

## Chapter 2

# Human Capital and Innovation—Basic Concepts, Measures, and Interdependencies

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With the acceleration of globalization processes, human capital stock and quality as well as invention and innovations have become particularly important. The greater mobility of capital on an international scale has led to a situation in which its allocation in a given country is increasingly determined by the quality of labor, in addition to such aspects as the price of labor, the tax system, and the quality of physical infrastructure and institutions. There are a few reasons for this. Production departments based on low-qualified labor force have been moved to areas where the labor costs are the lowest. The competition between the OECD (Organisation for Economic Co-operation and Development) countries and the dynamically developing countries, such as Chile, India, or Brazil, starts to concern the location of the technologically advanced production as well as allocation of research and development (R&D) works and R&D centers. The important elements of that competition are people, their knowledge, creativity, and the ability to convert these resources into innovation. For that reason, as the analysis of various theoretical approaches set out in the preceding section indicates, human capital and innovation are becoming increasingly critical for shaping the competitive advantage of countries and boosting benefits achieved in international exchange. The model approach to that kind of correlation as well as the empirical verification of its direction and strength requires supplementation of previous theoretical deliberations regarding the nature of international competitiveness with selected theoretical strands relating to human capital and innovation. This section is thus an attempt to integrate terms such as human

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capital and innovation based on the concept of innovation systems, as well as to present and select measures adequate for analyzing these complex and overlapping phenomena.

## 2.1 The Term Human Capital

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The term *human capital*, even though introduced as early as in the seventeenth century by Petty (1690) and discussed, among others, by Smith (1776),<sup>1</sup> disappeared from the sphere of interest of economics, *inter alia*, after the critique by Marshall (1930), who held that “while human beings are incontestably capital from an abstract and mathematical point of view, it would be out of touch with the market place to treat them as capital in practical analyses.”<sup>2</sup> The renaissance of research on human capital came in the 1960s, thanks to works by Mincer (1958), Schultz (1961), and Becker (1964).

It is also worth mentioning Machlup’s studies on transformations of economies in highly developed countries, which resulted in the concept of a knowledge-based economy. This term is commonly used today but it had to wait until the 1990s to become popularized by Drucker (1992). The key to success in the knowledge-based economy is the human capital.

New theories on economic growth treat human capital as an important determinant of economic development. Such theories have been developed since the 1980s and started with the pioneer publications by Romer (1986), Lucas (1988), and other researchers (e.g., Jones and Manuelli 1990). An up-to-date review of research in the field of the theories about the growth and the role of human capital and innovation in that process can be found in studies by Stroombergen et al. (2002), Woessmann (2003), Le et al. (2005), Florczak (2007), Liberda and Maj (2009), and Weresa (2012).

The issue of valuation of people’s skills and abilities has been covered by Adam Smith, Jean Baptiste Say, and many other economists over the last 400 years (Kiker 1966). The methods for estimation of human capital have evolved over the centuries, but its current definition as “the knowledge, skills, competences and other attributes embodied in individuals that are relevant to economic activity” (OECD 1998, p. 9) or “the knowledge, skills, competencies and attributes embodied in individuals that facilitate the creation of personal, social and economic well-being” (OECD 2001, p. 18) is not far from the definition by Adam Smith, who understood human capital as “all of the acquired and useful abilities of all of the inhabitants

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<sup>1</sup> “A man educated at the expense of much labor and time to any of those employments which require extraordinary dexterity and skill, may be compared to one of those expensive machines. The work which he learns to perform, it must be expected, over and above the usual wages of common labor, will replace to him the whole expense of his education, with at least the ordinary profits of an equally valuable capital.” (Smith 1776, p. 118).

<sup>2</sup> After Schultz (1961, p. 3).

of a country”<sup>3</sup> (Schultz 1961, p. 2). The above definitions make it impossible to directly measure the *stock* of human capital; the capital can only be estimated by means of measurable phenomena presented in statistics and proxies as well as in indexed combinations of those measures.

## 2.2 Methods of Human Capital Evaluation

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Although the availability of statistical data and development of mathematical methods had a significant impact on the way of estimating human capital, it is possible to distinguish two basic approaches to that issue. In one of them (the retrospective approach), the main focus is on establishing the *cost of production* of human capital which, depending on the study, may comprise living, health care, and education expenses or focus only on education spending. The originator of that method was Engel (1883). In the second (prospective) approach, the estimate of the human capital stock is based on the discounted stream of future income of workers in a given economy. The pioneer of that approach was Petty (1690). The approaches presented are well established in the theory of microeconomics. Unfortunately, due to the lack of relevant statistical data, it is not possible to apply those approaches in studies. The aforesaid problem has led to the development of the third approach related to the concept of the *cost of production* of human capital, the approach based on education level. Statistics on adult literacy rates, school enrollment rates, dropout rates, repetition rates, average years of schooling, and scores of competence tests (Program for International Student Assessment, PISA) were available for many countries and enabled both the comparative analyses (cross-sectional studies) and the analysis of trends and estimation of econometric models with the use of relevant time series. The last approach relied on the use of indexes, which were based on educational and demographic measures as well as detailed data from the labor market. The following subsections, based on Woessmann (2003) and Le et al. (2005), briefly present the main features of the approaches described:

1. Approach based on costs of production (retrospective approach),
2. Approach based on future income (prospective approach),
3. Approach based on education parameters (related to the retrospective approach),
4. Approaches using indexes (methods aggregating a number of variables) and *benchmarking* (competence tests, e.g., PISA, TIMSS, IALS).<sup>4</sup>

<sup>3</sup> “Adam Smith boldly included all of the acquired and useful abilities of all of the inhabitants of a country as a part of capital” (Schultz 1961, p. 2).

<sup>4</sup> Respectively: Program for International Student Assessment (PISA), International Adult Literacy Test (IALS) and Trends in International Mathematics and Science Study (TIMSS). Cf. further in this subsection.

## 2.2.1 Approach Based on Costs of Production

The originator of the approach based on production costs was Engel (1883). In this perspective, all expenses covering the cost of living and raising a human being from conception to the age of 25 should be treated as the *cost of production*. Engel proposed the following formula<sup>5</sup>:

$$c_{xi} = c_{0i} + xc_{0i} + \sum_1^x k_i c_{0i} = c_{0i} \left( 1 + x + \frac{k_i x(x+1)}{2} \right) \quad (2.1)$$

where  $i$  is the social class ( $i = 1, 2, 3$ , respectively, for lower, middle, and upper class),  $x$  the age,  $x < 26$ ,  $c_{0i}$  the costs incurred up to the point of birth, and  $c_{0i} + k_i c_{0i}$  the annual cost of living.

From the viewpoint of the theory of investment, the weakness of the formula was that it ignored the time value of money. From the viewpoint of the theory of economics, it did not take into account the intangible investments crucial for the final value of human capital stock. Kendrick (1976) tried to tackle the said problem by assuming that tangible investments are the cost of living of a child up to the age of 14, while the intangible component comprises expenditures on health and safety, mobility, education, and opportunity costs of time spent on education.

The above approach, however, has significant flaws:

1. The cost of production of capital does not necessarily translate into its quality.
2. The value of capital is determined by the demand, not by the cost of production.
3. Components of expenditures and their prices are not recognized well enough to make their cost estimates useful, especially when the line between consumption and investment is not clear (e.g., Kendrick (1976) considered expenditures on necessities such as clothing and food to be investments, while Machlup (1962) regarded them as consumption).
4. The approach does not take into account the social costs of production of human capital (Dagum and Slottje 2000).
5. Variability of the appreciation/depreciation rate of human capital value (knowledge and skills become outdated in an abrupt manner as technology advances, but there is also the straight-line loss of competence due to forgetting)—there is no unequivocal position on that issue in the literature (see Kendrick 1976; Mincer 1958).
6. In macro-level studies, there is a problem of how to distinguish between the investments which have been completed and the investments which are still in progress—it is very difficult to isolate the part of spending on education which has already delivered graduates (Jorgenson and Fraumeni 1990).

<sup>5</sup> Quote after Kiker (1966, p. 483).

### 2.2.2 Income-Based Approach

The originator of a completely new scientific approach to measurements of human capital value was Farr (1853). He proposed to evaluate the human capital of a given individual by estimating the current value of future earnings net of living expenses and adjusted on the basis of a life table. That concept was further developed (Dublin and Lotka 1977).<sup>6</sup> The authors took into account also the employment rate (W. Farr's model assumed full employment conditions). According to their formula, the human capital of an individual at birth may be expressed as follows<sup>7</sup>:

$$V_0 = \sum_{x=0}^{\infty} \frac{P_{0,x}(E_x Y_x - C_x)}{(1+i)^x} \quad (2.2)$$

where  $i$  is the interest rate,  $P_{0,x}$  is the probability (at birth) of living to age  $x$ ,  $E_x$  is the employment rate at age  $x$ ,  $Y_x$  is individual's annual earnings from age  $x$  to  $x+1$ , and  $C_x$  is the annual cost of living.

