Review of Income and Wealth
Series 50, Number 2, June 2004

MOVING HUMAN CAPITAL INSIDE THE PRODUCTION BOUNDARY

by Pirkko Aulin-Ahmavaara*

Statistics Finland and University of Helsinki

Moving human capital inside the production boundary requires human capital and its services to be treated as outputs of production processes. The primary input of labor ceases to exist, and it is necessary to redirect goods and services consumed by it as inputs in the industries that now produce human capital and its services, i.e. human time. A description of the total production system, which includes these industries, is given. This description is formalized by means of the dynamic input-output model. The potential uses of this approach are discussed. Two well-known approaches to include human capital in national accounts are discussed against this background. They lead to exceptionally high rates of return on inputs in human capital and, logically, also leave substantial resources available to net additions to the stocks of human capital.

1. Introduction

Traditionally human capital has been left outside the asset boundary of the System of National Accounts (e.g. ISWGNA, 1993). This is a logical consequence from the definition of production in it. If human capital were treated as an asset it should be a produced asset, and for this it should, obviously, be produced. This means that the production boundary of the SNA should be revised to include the production of human capital. But inputs in human capital formation are treated as consumption in the SNA. Classics of national accounting no doubt were fully aware of the problems relating to this. For example, Kuznets (1946) asks whether all of the flow of goods to consumers is "by consumers *qua* consumers" and "Is some of it wanted by consumers in their capacity as producers?" But he warns that the distinction between consumption and investment in human capital is tenuous: "For if education is conceived simply as preparation for livelihood and not as enhancement of living, . . . then, since the satisfactions of the consumer are inextricably bound up in the circle of means and ends with the needs of the producer, the whole category of ultimate consumption disappears."

In their work Richard and Nancy Ruggles seem to remain true to the view that the flow of goods to consumers represents final consumption and not intermediate inputs. In the Core Account of their Household Current Income and

Note: The author is researcher at Statistics Finland and docent of economics at the University of Helsinki. I presented an earlier, and somewhat different, version of the paper at the 27th General Conference of the International Association for Research in Income and Wealth. Thanks are due to all those who commented on it and especially to the discussant of my paper, Rob Edwards. The very useful comments of two anonymous referees and of the editors of this issue are gratefully acknowledged. The author is solely responsible for the views expressed in the paper as well as for the possible mistakes in it.

*Correspondence to: Pirkko Aulin-Ahmavaara, Oulunkyläntori 2 C 16, FIN-00640 Helsinki, Finland (aulin@nettilinja.fi; pirkko.aulin-ahmavaara@stat.fi).

Outlay Accounts (Ruggles and Ruggles, 1986), all the imputations, including the expenditure on owner occupied housing services, are excluded. The latter is replaced by direct cost on housing. In the Imputations Account the households are, implicitly, given a role as producers of housing services and services of consumer durables as well as of farm products for own final use. Benefits in kind, education included, appear in the Attribution Accounts. This could be an opening towards moving human capital within the production boundary, but education services are consumed, not used as inputs to produce human capital. Income in the Extended Account includes opportunity cost of students. But there is no indication that the time of students could be used as input in the production of human capital. Human capital does not appear in the balance sheet of the households. The Extended Account also includes income from household work, but household work obviously is not produced, the primary input labor seems to be directly consumed. From this it seems to be correct to conclude that the Ruggles consider human beings as consumers and as providers of a primary input, labor. Households can be involved in production, but only when it can be separated from the human beings themselves, i.e. could be done by other sectors for the households.

In fact, when discussing the treatment of government expenditures on durable goods, the Ruggleses (1961) point out that government expenditure, e.g. on research, education and public health also improves the amount of social capital available in the economy. But, at least at that stage, they are skeptical of the idea of a concept of government capital formation that would cover all the improvements in social capital since "this is a question not of objective fact but of political philosophy." They also find the valuation of non-market activities problematic (e.g. Ruggles and Ruggles, 1982) and argue for separating non-market activities from market transactions, not only because of the problems of valuation but also because "market transactions are often the vehicle for implementing economic and social policy" (Ruggles, 1982). As Richard Ruggles (1983) points out, the set of all possible imputations is unbounded, the only criterion being that they should be useful and necessary for the particular purpose at hand.

It is easy to agree with all this. It of course does not exclude the possibility of measuring human capital for particular purposes. But measurement of any capital is known to be a difficult and controversial issue. Discussing the concept and measurement of capital is hardly possible without selecting, as the Ruggleses (1961) do, the purpose of the measurement. In their case the purpose is the measurement of productivity. From this point of view they consider three alternatives for measuring capital stocks: by cost, by capacity of the system as a whole to produce output and by the contribution of capital to output. They favor measuring the current value of stocks and services of capital in terms of replacement cost.

