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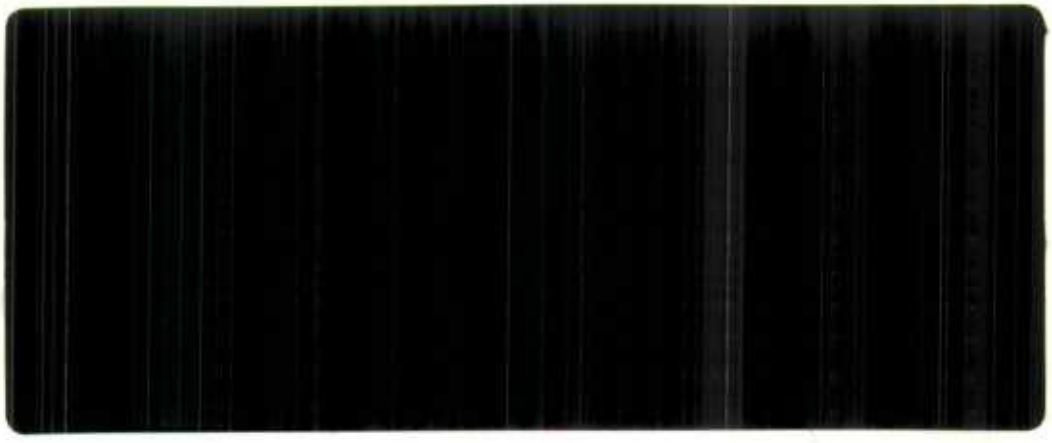

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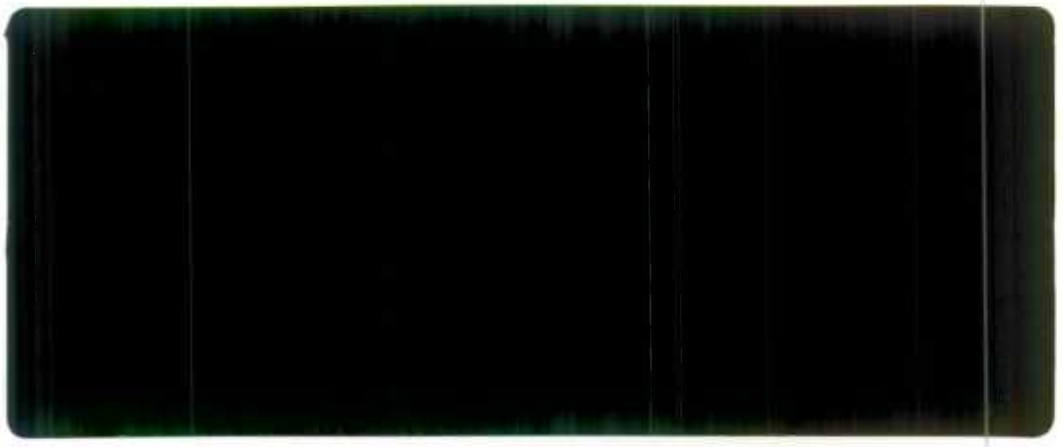

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Preliminary

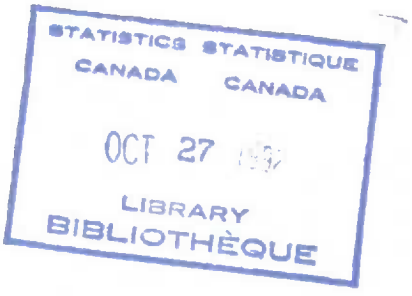
GROWTH ACCOUNTING AND THE QUALITY ADJUSTMENT OF THE CAPITAL STOCK

By

René Durand

26

February 1990



1 - Introduction

This note deals with the quality adjustment issue in the measurement of the capital stock. A change in the quality of capital goods is usually considered as equivalent to a change in the volume of these goods. Improvements in the quality of capital goods are translated into equivalent changes in volume by adjusting the price of the capital goods used to deflate the nominal investment flows.

It is usually recognized that one effect of technical progress is to improve the quality of capital goods produced through time. It is thereby also implicitly recognized that technical progress impacts on the growth of capital stock. This is, however, only one channel through which technical progress acts on the growth of the capital stock. Indeed, with technical progress, more of the same capital goods can be produced through time with the use of the same amount of inputs.

This note, therefore, begins by establishing a distinction between the inputs whose growth is subject to the direct impact of technical progress and those which are not. Produced inputs such as intermediate inputs (goods and services purchased by industries) are in the first category. Intermediate inputs are dealt with first in order to introduce the subject of the discussion. This leads to an alternative productivity index formula to assess productivity at the industry level. This formula is used as a building block when extended to take capital into account.

Secondly, the note attacks the question of adjusting capital **inputs** for quality changes. It is shown that the dynamic index number formula that we proposed (Durand and Salem (1987)) fully adjusts capital inputs for quality changes resulting from technical progress. It seems that Denison (1989, p.31, note 21) would agree with this view as he is agreeing with the similar view proposed by Rymes.

The dynamic index number formula does not solve the issue of the quality adjustment of capital goods as **outputs** of the production system, nor does Rymes alternative model. We therefore reject this method (what Denison (1989) calls method 4 in his recent book) to adjust capital goods for quality change on the basis of that principle.

We finally and tentatively suggest an alternative solution to the quality adjustment of capital goods as outputs of the production system. This alternative solution would not entirely solve the issue but it would alleviate it substantially on empirical grounds, given the importance of computers in the capital stock.

2 - Inputs Subject to Technical Progress

Denison has made the point that proper growth accounting must establish a clear distinction between the sources of growth. In particular, the growth in output resulting from the growth in inputs must be distinguish from the growth in output resulting from technical progress. The latter, following Denison, could be defined as the general advance in knowledge. Alternatively, technical progress may be defined as a shift through time in the production function so that more output can be obtained from a given set of inputs.

Technical progress, in most analyses, is considered as exogenously given and as a free gift of nature. Inputs, on the other hand, are considered as being supplied only at a sacrifice of some kind and, consequently, as being acquired at a cost. For instance, the labour input is considered as a sacrifice of leisure and the capital input is usually considered as a sacrifice of present consumption in exchange for future consumption or as a waiting sacrifice.

We consider two categories of inputs: produced and non produced inputs. Produced inputs, like intermediate inputs, are themselves outputs of the productive system. In fact, produced inputs are not given to the production system as a whole but are rather a function of its use of primary inputs. In other words, intermediate inputs are not acquired at a cost for the production system as a whole, and consequently, do not qualify as inputs according to the above definition of inputs. This would explain why, at the aggregate economy level, inputs are comprised only of primary (non produced) inputs and output is, consequently defined as net output.

As produced inputs are themselves outputs or the production system, technical progress increases the quantity of these which can be obtained from the inputs used in their production. It follows that growth in produced inputs can be broken down into two parts, namely, that part which results from growth in primary inputs used in their production, and that part which results from technical progress. From an aggregate point of view, proper growth accounting, therefore, requires that the growth in intermediate inputs in the productivity formula be separated into that portion resulting from the growth in primary inputs and that portion coming from technical progress[1].

To be sure, from the point of view of an industry looked at in isolation from the rest of the economy, the distinction between intermediate and primary inputs is not necessary nor relevant.

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[1] It can easily be shown that this distinction is at the heart of the weighting scheme of industries' productivity gain in aggregate business sector productivity growth. Domar(1961)'s aggregation weights sum to more than one simply to take into account that, when measuring productivity growth at the industry level, no distinction is made between primary and intermediate inputs.

From that point of view, both sets of inputs are acquired at a cost. Within a static accounting framework, we thus consider the traditional neoclassical view on productivity at the industry level to be perfectly legitimate.

It is only when looking at the productivity of an industry from the point of view of the economy as a whole that intermediate inputs can no longer be considered as exogenous, but rather must be considered as endogenous. An industry, when using intermediate inputs, is indirectly using the primary inputs of the economy. Indeed, in each period, intermediate inputs must first be produced before they are used as inputs.

For the business sector of the economy as a whole, therefore, the only exogenously (and costly) given inputs at the beginning of each period are the primary inputs. The latter are transformed into both intermediate and final end products. In the process, intermediate products, which are free to the system as a whole, are re-used as inputs. This leads to an alternative definition of productivity at the industry level suggested by Rymes and which we called the **interindustry** measure in our own work.

The interindustry measure of productivity refers to a fully vertically integrated set of production activities related to a given set of outputs. However, growth in inputs stemming from technical progress is now separated from basic input supply which refers only to primary inputs. Technical progress is now decomposed into that part which corresponds to improved efficiency of an industry and that part which correspond to improved efficiency of its supplying industries[2].

3 - Capital as an Input

Following the basic intuition provided by Rymes, we have decided to go one step further in the decomposition of growth between technical progress and input growth by extending the above reasoning to capital goods. In this extension, we have departed from Rymes in that we have adopted a fully dynamic scheme.

Capital goods are usually considered as primary inputs although they are produced inputs. This is perfectly legitimate in a static accounting framework where capital goods are exogenously given as

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[2] Denison(1989), in his recent book, suggests going one step further by considering final end products. Productivity on final end products is defined only in terms of the primary inputs directly and indirectly used in their production. It is therefore very similar in nature to the interindustry productivity index. Although, we tend to agree with this view, we still consider the interindustry index as useful on its own for the analysis of international competitiveness in an open economy. Indeed, industries not only deliver to final demand users but also to other industries. Some industries only deliver to the intermediate demand markets. On the latter markets, domestic supply is in direct competition with imports from other countries. We consider it useful to know how efficient is an economy in producing its intermediate inputs relative to its foreign competitors.

inputs to the productive system at the beginning of each period and are acquired at a cost. In a dynamic context, however, capital goods are not given but must be produced and accumulated. Saving or waiting becomes the true primary input which is paid for and capital becomes an intermediate (intertemporal) output of the system which is acquired at no additional cost.

The growth of the conventionally measured capital stock incorporates both the effect of past savings and the effect technical progress. Technical progress fosters the growth of the capital stock as the growth in investments is enhanced by technical progress given the inputs used in their production: indeed, with technical progress, the growth in the output of the capital goods producing industries exceeds the growth in their input use.

In simple terms, therefore, our dynamic formulation is based on the computation of a stock which results from pure savings. This is achieved by taking away all past contributions of technical progress to the growth of gross fixed capital formation and cumulating the residual investment flows into a stock. This stock is the cumulation through time of the contribution of savings net of discards and depreciation. Since it is different from the capital stock taken as the accumulation of durable goods for production use, it should be given a different name. Although our measure of that stock is different from Rymes' measure, we will also call it a stock of **waiting** for expository purposes.

Subtracting the rate of growth of the stock of waiting from the rate of growth of the conventionally measured capital stock gives the contribution of technical progress to capital accumulation. Following Denison's rule, this contribution of technical progress to capital growth and therefore to output growth, must be accounted for separately from the contribution of past savings and other inputs acquired at a cost.

Barring temporarily the issue of quality adjustment, therefore, capital as conventionally measured is not an improper measure of wealth accumulation resulting from both past savings and technical progress. The conventional measure of capital is improper only in the sense that if it is used as a measure of input into the production process, it attributes to much to past savings and not enough to technical progress. In other words, when capital is used as a measure of input in lieu of past savings or waiting, the resulting measure of productivity ascribes correctly to capital the resulting output growth. However, it must consequently be understood, that the residual productivity gains registered are exclusive of the productivity gains made in the process of capital accumulation. Clearly, the breakdown of output growth between its determinants is a matter of choice. Our own choice follows Denison's rule and fully separates inputs growth, in the sense we have just attributed to inputs, from technical progress, a pure (and costless) exogenous shift in the production function.

To clarify the above ideas further, it may perhaps be useful to establish a parallel with the measurement of labour input. We may consider a simple and well known paradigm whereby the household sector is considered as an additional industry of the business sector. As an industry, the household sector consumes various goods and services (intermediate inputs) and possibly directly some capital and labour inputs in order to produce an output of labour. The labour output of the economy is the labour force or workers who can be "purchased" on the market. The labour input is measured as hours worked. We may assume that the household industry experiences technical progress in that more labour force may be produced through time with the directly and indirectly used primary inputs. One of the impacts of technical progress on labour force is, therefore, to increase the number of workers per hour worked[3].

If employed workers (employment) were to be used as a measure of labour input instead of hours worked, than too much of the economy's output growth would be attributed to labour input (as a sacrifice of leisure) and the contribution of technical progress would consequently be underestimated. Of course, no one is actually suggesting to use employment as a better alternative to hours worked as a measure of labour input. But waiting is an input to the production system just like hours worked are. Similarly, capital goods are outputs of the production system like workers are in our simplified model. Nevertheless, it takes time to have the same idea that, similar to hours worked, past savings or capital purged of technical progress, should be used as a measure of input rather than the capital stock itself.

The difficulty in applying the above reasoning to capital goods is probably linked to the fact that, contrary to labour, capital, as an input, has no natural units, like hours, into which it could be measured. Labour inputs may be measured in hours worked but could alternatively be measured in consumption units of a base year by multiplying hours worked by the base year wage rate. Capital, as an input, can only be measured in consumption units of a base year. This measure is not intuitively as appealing as hours worked are for the labour input. In addition, the parallel between capital and labour stops there. Labour is a flow variable and even though capital services is also a flow variable, the capital per se is a stock variable. To transform capital goods from outputs of the productive system into consumption units foregone of a base year (a stock of waiting) involves a dynamic process which is not altogether intuitively obvious.

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[3] This is not unreasonable as, with the rise in the standard of living which has accompanied technical progress, the individual labour supply of hours has declined over the long run. Hours per person employed have been declining.

4 - Adjusting Capital for Quality Change

It should be intuitively clear from what precedes that adjusting the measure of capital goods for quality change has no impact on the measure of "capital", that is waiting, as an **input**. Indeed, whatever method is used to adjust the output of the capital goods producing industries, the stock of waiting will be the same as it is not immediately subject to the impact of technical progress. In other words, waiting is measured is base year consumption units which are homogeneous through time.

Now for capital goods as **outputs** of the production system, the quality adjustment issue remains totally unresolved. Clearly, Denison's suggestion of using Rymes'approach, or a similar approach like ours, to correct the measure of capital goods for quality change does apply only to capital goods as inputs (which transforms, in effect, capital goods into something else which we call waiting) but does not apply to capital goods as outputs.

But the more fundamental issue of whether capital goods should be considered at all as outputs of the production system should be addressed first. In a dynamic context, capital goods are valuable end products by themselves only to the extent that they represent potential future consumption. Indeed, capital goods represent a stock of wealth only insofar as they can be transformed into consumption goods in future periods. Capital goods may, in that sense, be considered as "intermediate-intertemporal" inputs. In other words, in a dynamic framework, what it seems that should be compared is the flow of inputs of labour and waiting with the flow of consumption through time. Capital goods are not part of such a comparison.

The comparison of two dynamic paths over an infinite time horizon, one corresponding to the inputs and the other to the outputs is simply not feasible. But an equivalent comparison can be performed on a period by period basis by transforming the future consumption flows into a stock variable. Over a limited time horizon, optimal growth could, alternatively, be formulated as a path which maximizes the continuous flow of consumption under the constraint that the stock of wealth reaches a given target level at the terminal date. The latter would represent discounted consumption over the extended future.

Looking at one period at a time, output growth could be measured in any time period as the growth in consumption and net worth. This may imply that output be defined net of depreciation as Denison has already suggested. But clearly, in a dynamic framework, capital goods have to be accounted for as valuable outputs of the productive system.

We are thus back to the necessity for correcting the measure of the capital stock for quality changes. We may not be quite back at the initial step, however, as we now have attributed a meaning to

capital goods as outputs of the productive system. Capital goods represent a stock of wealth, i.e. a flow of future consumption when open to the infinite time horizon. As such, the capital goods must clearly encompass both the effect of past savings and technical progress. But this also suggests that capital goods be measured, as outputs of the production process, in consumption units of the current year, that is on the basis of the relative prices prevailing at a given point in time. Given these prices, a dollar worth of output is a dollar worth of output, be it a consumer good output or a capital good output. We very tentatively suggest, therefore, considering to deflate the current price estimate of the capital stock, as a stock of wealth, by a consumer price index.

There are basically two advantages in using a consumer price deflator as a deflator of capital goods. First, for new construction, the quality changes are so substantial that for the most part, at least in Canada, the deflators are computed from input prices. This amounts to admit that, in fact, we do not have an output deflator for new construction. In addition, we know, from the dual price equation of productivity, that such a deflator takes productivity away from the construction industry and into using industries. Secondly, even for equipments, for which prices can be directly observed, quality changes are substantial and cannot be corrected for adequately. This is the case even when the prices of old (but unused) and new vintages can be compared on the same market for the same period as, over the short run, their relative price may not be indicative of their relative volume as would be their long run equilibrium relative price.

In addition, and perhaps more fundamentally, in the context of the theory of consumption forgone, insofar as the value of the capital stock is a measure of the discounted future consumption flows traded against present consumption, then it seems that it would only be logical that it be deflated by a consumer price index. Indeed, the two terms of the comparison are in effect two consumption baskets, not two investment baskets. Present consumption is traded against future consumption at a nominal interest rate whose real counterpart would logically be obtained by deflating the nominal interest rate with a consumer price index, not an investment price index. We believe that this is, at least, how households, as investors, would value their wealth.

Of course, consumer goods themselves are subject to quality change over time induced by technical progress. However, the extent of the quality change in consumer goods, presumably is not as extensive as in capital goods given the recent importance of computers and the rapid quality change experienced in these goods. Our suggested solution, therefore and for what it is worth, would only partly alleviate the issue of quality adjustment.

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