Formula (2.2) may be easily transformed to obtain the value of human capital at a given age  $a$ :

$$V_a = \frac{P_0}{P_a} \sum_{x=a}^{\infty} \frac{P_x (E_x Y_x - C_x)}{(1+i)^{x-a}} \quad (2.3)$$

Similarly, the total cost of living up to a given age  $a$  can be expressed as

$$C_a = \frac{1}{P_a} \sum_{x=a}^{a-1} \frac{P_x (C_x - E_x Y_x)}{(1+i)^{x-a}} \quad (2.4)$$

After combining formulas (2.2), (2.3), and (2.4), we have

$$C_a = V_a - \frac{(1+i)^a}{P_{0,a}} V_0 \quad (2.5)$$

Equation (2.5) may be interpreted in the following way: the cost of rearing a person up to a given age  $a$  equals the difference between his/her current value and the value at age  $a$  adjusted for the probability of living to age  $a$ .

Although the approach proposed by Dublin and Lotka was later developed and modified (*inter alia*, by the categorization of income based on education—cf. Mincer 1958), the above formulas provide sufficient discussion of the concept of prospective measurement of human capital.

One of the disputable areas is the approach to cost of living. Eisner (1989) considered subtracting the cost of living from income to be a mistake (which he justi-

<sup>6</sup> First edition in 1927.

<sup>7</sup> Quote after Kiker (1966, p. 484).

fied with the heterogeneity of the cost of living in a society and difficulty in distinguishing between investments in human capital and cost of living as well as of estimating the consumption of public goods). Other researchers (Graham and Webb 1979) held the view that net income (after deducting the cost of living) is a better estimate of the value of a given individual for others, while the total income better reflects the total social product (value for the society) of work done by a given person. Another problem considered in the literature was whether the prospective measurements should take into account the rise in real wages resulting from price adjustments which are an effect of economic growth (Houthakker 1959; Miller 1964). Characteristic features of the prospective approach include the following:

1. Valuation of human capital is expressed in market prices.
2. Valuation allows for the depreciation rate; hence, there is no need to determine it arbitrarily or to estimate it.
3. Data necessary to estimate human capital (life or mortality tables, wages, unemployment rate, and education structure) are available<sup>8</sup>; the only element which needs to be estimated is the term *structure of interest rates* (which can be traced, e.g., on the basis of treasury bond yield) used to discount income streams.

The main flaws of this approach are as follows:

1. The assumption that differences in wages truly reflect the differences as regards productivity (this is a critical assumption; if it is not met, the valuation model produces a wrong estimation of human capital stock; factors contributing to wages variation include, e.g., unemployment, which puts an employee in a worse negotiating position (wages do not keep up with productivity changes), local monopsony on the labor market, and redistribution of added value generated by lower-level workers for the benefit of employees at senior management levels of a company).
2. The measure is very sensitive to changes of the retirement age (change in number of financial flows) and of term *structure of interest rates* (change of discounting factors).

### 2.2.2.1 The Newest Studies Using Prospective Methods

The most important development of the method was proposed by Jorgenson and Fraumeni (1989, 1990). This model was used to estimate the human capital of the entire US population classified by the two sexes, 61 age groups, and 18 education types (0–17+ years of schooling) based on data collected from 2196 cohorts (Jorgenson and Fraumeni 1989). The basic model from the times of Engel was based on the assumption that a person at a given age  $x$  in  $n$  years will earn the same salary as the salary earned today by a person aged  $x + n$  of the same sex and with the

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<sup>8</sup> Data on wages in developing countries are very often unavailable or may contain an error in estimation. Until the mid-twentieth century, the data on wages were not a part of statistics of many developed countries.

same education. The proposed change involved the simplification of the discounting procedure of future income streams to the present value. The authors adopted a recursive formula in which the current value of the lifetime income stream ( $L_y(s, a, e)$ ) obtained by an individual at a given age is the income from the current year plus the total lifetime income computed for the following year ( $L_{y+1}(s, a+1, e)$ ), weighted by survival probabilities ( $S_y(s, a+1)$ ).