Human capital is, in principle, not different from the rest of capital or vice versa. The measurement of investment in and stocks of human capital can be based either on accumulated cost (e.g. Kendrick, 1976; Abramowitz and David, 1996) or on the discounted value of future incomes earned by human capital (e.g. Graham and Webb, 1979; Jorgenson and Fraumeni, 1989). Kendrick's (1976) starting point to capital stock estimates is similar to that of the Ruggleses. He gives preference to capital stocks based on investment estimates, which he considers, also referring to

Denison (1953) as the Ruggles (1961) do, better suited for productivity measurement. Also Jorgenson and Fraumeni (1989) define the purpose of their accounting system, which includes investment in human capital, to be to "provide a comprehensive perspective on the role of capital formation in U.S. economic growth."

Whichever the approach, if human capital is treated as a produced asset, the logic of accounting, and in fact the very definition of fixed asset in the SNA93 (par 10.26), requires it to be used to produce something. This something is often called services of human capital and part of it may be included in the revised GDP (e.g. Jorgenson and Fraumeni, 1989) in the form of household work or leisure. But if human capital and its services are to be included within the production boundary, it should be done on the basis of a consistent description of their production processes. For this production and producing units should be defined, and inputs and outputs used in the processes of production specified. Everything that has been produced should be accounted for, which is the case in the SNA itself. And everything that is used in any production process should be an output of a production process or imported, or else should be clearly treated as a non-produced asset and accordingly as a primary input. If the full description of the production process is not given, it is difficult to evaluate whether the expansion of the production boundary has been done in a consistent way.

In this paper we discuss the possibilities of expanding the production boundary to include the production of human capital and of its services. For this we first give a general description of these production processes as a part of the total production process of an economy. This is done in the line of the system introduced by Aulin-Ahmavaara (e.g. 1987, 1992, 1997). It is formalized by means of a dynamic input-output model to assign the unit prices, to the outputs and the inputs of the system, in Section 3. The interpretation of the results of the model is briefly discussed. Against the background of the general description in Section 2 we then try to detect the implicit, descriptions of the production system in two well-known approaches to include human capital and its services in the national accounts, i.e. those presented by Kendrick (1976) and by Jorgenson and Faumeni (1989). For this purpose we also briefly discuss some of their results as indicators of possible problems in the underlying descriptions. Finally in Section 5 some conclusions concerning the expansion of the production boundary to include the production of human capital and its services are drawn.

2. Production of Human Capital and of Human Time

In the SNA93 (par 6.6) production as economic activity is described in general terms as an activity in which an enterprise uses inputs to produce outputs of a kind that can be delivered or provided to other institutional units. In the System itself most of the household activities are, however, left outside the production boundary. We can define production as a process that utilizes human time (see Appendix for definition) directly or indirectly to bring about something that can be used up or transformed into another form in a process utilizing human time.[1]

[1]This means that scientific research which adds to the stock of knowledge of the mankind is not production since its results have permanent value and cannot be used up.

This might seem rather radical at first sight. But in the end time is the only scarce resource of a human being. This is also the implicit definition of production in all those revisions of national accounts, in which the value of time spent in schooling as well as household work and leisure are included in the output.

The producing unit in the SNA is an establishment. An establishment should have a principal activity and it can also have one or more secondary activities. Now also an individual is an establishment that produces human time and/or human capital. We could think of an individual as two separate establishments, in these two roles, but this is not essential for the description of the production process. Production of human time and production of human capital are in any case two separate activities. As to the unit of time of the description, a year is the obvious choice.

Output in the SNA is defined as those goods and services that become available outside the producing establishment (SNA93, par 6.38). On the other hand paragraph 6.6 mentions "outputs of a kind that can be delivered or provided to other institutional units." We can say that output consists of those products that can be delivered or provided outside the producing establishment or are used by the establishment itself outside the time unit during which they are produced. The second category is needed because of own-account production of fixed capital. In fact own-account production of fixed capital is included in the output in the SNA as well (SNA93, par 6.47). We also include products that are of the same type as those that normally become available outside the establishment but are used within the establishment to produce another unit of the same product. This will simplify the description of the production process of human time.

Anything that has been produced can, at least in principle, be used as input in the production process. All the produced inputs can appear both in the form of flows and in the form of stocks. Therefore a natural way to give a formal description of the overall production process is the dynamic input output model. If a material input is used in the production process at most for a year, then the flow of this input is the quantity of it used up during the year, represented by the flow coefficients a_{ij}. But it is also necessary to have some stocks of this input, represented by the stock coefficients b_{ij}, either as such or tied up in the inventories of semi-finished or finished products. Inputs of any kind of services, human time included, can also be tied up in the semi-finished or finished products. Some of the stocks are tied up in the production process for more than a year, i.e. are fixed assets. They can lose part of their productive capacity during each year. This capacity has to be replaced if the production is to be continued at its existing level. The replacement requirements of fixed capital are represented by the flow coefficients of replacement, expressed in terms of the stock coefficients and the rates of replacement of fixed capital ν_{ij} as follows:

$$a_{ij}^{R} = \nu_{ij} b_{ij}. \tag{1}$$

Now we have a general framework in which the processes of production can be described. When human capital and human time are included in the total production process the industries involved in it are:

G = the industries producing market and non-market goods and services (in the SNA sense of the word);

E = the industries producing different types of human capital; and
T = the industries producing different types of human time (services of human capital).

