results is that it matters more for output and productivity how investment is allocated among firms than what the total amount invested is. This suggests one reason why macro analyses of the role of capital investment in explaining productivity growth differ as much as they do.

The output of the raw material sector declines during the first ten years (in constant prices) in all of the simulations but rises during the last 15 years. This reflects the fact that in the base year (1982) there were many firms in this industry suffering from low or negative profitability as a result of the worldwide overcapacity in the basic metals industry. The profit margins in this industry fall dramatically in the first few years of each simulation. They rise in subsequent years but do not catch up with those in other industries even during a 25-year simulation.

Interpretation of Results

The first important observation that can be made on the basis of these results is that the conditions which determine resource allocation among firms and plants within each industry (including technical inefficiency) seem to be 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. This result confirms the findings of Nishimizu and Page (1982) and Førsund & Hjalmarsson (1987).

This is illustrated in Simulation 6 (Table 3). During the last 15 years of this simulation, the simulated productivity change is almost perfectly negatively correlated with the assumed rate of

δ_j: Sector 4 with the lowest rate of δ_j has the highest productivity increase, while Sector 1 with the highest δ_j has the lowest productivity growth. Also, as is evident in comparing the first set of simulations (1-4) with the second set (5-9), 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.

One implication of this 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.

Conclusion

This paper has raised a number of issues concerning productivity analysis. First of all, an attempt has been made to demonstrate the usefulness of a micro-based approach to productivity analysis. This approach challenges some of the basic assumptions of conventional analyses based on aggregate production functions. The paper has shown with the help of a micro- (firm-)based macro simulation model that once it is recognized that there are important differences among firms in economic competence, here represented by efficiency and investment behavior, the relationships between investment, productivity, and economic growth are much more complex and unpredictable than commonly assumed. The rate of technological progress as measured by the rate of change in best-practice technology seems to be less important than the elimination of inefficiency by closure of firms and/or by firms moving closer to their respective production frontiers.

While it is generally recognized in productivity analyses that resource allocation among sectors affects measured productivity growth, this paper has explored the impact of differences among firms in efficiency and investment behavior. It has been shown that the conditions which determine firm borrowing for investment (involving their interpretation of past profitability and expectations based on current capacity utilization) are more important for productivity and economic growth than the total amount invested. In other words, it matters less how much is invested than who does the investing, and under what incentives.

The implication of these results for productivity analysis is that unless diversity among economic units of the sort indicated here is taken into account, the results are likely to continue to be inconclusive. What is needed is much more of an integration of micro and macro theory than has been accomplished thus far. In particular, economic competence must be included. It is elusive and difficult to model even at the firm level -- but the task appears hopeless at the macro level. Thus, some form of micro-based modeling seems essential. The micro-to-macro model used in this paper offers a promising start. The results reported here suggest also that it would be useful to revise the model in several ways, and particularly to incorporate more aspects of economic competence.

Secondly, while the focus in this paper has been on identifying some microeconomic factors of importance to productivity analysis -- especially the role of economic competence -- rather than on explaining the recent slowdown in productivity growth, other simulations carried out on the micro-to-macro model have demonstrated the model's usefulness for that purpose as well. In an earlier study, Eliasson (1983) analyzed the impact of the price shocks of the 1970s, particularly in the oil market, on the economy as a whole. An interpretation of those results is that the oil price shocks not only created a great deal of uncertainty, directly influencing investment behavior as demonstrated in this paper, but also made obsolete a sizable portion of tacit knowledge -- resulting in increased inefficiency -- as well as a large part of physical capital, especially in the energy-intensive raw material-based industries. In other words, the model makes it possible to trace the impact of such shocks rather than having to assume their effects as in conventional macroeconomic models.

Thirdly, an attempt has been made to put productivity in the proper perspective, not as an object in and of itself but rather as a partial measure, at best, of economic performance at any level within the economy. At the firm level, profitability and market share growth are much more important and comprehensive indicators of economic performance; at the macroeconomic level, the corresponding indicator is international market share growth under conditions of stable terms of trade.

1. Wolff (1985) provides a good summary of recent attempts to estimate the contribution of various factors to the productivity slowdown.

2. See Jorgenson (1988) and references therein for some notable exceptions in the form of studies based on detailed industry-level data.