Jorgenson and Fraumeni identified five stages of the human life cycle (Fraumeni 2011):

- Preschool: no school and no work (age 0–4),
- School and preproduction: school but no work (age 5–13),
- School and production: school and work (age 14–34),
- Production: work but not school (age 35–74),
- Postproduction: no school or work (age 75+).

By assumption, the discounted income for the last age group is zero. The formalized<sup>9</sup> formula for the production group is as follows:

$$L_y(s, a, e) = Y_y(s, a, e) + S_y(s, a+1)L_{y+1}(s, a+1, e) \frac{(1+g_y)}{(1+i_y)} \quad (2.6)$$

where  $s$  is the sex,  $a$  the age,  $e$  the education, and  $y$  the year.  $Y_y(s, a, e)$  is the average income of a person of sex  $s$  at a given age  $a$ , with  $e$  education observed in year  $y$ , calculated as the product of average hourly rate and average number of hours worked, increased by *non-market* income, the estimation of the value of *non-commercial* activity (e.g., entertainment, sports, and self-education);  $L_y(s, a+1, e)$  is the discounted per income stream of year  $y$  of a person of sex  $s$  at a given age  $a$  with education  $e$ ;  $S_y(s, a+1)$  is the probability of living up to age  $a+1$  for a person of sex  $s$  at a given age  $a$ , observed in year  $y$ ;  $g_y$  is the real growth rate of remuneration; and  $i_y$  is the real discount rate.

Another important contribution made by Jorgenson and Fraumeni was to include the potential value generated by individuals who receive formal education at a given moment (age category 14–34). Allowance made for the years of schooling affects the lifetime income of individuals from the second and the third group. The correct formula is then

$$L_y(s, a, e) = Y_y(s, a, e) + [E_y(s, a, e)S_y(s, a+1)L_{y+1}(s, a+1, e+1) + (1-E_y(s, a, e))S_y(s, a+1)L_{y+1}(s, a+1, e)] \frac{(1+g_y)}{(1+i_y)} \quad (2.7)$$

where  $E_y(s, a, e)$  is the school enrollment rate for a given set ( $s, a, e$ ) in a given year.

The most serious objection to the approach proposed by Jorgenson and Fraumeni comes from the work of Dagum and Slottje (2000)—the approach does not take

<sup>9</sup> Designation changed. Full description of the method for all age groups is contained in Fraumeni, (2011, p. 3–5).

into consideration the differences in capabilities as well as the impact of gender and of environmental and social conditions on productivity achieved as a result of education. Nonformal schooling is not considered, nor are the differences between various types/fields of study. Another objection concerned the rough approximation of productivity during the time of schooling. Yet another objection was that the employment rate was not considered: the stock of human capital computed using formulas (2.6) and (2.7) will not change whether the employment rate is 100% or, e.g., 50% (Conrad 1992).

### 2.2.2.2 Index Measures Based on the Prospective Approach

The concept of index was proposed by Mulligan and Sala-i-Martin (1995). It involved the approximation of human capital using an index obtained by dividing the average salary in economy by the average salary of an unqualified worker.<sup>10</sup> The reason for the adoption of such a method was that the salary incorporates not only the skills and abilities of a given worker but also the physical capital available to him or her. This means that unqualified workers tend to receive higher wage rates in countries providing better technical conditions (due to differences in the productivity of unqualified labor depending on the stock of production capital used per one worker). It would lead to wrong estimation of the stock of human capital. Another reason for the adoption of the aforesaid method was the differentiation between the quality and material scope of education with regard to both time and location. When combined with the first factor, the cross-sectional studies for the same level of education may give different wage levels. Mulligan and Sala-i-Martin (1995) propose a method to reduce the impact of technical conditions of unqualified labor on the human capital index in the following way:

$$h_i(t) = \frac{\int_0^{\infty} w_i(t,s) \eta_i(t,s) ds}{w_i(t,0)} \quad (2.8)$$

where  $w_i(t,s)$  is the wage of a worker after  $s$  years of schooling in state  $i$ ,  $\eta_i(t,s)$  is the percentage of population receiving education for  $s$  years in state  $i$ , and  $w_i(t,0)$  is the wage of an uneducated worker in state  $i$ .