Both the matrix A flow coefficients and the matrix B of stock coefficients have the following structure:

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

The production of human capital starts from a newborn baby. In this system he is not a product. But then he starts consuming goods and services, childcare services included (block GE in matrix A). And after one year he represents the first phase of a unit of unqualified or simple human capital.[2] All the flows of inputs are tied up in the production of this phase on the average for half a year. Therefore they appear also as stock inputs (block GE in matrix B). This first phase is used, during the next year, as an input in the production process of second phase of the unit of human capital represented by the 2 year old toddler (block EE in matrix A). The first phase is also tied up as capital input in the production process of the second phase for an entire year (block EE in matrix B). The rest of the inputs are in principle the same as in the first phase. The rest of the phases of the unit of simple human capital are produced in the same way.

After finishing the basic education the individual has produced a unit of simple human capital and starts producing simple or unqualified human time.[3] The unit of simple human capital is used as capital input in this production process (block ET in matrices A and B). The rest of the inputs consist of the ordinary goods and services consumed by the individual (block GT in matrices A and B) as well as of household work performed for him and his leisure time (block TT in matrix A). The household work may be provided by himself or by other individuals.

The other possible uses of his human time consist of inputs in the production ordinary goods and services, of time spent in schooling, i.e. of inputs in the production of qualified human capital (block TE in matrices A and B), and of the household work performed for others. If this household work is performed for children it is used as input in the production of unqualified or simple human capital (block TE in matrices A and B). Otherwise it is used as input in the production of human time (block TT in matrix A). Since an individual uses himself all the time that is left from other uses, it really does not matter how much we think he produces. It should, of course, not exceed 24 hours a day but it should be enough to cover all the hours he uses in outside activities.

By participating in education at the next level the individual produces a unit of human capital corresponding to that level. As inputs he uses part of his own

[2]The expressions "unqualified human capital" and "unqualified human time" are, perhaps somewhat misleadingly, used by Aulin-Ahmavaara (e.g. 1990, 1991) instead of "simple human capital" or "tangible human capital" and "simple human time." See Appendix for selected glossary.

[3]Why is it that we do not treat the time of an individual under working age as output? Simply because it is not a product that could have been available outside the producing unit itself.

time (block *TE* of matrices *A* and *B*) as well as educational services (block *GE* of matrices *A* and *B*). The rest of the goods and services and of human time he consumes are now used as input in the production of simple human time. Again, as in the production of simple human capital, every phase of qualified human capital is used as input into the next one and is tied up in the production of the next phase for the entire year (block *EE* in matrices *A* and *B*).

When an individual has finished his first unit of qualified human capital he starts producing respective type of human time. Again he can use part of this human time as well as educational services to produce a unit of qualified human capital of some other type, normally at a higher level of education, and so on. It is also possible that there are several routes to the same educational attainment. An individual always produces that kind of human time that corresponds to his latest educational attainment. In this production he uses as capital inputs all the units of human capital produced by him (block *ET* in matrices *A* and *B*). The rest of the inputs in the production of human time consist of his consumption of ordinary goods and services (block *GT* in matrices *A* and *B*) and of human time (block *TT* in matrix *A*).

A unit of human capital stops producing human time when the individual becomes unable to work, or otherwise if his time is not any more available outside the producing unit itself. According to our definition, the output of a producing unit consists of only those products that become available outside the producing unit or outside time unit of production. Therefore the consumption of pensioners has to be taken into account by special coefficients u_j representing the ratio the number of persons in retirement to number of units of human capital in the same educational category. Then:

$$a^*_{iGjT} = a_{iGjT} + u_j a_{iGjR} \quad \text{and} \quad b^*_{iGjT} = b_{iGjT} + u_j b_{iGjR}, \tag{2}$$

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

3. Production Prices of Human Capital and of Human Time

The description of the total production system in the previous section was in fact based on physical quantities. No values were mentioned. Units of human capital are counted as the numbers of individuals having the respective qualifications. Human time is measured in years. As to the ordinary goods and services, the physical units are worth e.g. 1000 euros at current prices. In this section we are going to assign unit prices to all these products my means of the closed dynamic input-output model.

In the model outlined in the previous section there are two categories of coefficients that depend on the past development of the system, i.e. the rates of replacement v_{ij} and the ratios of the number of persons in retirement to number of units of human capital in the same educational category u_j. However if the economy is growing at a constant rate λ, then rate of replacement v_{ij} is a function of this constant rate of growth, and not of time, whichever patterns of mortality and efficiency decline of a fixed asset are assumed. This is especially important in the case

of human capital, since the simple case of geometric efficiency decline does not seem plausible for it. Also the coefficients u_j depend, in the case of constant growth, on the rate of growth and not on time. This is true regardless of the variation in the length of gestation periods, active periods and periods of retirement as well as of the possibility of different routes to same educational attainment (for proof see Aulin-Ahmavaara 1987, 1990, 1991).

