TECHNICAL CHANGE AND LONGEVITY OF CAPITAL IN SWEDISH SIMULATION MODEL

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The Model

The purpose of this paper is to explore the effects of varying assumptions on technical change and the longevity of capital on the performance of a microbased simulation model of the Swedish economy. This model has been described in several papers[1]. We shall be concerned here only with the block within the larger model where the output, employment and investment of firms are determined.

Like in all growth models, the assumptions regarding the way technological change enters in are crucial. In the particular model investigated here, the production function for each firm is of the form

$$Q(t) = QTOP(t) \cdot \left\{ 1 - e^{\frac{-TEC(t) \cdot L(t)}{QTOP(t)}} \right\} \qquad (1)$$

where $Q(t)$ = potential output (value added)
$QTOP(t)$ = the maximum level of output which is approached asymptotically when infinite amounts of labor are used, given a certain level of capital stock.
$TEC(t)$ = state of technology
$L(t)$ = firm employment and
t refers to the time period.

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[1] E.g. Gunnar Eliasson in collaboration with Gösta Olavi and Mats Heiman; A Micro Macro Interactive Simulation Model of the Swedish Economy. Preliminary Model Specification. IUI, Working Paper No. 7, 1976.

The production function is illustrated in figure 1. 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(t). The state of technology at time t is determined by the previous period's state of technology and the amounts and level of productivity of new capital:

$$\mathrm{TEC}(t) = \frac{\mathrm{TEC}(t-1)\cdot \mathrm{QTOP}(t-1) + \mathrm{MTEC}(t)\cdot \Delta\mathrm{QTOP}(t)}{\mathrm{QTOP}(t-1) + \Delta\mathrm{QTOP}(t)} \qquad (2)$$

where

$$\mathrm{MTEC}(t) = \mathrm{MTEC}(t-1)\cdot\{1 + \mathrm{DMTEC}(j)\}; \qquad (3)$$

$$\mathrm{QTOP}(t) = \mathrm{QTOP}(t-1)\cdot\{1-\mathrm{RHO}(j)\} + \Delta\mathrm{QTOP}(t); \qquad (4)$$

$$\Delta\mathrm{QTOP}(t) = \mathrm{INV}(t)\cdot \mathrm{INVEFF}(t); \qquad (5)$$

INV(t) = the level of investment in the firm in period t;

INVEFF(t) = the efficiency of newly installed capital (obtained from another part of the model and therefore treated here as exogenous);

MTEC(t) = the level of labor productivity associated with new capital;

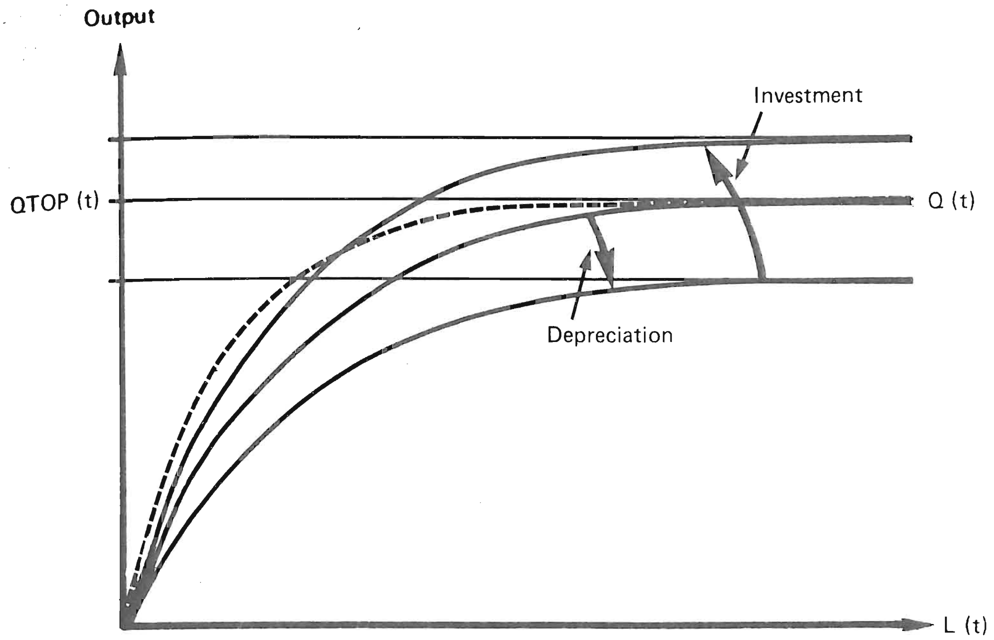
DMTEC(j) = the rate of change of MTEC(t) in sector j; exogenous;

RHO(j) = the rate of capital depreciation in sector j, j=1,...,4

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

Hence, capital enters into the production function indirectly via its effects on labor productivity, and technological change can therefore be regarded as embodied in new capital. Note that QTOP(t), the maximum output attained asymptotically when infinite amounts of labor are used, is not affected by TEC(t). 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). QTOP(t) is lowered due to the depreciation of capital and raised due to gross investment.

Figure 1. Production Function.



Note: Figure from Eliasson; A Micro-Macro Interactive Simulation Model of the Swedish Economy, p. 133. IUI Working Paper No. 7, 1976.

It can be seen that there are three factors which are essential to the growth of potential output, namely the level of investment INV(t), the productivity of new capital MTEC(t), and the rate of depreciation of capital RHO(j). The level of investment is determined endogenously in another block of the model; however, in the present paper it is treated as an exogenous variable. We will be concerned, therefore, with only two "growth factors", the rate of change of labor productivity associated with new capital and the rate of depreciation of capital. Both of these variables are regarded here as branch specific rather than firm specific. This is an assumption which can be changed when the synthetic firm data which are currently used in the model are replaced by real firm data. It will then be possible also to let both DMTEC(j) and RHO(j) vary over time as well as between firms.

In order to limit the system further and focus the analysis, we also treated household demand for industrial goods by sector as exogenous, even though this set of variables is determined endogenously in the full version of the model. The version used here has interindustry markets and a full input/output system but no public and monetary sectors.[1] The time period studied is 1955-75, and each simulation run covers 20 years.

Experiments with the Rates of Depreciation and Technological Change

Two sets of experiments were carried out. In the first set, the assumption in the original model regarding the longevity of capital DEPR(j) = 1/RHO(j) and the rate of growth of productivity of new investments DMTEC(j) were changed. The purpose of this experiment was to investigate the sensitivity of some key results in the model to changes of this sort.

In the second set of experiments, the idea was to apply empirical data from other sources regarding the rate of growth of labor productivity, i.e. the growth rate of TEC(t), in such a way that it was possible (1) to differentiate among the four industrial sectors in the model and (2) to determine what rate of change in the productivity of new capital, DMTEC(j), would be compatible with the observed differences in TEC(t), given the investments in each sector.

In the original model, the depreciation period of capital was assumed to be 10 years for all firms. In the first set of experiments the depreciation period was lengthened to 20 years and 30 years. At the same time, the assumed rate of growth of productivity of new investments, DMTEC, was allowed to vary from 3.0 percent per annum in the original model.

The combinations of assumptions made are shown in figure 2 and the results are summarized in figures 3-5, together with empirically observed trends. It can be seen that the rates of growth of labor productivity and production increase and the rate of decline of the industrial labor force slow down as the depreciation period is increased. The growth effect may seem surprising at first sight but it indicates that there is a capacity constraint depending on the longevity of capital which keeps down output and employment. A longer life of equipment, ceteris paribus, simply means that there will be more capital per employee to work with.

It is hardly surprising that production and labor productivity increase faster when the rate of growth of productivity of new capital rises. It is less obvious, however, that the rate of decline of the industrial labor force should not be correlated with the changes in

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1) See Figures 1 and 6 in Eliasson's presentation of The Swedish Micro-to-Macro Model, pp. 179 ff.

the productivity of new capital. Note that industrial employment has declined in the last 20 years and that this is reflected in all the experiments reported here. As can be seen in figure 5, the rate of decline in industrial employment becomes somewhat slower as DMTEC rises from zero to 1.5%. Then the rate of decline increases as DMTEC continues to increase. Our interpretation is that, on the one hand, higher productivity of new capital yields a higher profit to firms, thus supporting investment and growth in output and hence more expansive labor recruitment plans. But, on the other hand, as the productivity of new capital reaches beyond a certain point, the labor requirement is reduced and hence industrial employment decreases. This result depends on the fact that economic growth is fully endogenized in the model within the capacity constraint set by the rate at which new technology (MTEC) enters in.

The conclusion from these experiments is that the results in the model are fairly sensitive to the changes in assumptions made here. Generally speaking, the results seem to improve relative to those of the original version of the model as the depreciation period is lengthened from 10 years to 30 years, although they still leave a good deal to be desired. The results as far as technological change goes are much less clear. Therefore, we will turn now to a sensitivity analysis using various numerical specifications of DMTEC.

Figure 2. Assumptions

		DEPR=10 DMTEC=0.03	
DEPR=20 DMTEC=0.00	DEPR=20 DMTEC=0.015	DEPR=20 DMTEC=0.03	DEPR=20 DMTEC=0.06
		DEPR=30 DMTEC=0.03	

Figure 3. Rate of Growth of Labor Productivity

% anually

		3.98	
3.78	3.88	4.14	4.41
		4.27	

Empirically observed value: 6.1%.

Figure 4. Rate of Growth of Production

% anually

		2.64	
2.35	2.90	3.06	3.14
		3.32	

Empirically observed value: 4.6 %/year

Figure 5. Rate of Growth of Employment in Industrial Sector

% annually

		-1.28	
-1.38	-0.94	-1.04	-1.22
		-0.90	

Empirically observed value: -0.9 %/year

Technological Change Broken Down by Sector

In a study published recently by the Industrial Institute for Economic and Social Research (IUI)[1], an attempt was made to estimate "total producitivity" growth after allowance has been made for the increase in labor and capital inputs (the so-called residual). This concept is very closely related to the rate of change of TEC(t) in our model. TEC(t) is normally determined endogenously in the model, based on assumptions on DMTEC(j) as shown above. In the original model, DMTEC(j) is set to 3.0 percent per year in all four industrial sectors. The basic idea behind the second set of experiments was to try to "estimate" DMTEC(j) in each sector, given TEC(t) as obtained from the study just mentioned, and given exogenous values on investment. In this sense, the procedure used here is the reverse of that normally used in the model.

An iterative approach was used. As a starting point, DMTEC(j) was set equal to the empirically observed trend for TEC(t) in each sector. The depreciation period was assumed to be 20 years. The results are shown in the upper part of figure 6. Under these assumptions, the resulting trend for TEC(t) turns out to be higher than that observed in all four sectors (cf. bottom line in the figure). This is true especially for the consumer goods sector.

In another iteration, the same assumptions were made except for a longer depreciation period, namely 35 years instead of 20 years. The results are very similar to those of the first iteration, as shown in the middle section of figure 6, i.e. the length of the depreciation period beyond 20 years does not seem to make much difference.

The assumption of a 35-year depreciation period is based on empirical studies[2] which estimate the depreciation time at 35-40 years (an average for machine and building investments) depending on the sector in question. The assumption of a 35-year depreciation period was retained throughout the rest of the iterations.

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[1] G Eriksson, U Jakobsson and L Jansson, "Produktionsfunktioner och strukturomvandlingsanalys" (Production Functions and Analysis of Structural Change), in IUI:s långtidsbedömning 1976. Bilagor (IUI, Stockholm 1977).

[2] E.g. C O Cederbladh,"Realkapital och avskrivning" (Real Capital and Depreciation), Urval, no 4, National Central Bureau of Statistics. Stockholm 1971.

