TECHNICAL CHANGE AND LONGEVITY OF CAPITAL IN A 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:

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

where

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

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

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

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. <u>Production Function</u>.
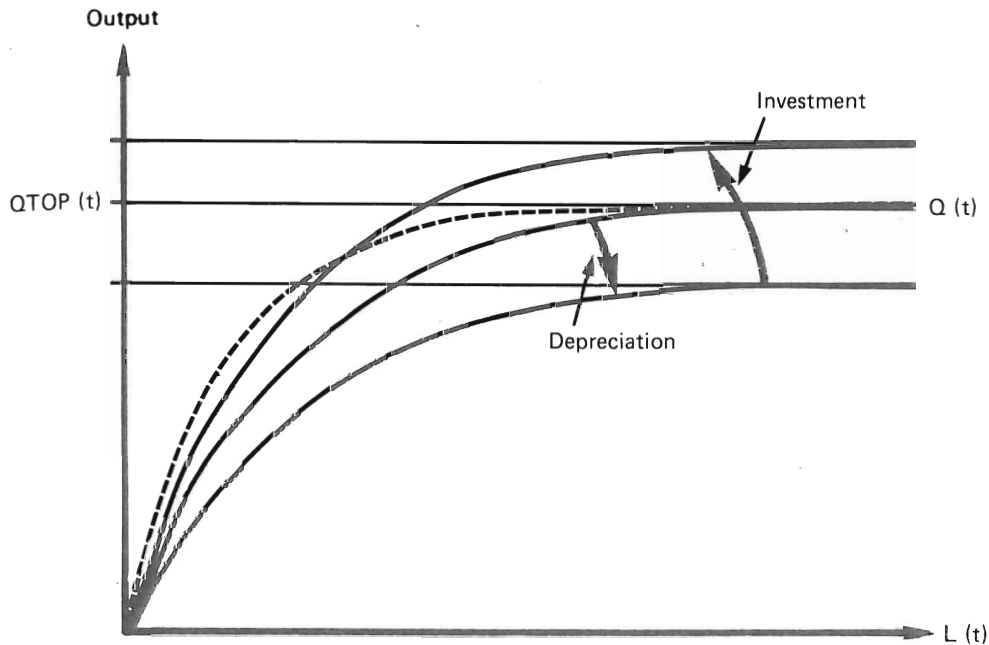
Output

Note: Figure from Eliasson; <u>A Micro-Macro Interactive</u>
<u>Simulation Model of the Swedish Economy</u>, 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) = l/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 pro-
ductivity, i.e. the growth rate of TEC(t), in
such a way that it was possible (1) to dif-
ferentiate 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 invest-
ments, 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, the first paper in
this conference volume.

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 in-
crease. 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 en-
dogenized in the model within the capacity
constraint set by the rate at which new tech-
nology (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 tech-
nological 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	

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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

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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 deter-
mined 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 result-
ing 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, "Produktions-
funktioner 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 compat-
ible 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 ex-
pected to be more embodied in highly capital in-
tensive industries than in industries where capi-
tal plays a relatively insignificant rôle.

This result might indicate that the hypothesis
that technological change is embodied attri-
butes too much to capital, especially in the
consumer goods industries. It appears reason-
able that technological change is more dis-
embodied in relatively labor and skill inten-
sive 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 in-
dustries and small in capital intensive in-
dustries. 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 techno-
logical 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

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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 re-
search 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 technologi-
cal change has been more rapid in capital inten-
sive 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 Pro-
cessing", 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 Struc-
tural Change, in Stockholm July 1977.