The matrices of flow and stock coefficients, A and B respectively, together with gestation periods and productive periods of physical and human capital as well as periods of retirement of human capital give a description of the production technology of the economy. The balanced growth path of an economy using this production technology can now be represented by the following closed dynamic input output model:

$$(I - A(\lambda))\bar{x} = \lambda B(\lambda)\bar{x}. \tag{3}$$

Here λ is the rate of balanced growth possible for the economy and $\bar{x}$ the vector of output proportions associated with it. Both of the matrices A and B depend on λ through the coefficients v_{ij} and u_j. The dual equation for price proportions $\bar{p}$ is:

$$\bar{p}'(I - A(\lambda)) = \bar{p}'\lambda B(\lambda). \tag{4}$$

Equations (3) and (4) have a unique solutions for the balanced rate of growth, which is equal to the average rate of profit, and for the vectors of output and price proportions associated with it (for proof, see e.g. Aulin-Ahmavaara 1987, 1990, 1991).

The balanced rate of growth is the fastest rate of growth that is, in the long run, possible for the economy using the technology represented by the two matrices A and B (for proof, see Bródy, 1970). In this sense it gives a measure of the growth potential of an economy utilizing this production technology. This property of the dynamic input-output model can be used, and has been used for instance by Carter (1974), to study the effects of the changes in the technical coefficients to the growth potential of an economy, that of the United States in her case. The vector of price proportions shows the relative prices that would lead the economy towards this path. The relative price of the output of an industry shows its production cost per unit of output when all the inputs to it are valued at their production cost and the inputs of the inputs are valued at their production cost etc. Therefore we are calling it the production price of the industry.

The rate of change in the balanced rate of growth can be interpreted to represent the rate of total factor productivity growth when the production processes of human capital and human time are included in the total production process (see Aulin-Ahmavaara, 1992, 1999). It is of course also possible to calculate the consequences of a hypothetical change in the production technology. The change can concern, besides the production technology of industries using ordinary goods and services, e.g. the general age of retirement, the number of years needed to obtain given educational qualifications etc. If the efficient production technology for some industries, e.g. for those producing human capital and human time, were known, it would of course be possible to use it as the hypothetical production technology. But what we are mainly interested in is not imaginary economies but real economies.

The calculations for Finland (cf. Aulin-Ahmavaara, 1992) show a fall in the rate of balanced growth from 2.1 percent in 1970 to 1.7 percent in 1980 and 1.25 percent in 1985. This implies on average a 3.4 percent annual fall in overall productivity. The reasons for the fall in potential rate of growth of the economy can be looked for from the changes in the production prices of different industries, which now include the industries producing human capital and human time. The price vector, of course, originally gives only the relative prices. One possibility to turn them absolute is to express them in terms of the price of a unit of simple human time. A decrease in the production price can be interpreted as an increase in the productivity of the industry, when all the industries that are delivering directly or indirectly inputs to the industry are vertically integrated to it.[4]

In Finland the production price of qualified human time in terms of simple human time increased from 1970 to 1985 in five of seven categories of qualified human time in the model. The reasons for this can be found in the increased production cost of qualified human capital tied up in these production processes. This again was caused by an increase in multiple education, in other words in the number of individuals having several different types of diplomas at the same level. The production prices of qualified human time with the matriculation examination fell. This was caused among other reasons by the fact that the share of dropouts and failures to pass to the next form declined. This might of course also be an indication of a change in the quality of education.

For some categories of qualified human time, the actual earnings ratios for qualified labor were higher than the respective ratios of unit production cost given by the model (see Aulin-Ahmavaara, 1987). In these cases the actual prices might have been artificially pushed up by the progressive taxation and could have led firms to use less labor with higher education or upper vocational education less than would have been in the best interest of the economy as a whole.

As to the industries producing ordinary goods and services, the production cost was declining, and productivity thus increasing, in all of them. Decrease in production prices was below average, e.g. in the industry "gas and electric and water services," probably because of the rising oil prices in the 1970s. The imports are in the model produced by means of exports. Comparing the relative prices of industries producing ordinary goods and services with their relative production prices shows, for example, that the relative production cost of agriculture is, on the basis of the model, very high in comparison to its relative price in real life. The reason for this is of course that agriculture is a heavily subsidized industry.

These are only a few examples of the possible uses of the model for analyzing an economy. There are, naturally, many kinds of problems in calculations like this. The model is rather complex, and its empirical application requires data from numerous different sources. This of course increases the possibility of errors, although on the other hand it provides an opportunity to check the consistency of different types of statistical data. Also the model may be sensitive to changes in the classifications. This has not been explored.

[4]Also the traditional measure of TFP change for an industry can be interpreted as the rate decrease in its production price (see Aulin-Ahmavaara, 1999).

In fact, as the Ruggleses (1961) point out, simple labor does not necessarily represent the same value in different years. Another and perhaps even more interesting possibility is to divide the change in the relative production prices into two parts. The first one, called the fully effective rate of industry-level productivity change, indicates the rate of decrease in the growth potential of the economy consumed by the industry, as a consequence of changes in production technology in the entire economy. The second term gives the rate of change of the long-run growth potential of the economy. This approach has however not been applied in practice as yet.[5]

4. The Implicit Production Systems of Two Approaches to Human Capital Measurement

In the present section the implicit production systems of two well known approaches (Kendrick, 1976; Jorgenson and Fraumeni, 1989) to human capital measurement in the context of national accounting, are studied against the background of the description of the production system in Section 2. The results are summarized in Table 1 at the end of this section.

Kendrick (1976) provides estimates of stocks and flows of both tangible (unqualified) and intangible (qualified) human capital based on accumulated cost. Investment in tangible human capital is equal to the rearing cost of children up to the age of 14, including the full value of their consumption. It does, however, not include any inputs of human time in the form of household work. Neither are intermediate stages of a unit of human capital treated as capital inputs in the production of the subsequent stages. This can be seen from the fact that no return on stocks tied up in this form in the production process is included in the production cost. Investment in intangible human capital includes, besides education and training, also health, mobility and R&D. Here we concentrate on education and training, which, in Kendrick's (1976) system includes the costs of schools and the foregone earnings of students 14 years of age and over. Investment both in tangible human capital and in intangible human capital are part of the adjusted GDP and can be interpreted to be outputs of production processes, with explicitly defined inputs.

Labor compensation, which also includes the foregone earnings of the students participating in education, represents in Kendrick's (1976) system return on total human capital employed. Human time is used as inputs in market production and in the production of intangible human capital. Since none of the rest of the human capital services in the Kendrick (1976) system is included in the GDP, they have to be used as intermediate inputs by the very units producing these services.

An interesting test of the plausibility of the description of the production system is to compare the net rates of return on human capital with those on non-human, or physical capital. In a market economy one would expect the net rates of return on different types of capital not to diverge significantly from each other. When calculating the rates of return on capital, Kendrick (1976) in fact deducts

[5]For the derivation of the results as well as for more details on this, see Aulin-Ahmavaara (1999).

maintenance cost of human capital, based on minimum budget estimates for families, from the estimated labor compensation, which, in his system, represents the value of the output produced by utilizing human capital. In this case maintenance costs, i.e. part of the consumption by adult population, are actually treated as intermediate inputs in the production of the services of human capital. However, even when the maintenance costs are deducted, net rates of return on human capital, calculated by Kendrick (1976) generally are, for the total domestic economy, at least 1.5 times those on non-human, or physical, capital. This result is determined by the choices made in the description of the processes of human capital and human time.

The Jorgenson and Fraumeni (1989) estimates of human capital are based on discounted future labor income. They also include in the labor income the value of the time spent in household work and leisure as well as the value of the time spent in formal schooling. They introduce a system of national accounts, in which investment in human capital as well as consumption of non-market services, i.e. of household work and leisure, are included in the GDP. This means that human capital and its services are treated as outputs of production processes.

Jorgenson and Fraumeni (1989) do not give any explicit description of the production system that lies behind their estimates. They define the "investment in human capital in any year as the sum of lifetime incomes for all individuals born in that year and all immigrants plus the imputed labor compensation for formal schooling for all individuals enrolled in school." Thus even newborn babies have a positive value, which in their production account is, together with the rest of the investment in human capital, added to the GDP. However, there seems to be no inputs in the production of human capital in the form of newborn babies, since nothing is deducted from the consumption expenditure shown in the original U.S. accounts. None of the time of the individuals at the working age is used as inputs in the production of unqualified human capital by taking care of children at home. All of their time is spent elsewhere, either in market activities or participating in education or consumed in the form of household work or leisure. The value of the human capital embodied in a child increases in the Jorgenson and Fraumeni (1989) system, when the child becomes a year older.[6] This means that stocks of each intermediate phase needed for the subsequent phase of unqualified human capital are taken into account. It is, however, not obvious in which way this increase in the value is recorded in the accounts. It is not included in the Jorgenson and Fraumeni (1989) definition of investment in human capital quoted above.

Time spent in formal schooling is, in the Jorgenson and Fraumeni (1989) system, the only input in the production of qualified human capital. Its value is equal to its impact on the full lifetime income (which also includes the value of the time spent in household work and leisure as well as the value of the time spent in formal schooling) less tuition and fees. Lifetime income of an individual with a given educational attainment is assumed to grow at an annual rate corresponding to the expected rate of Harrod-neutral technical change.

The value of the services of human capital consumed as household work and leisure is imputed on the basis of the hourly compensation of the respective services

[6]This can be concluded from the equations in the Appendix of Jorgenson and Fraumeni (1992).

in market production. Every individual at the age of 14 to 74 is assumed to produce services of human capital 14 hours per day, 7 days a week. This value is, in the Jorgenson and Fraumeni (1989) system, added to private consumption expenditure. Accordingly the only input in the production of human capital services is ten hours per day to satisfy physiological needs such as sleeping and eating. Neither goods (not even food to eat) nor services nor household work and leisure are needed.