3. In an interesting paper, Pelikan (1989) has demonstrated the importance of self-organization and of the rules which determine which economic agents are chosen at various levels, from the firm to the whole economy. He argues that the market for corporate control contributes to the effective evolution of organizational structures by selecting on the basis of economic competence, thus contributing to dynamic social efficiency. He also argues that it is precisely the absence of such a market for corporate control which makes centrally planned economies inferior to market economies.

4. For a review of the relevant literature in this area, see Sandberg (1987) and Fredriksson (1989).

5. A similar effect has been noted for a closely related phenomenon, namely technological change:

> There is no evidence which established definitely that technical or economic progress receives greater contributions from the few and rare large advances in knowledge than from the many and frequent smaller improvements. Economically, it might for a period well pay a community to starve its scientific and major technical work and to devote resources to the most thorough and systematic gathering together and exploitation of all the immediate and tiny practical improvements in ways of manufacture and design. (Jewkes, Sawers & Stillerman 1958, p. 6.)

6. Beginning in 1976, this model has been developed at the Industrial Institute for Economic and Social Research (IUI) in Stockholm under the leadership of Gunnar Eliasson. It is a very large model; it is programmed in APL, but if it were in FORTRAN, the program would require some 5-10,000 lines. About 50 variables are determined each quarter for each firm in the model. A 15-year simulation requires about 30 CPU minutes on a DEC 20 computer.

7. This section 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.

10. $INVEFF_{it}$ generally varies between 0.3 and 0.4 in the model.

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

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Figure 1. The Long-Run Production Function