In practice, depending on time series available, discrete forms of formula (2.8) are used (cf. Florczak 2007, p. 120):

$$h_i = \sum_e \frac{w_{i,e} L_{i,e}}{w_{i,0}} \quad (2.9)$$

<sup>10</sup> Hence, it is not a standardized ‘non-numéraire’ index; the *numéraire* is a wage of an unqualified worker.

where  $w_{i,e}$  is the wage of a worker with level of education  $e$  in state  $i$ ,  $w_{i,0}$  is the average wage of a worker with minimum level of education (basic or none education) in state  $i$ , and  $L_{i,e}$  is the percentage of labor force with  $e$  education in state  $i$ .

The advantages of this approach include:

1. Elimination of the impact of the accumulated physical capital on higher productivity of unqualified labor,
2. The possibility of capturing the impact of years of schooling (but not of its quality) on the wage variability,
3. Allowing for interstate differences in the stock of the human capital of individuals with the same years of schooling.

The approach proposed by the authors is not free from serious drawbacks (Wachtel 1997):

1. It relies on the assumption that an unqualified worker has the same stock of human capital irrespective of the country and time of observations (it does not apply to the modification with formula (2.9)).
2. The identical number of years of schooling in different countries and in different periods does not result in the identical growth of human capital; using the wage of an unqualified<sup>11</sup> worker (with no educational at all) in the denominator may be insufficient to obtain an index that can be compared among different countries.
3. It does not take into account the differences in wages that are not the result of a different value (marginal productivity) of human capital (the wage structure does not necessarily correspond to the structure of value added generated).
4. It ignores the contribution to human capital by factors other than formal schooling (*inter alia*, nonformal schooling, learning-by-doing, and vocational trainings, as well as health, which is inconsistent with models proposed, e.g., in Mincer (1974)).

The method proposed by Jorgenson and Fraumeni (1990) was further developed by Jeong (2002), who used the average wage in industry as the denominator in the formula. The change was justified with the observation that the nature of work in that sector is least diversified across countries. Individuals with no education constitute too small a percentage of the population in developed countries to use data for that group as a basis for international comparisons.

### 2.2.3 Approach Based on Educational Parameters

Studies using an approach in which educational parameters are applied to estimate human capital are based on the following variables:

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<sup>11</sup> The wage of an unqualified worker is estimated with the use of a power function with an exponent which is the constant from Mincer's wage regression, calculated separately for each country in each year of the studied period of time.

1. Adult literacy rates,
2. School enrollment rate,
3. Average years of schooling, including the following adjustments:
  - a. Dropout rates,
  - b. Repetition rates,
4. Competence test scores (e.g., PISA<sup>12</sup>).

The above indicators are used as indirect measures of educational investments which are considered to be at the center of human capital formation. At the beginning, the measures referred to above were used only as variables stratifying the population in research on market effectiveness of educational investments (cf. e.g., Mincer 1958).

Estimation of the stock of human capital using educational indicators is a convenient method considering the availability of statistical data; however, it does capture the most important aspect from the viewpoint of economics: how productively is the generated capital used and to what extent do the outlays translate into the real growth of human capital (effectiveness and quality of education).<sup>13</sup>

### 2.2.3.1 Adult Literacy Rates

The adult literacy rate is defined as the percentage of the population aged 15+ who can “read and write a simple statement on his or her everyday life.”<sup>14</sup> The indicator was used as a control variable in early studies on growth, which took into account the human capital factor (e.g., Romer 1989; Azariadis and Drazen 1990).

The main flaws of the indicator include the following:

1. The definition of adult literacy rate is not consistently applied, which results in discrepancies in international statistics, and the data are difficult to compare.
2. It misses out the *advanced* skills being the key components of human capital (from the point of view of their impact on workers’ productivity) in developed countries where education is universal.

### 2.2.3.2 School Enrollment Rates

The school enrollment rate is defined as<sup>15</sup>:

<sup>12</sup> <http://www.pisa.oecd.org/>

<sup>13</sup> See Woessmann (2003), p. 243. By definition, the quality of education is taken into account in the approach based on tests’ scores.

<sup>14</sup> Definition after UNESCO (1993).

<sup>15</sup> Depending on the country and customary or legal regulations, ‘schooling obligation’ might be only a matter of customary habits and might be not supported by any legal sanction.



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