The rate of return on human capital would no doubt, in the Jorgenson and Fraumeni (1989) system, be very high, if investment in it were calculated on the basis of its production cost. An indication of this is the imputed compensation per hour for time spent in schooling, which can, in the Jorgenson Fraumeni (1989) system, be far above the hourly compensation for the rest of the services of human capital. Jorgenson and Fraumeni (1989) do not give any figures on this. According to Jorgenson and Stiroh (2000, table C1) the hourly compensation for market labor activities was 14.2 dollars in 1986. From Jorgenson and Fraumeni (1992, tables 7.1 and 7.8 and Appendix), which uses the same methodology as Jorgenson and Fraumeni (1989), in 1986, for example, the hourly imputed compensation for the time spent in formal schooling was 75.7 dollars per hour. This is more than five times the hourly compensation for market labor activities. This in spite of the fact that about 80 percent of those enrolled in schools had less than high school education (Jorgenson and Fraumeni, 1992, table 7.1), while the corresponding percentage for the U.S. work force was less than 20 percent (Ho and Jorgenson, 1999, table C2).

This calculation is based on the assumptions of Jorgenson and Fraumeni (1989) about the total daily time available (14 hours), the annual growth rate of real income (2 percent), and the discount rate (4 percent). From Jorgenson and Fraumeni (1992) it is obvious that the results are very sensitive to these assumptions. Besides these results of course depend on the rest of the choices made in the underlying description of the production system.

The differences between the systems discussed in this section and the one outlined in Sections 2 and 3 are summarized in Table 1. The main reason for the high rates of return on the cost of investment in human capital in both of the systems discussed in this section obviously is the fact that only a part, if any, of final consumption is treated as input in the production of human capital and especially as input in the production of the services of human capital, i.e. of human time. In Kendrick's system, consumption of children under the age of 14 is treated as input in the production of tangible human capital and the consumption of educational services as input in the production of intangible human capital. In the system of Jorgenson and Fraumeni, none of the consumption of ordinary goods and services is treated as input in the production of human capital or of human time.

In the SNA, final consumption is, of course, not treated as input in the production of human capital and of human time since there is the primary input of labor. Consider, however, a closed economy without any physical capital and without any taxes and subsidies on production. In that economy final consumption is equal to gross domestic product, which is equal to net domestic product, which again is equal to labor compensation. Consumption of goods and services, which now would be equal to labor compensation, would be used for the replacement of human capital, to net additions to the stock of human capital or to satisfy

TABLE 1

PRODUCTION PROCESSES OF HUMAN CAPITAL AND OF HUMAN TIME[1]

	K[2]	J&F[3]	A-A[4]
Production of tangible or unqualified human capital			
Consumption of ordinary goods and services by children	Yes*	No*	Yes
Consumption of human capital services (human time) by children as household work	No	No	Yes
Intermediate stages of human capital as capital inputs for the subsequent stages	No	Yes	Yes
Production of qualified human capital			
Consumption of educational services	Yes	Yes	Yes
Consumption of human time by participating in education	Yes	Yes	Yes
Production of human time			
Consumption of ordinary goods and services by population at working age	No[5]	No	Yes
Consumption of services of human capital or human time as household work or leisure by population in working age	Yes[6]	10 hours per day	Yes
Consumption of goods and services by persons in retirement	No	No	Yes
Human capital	Yes	Yes	Yes

Notes:

[1]For explanations see text.

[2]Kendrick (1976).

[3]Jorgenson and Fraumeni (1989).

[4]Aulin-Ahmavaara (e.g. 1991, 1992).

[5]When calculating the rate of return on human capital Kendrick (1976) actually treats minimum budget consumption of goods and services as input in the production of goods and services.

[6]Later Kendrick (1979, 1987) includes also the value of household work and leisure in the GDP and accordingly no longer treats them as inputs in the production of human time.

*Yes = included in the inputs, No = not included in the inputs.

the current needs of the providers of the primary input of labor. But when we start treating human capital and its services as outputs of production processes, there is no longer any primary input of labor to be compensated.

5. CONCLUDING REMARKS

Human capital and its services have traditionally been left outside the production boundary of the SNA. The main reason for this seems to be the fact the goods and services which could be used as inputs in this production are at the same time constituents of the consumption of goods and services. Moving human capital, and accordingly also its services, inside the production boundary is always, at least implicitly, based on a description of the production processes of human capital and its services, i.e. of human time. For this description it is necessary to choose which part of the consumption of ordinary goods and services and of the consumption of human time is used as inputs in the production processes of human capital and human time. The choices made in the description of the

production system determine the results of the calculation, even when no explicit description of the production system is given.

We studied the choices made in two well-known systems for measuring human capital and integrating it in national accounts. Mostly these choices are problematic. For instance should all or none or part of the consumption of ordinary goods and services by people of working age be treated as inputs in the production of human time? Maybe only the consumption based on minimum budgets would be needed as suggested by Kendrick (1976), or maybe none as can be concluded from Jorgenson and Fraumeni (1989)? But would the individuals living at the subsistence level be equally productive as those with more extensive possibilities to consume, e.g. recreational services, household services, with better access to sports facilities, enough space in their homes and comfortable beds to have a good night's sleep etc.? It is also a fact of life that the active population has to provide the goods and services needed by the retirees. The quantities needed for this depend on the way in which human capital and human time are produced, i.e. on the lengths of gestation periods and productive periods of the units of human capital.

When only a part of consumption is treated as input in the production of human capital and of human time, the rates of return on human capital appear to be very high in comparison to those on physical capital, and substantial values appear to be created with none or very little cost. In the SNA there is the primary input of labor. Final consumption of goods and services would be used either for the replacement of human capital, to net additions to the stock of human capital or to satisfy the current needs of the providers of the primary input of labor. But when human capital and human time are treated as outputs of production processes, there is no longer any primary input of labor. There still is the primary input of human capital in the same sense as there is, in the SNA, that of physical capital. But as physical capital when it is used in the production processes, human capital is also only one of the inputs in the production of human time. In this case all of the goods and services in the original final consumption that are not redirected into the production processes of human time or of human capital are available to net additions to human capital. This would make those additions very large, but this is of course something that is suggested already by the very high rates of return on the cost of investment in human capital.

From the point of view of a consistent description of a production system, it therefore seems necessary to treat the resources that are used to obtain some outputs as inputs in the production processes of these outputs. If a primary input is moved within the production boundary then everything that was used by it in the capacity of a primary input becomes inputs in its production process. And vice versa of course; if we would start treating for instance agricultural products as primary inputs then all the inputs used earlier in their production process should be treated as "consumption." There might be some inefficiency in the production of human capital and human time, and accordingly all of the consumption might not be necessary as inputs in their production. But this of course might, in an economy with imperfect markets, be true of any of industries.

When final consumption is treated as input in the production processes of human capital and human time the complete production process of an economy

can be represented by means of a closed dynamic input-output model. This model makes it possible to calculate the long-run growth potential of an economy when the pattern of final consumption, as well as, for example, the duration of different types of education, lengths of the periods of retirement, participation rates in gainful employment, and length of the working hours are treated as part of the production technology. The rate of change can be interpreted as the rate of productivity growth in the overall production system. It is also possible to give to the changes in production prices an interpretation as measures of productivity change and to trace back the reasons for changes in the long-term growth potential of the economy.

But treating final consumption only as inputs in the production processes of human capital and human time is the exact opposite to the national accounts and obviously cannot be a part of its core system. However, it is built, as an extension, on the system national accounts. Like national accounts, it also, in the good Ruggleses (1986) spirit, both provides an overall framework to define the elements that should be included in the microdata and establishes "the basic control totals for microdata from different sources as well as relates the various parts of the production system to one another."

Appendix: Selected Glossary

Human capital stock: The capacity of the individuals belonging to the population of a country to perform work in different educational categories, created by rearing children and participating in education and training. It can be measured and valued in different ways.

Human capital services: See human time.

Human time: Any time use of individuals who have reached the working age and have not become unable to work. Output of the production processes utilizing human capital.

Intangible human capital: See qualified human capital.

Maintenance cost of human capital: Term used e.g. by Kendrick (1976) for the cost of maintaining the productive capacity of human capital, calculated, in his case, on the basis of minimum budget estimates.

Net rate of return on human capital: The ratio of net return on human capital to the value of human capital stock. Net return on human capital is equal to the value of the human capital services produced utilizing it, less depreciation of human capital and less the value of the other inputs used in this production process.

Simple unqualified human capital: Human capital created by rearing children up to the normal working age.

Qualified human capital: Human capital created by participating in education and training after the basic education.

Tangible human capital: See simple unqualified human capital.

References

Abramovitz, M. and P. A. David, "Technological Change and the Rise of Intangible Investments: The U.S. Economy's Growth-path in the Twentieth Century," *Employment and Growth in the Knowledge-based Economy*, OECD, Paris, 35–50, 1996.

Aulin-Ahmavaara, Pirkko, *A Dynamic Input-Output Model with Non-Homogeneous Labour for Evaluation of Technical Change*, Finnish Academy of Science and Letters, Helsinki, 1987.

———, "Dynamic Input-Output and Time," *Economic Systems Research*, 2, 329–34, 1990.

———, "Production Prices of Human Capital and Human Time," *Economic Systems Research*, 3, 345–65, 1991. (Reprinted in Heinz D. Kurz, Erik Dietzenbacher, and Christian Lager (eds), *Input-Output Analysis, Volume III*, The International Library of Critical Writings in Economics, Edward Elgar Publishing, Cheltenham, UK and Northampton, MA, 270–96, 1998.)

———, *Productivity of a Nation, The Measurement of Technical Change in the Total Production System (Example: Finland 1970–1985)*, Studies 195, Statistics Finland, 1992.