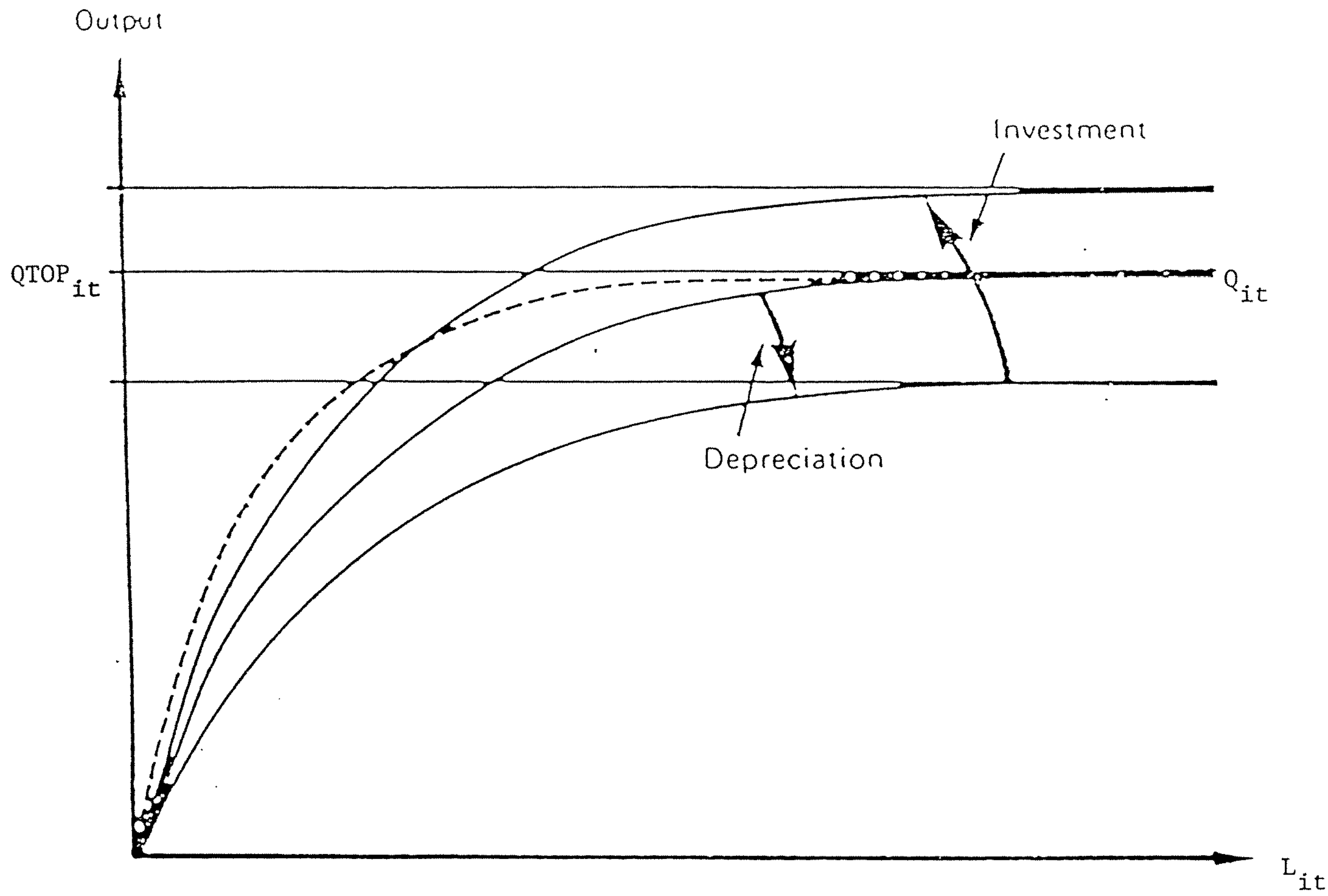

Figure 2. Short-Run Production Planning

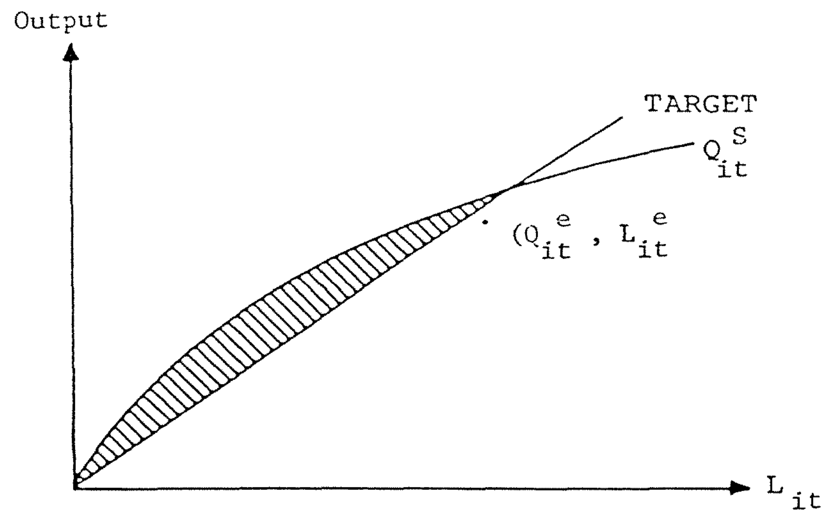

Table 1 **Simulation Results - First Set:**
Impact on labor productivity of varying assumptions on δ_j. Average annual percentage change. 10-year simulation

Sector	Simulation 1		Simulation 2		Simulation 3		Simulation 4	
	Assumed δ_j	Simulated productivity	Assumed δ_j	Simulated productivity	Assumed δ_j	Simulated productivity	Assumed δ_j	Simulated productivity
1	6.1	6.8	3.4	7.8	1.5	7.8	3.0	7.2
2	3.8	0.8	3.1	0.2	30.0	3.7	15.0	3.5
3	5.3	3.9	3.4	4.3	20.0	5.7	15.0	5.4
4	2.4	-0.1	2.8	0.5	6.0	0.5	13.0	2.5
Total manufact.	..	2.1	..	2.4	..	3.6	..	4.2
Manufacturing output		5.5		5.9		7.1		7.7
GNP		3.1		3.2		3.8		4.1

Table 2. **Simulation 4**

Assumptions:
$\beta = 1$; $\eta = 3$; $\delta_1 = 3.0$; $\delta_2 = 15.0$; $\delta_3 = 15.0$; $\delta_4 = 13.0$

Period	Output Growth Percent per year 1-10	Output Growth Percent per year 10-25	Productivity Percent per year 1-10	Productivity Percent per year 10-25	Average Investment Billion SEK 1-10	Average Investment Billion SEK 10-25
Sector 1	-3.2	3.7	7.2	4.2	1.3	3.4
Sector 2	6.2	13.4	3.5	8.4	14.9	136.7
Sector 3	6.6	16.0	5.4	11.4	12.6	200.7
Sector 4	9.7	15.3	2.5	11.4	13.7	247.6
Total Manufact.	7.7	12.1	4.2	10.8	42.5	588.5
GNP	4.1	9.3	..	..	..	..