In the lower section of figure 6, the results of the final iteration are shown. It turns out that the growth rates of the labor productivity associated with new capital which are compatible with the observed trends for TEC(t) are the following: 5.6% per year in the raw materials processing sector, 3.0% in the intermediate goods sector, 2.6% in the investment goods sector, and only 0.4% in the consumer goods sector. Thus, there seems to be a substantial reduction in the rate of growth of the labor productivity associated with new capital as we go from the heavy process industries to the light consumer goods industries, i.e., the rate of technological change seems to be reduced considerably. This is quite plausible, given the fact that technological change can be expected to be more embodied in highly capital intensive industries than in industries where capital plays a relatively insignificant rôle.

This result might indicate that the hypothesis that technological change is embodied attributes too much to capital, especially in the consumer goods industries. It appears reasonable that technological change is more disembodied in relatively labor and skill intensive industries than in capital intensive industries. This type of interpretation would explain why the difference between DMTEC(j) and the trend for TEC(t) is large in these industries and small in capital intensive industries. However, even if this should be true, the fact that the rate of growth of TEC(t) is relatively small in the consumer goods industries would indicate that the disembodied technological change has been slow, even if all technological change were attributed to this factor.

It can be demonstrated that if

DMTEC > (RHO + Net Capacity Growth),

i.e. if the rate of growth of marginal labor productivity is higher than the sum of the rate of depreciation and the net capacity growth, the growth of average productivity of firms would not be able to keep up with DMTEC but would lag more and more behind. With RHO = 2.9% per year (35-year depreciation), and as long as net capacity expands, such an increasing gap would arise only at rates of growth of MTEC substantially exceeding 2.9%. As is shown in the lower part of figure 6, this would be most likely to occur in the raw materials processing sector, since that is the only sector where

Figure 6. Results of Experiments with Varying Assumptions on Technological Change and the Longevity of Capital

	Raw Materials Processing	Inter-mediate Goods	Invest-ment Goods	Consumer Goods
DMTEC =	5.9%	3.9%	3.6%	1.5%
Resulting trend for TEC DEPR = 20 years	6,1%	4.8%	4.5%	2.7%
DMTEC =	5.9%	3.9%	3.6%	1.5%
Resulting trend for TEC DEPR = 35 years	5.8%	5.0%	4.5%	2.7%
DMTEC =	5.6%	3.0%	2.6%	0.4%
Resulting trend for TEC DEPR = 35 years	5.9%	3.9%	3.6%	1.5%
ACTUAL trend for TEC	5.9%	3.9%	3.6%	1.5%

DMTEC > 3%/year. However, even in this sector, like in the others, the "estimated" DMTEC is lower than the trend for TEC in all four sectors but especially in the consumer goods sector. This implies that investment must have taken place at such a high rate that the average labor productivity has risen faster than that of new capital, i.e. that the gap between average and best practice technology has diminished. This finding, if it is borne out in further analysis, is directly opposite to results obtained in some other IUI studies[1] which have indicated an increasing gap.

The question thus arises whether the results in the studies cited here hold only for the relatively homogeneous sectors for which they were obtained or if they have more general application. This is being analyzed in a research project currently going on at the IUI. Another issue which is also the object of further study within the same project is whether it is true, as indicated above, that technological change has been more rapid in capital intensive than in labor and skill intensive industries and how such differences could be explained at both industry and firm level. The simulation model used in the current paper will provide a means of analyzing the impact at the macro (economy-wide) level of technological and productivity changes at the micro level.

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[1] L Hjalmarsson and F Førsund, "Technical Progress and Structural Efficiency in Swedish Milk Processing", paper presented at the international colloquium on Capital in the Production Function at Paris-Nanterre, November 18-20, 1976; Hjalmarsson and Førsund, "Production Functions in Swedish Particle Board Industry", paper presented at the same conference; A Grufman, "Technical Change in the Swedish Hydro Power Sector 1900-1975", paper presented at the IUI Conference on Production, Technology and Structural Change, in Stockholm July 1977.