———, "Measuring the Productivity of Nations," in A. Simonovits and A. E. Steenge (eds), *Prices, Growth and Cycles: Essays in Honour of András Bródy*, Macmillan, London, 132–48, 1997.

———, "Effective Rates of Sectoral Productivity Change," *Economic Systems Research*, 11, 349–63, 1999.

Bródy, András, *Proportions, Prices and Planning*, North-Holland, Amsterdam, London, 1970.

Carter, Anne P., "Energy, Environment and Economic Growth," *Bell Journal of Economic Management Science*, 5, 578–92, 1974.

Denison, Edward, "Theoretical Aspects of Quality Change, Capital Consumption and Net Capital Formation," *Problems of Capital Formation, Studies in Income and Wealth*, 19, 215–61, 1953.

Graham, J. W. and R. H. Webb, "Stocks and Depreciation of Human Capital: New Evidence from a Present-Value Perspective," *The Review of Income and Wealth*, 25, 209–24, June 1979.

Ho, Mun S. and Dale Jorgenson, *The Quality of U.S. Workforce, 1948–1995*, Department of Economics, Harvard University, Cambridge, MA, 1999.

ISWGNA, The Inter-Secretariat Working Group on National Accounts, *System of National Accounts*, Commission of the European Communities–Eurostat, International Monetary Fund, OECD, United Nations, Brussels/Luxembourg, New York, Paris, Washington, D.C., 1993.

Jorgenson, Dale W. and Barbara M. Fraumeni, "The Accumulation of Human and Nonhuman Capital, 1984–84," in R. E. Lipsey and H. S. Tice (eds), *The Measurement of Saving, Investment, and Wealth*, Studies in Income and Wealth, Vol. 52, University of Chicago Press, Chicago, IL, 1989. (Reprinted in Dale W. Jorgenson, *Productivity, Volume 1: Postwar U.S. Economic Growth*, The MIT Press, Cambridge, MA and London, UK, 273–331, 1995.)

———, "The Output of Education Sector," in Z. Griliches (ed.), *Output Measurement in the Services Sector*, Studies in Income and Wealth, Vol. 55, University of Chicago, Chicago, IL, 1992. (Reprinted in Dale W. Jorgenson, *Productivity, Volume 1: Postwar U.S. Economic Growth*, The MIT Press Cambridge, MA and London, UK, 333–69, 1995.)

Jorgenson, Dale W. and Kevin J. Stiroh, "Appendix B. Estimating Capital Services for the United States," in Dale W. Jorgenson and Frank C. Lee (eds), *Industry-level Productivity and International Competitiveness Between Canada and the United States*, Industry Canada Research Monograph, 185–200, March 2000.

Kendrick, John W., *The Formation and Stocks of Total Capital*, Columbia University Press for NBER, New York, 1976.

———, "Expanding Imputed Values in the National Income and Product Accounts," *The Review of Income and Wealth*, 25, 349–63, December 1979.

———, "The Concept and Estimation of Full Personal Income in Current and Constant Prices," Prepared for meetings of the International Association for Research in Income and Wealth in Rocca di Papa, Italy, August 1987.

Kuznets, Simon, *National Income: A Summary of Findings*, National Bureau of Economic Research, New York, 1946.

Ruggles, Richard, "The System of National Accounts: Review of Major Issues," *Expert Paper for the United Nations Statistical Office*, ESA/STAT/AC.15.2, April 1982. (Reprinted in Nancy D. Ruggles and Richard Ruggles, *National Accounting and Economic Policy*, Edward Elgar, Cheltenham, UK and Northampton, MA, 345–413, 1999.)

———, "The United States National Income Accounts, 1947–77: Their Conceptual Basis and evolution," in Murray Foss (ed.), *The U.S. National Income and Product Accounts, Selected Topics*, Studies in Income and Wealth, Vol. 47, University of Chicago Press for the National Bureau of Economic Research, 1983. (Reprinted in Nancy D. Ruggles and Richard Ruggles, *National Accounting and Economic Policy*, Edward Elgar, Cheltenham, UK and Northampton, MA, 185–242, 1999.)

Ruggles, Richard and Nancy D. Ruggles, "Concepts of Real Capital Stocks and Services," *Output, Input and Productivity Measurement*, Studies in Income and Wealth, Vol. 25, National Bureau of Economic Research, 1961. (Reprinted in Nancy D. Ruggles and Richard Ruggles, *National Accounting and Economic Policy*, Edward Elgar, Cheltenham, UK and Northampton, MA, 39–55, 1999.)

———, "Integrated Economic Accounts for the United States, 1947–80," *Survey of Current Business*, 62(5), 1982. (Reprinted in Nancy D. Ruggles and Richard Ruggles, *National Accounting and Economic Policy*, Edward Elgar, Cheltenham, UK and Northampton, MA, 243–304, 1999.)

———, "The Integration of Macro and Micro Data for the Household Sector," *The Review of Income and Wealth*, 32, 245–76, September 1986.