Table 3. **Simulation Results - Second Set:**
Varying assumptions on ß

SIMULATION 5

Assumptions:
$\beta = 1; \eta = 3; \delta_1 = 6.1; \delta_2 = 3.8; \delta_3 = 5.3; \delta_4 = 2.4$

Period	Output Growth Percent per year 1-10	10-25	Productivity Percent per year 1-10	10-25	Average Investment Billion SEK 1-10	10-25
Sector 1	-0.6	4.3	6.8	2.6	1.3	5.9
Sector 2	5.3	6.9	0.8	4.3	12.3	46.7
Sector 3	5.2	4.5	3.9	4.7	10.3	18.1
Sector 4	7.3	4.1	-0.1	5.6	9.2	21.6
Total Manufact.	5.5	5.2	2.1	5.0	33.1	92.4
GNP	3.1	4.1	..	..	..	..

SIMULATION 6

Assumptions:
$\beta = 2; \eta = 3; \delta_1 = 6.1; \delta_2 = 3.8; \delta_3 = 5.3; \delta_4 = 2.4$

Period	Output Growth Percent per year 1-10	10-25	Productivity Percent per year 1-10	10-25	Average Investment Billion SEK 1-10	10-25
Sector 1	-1.5	5.7	6.6	2.3	1.2	7.1
Sector 2	6.9	8.3	3.1	3.2	14.1	81.4
Sector 3	6.9	0.5	5.1	3.7	10.2	9.8
Sector 4	8.3	3.4	0.9	5.6	12.6	19.8
Total Manufact.	6.8	4.6	3.8	4.3	38.2	118.1
GNP	3.7	3.8	..	..	..	..

Table 3 (continued)

SIMULATION 7

Assumptions:
$\beta = 3$; $\eta = 3$; $\delta_1 = 6.1$; $\delta_2 = 3.8$; $\delta_3 = 5.3$; $\delta_4 = 2.4$

Period	Output Growth Percent per year 1-10	10-25	Productivity Percent per year 1-10	10-25	Average Investment Billion SEK 1-10	10-25
Sector 1	-2.2	6.1	8.6	1.9	1.4	6.8
Sector 2	5.8	9.9	2.7	4.0	11.0	88.1
Sector 3	6.2	3.0	4.4	4.9	10.9	15.0
Sector 4	9.3	2.0	0.6	5.8	10.1	16.2
Total Manufact.	6.5	5.5	3.3	5.3	33.4	126.1
GNP	3.6	4.3	..	..	..	..

Table 4 **Simulation Results - Third Set:**
Varying assumptions on η

SIMULATION 5

Assumptions:
$\beta = 1;\ \eta = 3;\ \delta_1 = 6.1;\ \delta_2 = 3.8;\ \delta_3 = 5.3;\ \delta_4 = 2.4$

Period	Output Growth Percent per year 1-10	Productivity Percent per year 1-10	Average Investment Billion SEK 1-10
Sector 1	-0.6	6.8	1.3
Sector 2	5.3	0.8	12.3
Sector 3	5.2	3.9	10.3
Sector 4	7.3	-0.1	9.2
Total Manufact.	5.5	2.1	9.2
GNP	3.1	..	..

SIMULATION 8

Assumptions:
$\beta = 1;\ \eta = 4;\ \delta_1 = 6.1;\ \delta_2 = 3.8;\ \delta_3 = 5.3;\ \delta_4 = 2.4$

Period	Output Growth Percent per year 1-10	Productivity Percent per year 1-10	Average Investment Billion SEK 1-10
Sector 1	-2.4	8.4	1.2
Sector 2	5.8	0.5	13.0
Sector 3	5.5	4.2	8.2
Sector 4	8.6	1.0	9.6
Total Manufact.	6.0	2.9	32.1
GNP	3.4	..	..

Table 4 (continued)

SIMULATION 9

Assumptions:
$\beta = 1$; $\eta = 1$; $\delta_1 = 6.1$; $\delta_2 = 3.8$; $\delta_3 = 5.3$; $\delta_4 = 2.4$

Period	Output Growth Percent per year 1-10	Productivity Percent per year 1-10	Average Investment Billion SEK 1-10
Sector 1	-3.7	8.0	1.2
Sector 2	5.2	0.5	12.3
Sector 3	5.2	3.4	11.9
Sector 4	7.8	-0.5	9.1
Total Manufact.	5.4	2.1	34.5
GNP	2.9	..	..