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Measuring the Stock of Human Capital for International and Intertemporal Comparisons

Gang Liu

15.1 Introduction

Although the economics profession has long recognized that human beings and their acquired abilities are important components of the wealth of nations (Petty 1690; Smith 1776; Farr 1853; Engel 1883), it has only been with the seminal work done by Schultz (1961), Becker (1964), and Mincer (1974) that the concept of human capital has in a comprehensive way entered policy discussions and been used for addressing various research questions.

Several authors have underscored the critical role of human capital in driving economic growth (e.g., Romer 1986, 1989; Lucas 1988; Aghion and Howitt 1998; World Bank 2006a). In addition, people's material well-being is considered as encompassing not only their current income, but also the assets they own, including not only housing property and financial instruments but also human capital, since all these assets will generate income streams over their lifetimes.

The concept of human capital is a broad one: the Organisation for Economic Co-operation and Development (OECD) defined it as "the knowledge, skills, competencies and attributes embodied in individuals that

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facilitate the creation of personal, social and economic well-being" (OECD 2001, 18).

This definition embraces a wide range of attributes of individuals (their formal education, but also the competencies that they have gained outside school settings, as well as people's health conditions) and a broad range of benefits stemming from it. These include not only the economic benefits that education delivers to individuals, but also noneconomic benefits in the form of improved heath conditions, longer life spans, better lifestyles, and even higher subjective well-being (Dolan, Peasgood, and White 2008), as well as the benefits that spill over to society at large, as in the case when education contributes to making people becoming better citizens, more tolerant and open to diversity, more willing to participate in democratic life, and better informed of environmental conditions.

While this broad definition is a useful reference point, all existing operational measures of human capital typically focus on a subset of these dimensions, or rely on different measures for its various aspects, with no ambition to bring all these aspects together into a single metric.

The notion of human capital is especially relevant for discussions on how to measure sustainable development. In recent debates on the subject, the UNECE/OECD/Eurostat working group on statistics for sustainable development suggested that a necessary condition for a country to grow along a sustainable development path is that its total capital stock (financial, produced, natural, human, and social capital) in per capita terms does not decline over time (UNECE 2009).

This "capital approach" implies that, to monitor sustainability, one should measure changes in different types of capital. Further, when these types of capital are deemed to be substitutable with each other in the production of different well-being outcomes, measures of different types of capital should be based on a common metric, so as to allow assessing whether declines in one type of capital are offset by increases in other types.

Despite this wide interest in human capital, there is no agreement on how to measure it, even when the broad concept of human capital mentioned above is narrowed down to formal education only.

Some analysts have relied on physical indicators, such as average school years, shares of the population having reached various levels of educational attainment, and measures of people's competencies. Others have focused on expenditures in the education system, and others yet have relied on measure of the stock of human capital based on the concept of lifetime earnings.[1] This diversity of approaches makes it hard to draw policy implications from comparisons of the stock of human capital across countries and calls for efforts to develop broader and more consistent methodologies.

1. All these approaches to measuring human capital have their pros and cons. For balanced discussions, see Stroombergen, Rose, and Nana (2002); Le, Gibson, and Oxley (2003); Fraumeni (2008); Liu and Greaker (2009); and Boarini, Mira d'Ercole, and Liu (2012).

The OECD has a long tradition in collecting and disseminating large sets of educational indicators,[2] as well as in developing methodologies for measuring the volume of education output within the System of National Accounts (SNA) (Schreyer 2010). What has been lacking until now is a framework suitable for measuring human capital in its own right, and for bringing together the wide range of factors shaping its evolution (e.g., demographic, education, and labor market factors). Further, even if such an accounting framework were in place, work would need to be done to identify the corresponding data requirements and the simplified assumptions required for making this accounting framework operational.

To initiate efforts along these lines, the OECD, together with the Fondazione Giovanni Agnelli (a leading Italian institution working on these issues), organized a workshop on human capital measurement in Turin in 2008[3] that gathered some of the leading researchers and practitioners in this field from several OECD and non-OECD countries. At that workshop, a consensus was reached that measuring human capital by the lifetime income approach was the best practical option. This conclusion was supported by the several national studies that had already applied the same approach.[4]

As a follow-up to the Turin workshop, a proposal to launch an "OECD human capital project" was presented to, and endorsed by, the OECD Committee on Statistics (CSTAT) at its meeting of June 2009. The purpose of this project was to identify common methodologies for measuring the stock of human capital for comparative analysis, both across countries and over time, and to implement these methodologies by means of existing OECD data.[5]

The OECD Human Capital Project started in October 2009 and took the form of an international consortium, consisting of sixteen OECD countries (Australia, Canada, Denmark, France, Israel, Italy, Japan, Korea, Mexico, the Netherlands, New Zealand, Norway, Poland, Spain, the United Kingdom, and the United States), Russia and Romania; Eurostat and the International Labor Organization (ILO) also participated in the consortium. The consortium was coordinated by the OECD Secretariat, thanks to support provided by Statistics Norway.

Up to this point, the OECD project has set up the databases and estimated

2. See various issues of *Education at a Glance*, OECD Publishing, Paris.

3. More information about the Turin workshop in 2008 is available at the following website: http://www.oecd.org/document/39/0,3343,en_2649_33715_41153767_1_1_1_1,00.html.

4. By the time of the Turin workshop, estimates of the value of human capital based on this methodology were available for the United States (Jorgenson and Fraumeni 1989, 1992a, 1992b); Sweden (Ahlroth, Björklund, and Forslund 1997); Norway (Ervik, Holmøy, and Hægeland 2003; Greaker and Liu, 2008); the United Kingdom (O'Mahony and Stevens, 2004); Australia (Wei 2004, 2007); New Zealand (Le, Gibson, and Oxley 2006); and Canada (Gu and Wong 2008).

5. Monetary estimates of the stock of human capital based on the lifetime income approach used in this project could both complement and benefit from direct measures of people's skills and competencies such as those that are being developed through the OECD Programme for the International Assessment of Adult Competencies (PIAAC) (for more information on the PIAAC program, see Schleicher 2008).

the value of human capital for sixteen participating countries (Australia, Canada, Denmark, France, Israel, Italy, Japan, Korea, the Netherlands, New Zealand, Norway, Poland, Romania, Spain, the United Kingdom, and the United States) over various observed years. All the detailed information on country databases and the corresponding estimates are available online at http://www.oecd.org/std/publicationsdocuments/workingpapers/.

This chapter summarizes the outcomes from the project. In doing so, the chapter also serves two other goals. First, it shows the feasibility of measuring human capital by applying the lifetime income approach based on data already available from the OECD statistical system. Second, it highlights some of the policy messages that can be drawn from analysis based on these measures of human capital stock.

The rest of the chapter is organized in the following way. Section 15.2 discusses the lifetime income approach that was used in this project, comparing these measures of human capital with those for conventional economic capital available within the SNA; this section also describes the scope of this project and details the implementation procedures of the lifetime income approach. