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The Productivity of a Nation

The measurement of technical change in the total production system (Example: Finland 1970–1985)

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Foreword

The foundations of generalized input-output dynamics, including the production of heteregeneous human capital and of active human time (or heteregenous labour), were introduced in my doctoral dissertation (1987).

Further theoretical developments have been reported in three articles in the Economic Systems Research, Journal of the International Input-Output Association, (1989, 1990, and 1991) and in a chapter I have written together with Arvid Aulin to his book (1992).

In the present study 1) overall and sectoral measures of technical change based on the generalized input-output dynamics are introduced as a generalization of earlier measures (including those of Peterson (1979), Wolff (1985) and Cas and Rymes (1991)) and 2) the empirical results concerning the technical change in the Finnish national economy in period 1970-1985 are presented.

This research project has been made possible by the co-operation of the Academy of Finland and the Statistics Finland. The Academy of Finland has financed it. The Statistics Finland has readily provided empirical data, access to computers and programs as well as office space, and now publishes this study in their series, for all of which I acknowledge my gratitude. I'm also grateful to several members of their staff who have kindly given me expert help in the utilization of their statistical data.

Helsinki, September 1992 *Pirkko Aulin-Ahmavaara*

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1 Introduction

Technical change, or change in total factor productivity, is normally measured by the difference between the growth rate of output and the weighted sum of the growth rates of productive inputs. If output is represented by the value added then only capital and labour are regarded as productive inputs, or as factors of production. On the other hand, also intermediate inputs can be treated as factors of production. In this case they have to be included in the value of output as well.

However, sectors do not benefit only from improvements in their own immediate production techniques but also from technical progress in sectors producing inputs for them. This fact is taken into account in a measure of technical change in which all the sectors contributing, directly or undirectly, to the final output of a sector are thought to be vertically integrated to that sector. This measure has been derived, in different ways, by Peterson (1979), Wolff (1985) and Cas & Rymes (1991). All of them have also suggested different ways of treating also capital stock as a produced input.

In this study we are going even further. Also human capital and active human time are treated as products. This is dictated by the inner logic of the definition of total production suggested in this study, and not just by the opinion of this author. It also follows, directly from the definition of production, that the natural way of representing the total production system is the dynamic input-output model, modified to deal with long gestation and productive periods and generalized to include the production of human capital and of active human time.

Then the concept of technical change is generalized to the total production system defined in this study. The *rate of change of the balanced rate of growth*, suggested here as the overall measure of technical change, is a generalization to the total production system of the traditional overall measure of technical change. Likewise the *rate of change of the production price* based on the generalized input-output dynamics, suggested here as the sectoral measure of technical change, is a generalization to the total production system of the sectoral measure for the wholly integrated sectors. A decrease in the production price, of course, signifies technical progress. The balanced rate of growth of the dynamic input-output model as such has been used as an indicator of the growth potential of an economy e.g. by Carter (1974).

Treating human capital as a product means, among other things, that the efficiency of producing educated human capital, i.e. the efficiency of the education system, is taken into account in the overall measure of technical change. Treating active human time as a product means, for instance, that the cost of free services used by persons producing labour of a given type are taken into account in the sectoral measures of technical change for the sectors utilizing labour of this type. This concerns also all the other costs: the production prices on which the sectoral measures are based include the ultimate production costs of all the materials, public services etc. used to bring about the product and not only what is paid for these inputs by the producers.

Since also human capital and active human time are produced within the production system the only primary input is the postponement in the using-up of different products tied up in the production process. This can be called "waiting" following Rymes (in Cas & Rymes (1991)).

> *The rate of balanced growth in the total production system, in the last analysis, measures the productivity of the nation, i.e. the efficiency of the nation in the utilization of its natural resources, the natural talents of its members included.*

Because the generalized input-output dynamics cover the production of human capital and of active human time its empirical application requires data from a very large variety statistical sources. At the same time, it offers a natural systemizing framework for the social statistics, that part of social statistics that falls outside the national accounts proper included.

*

A sector producing labour, or manpower, was included in the dynamic input-output model presented by Brody (1970). This idea was developed further in my doctoral dissertation (1987) in which I presented a generalized dynamic input-ouput model including the production of heterogeneous human capital and active human time (or labour). In my present research project I have developed this model further. The results of this work have been published in three articles in the Economic Systems Research (1989, 1990, and 1991). Here only those parts of the generalized input output dynamics, that are necessary for the understanding of the empirical application of this study, are represented. A more comprehensive representation of the generalized input-output dynamics is given in a chapter I have written together with Arvid Aulin to his book (1992).

2 The Concept of Total Production

2.1 Why is it needed ?

The productive performance of an economy is normally measured by its gross domestic product, which is equal to its final uses of goods and services less the imports. The final uses again consist of the consumption of goods and services, the gross capital formation and the exports. Actually the net domestic product, equal to GDP less the consumption of fixed capital, would be the preferred measure. Because of serious measurement problems it is however less frequently used.

All this seems plain enough. However, before being able to measure the domestic product, gross or net, one has to decide, what is meant by production, which part of the products are consumed as intermediate products and which part belongs to the final use, and how all these products – intermediate or final – should be valued.

The UN recommendations called the System of National Accounts (UN (1968)) are currently under revision. According to a draft revision (UN(1991)) "economic production may be defined as an activity carried out under the control and responsibility of an institutional unit that uses inputs of labour, capital, and goods and services to produce outputs of goods and services". In the last analysis it is of course the definitions of goods and services that delimit production in this case.

Goods are defined as physical objects whose ownership rights can be transferred from one institutional unit to another. Services again are heterogeneous outputs that can be ordered from other units and "typically consist of changes in the conditions of the consuming units realized by the activities of the producers at the demand of the consumers" (UN(1991)). Domestic services for own final consumption within the same household are, however, excluded.

The SNA definition of production , in its current formulation, is vulnerable to the following criticism.

1. Many of the services earlier produced by the households to themselves have, along with the increased labour force participation of women, now been taken over by market and government sectors. On the other hand shortages of labour in the service industries as well as the advanced household technologies might partly have reversed this trend. This means that GDP based on the above SNA definition of production is not a consistent

measure of the results of the production process in different times and in different national economies.

2. Labour as a matter of fact meets the conditions of the SNA definition of production. It is a service that can be ordered. But it is not treated as a product by the SNA. Or, as a matter of fact, it is treated as a product when it is provided by one household to another to produce domestic services utilizing materials and equipment owned by the latter. But it is not regarded as a product when it is provided by a household to an enterprise to produce something utilizing equipment and materials owned by the enterprise.

3. Contrary to the treatment of physical capital equipment, human capital needed to produce labour is not regarded as a product by the SNA. Obviously its ownership rights cannot be transferred. However human capital is equally indispensable to the continuation of the production process as is physical capital.

4. The boundary between intermediate and final products should be consistent with the definition of production. Normally the result of production is a product that can be used either in intermediate or in final consumption. But the non-market products of the producers of government services and of non-profit services cannot be used as intermediate products in the SNA. On the contrary, the inputs to this production are treated as a part of final consumption. This actually means that the government sector and the private non-profit sector are not treated as production sectors in the same sense as the rest of the sectors. Accordingly the measures of overall technical change usually concern only the so called business sector.

5. According to the UN recommendations there are several possible sets of prices for valuation of products. All of them are based on the prices paid or received in the market – they differ from each other in the treatment of taxes and of subsidies on production. The reason why market prices should, in one form or other, be taken as the basis of valuation is, of course, that they can be expected to be proportional to the direct or indirect relative marginal utilities derived from products. The existence of taxes and subsidies on production, market imbalances and the fact that all the products are not sold in the market makes it however impossible to find a set of prices that would meet this condition. Just because there are no pure market economies, there is a formidable insoluble problem of valuation even in the business sector.

Because of the defects or inconsistencies 1-5 in the SNA definition of production, as currently known, we shall here replace it by a definition of the *total production system*, where the production of tangible human capital and of active human time is included. Production is first defined in a consistent way and a representation of the total production system by means of a generalized dynamic input-output model is given. The valuation of products is based on this model.

2.2 Human capital and active human time as products

It is obvious that human beings are in one way or other needed in the production process. When human beings are involved in something they have to use their time, which will here be called active human time. As a matter fact human time is the only really scarce commodity. It can of course be argued that natural resources are scarce as well. But it is not the natural resources, but products made of them, that actually are needed. Given enough time human beings are able to produce what they need, of the natural resources available to them. The problem is, whether they can survive long enough to satisfy their needs, i. e. whether they have enough time.

Accordingly in this study production is defined as follows:

> *Production is direct or undirect utilization of active human time to bring about something that can be used up or transformed into another form in a process utilizing active human time directly or undirectly.*

This defines, following the tradition iniated by Francois Quesnay (1694-1774), production as a circular process in which commodities are produced by means commodities. Still a definition of active human time is needed.

> *Active human time is any use of time by human beings who have passed their basic education and have not become unable to work.*

And finally a product has to be distinguished from its intermediate phases:

> *A product is a result of the production process that is used either outside the unit that has produced it or outside the time unit during which it has been produced or to produce another unit of similar product.*

From these definitions it is obvious that active human time is also a product. The time of persons in retirement because of incapability of work has been excluded since their time cannot any more be used to produce something that could be used elsewhere in the production process. (In actual practice also those in retirement because of age – however capable of working they meay still be – have to be excluded , since their working capabilities are not registered in national statistics.) The time of children and young people under compulsary basic education has been excluded for the same reason. As to the time of the rest of the population it is a product no matter in which way it is used. Labour and leisure are only different uses of the same product, viz. active human time.

It follows from the definition of production that also that part of human capital which is created by raising children and by participating in education, i.e. *human capital*, has to be regarded as a product. It is used up in the production of active human time. Also the intermediate phases of human capital are products because they are moved over to the next time period in order to be used in the production of subsequent phases of human capital.

Let it be emphasized that production, as defined above, does not include the creation of new human knowledge, although it includes the transfer of knowledge and skills called education. The creation of new knowledge (e.g. in science) of course is indispensable to the production process and especially to its technical progress. But it outlives the individual who has created it and accordingly it cannot be used up in the production process. The creation of new knowledge is not simply a product of the factors of production but something more. There is still another part of human capital that cannot be produced in the normal production process, viz. the human beings themselves and their natural talents and characteristics. This part of human capital is comparable to the natural resources.

Different kinds of human capital and of active human time are the only output of households they can use themselves. All the consumption of goods and services by them is used directly as an input in this production and not for instance as an input in the production of meals, or cleaning services or child care services for themselves. This follows from our definition of a product. In addition to this households, naturally, can also produce goods and services to be used by other units of production.

A problem of aggregation, which doesn't concern merely the production process of active human time, is to decide how the production units should defined and the length of the time unit chosen. The latter is discussed in Aulin-Ahmavaara (1990).

3 Generalized Input-Output Dynamics and the Measurement of Technical Change

3.1 Total production system including human capital and active human time

A natural way of representing a production process as defined above is Leontief's (1953) dynamic input-output model. Production of labour was explicitly introduced to this model by Bródy (1970). His model however includes the production of labour still on a relatively general level and does not include production of human capital as a separate product. A dynamic input-output model generalized to include the production of heterogeneous human capital and heteregeneous active human time (or labour) has been introduced and developed further in Aulin-Ahmavaara (1987), (1990), and (1991). The most comprehensive representation of its present state is given in Aulin-Ahmavaara and Aulin (1992). In this section its main features will be delineated.

Two matrices of coefficients are needed in a dynamic input-output model: the matrix of input coefficients A for the flows of different kinds of input per unit of output in each of the production sectors and the corresponding matrix of stock coefficients B for different kinds of stocks per unit of output. These stocks include both fixed capital and inventories.

Flow coefficients are needed to ensure that the inputs that flow out of the sector during a basic interval of time of the model are replaced during this same interval. Stock coefficients again take care that the stocks are at the beginning of each basic interval of time at the required level.

Two sets of essential time periods in the representation of the production process by means of a dynamic input output model are the gestation periods of units of output and the productive periods of units of input. They are defined as follows:

> *Gestation period* S_j of a unit of output of a production unit j starts when the first unit of any input is involved in the production of this unit of output and ends when this unit of output is moved to the stocks of some other production unit.
>
> *Productive period* P_{ij} of a unit of input i in a production unit j starts when the delivery to which this unit of input belongs is first used in the production unit j, and it ends when the last

unit of output in the production of which it is involved leaves the stocks of the production unit j.

It is also possible that inputs belong to the stocks of a production unit for some time before they are actually used in the production. For the sake of simplicity this possibility is here disregarded and all the inputs are assumed to be involved in the production immediately when they enter the stocks of the production unit. This possibility has been taken into account in the formalism of Aulin-Ahmavaara (1990).

A production unit can also use itself part of its own output. In this case the gestation period of a unit of output ends and its productive period starts when the unit of output is first involved in the production of another unit of output.

The definitions of the time periods connected with the dynamic input-output model as well as the significance of the choice of the basic interval of time of the model are discussed in more detail elsewhere (see Aulin-Ahmavaara (1990)).

Both gestation periods and/or productive periods of some of the products inevitably exceed the length of the basic interval of time in the model. As to the productive periods this concerns both physical capital and human capital. As to the gestation periods it concerns especially human capital, though to a lesser extent also physical capital. The units of human capital have the additional feature that they can outlive their productive periods, ie. become incapable of work. All this means that the coefficients of the model depend on the earlier path of the economy (see e.g. Aulin-Ahmavaara (1990)).

The *structure of the generalized input-output dynamics* is here represented by means of the matrices of its balanced growth path given by the following equation

$$x - A^*x = \lambda B^*x \ . \tag{1}$$

where λ is the uniform rate of growth and the asterisks are used to denote that part of the elements of the matrices are not ordinary input and stock coefficients. They have been modified to deal 1) with productive periods and gestation periods exceeding the basic time interval and 2) with periods of retirement.

Both the matrix A^* of input coefficients and the matrix B^* of stock coefficients have the following structure in the generalized input-output dynamics:

$$\begin{pmatrix} GG & GE & GT \\ 0 & EE & ET \\ TG & TE & TT \end{pmatrix}$$

Here

G =the totality of sectors producing market or non-market goods and services. It includes also a sector producing foreign goods and services.

E =the totality of sectors producing different types of human capital. Every person who has finished his basic education $1E$ has formed a unit of *simple human capital.* It should be noted that he has this unit of simple human capital until his retirement or death. He can then participate in some other education say iE. When he has finished this education iE he has produced a unit of human capital of type i and has also this unit of human capital in his possession for the rest of his productive life, and so on.

$T=$ the totality sectors producing different types of active human time. Every person who has finished his basic education and has not retired produces human time of the type which matches his latest education. In this production all the units of human capital produced by him are used as capital equipment. He can use this active human time produced by him either in the production of goods and services, in the production of human capital of type $1E$ by taking care of children, in the production of human capital of some type he does not posess as yet by participating in education, or in the production of active human time in the form of household work or leisure.

Production of goods and services is represented by the fields GG, EG and TG in matrices A^* and B^* with:

a_{iGjG}, b_{iGjG}=coefficients from the sectors producing goods, with productive periods not longer than a year, or services to the sectors producing goods or services. These are normal input and stock coefficients except in the case when the gestation period of the output covers several years. Exports are regarded as inputs in the production of imports. The input coefficients are determined so that the value of exports equals the value of imports. That part of the goverment services that is not consumed directly by the population is allocated to the industries in proportion to the value added created by them.

The problem of *gestation periods longer than a year* can be solved by dividing the production of an output with long gestation period into phases and treating different phases as different products. Let the gestation period of the product of one unit of sector i be S_i. In other words, the making of one unit of the product of sector i takes S_i units of time, let us say S_i years.

We divide the gestation period S_i into phases $s = 1, 2, ..., S_i$, each of them – with the possible exception of the first and the last phase – being of unit length (i.e. a year). This corresponds to the division of sector i in S_i subsectors $i1, i2, ..., iS_i$ whose products x_{is} (for $r = 1, 2, ..., S_i$) are the components of the vector x_i:

$$x_i = (x_{i1}, x_{i2}, ..., x_{iS_i}) \ \forall i = 1, 2, ..., n \ .$$

The production of each final phase x_{iS_i} takes S_i unit periods , during which the *same units* in intermediate phases x_{is} (for $s = 1, 2, ..., S_i - 1$) are only transferred from each subsector s to the next subsector $s + 1$. This is taken into account in the above formula by requiring that the $S_i \times S_i$ matrix A_{ii} has the form

$$A_{ii} = \begin{bmatrix} 0 & a_{i,1;i,2} & 0 & 0 & \dots & 0 & 0 \\ 0 & 0 & a_{i,2;i,3} & 0 & \dots & 0 & 0 \\ 0 & 0 & 0 & a_{i,3;i,4} & \dots & 0 & 0 \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ 0 & 0 & 0 & 0 & \dots & 0 & 0 \\ 0 & 0 & 0 & 0 & \dots & 0 & a_{i,S_i-1;iS_i} \\ 0 & 0 & 0 & 0 & \dots & 0 & 0 \end{bmatrix} , \qquad (2)$$

the matrix B_{ii} is of the same form as the matrix A_{ii}., with the elements

Because each unit of an intermediate phase s is tied up in the production of the next phase $s+1$ for one unit period, we have $b_{i,s;i,s+1} = a_{i,s;i,s+1}$. Then in the case of balanced growth

$$x_{is} = a_{i,s;s+1}x_{i,s+1} + \lambda b_{i,s;s+1}x_{i,s+1} = (1 + \lambda)a_{i,s;s+1}x_{i,s+1} \qquad (3)$$

For further details see Aulin-Ahmavaara (1987) and (1990)

a^*_{iGjG}, b_{iGjG} = coefficients from the sectors producing goods with *productive periods longer than a year* to the sectors producing goods or services. In this case the input coefficients are transformed to the coefficients of replacement

$$a^*_{iGjG} = v_{iGjG}b_{iGjG} \ , \qquad (4)$$

with

$$v_{iGjG} = \frac{\lambda}{(1 + \lambda)^{P_{iGjG}} - 1} . \qquad (5)$$

Replacement coefficients on the assumption of fixed productive periods,as assumed in this study, are derived in Aulin-Ahmavaara (1987). A method, based on the gradual decrease in productive capacity, of dealing with productive periods of variable length has been introduced by Åberg and Persson (1981) and developed further in Aulin-Ahmavaara (1990). The formulae of replacement coefficients based directly on the variation in the lengths productive periods are given in Aulin-Ahmavaara (1991).

$a_{iEjG}, b_{iEjG} = 0$, because there are no direct inputs from the sectors of human capital to the sectors producing goods and services.

$a_{iTjG}, b_{iTiG}=$ coefficients from the sectors producing active human time to the sectors producing goods and services. The input coefficients represent the quantities of labour used per unit of output in these sectors. Labour of course cannot be stored as such. Nevertheless there can be non-zero stock coefficients b_{iTjG}, because labour can be stored as a constituent of the stocks of semifinished products (for further discussion see Aulin-Ahmavaara (1987) and (1990)).

Production of human capital is represented by the fields GE, EE and TE of the matrices A^* and B^*. In these fields we have the following coefficients:

$a_{iGjE}, b_{iGjE} =$ coefficients from the sectors producing goods and services to the sectors producing human capital. Inputs to the production of simple human capital consist of the consumption of goods and services, the goverment services included, by children at the pre-school age and in basic education. Inputs to the production of other categories of human capital consist of the educational services. The rest of the consumption of persons who have finished their basic education is used as input in their production of active human time, whichever the way they use their time.

$a_{iEjE}, b_{iEjE} =$ coefficients from sector iE of human capital to sector jE of human capital. Since we can represent also the *gestation of human capital* as a process of transferring the same units of human capital from a subsector or phase s to the next phase $s+1$, the coefficients for $i = j$ are matrices having the structure shown in equation (2). We have $a_{iEjE} = b_{iEjE} = 0$ for $i \neq j$.

$a_{iTiE}, b_{iTiE} =$ coefficients from the sectors producing active human time to the sectors producing human capital. The input of active human time in the production of simple human capital consists of the household work made by other persons to take care of needs of the children. The input of human time in the production of a unit of human capital of type iE consists of the time a person producing this unit uses in the education of type iE. We have $a_{iTjE} = b_{iTjE} = 0$ for $i = j$ because a person producing a unit of human capital of type i is not yet capable of producing active human time of type i.

Production of active human time is represented by the fields GT,ET and TT of the matrices A^* and B^* with the following coefficients:

a^*_{iGjT}, b^*_{iGjT} = coefficients from the sectors producing goods and services to the sectors producing active human time. These inputs consist of the consumption of goods and services, the consumption of goverment services included, by persons in the active age and by persons in retirement. Educational services other than adult education are excluded because they are used in the production of human capital. These coefficients are formed as follows:

$$a^*_{iGjT} = a_{iGjT} + u_j a_{iGjR} \, , \tag{6}$$

$$b^*_{iGjT} = b_{iGjT} + u_j b_{iGjR} \, . \tag{7}$$

where a_{iGjT}, a_{iGjR} stand for consumption of goods and services per person in active age and per person in retirement, respectively, and b_{iGjT}, b_{iGjR} for corresponding stocks.

For simple human time we have

$$u_1 = \frac{(1+\lambda)^{-P_1} - (1+\lambda)^{-P_1-R_1}}{1-(1+\lambda)^{-P_1}} \, , \tag{8}$$

where R_1 stands for the period of retirement. Furthermore (see Aulin-Ahmavaara (1987))

$$u_i = u_1 \text{ for } P_i + S_i = P_1 \text{ and } R_i = R_1 \, . \tag{9}$$

In this study it has been assumed, because of the lack of data, that the conditions of equation (9) are met. For the formulae of u in more complicated cases see Aulin-Ahmavaara (1991).

a^*_{iEjT}, b^*_{iEjT} = coefficients from the sectors producing different types of human capital to the sectors producing active human time. The unit of human time suitably chosen we'll, in the case that there is only one route to each type of education, have

$$b^*_{iEjT} = b_{iEjT} = 1 \tag{10}$$

for all types of human capital involved in the production of type i of labour. In the case that there are several routes we'll have for each route

$$b^*(\alpha)_{iEjT} = q(\alpha)_j \ , \tag{11}$$

whith

$$q(\alpha)_i = \frac{q'(\alpha)_i\left[1-(1+\lambda)^{d(\alpha)_i}\right]}{\sum_{\alpha=1}^{N} q'(n)_i\left[1-(1+\lambda)^{d(\alpha)_i}\right]}, \tag{12}$$

where $q'(\alpha)_i$ represents the proportion of persons coming through the route α of all the persons who enter educational category i (Aulin-Ahmavaara (1991)).

For the coefficients of replacement a^*_{iEjT} we have, in view of equations (4) and (11)

$$a^*_{iEjT} = \sum q(\alpha)v(\alpha)_i \ . \tag{13}$$

The derivation of the coefficients v in the case of human capital is complicated by the fact that the units of human capital are not always used up in one sector producing active human time but can be moved to the production of another type of active human time. In case the length of the productive period of a unit of human capital is not assumed to depend on the later educational attainments of a person the coefficients $v(\alpha)_i$ in equation (13) are formally equal to the coefficent v_{iGjG} of equation (5). For the derivation of the stock coefficients and of the coefficients of replacement of human capital as well as for the formulae of these coefficients in more complicated cases see Aulin-Ahmavaara (1987) and (1991).

a_{iTjT}, b_{iTjT} = coefficients from the sectors producing active human time to the sectors producing active human time. These inputs consist of the household work done for the active persons either by themselves or by others as well as of their leisure time. The stock coefficients $b_{iTjT} = 0 \ \forall \ i,j$ because human time cannot be stored in the production of human time. There are no intermediate stocks of active human time.

In the generalized input-output dynamics the *vector of final product* is formally equal to the vector of final product in the ordinary static input-output model, i.e. equal to the differences of the outputs and the uses as inputs of the products of the sectors. It however includes only the contributions to the net investment either in the form of fixed capital or of inventories from the different sectors of the economy. Replacement of fixed capital is included in the intermediate consumption. On the other hand it contains net investment in all the sectors of economy, sectors producing human capital and human time included.

The *contribution to the present welfare* would again consist of the inputs from the sectors producing goods and services and active human time to the sectors producing human capital and human time. To avoid double counting the consumption needed in production of that part of human capital and active human time that belongs to the net investment vector has to be subtracted from total consumption when the total welfare contribution is calculated.

3.2 Production prices in the total production system

In a general equilibrium the marginal rates of substitution between pairs of goods and services are for each consumer, and the marginal rates of transformation between pairs of inputs and outputs for each producer, equal to the corresponding price ratios. Market prices can then be said to reflect the direct or undirect welfare contributions of different goods and services. This is why they can be regarded as correct in valuation of products. But in reality the prices paid by the purchasers of goods and services are, because of taxes and subsidies on products, different from the prices finally received by the producers.

Furthermore all the markets are not in equilibrium and all the products are not even sold in the market. As to the free goods and services obviously it is advantageous to use them until their marginal utility or marginal product is equal to zero. So there is no reason to believe that the relative direct or undirect utilities derived by the users of free government services from these services should be proportional to the calculated costs of production of these services. And in the case products with market disequilibrium there are always consumers or producers to whom the relative marginal utilities of these product are smaller or larger than their relative prices.

As to the prices of different kinds of active human time, they could in principle be valued at the prices paid for different kinds of labour in the market. But in the labour market both shortages and unemployment are usual phenomena. Another problem is, that price paid by the employer is by far not the same as the one finally received by the employee.

Human capital again is never directly sold in the market. Its unit value could in principle be calculated from the discounted value of labour that can be produced by utilizing it. But for this there should be an unambigious way of determining the value of labour.

For these reasons a consistent price system for the total production system cannot be based on the prices paid in the market.

In this study the valuation of all the products, active human time and human capital included, is based on the comprehensive production price system, which can be found as the dual of the balanced growth solution of the generalized dynamic input-output model. Relative prices, the average rate of profit r on capital included, are determined by the equation

$$p = pA^* + rpB^* \ . \tag{14}$$

In this price system all the prices are determined according to same principle, by the structure of the total production system. The price ratio between two products tells how many units of one product could have been produced by giving up the production of one unit of the other one.

The prices of equation (14) represent production costs in a balanced growth situation. They include the ultimate production costs of all the inputs to bring about the product and not only what is paid for it. It should be noted that in this case the coefficients of replacement reflect the replacement requirements in a balanced growth situation and not the actual ones. Since the actual replacement requirements depend on the current age distribution of fixed capital they would not give a correct picture of the actual costs associated with a given production technology.

The average rate of profit on capital, r, in equation (14) is equal to the rate of growth λ. It is the reward for the postponement, for the period of a time unit, in the using-up of different products tied up in the production process. It is the price of waiting. And it, too, is determined by the structure of the total production system.

The unit production cost or the production price of one of the products can be chosen as a common standard of value. If the price of a unit of simple human time is chosen as the common standard the price of each products is equal to the number of units of simple human time that could have been produced instead of it. Simple human time, however, is of course not a standard of value that could directly be used in comparisons of economies applying different production techniques. It is produced in different ways and has different productive powers in different economies.

If the rest of the products in two different years were identical with identical physical units and if none of the simple human time were used as an input in the production of simple human time itself, then we would have the following equation for the unit production costs $\hat{p}^0_{1T(1)}$ in year 0 of a unit of simple human time of the type produced in year 1

$$\hat{p}^0_{1T(1)} = \sum_{i \neq 1T} a^1_{i,1T} p^0_i + \lambda^0 \sum_{i \neq 1T} b^1_{i,1T} p^0_i .$$

But the assumption of identical products and identical physical units is a very unrealistic one. Next the sectors will be divided into two categories, viz. the sectors G producing goods and services and the sectors $\overline{G}$ producing human capital and human time. For the first category of sectors we shall assume that it is possible, by utilizing the price indices of the national accounts, to convert the physical units of the year 1 to the physical units of the year 0. If the values of these price indices in years 0 and 1 are denoted by π^0_{iG} and π^1_{iG} then we can write the coefficients of the year 1 from the sectors producing goods and services to the sectors producing human capital and human time in terms of the physical units of the year 0 as follows:

$$a^{1(0)}_{iGj\overline{G}} = \frac{\pi^0_{iG}}{\pi^1_{iG}} a^1_{iGj\overline{G}} \quad \text{and} \quad b^{1(0)}_{iGj\overline{G}} = \frac{\pi^0_{iG}}{\pi^1_{iG}} b^1_{iGj\overline{G}} . \tag{15}$$

These coefficients form two $(m \times (n-m))$ -matrices $A^{1(0)}_{G\overline{G}}$ and $B^{1(0)}_{G\overline{G}}$, m being the number of sectors producing goods and services.

As to the units of different types of active human time and of human capital they have different welfare contents and different productive powers in different years and accordingly have to be regarded as different products when produced in different years. The problem is to calculate the $(1 \times (n-m))$-vector $\hat{p}^0_{\overline{G}(1)}$ of the unit production costs of different categories of human time and human capital of the kind produced in year 1 in terms of the production costs of goods and services in year 0. This can be done as follows:

$$\hat{p}^0_{\overline{G}(1)} = \hat{p}^0_{\overline{G}(1)} \left[A^1_{\overline{G}\overline{G}} + \lambda^0 B^1_{\overline{G}\overline{G}} \right] + p^0_G \left[A^{1(0)}_{G\overline{G}} + \lambda^0 B^{1(0)}_{G\overline{G}} \right] = \hat{p}^0_{\overline{G}(1)} C + g . \tag{16}$$

Here $C = A^1_{\overline{G}\overline{G}} + \lambda^0 B^1_{\overline{G}\overline{G}}$ is an $(n-m) \times (n-m)$ -matrix of known coefficients and $g = p^0_G \left[A^{1(0)}_{G\overline{G}} + \lambda^0 B^{1(0)}_{G\overline{G}} \right]$ is an $1 \times (n-m)$ -vector of known constants. It should be noted that λ^0 actually represents the price of time in year 0, ie. the price that has to be paid for keeping one value unit tied up in the production for the whole year 0.

The solution of the equation (16) makes it possible to calculate the ratio of the production price of a unit of simple human time of the type produced in year 1 to the productions costs of a unit of simple human time of the type produced in year 0. When all the production prices in both of the years are expressed by means of the production price of simple human time in the respective year then this ratio can be used as a link between these two price vectors. Comparisons between different countries again can in principle be made in the same way as the intertemporal comparisons.

The fact however remains that there are qualitative differences in the units of simple human capital and simple human time produced by different production techniques. More extended basic education, better health services, better housing and so on no doubt tend to increase the productive capacity of active human time. There can be qualitative differences also in the units of different types of educated human capital and human time produced in different years. The values of these products can nevertehless be expressed in terms of the unit production costs of simple human time in the base year.

3.3 The generalized measures of technical change

The rate of balanced growth associated with the dynamic input-output model gives a measure of the growth possibilities of the economy. Balanced growth path maximizes the growth for an infinite time horizon, though greater speed can temporarily be achieved on some other path.

The growth potential represented by the balanced rate of growth λ can in reality be used for different purposes, for instance increased consumption of goods and services, which implies a change in the production technique of active human time.

In this study the *rate of overall technical change* of the total production system of an economy is measured by the rate of change $d\lambda/\lambda$ of the balanced rate of growth associated with it. The *rate of sectoral technical change* of a sector i again is measured by the rate of change dp_i/p_i in its production price p_i. A decrease in the production price, of course, signifies technical progress.

In this section it will be shown that the overall measure suggested here is a generalization to the total production system of the traditional measure of change in total factor productivity, and that the sectoral measure is a generalization of the sectoral measure for wholly integrated sectors suggested by Peterson (1979) and by Wolff (1985). The differences are in the definition of production and in the fact that the postponement in the using-up of different products tied up in the production process appears as the only factor of production in our analysis.

The representation of the earlier measures follows here rather closely the work of Wolff (1985). That representation offers a good basis for showing the formal similarity between the measures suggested in this study and the measures suggested elsewhere.

Following symbols will be used, in addition, to those given in the previous sections:

X = vector of gross output by sector
Y = vector of final demand by sector
l =vector of labor coefficients
k = vector of capital stock coefficients
p = vector of prices
w = the uniform annual wage rate
y = pY = gross national product at current prices
L = lX = total employment
K = kX = total capital stock

All these variables refer to time t.

The standard overall measure of the rate of productivity growth is defined as

$$\rho = (pdY - wdL - rdK)/y. \tag{17}$$

Usually this measure is represented in an equivalent but outwardly different form as a difference of the rate of growth of GNP (or value added) and the weighted sum of the growth rates of labour and capital inputs, factor shares being used as weights. It is also possible to disaggregate the labour and capital inputs into different categories and again use factor shares for aggregation (see e.g. Jorgenson et. al. (1987)).

Because the measurement of total factor productivity is based on the assumption of competitive equilibrium, a uniform wage rate w as well as a uniform rate of profit r can be assumed. The equilibrium price vector can then be computed from

$$p = (wl + rk)(I - A)^{-1} . \tag{18}$$

Furthermore in the static input-output model

$$Y = (I - A)X . \tag{19}$$

The rate of aggregate total factor productivity growth can now (Wolff(1985) p.269) in view of (17)-(19) and of definitions of L and K be expressed as

$$\rho = -(pdA + wdl + rdk)X/y \ . \tag{20}$$

While the overall measure of the rate of total productivity growth is defined for the value added or for the final product, the sectoral measure of total productivity growth again is more naturally defined for the total output of the sector,i.e. as follows:

$$\pi_j = (p_j dX_j - pdM_j - wdL_j - rdK_j)/p_j X_j \ .$$

Here M_j is the row vector of intermediate inputs to sector j. Substituting $A_j X_j, l_j X_j$ and $k_j X_j$ for M_j, L_j and K_j respectively in this equation gives, in view of (18):

$$\pi_j = -(pdA_j + wdl_j + rdk_j)/p_j \ . \tag{21}$$

Here A_j is the j'th column of the matrix A. This measure is a continuous analog to the Leontief (1953) sectoral index of structural change.

From (20) and (21) we get

$$\rho = \pi \hat{p} X/y \ , \tag{22}$$

where $\hat{p}$ indicates a diagonal matrix with vector p as its diagonal and π is the row vector of the sectoral measures, π_j. Obviously the sum of weights in the aggregation is larger than unity.

In the static input-output model the total requirements of labour and capital per unit of final output are

$$\beta = l(I - A)^{-1} \tag{23}$$

$$\gamma = k(I - A)^{-1} \ , \tag{24}$$

respectively. The overall total factor productivity growth rate can now (cf. Wolff (ibid.),p.270), in view of (17), (18), (23), and (24) be expressed as follows:

$$\rho = -(wd\beta + rd\gamma)Y/y \ . \tag{25}$$

The sectoral rate of total factor productivity growth is then defined as "the inverse of the rate of decrease in total factor requirements per unit of output" (Wolff, ibid.), as follows:

$$\pi_j^* = \frac{-(wd\beta_j + rd\gamma_j)}{w\beta_j + r\gamma_j} = \frac{-(wd\beta_j + rd\gamma_j)}{p_j} \ . \tag{26}$$

Thus the sectoral measure can also be said to represent the rate of decrease in the equilibrium price of the product of the sector caused by changes in the total factor requirements.

Obviously

$$\rho = \pi^* \hat{p} Y / y \tag{27}$$

and the sum of weights in aggregation is equal to unity.

The sectoral measure represented by (26) takes into account, likewise as the overall measure, the productivity gains in the production of intermediate inputs. It concerns a composite sector j, in which all the sectors contributing directly or undirectly to the final output of sector j are vertically integrated to it.

In fact however also capital inputs are produced inputs. This can be taken into account for instance by augmenting the matrix A by a column showing the interindustry inputs required to produce a unit of capital stock, and by a row vector showing either the depreciation per unit of output (Wolff (1985)) or gross increase in capital stock per unit of output (Peterson (1979)).

The measures suggested in this study go even further, since also human capital and active human time are treated as produced inputs. The rate of change $d\lambda/\lambda$ of the balanced rate of growth is proposed as the overall measure of the rate of technical change, or of total productivity growth.

Multiplying both sides of equation (1) by the equilibrium price vector of the dynamic input-output model p gives

$$\lambda = \frac{p(I - A)x}{pBx} \ . \tag{28}$$

It can be proved (Brody (1970)) and (Johansen (1978)) that we have, in the first approximation:

$$d\lambda = -p(dA + \lambda dB)x / pBx \ . \tag{29}$$

From (28) and (29) we get

$$d\lambda/\lambda = \tilde{\rho} = \frac{-p(dA + \lambda dB)x}{p(I - A)x} = -p(dA + \lambda dB)x/y \ , \tag{30}$$

with $\tilde{\rho}$ formally similar to ρ in (20). The definition of production is, however, more comprehensive in our analysis and the matrix A now contains, in addition to the ordinary flow coefficients, also the coefficients of replacement of fixed capital.

(By the way, from (30) it is obvious in which way a sectoral measure corresponding to π_j in (21) could be formed. The aggregation procedure would be the same as in the case of the traditional measures in (22).)

In the dynamic input-output model the total factor requirements, i.e. the contributions from different sectors to the stocks in "waiting" per unit of output in different sectors, are:

$$R = B(I - A)^{-1} . \tag{31}$$

The ij'th element of matrix R represents the total quantity of the product of sector i that is tied up, directly or undirectly, in the production of a unit of output of sector j.

Differentiating (31) gives

$$dR = B(I - A)^{-1} dA (I - A)^{-1} + dB(I - A)^{-1} . \tag{32}$$

The overall measure $\tilde{\rho}$ can now be expressed in a form analogous with equation (25)

$$\frac{d\lambda}{\lambda} = \tilde{\rho} = \frac{-p\lambda\, dRY}{y} . \tag{33}$$

This can be proved by inserting dR and Y from (32) and (19), respectively, in (33) and finally using the equation (14). Again the definition of production is however more extensive in our analysis.

An obvious generalization to the total production system of the sectoral measures π_j^* in (26), is

$$\tilde{\pi}_j^* = \frac{-p\lambda\ dR_j}{p_j} , \tag{34}$$

where dR_j is the j'th column of the matrix dR. Utilizing the same aggregation as in (27) gives

$$\tilde{\rho} = \tilde{\pi}^* \hat{p} Y / y . \tag{35}$$

In view of (14) the differentiation of the price vector gives, in the first approximation:

$$dp = p\lambda dR + d\lambda pR + \lambda dpR . \tag{36}$$

Thus the sectoral measures $\tilde{\pi}_j^*$ are equal to the price changes caused by the direct effects of technical changes. In these sectoral measures secondary effects due to the changes in the production costs of the stocks of products being tied up in the production process as well as those due to the efficiency of "waiting" λ are disregarded.

The unit price of a product, expressed in the unit production costs of simple human time, actually tells how many units of simple human time could have been produced by employing the resources used up by a unit of this product. Thus a change in the price of a product can be interpreted as a change in the total factor requirements, per unit of this product, measured in terms of the factor requirements per a unit simple human time. Accordingly we can give another, more accurate, form to the sectoral measure of technical change in the total production system:

$$\check{\pi}_j^* = \frac{-dp_j}{p_j} \; . \tag{37}$$

Using the same aggregation as in (27) gives

$$\check{\pi}^* \hat{p} Y/y = -dpY/y \; . \tag{38}$$

If the total value of final product, measured in terms of the unit production costs of simple human time, is kept constant, we have $-dpY = pdY$ and accordignly

$$\check{\pi}^* \hat{p} Y/y = pdY/y = d\lambda/\lambda \; , \tag{39}$$

provided that also the total value of capital measured in terms of the unit production costs of simple human time is unchanged.

To calculate the values of the sectoral measures in (37), we should be able to express the production prices of the year of comparison in terms of the production price of a unit of simple human time in the base year. A method of establishing the link between the prices of two different years was introduced in the previous section. Another method, and on theoretical grounds better justified,would be to utilize the formula (39). The only unknown on the left hand side is the relative price change of a unit of simple human time, which can be calculated, because also the right hand side is known.

On the other hand, comparisons between the rest of the sectors, with respect to the development of their productivity can be simply performed on the basis of the prices measured in terms of the current year production costs of simple human time. A change in the price of a unit of simple human time only means a uniform relative change in the prices of the rest of the sectors. The fact remains that we are not able to distinguish the changes in the quality of different types of human capital and human time from the changes in their production costs.

The reasons of the changes in the sectoral production costs can be analysed by decomposing these changes for instance into changes in the labour costs, in the costs of intermediate products, in the costs of fixed capital and depreciation. It should be noted that it is the ultimate costs of these inputs, and not the prices paid for them, that matter in this analysis. For instance the labour costs would in this case comprise all the costs of producing a given type of labour, including the costs of human capital and the consumption of free or subsidized services and of time in retirement.

An increase in the overall productivity, i.e. in the balanced rate of growth, can in the generalized input-ouput dynamics only be caused by improvements in the ways the nation can utilize its natural resources, the natural talents of its members included.

Actually an economy can use part of its growth potential in the increased consumption of goods and services. It is of course possible to calculate the balanced rate of growth when the per capita consumption of goods and services is kept on some base year level. The problem is however that the level of consumption might affect the productive abilities of the population so that it would not have been possible to bring about the same output with lower per capita consumption.

4 Empirical Application to the Finnish Total Production System

4.1 Sectors of production and the two versions of the application

The generalized dynamic input-output model is in this study applied to the Finnish economy in 1970, 1980 and 1985. This empirical application has the *following groups of sectors*:

1. Sectors producing goods and services, $G1 - G16$
2. Sectors producing simple human capital, $E1(1) - E1(16)$
3. Sectors producing different types of qualified human capital, $E2,1(1)-E8,5$
4. Sectors producing different types of active human time, T1-T8.

The number after the comma identifies the phase of production, while the number in the parenthesis stands for the route of education.

In all the three years there are the following *sectors*, numbered from 1 to 16 and labeled $G1 - G16$, *producing goods and services*

$G1$	Agriculture and fishing
$G2$	Forestry
$G3$	Manufacture of consumption goods
$G4$	Manufacture of wood and paper
$G5$	Mining and metal industries
$G6$	Other manufacturing
$G7$	Building
$G8$	Other construction
$G9$	Electricity, gas and water
$G10$	Trade, financial institutions and insurance
$G11$	Transport, storage and communication
$G12$	Educational services
$G13$	Other government services
$G14$	Ownership of dwellings
$G15$	Other services
$G16$	Foreign trade

In all the three years there are 16 *sectors producing simple human capital* numbered from 17 to 32 and denoted by $E1(1) - E1(16)$. The first seven of them represent the pre-school years of children, the average age entering the education system being in Finland about 7. The following years represent the years normally spent in compulsory basic education. In 1970 it actually lasted 9 years only for about half of the youngsters leaving it. This has been taken into account in the coefficients to the sector $E1(16)$ in 1970.

In all the years there are 8 *sectors producing different types of active human time* numbered from 71-78 in 1970 and 1985 and 73-80 in 1980 and denoted by $T1-T8$. The different categories of human time are characterized by the respective categories of education:

$T1$ Basic education
$T2$ Lower level of secondary vocational education
$T3$ Upper level of secondary vocational education
$T4$ Upper level of secondary non-vocational education
$T5$ Lowest level of higher education
$T6$ Undergraduate level of higher education
$T7$ Graduate level of higher education
$T8$ Postgraduate or equivalent education

The number of *sectors involved in the production of educated human capital* varies. It depends on the number of routes to different types of education, on the length of these routes and on the possibility of common phases for different routes. Routes in different years and the relative numbers of persons coming through each of these routes are given in Appendix 1.

The two versions of the application differ in the treatment of the production of simple human capital and of the consumption of persons in retirement:

In the *basic version* it is assumed that, in equation (3), $a_{i;s;i;s+1} = 1$, for the production of simple human capital. As can be seen from equation (3) this would mean that, in the balanced growth situation, the size of each generation of children should be $1 + \lambda$ times the size of the previous one. This, of course, is not usually the case.

In fact the productivity of labour is normally increasing so that there is no need for the number of children to be equal to the one implied by the balanced growth solution. This is taken into account in the modified version of the application. In the *modified version* it is assumed that a child belonging to each generation is 1.032 times as productive as a child belonging to the previous one. This means that in equation (3) $a_{i;s;i;s+1} = 1/1.032$. The number 1.032 has been chosen, because, during the period 1979-88, the growth rate of labour productivity in the business sector in Finland was 3.2 per cent (OECD (1990)). Earlier in the 70's it was somewhat larger, but it is actually the future development of labour producvitity that matters in this case.

It should be noted that for the number of children implied by the modified version to be large enough for the balanced rate of growth given by this version, the productivity of labour should be increasing at the same rate in all its uses, not only in the production of goods and services in the business sector.

In the *basic version* the ratio of the number of persons in retirement to the number of active persons depends, through the coefficients u in (6) and (7), on the rate of growth λ and on the length of the productive period and of the period of retirement of human beings. The actual ratios tend to be larger than the ones implied by the basic version of the model. In the *modified version* the coefficient u has been replaced by the actual ratio of number of persons in retirement to the number of active persons.

4.2 The method of solution

For calulating the growth rate λ, output proportions and price proportion on the balanced growth path the following four *empirical matrices* are needed:

$A_1(\lambda)$	matrix of ordinary input coefficients
$A_2(\lambda)$	matrix of replacement coefficients
$B_1(\lambda)$	matrix of the coefficients of inventory
$B_2(\lambda)$	matrix of the coefficients of fixed capital

The complete matrix of input coefficients obviously is

$$A(\lambda) = A_1(\lambda) + A_2(\lambda) \ ,$$

and the complete matrix of stock coefficients

$$B(\lambda) = B_1(\lambda) + B_2(\lambda) \ .$$

The input coefficients from the sectors producing goods or services to the sectors producing active human time in $A_1(\lambda)$ and the corresponding coefficients of inventory in $B_1(\lambda)$ depend on λ through the coefficients u for the consumption of persons in retirement (see equations (6) - (9)). The coefficients of replacement in $A_2(\lambda)$ depend on λ in the way given in equations (4), (5), (12) and (13). When there are several routes to the same education part of the coefficients in the matrix B_2, i.e. the stock coefficients of different types of human capital in the production of different types of active human time, also depend on λ in the way shown in equations (11) and (12).

The solution technique is similar to the one introduced in Aulin-Ahmavaara (1987), only this time the dependence of the coefficients on λ is somewhat more complicated. The technique consists of two series of iteration. The first of these series is based on a method of solution of input-output models presented by Tsukui and Murakami (1979). The starting point is the general solution of the difference equation written for a Frobenius matrix D:

$$s(t+1) = Ds(t) \; , \quad \text{with} \;\; D = (I-A)^{-1}B > 0 \; . \tag{40}$$

Provided that all the characteristic roots η_j of D are single eigenvalues, the general solution has the form

$$s(t) = \eta_1 c_1 h_1 + \sum_{j=2}^{n} \eta_j^t c_j h_j \; ,$$

where the h_j are the eigenvectors, with the norm

$$||h_j|| = 1 \quad \forall \, j \; ,$$

belonging to the respective eigenvalues η_j, the c_j being complex numbers. The first root

$$\eta_1 = \frac{1}{\lambda}$$

is the Frobenius root, i.e. the positive root with a value larger than the modulus of any other eigenvalue, and with a positive eigenvector h_1, the constant c_1 being a positive number. For any semipositive initial state vector $s(0)$ we then have:

$$\lim_{t\to\infty} \frac{s(t)}{||s(t)||} = \lim_{t\to\infty} \frac{D^t s(0)}{||D^t s(0)||} = \frac{h_1}{||h_1||} = h_1 \; , \tag{41}$$

$$\lim_{t\to\infty} \frac{||s(t+1)||}{||s(t)||} = \lim_{t\to\infty} \frac{||D^{t+1} s(0)||}{||D^t s(0)||} = \eta_1 = \frac{1}{\lambda} \; , \tag{42}$$

$$\text{with} \;\; ||s|| = \sum_i |s_i| \; .$$

The empirical solution starts by composing the matrix

$$D_o = \{I - \{A_1(0) + A_2(0)\}\}^{-1} [B_1(0) + B_2(0)]$$

for $\lambda = 0$.

The calculation then proceeds in the following successive steps:

The first round of the outer iteration:

1) Compute the successive values of

$$\frac{ED_o^k E'}{ED_o^{k+1} E'} \quad \text{where } E = (1, 1, ..., 1) \; ,$$

to approximate λ_o in accordance with (42). Here and in the following the notation M' is used for the transpose of any matrix M. Let K be the number of iterations needed.

2) Compute the approximations (cf.(41))

$$x_o = \frac{D_o^K E'}{ED_o^K E'} \quad \text{and} \quad p_o = \frac{G_o^K E'}{EG_o^K E'} \; , \quad \text{where}$$

$$G_o = \left\{\{A_1(0) + A_2(0)\}^{-1}\right\}' [B_1(0) + B_2(0)]' \; .$$

3) Compute the matrices $A_1(\lambda_o)$, $A_2(\lambda_o)$, $B_1(\lambda_o)$ and $B_2(\lambda_o)$ taking the dependence on λ into account in the way indicated at the beginning of this section and compose the the matrix D_1 with these matrices.

The other rounds of the outer iteration:

1) Repeat the iteration as above but substituting for D_o now the matrix D_1 just computed – this gives the matrix D_2.

2) Repeat the iteration then with the matrix D_2 so obtained, etc. The iterations are continued until

$$\lambda_{n+1} = \lambda_n \; .$$

The values of x and p given by the last iteration are of course the calculated estimates for the balanced-growth output and price vectors, respectively.

The difference $\lambda_n - \lambda_o$ tells the amount of *growth created by growth*, i.e. the growth potential gained because the coefficients of replacement as well as coefficients for the consumption of pensioners are decreasing functions of the rate of growth (see Aulin-Ahmavaara (1987) and (1989)).

4.3 Data requirements

The data requirements of the generalized dynamic input-output are very extensive. All the four empirical matrices are of the order 78 × 78 in 1970 and 1985 and of the order 80 × 80 in 1980. The calculation of the matrices $A_1(\lambda)$ and $B_1(\lambda)$ requires data on the ordinary input flows from all the 78 (80) sectors to all the 78 (80) sectors and on the inventories of these sectors classified by sector of origin as well as on the lengths of productive periods and on the periods of retirement of persons with different educational backgrounds. Also data on different routes to different educational qualifications are needed. Part of the ordinary flow coefficients and coefficients of inventory, are, it is true, zeros per definition (see section 3.1).

Calculation of the matrix $B_2(\lambda)$ requires data on the stocks of fixed capital in the production of goods and services as well as on different routes to different educational qualifications and of the lenghts of productive periods of persons with different educational backgrounds. Calculation of the matrix $A_2(\lambda)$ requires, in addition to this, data on the productive periods of fixed physical capital.

All the data used in this study are, with a few minor exceptions, collected from published or unpublished statistical tables of Statistics Finland. Some new tables have been produced from the existing data bases. Here only the main problems in getting suitable data are briefly discussed and the main data sources mentioned. Additional information about the data sources is available from the author.

National accounts and the input-output tables connected with them provide a reliable framework for the coefficients between and from the sectors producing goods or services:

The main problem is that up-to-date data on the consumption of goods and services by the producers of government services, cross-classified by sector of origin and by purpose of the services, are lacking. In this study the distributions of 1970 were used as the basis of calculations. Another problem is that data on investment to the sectors producing goods and services are not cross-classified by sector of origin and by sector of destination.

Also the relatively large statistical errors in some of the sectors, as well as the fact that the imputed bank service charge is not allocated to the users of these services, cause porblems. In this study the imputed bank service charge has been distributed to the sectors of production proportionately to the stocks of credit granted to them by the financial institutions.

Hours worked shown in the national account give a framework for the coefficients from sectors producing labour to the sectors producing goods and services. Their distribution by categories of education can be calculated on the basis of the census data concerning the corresponding distribution of the economically active population, though these two distributions do, no doubt, differ to some extent.

Fixed capital stocks are also calculated as a part of national accounting. Data on inventories again are produced in different parts of economic statistics, though comprehensive and uniform statistics are lacking.

In the social statistics falling outside the field of national accounts a general systemizing idea is lacking:

The calculation of the replacement and stock coefficients of human capital in the production of active human time as well as the calculation of the coefficients of different types of active human time and of different phases of human capital in the production of human capital, requires reconstruction of the different routes through the education system. For this purpose data on the flows from one type of education to another would be needed. No such data are however readily available. The routes represented here are based on statitistics over the earlier educational attainments of persons who have completed different types of education and on statistics over the length of different types of education. In many cases different routes that seem to be close to each other have been merged into one route.

Another problem in the reconstruction of the routes is that the level of education, in the classification of education, though in principle connected with the length of education, does actually not tell it. Also the information about flows within different parts of the education system is rather scattered.

The calculation of the coefficients of replacement of human capital in the production of active human time as well as of the coefficients for the consumption of pensioners would require data on rates of retirement and of death by age and education. These together with data on the death rates of persons in retirement by age and education would make it possible to calculate the average durations of the productive periods and of the periods of retirement for persons in different categories of education. In this study it has been assumed, because of the lack of suitable data, that neither the probabilities of retirement nor the lenght of the periods of retirement depend on educational background.

In the case of the flows from the sectors producing human time to these sectors themselves and to the sectors producing human capital the operational definitions already create some problems:

The first one is the time used in education. Time use surveys provide information of this, based on the answers given by the persons under education themselves. But on the other hand education prevents people from participating in other activities. The fact that a person is participating in full time education usually means that he or she cannot simultaneously be participating in the production of goods and services. Time use surveys also tell that students use less time in taking care of children than the rest of the adult population. In this study the time used in fulltime education is assumed to be equal to the decrease in the time used to these two other activities.

As to the time used in child care it is difficult to tell which part of it is necessary for taking care of the childs' needs and which part is merely spending time with the child, useful as it, too, can bee. Here the answers given by employed persons in the time use surveys have been taken as reliable. The only problem is that the time use surveys do not have data on the average time used per child. As to the children who receive fulltime care at home, the extra time used per child is calculated on the basis of the number of children per employee in the child day care services.

If each person would do household work, other than child care, only for himself or herfself, it wouldn't be necessary to make the sometimes difficult distinction between household work and leisure. But part of the household work made by a person can be used by children and other members of the household. Evaluation of the quantities of this work would have required more detailed data than was available on the composition of households and on the quantity of household work made in different types of households. Therefore it has been assumed, instead, that active persons in different educational categories use the same proportion of their time for themselves, either as household work or leisure. The rest of their time that is left over from the other activities has been allocated evenly to all the categories of human time.

5 Technical change in The Finnish Total Production System 1970-1985: The Main Results

5.1 The declining overall productivity

The calculated balanced rates of growth indicate a clear fall in the overall productivity of the Finnish total production system during the 70's and an even faster decrease during the first half of the 80's.

Table 1. Rates of balanced growth, per cent

Year	Basic version		Modified version	
	First round	Final round	First round	Final round
1970	1.192	2.092	1.843	2.657
1980	.884	1.668	1.408	2.123
1985	.614	1.249	1.106	1.718

Table 2. Changes in the overall productivity, per cent

Period	Entire period		Annual average	
	Basic vers.	Mod. vers.	Basic vers.	Mod. vers.
1970-1980	- 20.28	- 20.08	- 2.24	- 2.22
1980-1985	- 25.09	- 19.08	- 5.61	- 4.15
1970-1985	- 40.28	- 35.34	- 3.38	-2.86

In the modified version of the application the increasing productivity of labour is taken into account in the coefficients from one phase of simple human capital to the next one. Also the ratio of the number of persons in retirement to the number of active persons is set equal to the actual one, instead of the number required by the equilibrium solution. In all the other respects the two versions are identical. For a more detailed description of differences between the two versions, see section 4.1.

For the 70's both of the versions give remarkably similar results. Also the acceleration of the decline in total productivity is obvious according to both of them. The reason why the decline in the 80's is smaller in the modified version than in the basic version is that the ratio of the total number of adult persons to the number of active persons rises faster in the balanced growth solutions of the basic version than in reality, see Table 3.

Table 3. Ratios of the total number of adult persons to the number of active persons

Year	Stand. vers.	Actual
1970	1.148	1.239
1980	1.192	1.291
1985	1.240	1.306

Table 4. Ratios of the number of children to the number of active persons

Year	Basic vers.	Modif. vers.	Actual
1970	.624	.567	.418
1980	.553	.491	.359
1985	.497	.445	.340

The actual growth rates of GDP in the 70's and in the first half of the 80's, about 3 per cent on the average, were larger than the growth rates displayed in Table 1. An obvious reason to this is the increasing productivity of labour in the sectors producing goods or services. Therefore the population can grow, and actually did grow in the period in question, at a lower rate than the production of goods and services.

As a matter of fact the ratio of the number of children to the number of active persons is, Table 4, in reality even smaller than the one implied by the modified version in which the increase in productivity of simple human time has been taken into account. This, too, gives more room for a temporarily faster growth, which however cannot be sustained in the long run, unless the labour productivity growth accelerates.

Table 1 shows, besides the calculated final growth rates, also the results of the first round of the outer iteration, which do not include the growth created by growth, i.e. the effects of the rate of growth on the coefficients of replacement v and the coefficients for the consumption of persons in retirement u (see section 4.2).

Table 5. Rates of balanced growth with unchanging per capita consumption of goods and services, per cent

Base year	Year	Basic version	Modif. version
1970	1970	2.092	2.657
	1980	2.751	3.252
	1985	2.851	3.351
1980	1980	1.668	2.123
	1985	1.920	2.372

In the balanced rates of growth displayed in Table 5 the per capita consumption of goods and services, apart from the educational services used in the production of educated human capital, has been kept on the base year level. It seems that

the growth potential of the Finnish economy would have been increasing had the consumption of goods and services not increased.

This increase in productivity has however almost literally been eaten up. The problem with this interpretation is that the increased consumption of goods and services has possibly, at least to some extent; been necessary for the improvement of productive capacity of population.

Though the increasing trend of the balanced rate of growth on the assumptions of unchanging per capita consumption is obvious in Table 5, the results seem partly to depend on the choice of the base year, i.e. on the structure of the consumption of goods and services.

5.2 The proximity of the balanced growth output proportions to the actual ones

The main imbalance in the actual output proportions is that the actual ratio of the number of children to the number of active persons is remarkably smaller than the one implied by the balanced growth output proportions.

This can be seen from Table 4, above. In the case of the basic version this is natural because of the increasing productivity of labour. But in the case of the modified version it has been assumed, in the calculation of the coefficients to the production of simple human capital, that there is a 3.2 per cent increase in the productivity of simple human time in all its uses (see section 4.1). Even in this case the actual ratio remains smaller than the calculated one.

Another imbalance is that the ratio of the total number of adult persons to the number of active persons is in reality larger than according to the balanced growth solution of the basic version. This can be seen from Table 3. In the modified version this ratio is assumed to be equal the actual one. Here active person is a person who has not retired because of inability to work, unemployment, or over 64 years of age.

Also the ratio of the total number of active persons to the total output of goods and services is, see Table 6, according the balanced growth solution of the basic version somewhat larger than the actual one. The modified version is very close to the actual situation.

Table 6. Deviations of the balanced growth ratio of the total number of active persons to the total output of goods and services from the corresponding actual ratio, per cent

Year	Basic version	Modif. version
1970	+ 7.1	+ 2.3
1980	+ 5.2	+ 0.7
1985	+ 3.6	+ 0.4

Table 7. Shares of different types of education in the total output of active human time

Type	1970			1980			1985		
of ed.	Basic	Mod.	Act.	Basic	Mod.	Act.	Basic	Mod.	Act.
L1	.704	.704	.700	.530	.533	.528	.446	.451	.447
L2	.160	.160	.160	.253	.251	.256	.288	.286	.291
L3	.055	.055	.053	.074	.073	.071	.102	.101	.102
L4	.023	.024	.032	.049	.050	.053	.061	.063	.065
L5	.026	.026	.024	.040	.039	.039	.040	.039	.038
L6	.011	.011	.012	.021	.020	.020	.020	.020	.020
L7	.018	.018	.017	.031	.031	.028	.038	.037	.035
L8	.002	.002	.002	.003	.003	.003	.004	.004	.003

L1 = basic, L2 = secondary, lower level, L3 = secondary upper level, vocational, L4 = secondary upper level, nonvocational, L5 = higher, lowest level, L6 = undergraduate level, L7 = graduate level, L8 = postgraduate level

Table 8. Shares of different sectors in the total output of goods and services

Type of ed.	1970 Basic	1970 Mod.	1970 Act.	1980 Basic	1980 Mod.	1980 Act.	1985 Basic	1985 Mod.	1985 Act.
G1	.064	.063	.059	.035	.034	.036	.035	.034	.034
G2	.027	.028	.029	.020	.020	.020	.016	.016	.016
G3	.121	.119	.109	.087	.086	.082	.079	.078	.075
G4	.089	.089	.091	.087	.088	.089	.071	.072	.075
G5	.091	.093	.097	.094	.095	.098	.101	.103	.100
G6	.056	.057	.057	.087	.088	.084	.076	.076	.079
G7	.048	.052	.063	.045	.048	.061	.047	.050	.059
G8	.020	.022	.025	.019	.020	.018	.018	.019	.018
G9	.023	.023	.022	.042	.042	.041	.042	.042	.041
G10	.078	.076	.073	.083	.082	.082	.089	.088	.086
G11	.052	.052	.050	.058	.058	.057	.058	.057	.054
G12	.028	.027	.027	.024	.023	.022	.030	.027	.025
G13	.060	.059	.055	.067	.065	.061	.083	.081	.077
G14	.056	.055	.050	.037	.036	.034	.041	.040	.037
G15	.072	.071	.066	.075	.075	.072	.092	.091	.094
G16	.115	.116	.127	.138	.139	.144	.125	.125	.130

G1 = agricult. & fishing, G2 = forestry, G3 = manuf. of cons. goods, G4 = manuf. of wood and paper, G5 = mining & metal industries, G6 = other manuf., G7 = building, G8 = other contsr., G9 = electr., gas & water, G10 = trade, financ. inst. & insurance, G11 = transport & communic., G12 = education, G13 = other government serv., G14 = ownership of dwellings, G15 = other serv., G16 = foreign trade

The distributions of the total output of active human time by type of education are according to the balanced growth output proportions of both of the versions very near to the actual distributions.

This can be seen from Table 7. There seems, though, to be a sligth tendency of the actual distribution to have too large a share of persons with only matriculation examination (L4) and too small a share of persons with higher education at the graduate level (L7). *There probably are too many students in Finland.* On the other hand, as can be seen from Table 8, both educational services (G12) and other government services (G13), each of them rather academic intensive sectors, are to some extent overrepresented in the balanced growth solutions.

The proximity of the balanced growth proportions to the actual proportions is, according to both of the versions, very close also in the case of the sectors producing goods and services.

The main exception is the building sector (G7). A possible explanation to this is the higher growth rate of the sectors producing goods or services. The investment rate of the Finnish economy is also rather high. The sectors producing consumption goods (G3) and services (G12-G13) seem, likewise, to be somewhat overrepresented in the balanced growth solutions, slightly more in the basic version than in the modified one. A possible explanation to this is that the actual number of children is, see Table 3, smaller than the one implied by the balanced growth solutions.

The entire balanced growth output vectors are displayed in Appendix 2.

5.3 The increasing production prices of active human time

Table 9 shows the changes in the production prices of simple human time evaluated by the method explained in section 3.2.

Table 9. Changes in the production costs of simple human time, per cent

Base year	Period	Entire period		Annual average	
		Bas. vers.	Mod. vers.	Bas. vers.	Mod. vers.
1970	80/70	48.09	47.82	4.00	3.99
	85/80	27.20	23.57	4.93	4.32
	85/70	88.37	82.66	4.31	4.10
1980	85/80	27.17	23.40	4.92	4.29

The increase in the production costs of simple human time has according to both of the models been somewhat faster during the first half of the 80's than during the 70's.

The basic version gives a larger increase to the production price of simple human time for the period 1980-85 than the modified version. This can be attributed to the larger increase in relative number of persons in retirement according to the basic version. What is remarkable, however, is that the results for the period 1980-1985 are, according to both of the versions, rather unaffected by the choice of the base year and that the results for the 70's are rather similar according to both of the versions.

The method of section 3.2 for calculating the change in the production price of simple human time is, however, not necessarily compatible with the sectoral productivity measures in (37). A compatible method could have been based on the equation (39). Because the description of the production of human capital involves different sectors in different years it is not possible to utilize the equation (39) directly in this application.

However, changes of the production prices expressed in terms of current year production prices of simple human time give as such already a sufficient basis for comparisons between the rest of the sectors. Taking into account the change of the unit production price of simple human time into account would only have meant an equal relative change in the production prices of the rest of sectors.

The general tendency seems to have been an increase in the production prices of educated human time in most of the educational categories during the 70's when compared with the current year production price of simple human time.

This has partly continued during the first half of the 80's: Tables 10 and 11.

Taking into account the assumption of similar patterns of retirement and of consumption of goods and services and of human time, we can conclude that the observed differences in the production prices are mainly determined by the differences in the production costs of human capital, involved in the production of different types of active human time and in the replacement requirements of this human capital.

Table 10. Ratios of the production prices of different types of active human time to the production price of simple human time

Type of education	Basic version			Modified version		
	1970	1980	1985	1970	1980	1985
Basic	1.000	1.000	1.000	1.000	1.000	1.000
Sec., lower level	1.087	1.125	1.114	1.099	1.137	1.129
Sec., upper level, voc	1.148	1.185	1.214	1.167	1.207	1.239
Sec., upper level, nonvoc.	1.130	1.127	1.115	1.146	1.140	1.128
Higher, lowest level	1.236	1.286	1.303	1.266	1.317	1.338
Undergraduate level	1.352	1.341	1.342	1.396	1.378	1.381
Graduate level	1.399	1.434	1.438	1.452	1.482	1.489
Postgraduate level	1.669	1.745	1.792	1.762	1.833	1.884

Table 11. Annual average changes in the ratios of the production prices of different types of active human time to the production price of simple human time, per cent

Type of education	Basic version			Modified version		
	80/70	85/80	85/70	80/70	85/80	85/70
Sec., lower level	.33	-.18	.16	.34	-.14	.18
Sec., upper level, voc.	.32	.48	.37	.33	.53	.40
Sec., upper level, nonvoc.	-.03	-.21	-.09	-.05	-.22	-.11
Higher, lowest level	.40	.26	.36	.39	.32	.36
Undergraduate level	-.09	.01	-.06	-.12	.03	-.07
Graduate level	.25	.05	.18	.21	.08	.17
Postgraduate level	.45	.53	.48	.40	.54	.44

It can of course be argued that different types of educated human time produced in different times are also different products products. And this, of course, is true. But the educated human resources and the human capital connected with them and created by them are, in the last analysis, the only possible sources of increasing productivity of the total production system. Therefore the failure of this productivity to grow implies that the *quality of the active human time produced under different categories has mostly not been improving.*

5.4 The increasing production prices of vocationally educated human capital

The production prices of educated human capital in terms of current year production cost of simple human time have had in general an increasing trend.

The exceptions are the non-vocational secondary education at the upper level and the postgraduate education. One reason for this is that the number of average working hours, which partly determines the calculated time used in education, has been decreasing. Also the share of drop-outs and failures to pass one's form have decreased in nonvocational secondary education. The latter might also imply that the product of this education does not any more have as high a quality as it had earlier.

Table 12. Ratios of the production prices of different types of human capital to the production price of simple human time

Type of education	Basic version			Modified version		
	1970	1980	1985	1970	1980	1985
Basic	5.553	5.385	5.184	4.464	4.335	4.208
Sec., lower level	1.019	1.081	1.178	1.032	1.096	1.196
Sec., upper level, voc.	1.165	1.282	1.234	1.184	1.307	1.262
Sec., upper level, nonvoc.	1.550	1.341	1.276	1.570	1.356	1.291
Higher, lowest level	1.327	1.223	1.333	1.366	1.251	1.367
Undergraduate level	2.134	2.099	2.244	2.199	2.154	2.308
Graduate level	2.857	2.928	3.106	3.112	2.955	3.204
Postgraduate level	3.097	2.952	2.901	3.260	3.085	3.039

Table 13. Annual average changes in the ratios of the production prices of different types of human capital to the production price of simple human time, per cent

Type of education	Basic version			Modified version		
	80/70	85/80	85/70	80/70	85/80	85/70
Basic	-.31	-.76	-.46	-.29	-.59	-.39
Sec., lower level	.60	1.72	.97	.60	1.77	.99
Sec., upper level, voc.	.96	-.76	.38	.99	-.69	.43
Sec., upper level, nonvoc.	-1.43	-1.0	-1.29	-1.45	-.98	-1.30
Higher, lowest level	-.81	1.74	.03	-.87	1.79	0
Undergraduate level	-.16	1.35	.34	-.21	1.39	.32
Graduate level	.24	1.19	.56	.19	1.24	.54
Postgraduate level	-.48	-.35	-.44	-.55	-.30	-.46

The production price of a unit of simple human capital, measured in the current year production price of simple human time, again seems to have slightly decreased. This is partly due to the fact that the balanced rate of growth, and with it the rate of interest used in the calculations, has been decreasing. Another reason seems to be that the proportion of children nursed at home has been decreasing, and according to the figures used in the calculations, other day care systems are less expensive. In this case the data, however, are deficient and do not allow very firm conclusions.

Units of a given type of educated human capital produced through different routes can naturally have different raising times as well as different production costs. The production prices displayed in Tables 12 and 13 are weighted averages of the production prices of different routes to same education. The relative shares of these routes in the capital coefficients of the balanced growth solution have been used as weights.

The unit production prices of different types of human capital displayed in Table 12 might seem small, taking into account the average duration of the respective types of education. The explanation to this is that the price of a unit of simple human time is the price of the total amount of time produced by a person during a year assuming that he produces 16 hours daily. The number of hours used in the production of educated human capital per person again is assumed to be equal to the average hours of work of an employed person, added by the difference in the time used in child care by students and persons in employment.

It is not (except in the case of simple human time) enough to have a unit of human capital of a given type to produce active human time of this same type. For instance to produce human time at the graduate level at least a unit of simple human capital and a unit of human capital with secondary education at the upper level are needed, in addition to a unit of graduate level human capital. Thus the total production costs of educated human capital involved in the production of different types of active human time actually are larger than those displayed in Table 12.

The rise in the total production costs of educated human capital involved in the production of human time with vocational education has speeded up during the first half of the 80's.

Table 14. Ratios of the production costs of educated human capital tied up in the production of different types of active human time to the production price of a simple human time

Level of education	Basic version			Modified version		
	1970	1980	1985	1970	1980	1985
Sec., lower	1.079	1.237	1.412	1.093	1.253	1.434
Sec., upper, voc.	1.750	2.048	2.300	1.777	2.082	2.341
Sec., upper, nonvoc.	1.550	1.341	1.276	1.570	1.356	1.291
Higher, lowest	2.754	2.849	3.181	2.812	2.898	3.243
Undergraduate	3.683	3.441	3.521	3.769	3.510	3.598
Graduate	4.407	4.269	4.382	4.525	4.369	4.495
Postgraduate	7.222	7.221	7.024	7.489	7.454	7.263

Table 15. Annual average changes in the ratios of the production prices of educated human capital tied up in the production of different types of human time to the production price of simple human time, per cent

Type of education	Basic version			Modified version		
	80/70	85/80	85/70	80/70	85/80	85/70
Sec., lower	1.38	2.69	1.81	1.38	2.73	1.82
Sec., upper, voc.	1.59	2.35	1.84	1.59	2.57	1.85
Sec., upper, nonvoc.	-1.43	-1.00	-1.29	-1.45	-.98	-1.30
Higher, lowest level	.34	2.23	.97	.30	2.28	.95
Undergraduate level	-.68	.46	-.30	-.71	.50	-.31
Graduate level	-.32	.52	-.04	-.35	.57	-.04
Postgraduate level	0	-.55	-.19	-.05	-.52	-.20

The development of the total production costs of educated human capital involved in the production of human time with university education is more favourable in Table 14 than the development of the production costs in Table 12. The reason for this is the decreased production price of human capital with matriculation examination, discussed above.

Taking into account the problems with the data on the flows within the education system, it is possible that the rise in these costs has in the case of vocational education been even larger than shown in Table 15. The development of the production costs, however, is remarkably similar according to both of the versions.

In any case the results displayed in Tables 12, 13, 14 and 15 give enough evidence for the increasing production costs of human capital involved in the production of educated human time to invite a more closer look at the efficiency of the education system. This however would require much better data on the flows through the education system.

5.5 The uneven development of the production prices of goods and services

The units of measurement of the quantities of goods and services are in each of the years equal to a quantity worth 100 000 FIM. This of course means that the units gets smaller along with the rising prices. In Table 16 this has been taken into account by multiplying the production prices by the implicit price indices of the respective sectors in the national accounts, with 1970 as the base year.

Table 16. Ratios of the production prices of goods and services to the production price of simple human time

Sector	Basic version			Modified version		
	1970	1980	1985	1970	1980	1985
Agric.& fishing	5.330	3.534	3.142	5.423	3.603	3.209
Forestry	1.801	1.097	1.097	1.840	1.126	1.128
Man. of cons. goods	3.469	2.218	1.913	3.540	2.265	1.958
Man. of wood & paper	1.981	1.609	1.343	2.035	1.653	1.384
Mining & metal ind.	2.148	1.397	1.044	2.201	1.429	1.071
Other manufact.	2.045	2.292	1.887	2.098	2.351	1.938
Building	2.127	1.802	1.673	2.170	1.839	1.709
Other construct.	2.284	1.933	1.670	2.334	1.972	1.706
Electr. ,gas & water	1.961	2.225	1.608	2.061	2.312	1.675
Trade, fin. inst. & ins.	2.434	1.826	1.596	2.487	1.865	1.633
Transport & comm.	2.336	1.783	1.600	2.397	1.829	1.643
Education	1.343	1.376	1.336	1.392	1.419	1.383
Other gov. serv.	2.551	2.047	1.785	2.640	2.108	1.838
Ownership of dwell.	1.582	1.178	1.044	1.718	1.286	1.144
Other services	2.203	1.944	1.765	2.257	1.991	1.811
Foreign trade	2.432	1.791	1.744	2.493	1.836	1.790

Because of the unit of measurement, all the sectors producing goods and services have the same unit price, 100 000 FIM. If the actual price proportions were equal to the production prices calculated by the model i.e. to the ultimate production costs, then obviously the production prices of all the sectors producing goods and services should be equal. As can be readily seen from Table 16 this however is by far not the case.

> *The production price of the agricultural sector is exceptionally high.*

This is partly due to the relatively large net subsidies received by the agricultural sector. In this study all the market industries are assumed to participate on equal basis to the expenditures of those government services which are not used directly as personal services by population. Accordingly they are allocated as inputs to the market industries in proportion to the value added generated by these industries.

An even more important reason for the high production prices in agriculture is that the share of labour costs in the unit price is according to our analysis remarkably higher than it is according to the national accounts. However, the latter cannot be exactly calculated because the labour costs of the farmers are not separated from their operating surplus in the national accounts.

The higher ultimate labour costs in agriculture shown by the model are due to the fact that the ratio of the production price of simple human time to the production costs of other types of human time is higher than the corresponding wage ratio. This is to be expected because of progressive taxation and the differences in the receipts of income transfers and in the use of free or subsidized services between persons at different income levels. This means that

> *sectors utilizing human time with higher educational qualifications are actually paying part of the production costs of sectors utilizing human time with lower education.*

Agriculture is typically a sector of the latter type. In the production prices calculated in this study it is the ultimate actual costs of inputs and not the amounts paid for them that matter.

The relatively high production price of *manufacturing of consumption goods* again can be attributed to the high production price of agriculture. An additional reason is the commodity subsidies paid for the farm products.

An exceptionally low production price can be found in *forestry*. This is due to the fact that capital stock tied up with the timber growing in the forests has not been taken into account. Partly it belongs to the natural resources and needn't be taken into account in the production costs in the sense of this study. But partly this stock is a result of different measures to improve forests. This part actually belongs to the produced capital stock.

The fact that *educational services* is a sector utilizing human time with higher education, again, makes it a sector of a relatively low production price. One reason to the relatively low production price of the sector producing *dwelling services* is that, in the model, it is the real interest rates and not the nominal ones that count. And the real interest rates given by the model of course ar smaller than the actual ones.

The production prices in terms of current year production prices of simple human time have been declining , with a few exceptions, in all the sectors producing goods and services according to both of the versions.

Table 17. Annual average changes in the ratios of the production prices of goods and services to the production price of simple human time

Sector	Basic vesion			Modified version		
	80/70	85/80	85/70	80/70	85/80	85/70
Agriculture & fishing	-4.03	-2.32	-3.46	-4.01	-2.28	-3.44
Forestry	-4.84	-0.01	-3.25	-4.79	+0.03	-3.21
Man. of cons. goods	-4.37	-2.91	-3.89	-4.37	-2.87	-3.87
Man. of wood &paper	-2.06	-3.55	-2.56	-2.06	-3.50	-2.54
Mining & metal ind.	-4.21	-5.65	-4.69	-4.22	-5.61	-4.69
Other manufacturing	+1.14	-3.82	-0.54	+1.14	-3.79	-0.53
Building	-1.64	-1.48	-1.59	-1.64	-1.45	-1.58
Other construction	-1.66	-2.88	-2.06	-1.67	-2.85	-2.07
Electric.,gas & water	+1.27	-6.28	-1.31	+1.16	-6.24	-1.37
Trade, fin. inst. & ins.	-2.83	-2.66	-2.78	-2.84	-2.62	-2.76
Transport & commun.	-2.66	-2.15	-2.49	-2.67	-2.13	-2.49
Education	+0.24	-0.58	-0.04	+0.18	-0.51	-0.04
Other gov. services	-2.18	-2.70	-2.35	-2.23	-2.70	-2.39
Ownership of dwell.	-2.90	-2.39	-2.73	-2.85	-2.31	-2.67
Other services	-1.24	-1.92	-1.47	-1.25	-1.88	-1.46
Foreign trade	-3.01	-0.54	-2.19	-3.01	-0.50	-2.18

Accordingly

the sectors producing ordinary goods or services have shown better productivity development than the sectors producing human capital.

The results based on the two versions of the model are very similar.

Tables 18 and 19 serve to explain the changes in the unit prices displayed in Table 17. The results given in Table 18 as well as those in the first two columns of Table 19 are based on the basic version of the model. The corresponding results based on the modified version are not shown here, because they are practically identical with those of the basic version, the largest difference being 0.1 percentage points. The results concerning the unit production costs of replacement of fixed capital are given, in Table 19, according to both of the versions. The differences between the models are in this case somewhat larger, although still very small indeed.

Table 18. Annual average changes in the ratios of the production costs of the intermediate inputs of goods and services and of human time to the sectors producing goods and services to the production price of simple human time, per cent

Sector	Goods and serv.		Human time	
	80/70	85/80	80/70	85/80
Agriculture & fishing	-5.5	-2.3	-3.8	-2.1
Forestry	-4.4	-0.6	-6.0	+0.4
Man. of cons. goods	-4.5	-2.6	-3.6	-4.4
Man. of wood & paper	-1.7	-3.1	-3.2	-5.2
Mining & metal ind.	-4.2	-5.7	-4.2	- 5.2
Other manufacturing	+ 3.0	-4.2	-3.7	-1.9
Building	-1.4	-2.2	-1.9	-0.1
Other construction	- 1.8	-2.7	-1.3	-2.7
Electric.,gas & water	+4.0	-6.5	-3.6	-4.0
Trade, fin. inst. & ins.	-0.8	-3.0	-4.1	-2.2
Transport & commun.	-1.1	-3.5	-4.3	0
Education	+ 0.4	-1.5	+0.4	+0.4
Other gov. services	-2.9	-2.2	-1.5	-2.5
Ownership of dwell.	-4.6	-1.2	..	..
Other services	-2.0	-.7	-0.7	-3.2
Foreign trade	-3.0	-.5	..	..

The unfavourable productivity development in *other manufacturing and in electricity, gas and water services* is, Tables 18 and 19, mainly due to the increasing unit costs of inputs of goods and service. This can in both cases be attributed to the rising oil prices.

Up-to-date data on the distribution by industry of the intermediate use of goods and services in different types of government services and nonprofit services are not available. There are, it is true, also some other problems with the data on the education sector especially concerning 1970. However, all the evidence points to the unfavourable development in the productivity *educational services.*

Considering the way in which the value of the government services is calculated in the national accounts a possible explanation to the increasing production costs of the educational services is, Table 18, that the costs of educating teachers has increased more than their actual remuneration.

Table 19. Annual average changes in the ratios of the production costs of fixed capital and replacement of fixed capital tied up in the production of goods and services to the production price of simple human time, per cent

Sector	Fixed capital		Replac. of fixed capital			
			Basic vers.		Mod. vers.	
	80/70	85/80	80/70	85/80	80/70	85/80
Agriculture & fishing	+0.1	-2.4	+2.7	-1.8	+2.9	-1.8
Forestry	+0.5	+2.2	+0.7	+1.4	+0.8	+1.3
Man. of cons. goods	-2.6	-2.9	-2.3	-2.6	-2.2	-2.6
Man. of wood &paper	-1.5	-2.8	-1.0	-2.6	-0.8	-2.6
Mining & metal ind.	-3.2	-5.6	-2.7	-5.7	-2.6	-5.7
Other manufacturing	-2.3	-2.1	-2.0	-1.6	-1.9	-1.6
Building	-0.2	-0.3	-1.5	-2.1	-1.5	-2.1
Other construction	-0.5	-4.6	-1.2	-5.2	-1.2	-5.2
Electric.,gas & water	-3.9	-5.5	-3.1	-4.6	-2.9	-4.6
Trade, fin. inst. & ins.	-3.3	-2.4	-2.3	-1.7	-2.2	-1.7
Transport & commun.	-2.5	-1.9	-2.4	-1.6	-2.3	1.6
Education	+0.2	-0.6	+1.1	+0.9	+1.3	+0.9
Other gov. services	-2.9	-3.3	-1.9	-1.3	-1.6	-1.3
Ownership of dwell.	+0.7	-1.2	+2.0	+1.3	+2.4	+1.3
Other services	+0.6	-1.5	+2.1	+0.9	+2.4	+1.0
Foreign trade	..	..	..	..	..	..

Another explanation is, Table 19, that the interest on capital, which in the case of government services is not taken into account in the national accounts, has in the educational services increased more than in the rest of the government services. Besides, in the calculations based on the model of this study the investment in the school buildings also has an immediate effect on the replacement requirements. In national accounts the effects on capital consumption allowances of the increased investement in school buildings will be seen only later.

The relatively unfavourable development of productivity in *manufacturing of wood and paper* in the 70's can be partly attributed to the oil price shock. But also costs of the services of fixed capital, Table 19, seem to have developed less well than in the other manufacturing sectors.

The relatively favourable development in the *metal industries* as compared with for instance the forest industries is explained by the more favourable development of the production costs of both intermediate inputs, Table 18, and of fixed capital and replacement, Table 19.

The relatively large decrease in the production price in *agriculture* in the 70's seems to be due to the deacrease in the production cost of intermediate inputs. This again is mainly caused by the fact that the input from this sector to itself has, according to the input-output tables, fallen sharply from the level of 1970. This might be caused by some change in the compilation of the statistics.

The analysis of the production costs has here been based on the production costs expressed in current year unit production costs of simple human time. Taking into account also the increase in the production price of simple human time would only cause the same relative increase in the production prices. Therefore it was possible to make comparisons between developments in different sectors even though the final levels of the changes in production prices, i.e. in sectoral productivities, are not known. The entire balanced growth price vectors are displayed in Appendix 2.

6 Summary and Conclusions

6.1 Measures of productivity in the total production system

This study starts by criticizing the SNA definition of production for the lack of consistency (see points 1-5 on pp. 10 -11).

> *A consistent definition of production is introduced. It involves the extension of the concept of production to the production of human capital and of active human time as well.*

A representation of the total production system based on this extended definition is given by means of the generalized dynamic input-output model.

Measures of overall and sectoral productivity in the total production system based on the generalized dynamic input-output model are suggested.

> *The rate of change of the balanced growth rate based on the generalized dynamic input-output model is suggested as the overall measure of technical change and it is shown to be a generalization, to the total production system, of the traditional measure of overall technical change.*

It measures the changes in the efficiency of the total production system when also changes in the efficiency of producing tangible human capital and active human time are taken into account.

> *The rate of change in the production price of the balanced growth solution of the generalized input-output dynamics is suggested as the sectoral measure, and it is shown to be a generalization, to the total production system, of a sectoral measure for wholly integrated sectors.*

In this measure also the productivity gains of the sectors contributing, directly or undirectly, to the final product of a sector are taken into account. The production prices on which the sectoral measures are based include the ultimate production costs of all the inputs used to bring about the product and not only what is paid for these inputs.

To make the production prices of different years comparable with each other the unit production costs of simple human time is chosen as the unit of measurement. A method of expressing the production price of a unit of simple human time produced in one year in terms of the production costs of simple human time produced in another year is introduced. This method is however not necessarily compatible with the sectoral productivity measures.

The utilization of a compatible method, based on the relationship between the sectoral and overall productivity measures, is complicated by the fact that the description of the production of human capital involves different sectors in different years. Therefore the comparisons between different sectors are here based on changes of the production prices expressed in current year production prices of simple human time. Taking into account the change of the unit production price of simple human time would only have meant an equal relative change in the production prices of the rest of sectors.

6.2 The observed fall in the productivity of the Finnish total production system

An empirical application of the model was made to the Finnish data from 1970,1980 and 1985. Two versions of application were used. The *basic version* is the one presented in section 3. In the *modified version* the growth of the productivity of labour was taken into account, in the coefficients from one phase of simple human capital to the next one. Also the ratio of the total number of adult persons to the number of active persons was set equal to the actual one.

> *Both versions of application show a decline in the overall productivity of the Finnish total production system, i.e. in the productivity of the Finnish nation, from 1970 to 1980 to 1985. This fall was faster during the first half of the 80's than it was during the 70's.*

Accordingly the growth potential of the Finnish economy has been shrinking.

If the per capita consumption of goods and services is kept at the base year level and composition, both of the versions show a steady increase in the growth potential. But this increase has fallen short of the effects of increased consumption, even more so during the first half of the 80's than in the 70's. Part of the increased consumption no doubt has been necessary for the achievement of the actual level of productivity in the sectors producing goods and services.

When looking for causes of the decline in productivity, we made the following observation:

> *The productivity development in the sectors producing human capital seems as a rule to have been by far inferior to that in the production of goods and services.*

This becomes even more evident when the total costs of educated human capital involved in the production of different types of human time are computed. It can of course be argued that with the increased cost also the products have changed. This is possible, but there is no proof that the change would have been for the better.

> *Among the sectors producing goods and services the worst total productivity development has been in the 70's shown by the oil-intensive sectors.*

With the sectoral classification of this study this can be seen in the development of the production prices of electricity etc. and of other manufacturing. Also the energy intensive forest industry has performed worse than the rest of the manufacturing sectors, though this can be attributed to some extent to the worse development in the costs of capital services per unit of output.

Concerning the sectors producing government services we can make the following observation:

> *The productivity development in the sector producing education services seems to have been inferior to that of other government services.*

The unit of measurement in the sectors producing goods and services is the quantity of product worth 100 000 FIM. Therefore the differences between the production prices of these sectors tell that, quite generally, the unit values of their products in the national accounts are not in proportion to their calculated ultimate production costs. One reason for this is that the ratios of the ultimate production costs of different types of educated human time to the ultimate production costs of simple human time are smaller than the actual wage ratios. This again can be attributed to the effects of progressive taxation, income transfers and free or subsidized public services on income distribution. In fact it means that

> *sectors utilizing active human time with higher educational qualifications are actually paying part of the production costs of sectors utilizing human time with lower education.*

Agriculture is typically a sector of the latter type, which is one reason of the high ultimate production costs of agriculture shown by the model. Additional reasons are the subsidies paid to it, as well as such government services as public order and safety and national defence, actually provided by other sectors for it.

The disproportionately high prices of educated human time caused e.g. by progressive taxation can delay introduction of more advanced production techniques and thwart technological development.

6.3 Conclusions concerning economic policy

This study has offered conclusive evidence for the necessity of some economic policies, which themselves are not new or unheard of. The results reported above strongly suggest the following:

1. The declining growth potential as such suggests that more attention should be paid to improving the efficiency of the total production system. This requires high level of scientific knowledge and its efficient transition through the education system.

Existing human knowledge should also be utilized more efficiently in the economy. This should be extended to the leading positions too: expert knowledge in substance matters should be given a higher standing in what is called the 'leadership qualities'.

Improving the efficiency of the total production system also requires that expenditures are, as far as possible, covered by those who have caused them. This would make people to feel responsible of the way they use resources, their own time included. For instance the unemployment benefit and pension systems should largely be based on personal insurance schemes. And it should never be more advantageous for a person to stay unemployed or retire than to have a job, unless of course he has paid all the costs of this himself.

2. The educated human capital being the main source of technical progress the decreasing growth potential especially suggests that the education system requires improvements. The relatively bad productivity performance of the human capital production and of the sector producing education services point to this same direction.

3. The relatively high production price of simple human time compared with its remuneration suggests that, when decisions about progressive taxation and various benefits and free services are made, their distorting effects on the wage ratios of different types of labour and through this to the ultimate production costs of different sectors should be taken into account. This of course concerns also subsidies paid to agriculture and other sectors producing goods and services and differences in their tax treatment. Expenditures that someone fails to pay are always removed to somebody else. This distorts the cost structure and accordingly the efficient use of resources.

4. All the years studied here are years of relatively low unemployment. The present high unemployment actually means that costs of producing active human time have considerably risen and, along with it, the growth potential of economy has further declined. This adds to the urgency of the policies suggested above.

6.4 Suggested improvements in national accounting

Obviously when economic and social policy decisions are made their ultimate effects on the production costs of different sectors of economy should be known. The generalized dynamic input-output model is a powerful method for calculating these effects. Making these calculations more accurate would however require some improvements in national accounting.

1.This study has shown the necessity of extending national accounting outside the field of traditional economic statistics, to include some important social statistics. We suggest:

The ultimate total production costs point of view proposed in this study offers a systemizing idea that covers both the traditional economic and the rest of social statistics.

The application of this idea would require better data on flows through the education system, on the transitions from one part of the education system to another one and on the distribution of actual durations of different types of education. Also data about the distributions and expectations of the durations of active periods and periods of retirement for persons with different educational backgrounds would be required. All this concerns, of course, not only Finland.

Considering the importance of the education and pensions systems to the productivity, costs and availability of labour, the lack of this type of consistent data is actually amazing.

2. As to the available data concerning the sectors producing goods and services,

the national accounts and the input-output tables connected with them give a consistent general framework for the data concerning the sectors producing goods and services, but there still are some deficiencies.

The main problems, from the total production system point of view, are the lacking data on the intermediate consumption of goods and services by producers of government services, cross-classified by the sector of origin and by the purpose of the service, as well as on the investment to the sectors producing goods and services cross-classified by the sector of origin and the sector of destination.

The relatively large statistical errors in some of the sectors of the input-output tables as well as the imputed bank service charge, not allocated to the users of these services, are somewhat annoying. Comprehensive statistics on inventories as well as statistics on the distribution by educational level of the hours worked in sectors producing goods and services would be helpful.

6.5 How should this study be continued?

The results of this study show that the generalized dynamic input-output model has performed very well in analysing productivity development. For instance:

> *Generally the proximity of the output proportions given by the balanced growth solutions of the model to the actual ones was very close.*

Also the results given by both of the versions were mostly very similar.

The major deviation of the actual situation from the balanced growth path is the proportionately too small number of children. Another one is the proportionately too large number of pensioners. The number of children is too small even in the modified version, in which the effect of labour productivity growth to the required number of children has been taken into account, though the gap has been narrowing.

Further analysis should concern additional years with Finnish data, but no doubt experiments with data from other countries would be highly desirable. Better data on education and pensions systems referred to above would improve the accuracy of the results of the model.

Some interesting additional analysis could however have been performed already on the basis of the matrices of coefficients that were constructed for this study. It would have been possible to calculate the value of human capital and of physical capital tied up in different parts of the total production process in different years. It would also have been instructive to calculate the the value of the final product coming from different parts of the production process: to which extent it consists of human capital and human time on the one hand and of goods and services on the other? These results would have given a better insight into the changing structure of the production system. The time limit imposed on this study however prevented these calculations at this time.

Appendix A

Different routes to different types of education

Table A.1. Different routes to different types of education and shares of persons coming along each of the routes of the total number of persons completing each type of education in 1970

Type of educ.	Final educ., no. of route/years	Earlier education no/route/years	Share, per cent	Final sector of production
2	1/1	none	10	E2,1(1)
	1/2	none	46	E2,2(1)
	1/3	none	40	E2,3(1)
	2/2	4/1/3	4	E2,2(2)
3	1/2	none	4	E3,2(1)
	1/3	none	30	E3,3(1)
	1/4	none	28	E3,4(1)
	2/1	4/1/3	28	E3,1(2)
	2/2	4/1/3	10	E3,2(2)
4	1/3	none	100	E4,3
5	1/1	4/1/3	10	E5,1(1)
	1/4	4/1/3	36	E5,4(1)
	2/1	3/1/3	27	E5,1(2)
	2/3	3/1/3	27	E5,3(2)
6	1/4	4/1/3	90	E6,4
	1/6	4/1/3	10	E6,6
7	1/5	4/1/3	50	E7,5
	1/6	4/1/3	50	E7,6
8	1/5	4/1/3,7/1/5	100	E8,5

Table A.2. Different routes to different types of education and shares of persons coming along different routes of the total number of persons completing each type of education in 1980

Type of educ.	Final educ., no. of route/years	Earlier education no/route/years	Share, per cent	Final sector of production
2	1/2	none	62	E2,2(1)
	1/3	none	8	E2,3(1)
	1/4	none	18	E2,4(1)
	2/2	4/1/3	12	E2,2(2)
3	1/3	none	24	E3,3(1)
	2/3	4/1/3	26	E3,3(2)
	3/1	2/1/2	12	E3,1(3)
	3/3	2/1/2	38	E3,3(3)
4	1/3	none	100	E4,3
5	1/2	4/1/3	42	E5,2(1)
	1/4	4/1/3	38	E5,4(1)
	2/1	4/1/3, 3/2/3	20	E5,1(2)
6	1/4	4/1/3	79	E6,4
	1/6	4/1/3	21	E6,6
7	1/6	4/1/3	100	E7,6
8	1/5	4/1/3, 7/1/6	100	E8,5

Table A.3. Different routes to different types of education and shares of persons coming along different routes of the total number of persons completing each type of education in 1985

Type of educ.	Final educ., no. of route/years	Earlier education no/route/years	Share, per cent	Final sector of production
2	1/2	none	46	E2,2(1)
	1/3	none	10	E2,3(1)
	1/4	none	25	E2,4(1)
	2/2	4/1/3	19	E2,2(2)
3	1/2	4/1/3	24	E3,2(1)
	1/3	4/1/3	27	E3,3(1)
	2/1	2/1/2	7	E3,1(2)
	2/3	2/1/2	46	E3,3(2)
4	1/3	none	100	E4,3
5	1/4	4/1/3	60	E5,4(1)
	2/1	4/1/3, 3/1/3	40	E5,1(2)
6	1/4	4/1/3	59	E6,4
	1/6	4/1/3	41	E6,6
7	1/6	4/1/3	50	E7,6
	1/7	4/1/3	50	E7,7
8	1/5	4/1/3, 7/1/6	100	E8,5

Appendix B

Table B.1. Balanced growth output proportions in 1970

Sector	Basic vers.	Mod. vers.	Sector	Basic vers.	Mod. vers.
G1	.0104487	.0109882	E3,3(1)	.0008192	.0009267
G2	.0044433	.0047817	E3,4(1)	.0002700	.0003053
G3	.0196744	.0206297	E3,1(2)	.0003713	.0004205
G4	.0144480	.0155493	E3,2(2)	.0000964	.0001090
G5	.0148312	.0161462	E4,1	.0026404	.0030414
G6	.0091882	.0098405	E4,2	.0021019	.0024064
G7	.0078105	.0090027	E4,3	.0016495	.0018762
G8	.0033377	.0037767	E5,1(1)	.0002419	.0002748
G9	.0037660	.0039892	E5,2(1)	.0001859	.0002106
G10	.0126378	.0132944	E5,3(1)	.0001771	.0001996
G11	.0084453	.0089911	E5,4(1)	.0001688	.0001892
G12	.0044908	.0046843	E5,1(2)	.0002660	.0002999
G13	.0097691	.0102563	E5,2(2)	.0001328	.0001497
G14	.0091829	.0095332	E5,3(2)	.0001266	.0001419
G15	.0117422	.0123031	E6,1	.0002307	.0002591
G16	.0187994	.0201377	E6,2	.0002231	.0002492
E1,1	.0227684	.0172871	E6,3	.0002158	.0002397
E1,2	.0223019	.0173963	E6,4	.0002087	.0002306
E1,3	.0218449	.0175062	E6,5	.0000214	.0000237
E1,4	.0213973	.0176168	E6,6	.0000207	.0000228
E1,5	.0209589	.0177281	E7,1	.0004403	.0005048
E1,6	.0205295	.0178401	E7,2	.0004258	.0004855
E1,7	.0201088	.0179528	E7,3	.0004118	.0004670
E1,8	.0196968	.0180662	E7,4	.0003983	.0004491
E1,9	.0192932	.0181803	E7,5	.0003852	.0004320
E1,10	.0188979	.0182952	E7,6	.0001735	.0001940
E1,11	.0185107	.0184108	E8,1	.0000401	.0000456
E1,12	.0181314	.0185271	E8,2	.0000388	.0000439
E1,13	.0177599	.0186441	E8,3	.0000375	.0000422
E1,14	.0173960	.0187619	E8,4	.0000363	.0000406
E1,15	.0170396	.0188804	E8,5	.0000351	.0000390
E1,16	.0166905	.0189997	T1	.3535936	.3602340
E2,1(1)	.0029137	.0033213	T2	.0806517	.0820233
E2,2(1)	.0024569	.0027873	T3	.0276676	.0281912
E2,3(1)	.0011049	.0012502	T4	.0117189	.0122779
E2,1(2)	.0001186	.0001349	T5	.0130964	.0132693
E2,2(2)	.0001104	.0001250	T6	.0056520	.0056556
E3,1(1)	.0009443	.0010798	T7	.0092693	.0094235
E3,2(1)	.0008990	.0010224	T8	.0008662	.0008832

The symbols of the sectors are explained in section 4.1.

Table B.2. Balanced growth output proportions in 1980

Sector	Basic vers.	Mod. vers.	Sector	Basic vers.	Mod. vers.
G1	.0166084	.0170970	E3,3(1)	.0001857	.0001993
G2	.0096785	.0101769	E3,1(2)	.0003274	.0003541
G3	.0413809	.0425716	E3,2(2)	.0003056	.0003290
G4	.0415385	.0435685	E3,3(2)	.0002852	.0003058
G5	.0449077	.0473442	E3,1(3)	.0004302	.0004651
G6	.0416804	.0434805	E3,2(3)	.0003149	.0003396
G7	.0216142	.0240764	E3,3(3)	.0002940	.0003156
G8	.0092766	.0100966	E4,1	.0027706	.0030354
G9	.0202541	.0209274	E4,2	.0023128	.0025218
G10	.0396284	.0408729	E4,3	.0019657	.0021326
G11	.0275292	.0285758	E5,1(1)	.0003840	.0004132
G12	.0114412	.0116024	E5,2(1)	.0003622	.0003880
G13	.0319402	.0322700	E5,3(1)	.0001722	.0001845
G14	.0177958	.0181239	E5,4(1)	.0001625	.0001732
G15	.0360029	.0370876	E5,1(2)	.0000855	.0000912
G16	.0659606	.0689602	E6,1	.0002557	.0002733
E1,1	.0125733	.0090362	E6,2	.0002474	.0002632
E1,2	.0123671	.0091408	E6,3	.0002393	.0002535
E1,3	.0121642	.0092466	E6,4	.0002315	.0002442
E1,4	.0119647	.0093537	E6,5	.0000495	.0000523
E1,5	.0117685	.0094620	E6,6	.0000479	.0000504
E1,6	.0115754	.0095715	E7,1	.0004554	.0004950
E1,7	.0113856	.0096823	E7,2	.0004406	.0004767
E1,8	.0111988	.0097944	E7,3	.0004263	.0004591
E1,9	.0110151	.0099078	E7,4	.0004124	.0004422
E1,10	.0108344	.0100225	E7,5	.0003990	.0004259
E1,11	.0106567	.0101386	E7,6	.0003860	.0004102
E1,12	.0104819	.0102559	E8,1	.0000422	.0000454
E1,13	.0103100	.0103747	E8,2	.0000408	.0000438
E1,14	.0101409	.0104948	E8,3	.0000395	.0000422
E1,15	.0099745	.0106163	E8,4	.0000382	.0000406
E1,16	.0098109	.0107392	E8,5	.0000370	.0000391
E2,1(1)	.0030422	.0033127	T1	.1708840	.1713298
E2,2(1)	.0027619	.0029941	T2	.0814120	.0805879
E2,3(1)	.0007176	.0007792	T3	.0237819	.0234174
E2,4(1)	.0004642	.0005024	T4	.0157617	.0160920
E2,1(2)	.0003409	.0003706	T5	.0128060	.0125580
E2,2(2)	.0003094	.0003349	T6	.0066925	.0064914
E3,1(1)	.0002131	.0002308	T7	.0100486	.0098646
E3,2(1)	.0001989	.0002145	T8	.0009543	.0009412

The symbols of the sectors are explained in section 4.1.

Table B.3. Balanced growth output proportions in 1985

Sector	Basic vers.	Mod. vers.	Sector	Basic vers.	Mod. vers.
G1	.0208405	.0211105	E3,2(1)	.0005645	.0006062
G2	.0094926	.0098085	E3,3(1)	.0003442	.0003679
G3	.0475897	.0481438	E3,1(2)	.0004493	.0004866
G4	.0429783	.0443449	E3,2(2)	.0003633	.0003920
G5	.0608716	.0630733	E3,3(2)	.0003355	.0003604
G6	.0455909	.0468235	E4,1	.0026515	.0028971
G7	.0279312	.0307820	E4,2	.0022973	.0024979
G8	.0108131	.0116208	E4,3	.0020147	.0021794
G9	.0254137	.0258426	E5,1(1)	.0002247	.0002416
G10	.0533931	.0541945	E5,2(1)	.0002135	.0002285
G11	.0345651	.0352654	E5,3(1)	.0002029	.0002161
G12	.0161800	.0164639	E5,4(1)	.0001928	.0002043
G13	.0498732	.0494753	E5,1(2)	.0001261	.0001339
G14	.0247302	.0247591	E6,1	.0001858	.0001982
G15	.0550927	.0558080	E6,2	.0001805	.0001917
G16	.0747757	.0767833	E6,3	.0001754	.0001853
E1,1	.0086110	.0062053	E6,4	.0001704	.0001792
E1,2	.0085047	.0063021	E6,5	.0000702	.0000738
E1,3	.0083998	.0064005	E6,6	.0000681	.0000714
E1,4	.0082962	.0065004	E7,1	.0004145	.0004434
E1,5	.0081938	.0066019	E7,2	.0004027	.0004287
E1,6	.0080927	.0067049	E7,3	.0003912	.0004146
E1,7	.0079928	.0068095	E7,4	.0003800	.0004009
E1,8	.0078942	.0069158	E7,5	.0003691	.0003876
E1,9	.0077968	.0070238	E7,6	.0003586	.0003748
E1,10	.0077006	.0071334	E7,7	.0001619	.0001688
E1,11	.0076056	.0072447	E8,1	.0000376	.0000398
E1,12	.0075118	.0073578	E8,2	.0000365	.0000385
E1,13	.0074191	.0074726	E8,3	.0000355	.0000372
E1,14	.0073275	.0075893	E8,4	.0000344	.0000360
E1,15	.0072371	.0077077	E8,5	.0000335	.0000348
E1,16	.0071478	.0078280	T1	.1129194	.1132326
E2,1(1)	.0025660	.0027915	T2	.0728856	.0716971
E2,2(1)	.0022935	.0024835	T3	.0259229	.0254688
E2,3(1)	.0008239	.0008923	T4	.0154592	.0157422
E2,4(1)	.0005424	.0005855	T5	.0100684	.0097965
E2,1(2)	.0004612	.0005001	T6	.0051280	.0049391
E2,2(2)	.0004122	.0004450	T7	.0096511	.0092769
E3,1(1)	.0006112	.0006595	T8	.0009016	.0008719

The symbols of the sectors are explained in section 4.1.

Table B.4. Balanced growth price proportions in 1970

Sector	Basic vers.	Mod. vers.	Sector	Basic vers.	Mod. vers.
G1	.0355011	.0369227	E3,3(1)	.0088162	.0091347
G2	.0119969	.0125292	E3,4(1)	.0120555	.0125277
G3	.0231044	.0241032	E3,1(2)	.0031090	.0032420
G4	.0131943	.0138534	E3,2(2)	.0063745	.0066661
G5	.0143040	.0149822	E4,1	.0029012	.0029843
G6	.0136228	.0142851	E4,2	.0069796	.0072070
G7	.0141655	.0147760	E4,3	.0103202	.0106891
G8	.0152102	.0158910	E5,1(1)	.0032049	.0033440
G9	.0130578	.0140282	E5,2(1)	.0065676	.0068720
G10	.0162113	.0169344	E5,3(1)	.0100956	.0105940
G11	.0155558	.0163207	E5,4(1)	.0137973	.0145208
G12	.0089437	.0094784	E5,1(2)	.0032484	.0033948
G13	.0169884	.0179773	E5,2(2)	.0066568	.0069764
G14	.0105331	.0116941	E5,3(2)	.0102328	.0107549
G15	.0146747	.0153667	E6,1	.0032049	.0033440
G16	.0161950	.0169718	E6,2	.0065188	.0068208
E1,1	.0025734	.0026785	E6,3	.0099453	.0104357
E1,2	.0052007	.0053402	E6,4	.0134883	.0141942
E1,3	.0078829	.0079852	E6,5	.0171516	.0181019
E1,4	.0106213	.0106135	E6,6	.0209395	.0221648
E1,5	.0134169	.0132254	E7,1	.0032049	.0033440
E1,6	.0162710	.0158209	E7,2	.0065188	.0068208
E1,7	.0191849	.0184001	E7,3	.0099453	.0104357
E1,8	.0210792	.0198561	E7,4	.0134883	.0141942
E1,9	.0230132	.0213029	E7,5	.0171516	.0181019
E1,10	.0249876	.0227406	E7,6	.0209395	.0221648
E1,11	.0270033	.0241693	E8,1	.0038544	.0040993
E1,12	.0290612	.0255891	E8,2	.0078398	.0083615
E1,13	.0311621	.0269999	E8,3	.0119607	.0127930
E1,14	.0333070	.0284019	E8,4	.0162217	.0174005
E1,15	.0354968	.0297950	E8,5	.0206274	.0221909
E1,16	.0369858	.0303937	T1	.0066602	.0068079
E2,1(1)	.0027957	.0028801	T2	.0072447	.0074833
E2,2(1)	.0057968	.0059891	T3	.0076456	.0079443
E2,3(1)	.0090186	.0093451	T4	.0075254	.0078044
E2,1(2)	.0030073	.0031254	T5	.0082292	.0086245
E2,2(2)	.0062357	.0064992	T6	.0090100	.0095064
E3,1(1)	.0027957	.0028801	T7	.0093188	.0098844
E3,2(1)	.0057320	.0059220	T8	.0111139	.0119973

The symbols of the sectors are explained in section 4.1.

Table B.5. Balanced growth price proportions in 1980

Sector	Basic vers.	Mod. vers.	Sector	Basic vers.	Mod. vers.
G1	.0096645	.0102098	E3,3(1)	.0109417	.0114772
G2	.0030390	.0032324	E3,1(2)	.0037587	.0039615
G3	.0070470	.0074581	E3,2(2)	.0077853	.0082243
G4	.0040136	.0042726	E3,3(2)	.0120988	.0128115
G5	.0046851	.0049691	E3,1(3)	.0037518	.0039524
G6	.0043590	.0046319	E3,2(3)	.0077711	.0082056
G7	.0044232	.0046765	E3,3(3)	.0120768	.0127823
G8	.0048618	.0051406	E4,1	.0033283	.0034683
G9	.0043541	.0046893	E4,2	.0077785	.0081292
G10	.0047698	.0050499	E4,3	.0112777	.0118140
G11	.0049155	.0052251	E5,1(1)	.0037705	.0039741
G12	.0036399	.0038904	E5,2(1)	.0077680	.0082064
G13	.0055192	.0058898	E5,3(1)	.0120061	.0127136
G14	.0041158	.0046558	E5,4(1)	.0164993	.0175135
G15	.0047528	.0050429	E5,1(2)	.0039352	.0041686
G16	.0048527	.0051536	E6,1	.0037705	.0039741
E1,1	.0031897	.0033748	E6,2	.0076680	.0081005
E1,2	.0064327	.0067111	E6,3	.0116966	.0123849
E1,3	.0097297	.0100092	E6,4	.0158608	.0168333
E1,4	.0130817	.0132696	E6,5	.0201651	.0214520
E1,5	.0164897	.0164926	E6,6	.0246144	.0262476
E1,6	.0199544	.0196787	E7,1	.0037705	.0039741
E1,7	.0234770	.0228284	E7,2	.0076680	.0081005
E1,8	.0257421	.0245661	E7,3	.0116966	.0123849
E1,9	.0280450	.0262840	E7,4	.0158608	.0168333
E1,10	.0303863	.0279822	E7,5	.0201651	.0214520
E1,11	.0327667	.0296610	E7,6	.0246144	.0262476
E1,12	.0351868	.0313205	E8,1	.0046400	.0049796
E1,13	.0376472	.0329611	E8,2	.0094361	.0101498
E1,14	.0401487	.0345829	E8,3	.0143937	.0155181
E1,15	.0426918	.0361861	E8,4	.0195182	.0210918
E1,16	.0452774	.0377710	E8,5	.0248151	.0268790
E2,1(1)	.0033992	.0035489	T1	.0084069	.0087116
E2,2(1)	.0071433	.0074754	T2	.0094543	.0099075
E2,3(1)	.0112673	.0118198	T3	.0099637	.0105106
E2,4(1)	.0158098	.0166264	T4	.0094747	.0099342
E2,1(2)	.0037587	.0039615	T5	.0108138	.0114707
E2,2(2)	.0078988	.0083445	T6	.0112747	.0120101
E3,1(1)	.0033992	.0035489	T7	.0120571	.0129137
E3,2(1)	.0070406	.0073678	T8	.0146725	.0159717

The symbols of the sectors are explained in section 4.1.

Table B.6. Balanced growth price proportions in 1985

Sector	Basic vers.	Mod. vers.	Sector	Basic vers.	Mod. vers.
G1	.0059695	.0063014	E3,2(1)	.0080425	.0084791
G2	.0021244	.0022581	E3,3(1)	.0125702	.0132854
G3	.0045922	.0048569	E3,1(2)	.0038596	.0040646
G4	.0027192	.0028942	E3,2(2)	.0080391	.0084864
G5	.0028589	.0030295	E3,3(2)	.0125649	.0132967
G6	.0028053	.0029778	E4,1	.0034107	.0035468
G7	.0028370	.0029957	E4,2	.0077612	.0080944
G8	.0029997	.0031675	E4,3	.0112144	.0117238
G9	.0025528	.0027469	E5,1(1)	.0038744	.0040752
G10	.0030266	.0032009	E5,2(1)	.0079522	.0083843
G11	.0029936	.0031770	E5,3(1)	.0122440	.0129405
G12	.0022505	.0024080	E5,4(1)	.0167611	.0177580
G13	.0031414	.0033424	E5,1(2)	.0041606	.0044070
G14	.0025300	.0028650	E6,1	.0038744	.0040752
G15	.0028010	.0029705	E6,2	.0078628	.0082898
G16	.0031946	.0033897	E6,3	.0119684	.0126483
E1,1	.0032918	.0034854	E6,4	.0161947	.0171558
E1,2	.0066247	.0069173	E6,5	.0205453	.0218172
E1,3	.0099993	.0102964	E6,6	.0250238	.0266380
E1,4	.0134160	.0136236	E7,1	.0038744	.0040752
E1,5	.0168754	.0168997	E7,2	.0078628	.0082898
E1,6	.0203780	.0201254	E7,3	.0119648	.0126483
E1,7	.0239244	.0233016	E7,4	.0161947	.0171558
E1,8	.0262113	.0250640	E7,5	.0205453	.0218172
E1,9	.0285267	.0267994	E7,6	.0250238	.0266380
E1,10	.0308711	.0285081	E7,7	.0296340	.0316235
E1,11	.0332447	.0301905	E8,1	.0048081	.0051566
E1,12	.0356480	.0318470	E8,2	.0097576	.0104894
E1,13	.0380813	.0334781	E8,3	.0148527	.0160045
E1,14	.0405451	.0350842	E8,4	.0200975	.0217079
E1,15	.0430396	.0366655	E8,5	.0254965	.0276063
E1,16	.0455652	.0382226	T1	.0087894	.0090828
E2,1(1)	.0035278	.0036772	T2	.0097968	.0102559
E2,2(1)	.0074747	.0078104	T3	.0106703	.0112501
E2,3(1)	.0118905	.0124560	T4	.0098017	.0102454
E2,4(1)	.0168310	.0176776	T5	.0114553	.0121519
E2,1(2)	.0038612	.0040611	T6	.0117913	.0125428
E2,2(2)	.0081813	.0086258	T7	.0126358	.0135201
E3,1(1)	.0038612	.0040611	T8	.0157484	.0171085

The symbols of the sectors are explained in section 4.1.

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Abstract

A general definition of production is given. The total production system is represented by means of the dynamic input-output -model, generalized to include the production of heterogenous human capital and human time.

The rate of change of the balanced rate of growth is suggested as a measure of overall technical change. The rate decrease of the production price is suggested as a sectoral measure of technical progress. They are generalizations of more traditional measures of technical change to the total production system.

The results of an empirical application to the Finnish data in 1970, 1980 and 1985 are given.

Keywords

Dynamic input-output analysis, technical change, productivity, total production, economic growth.

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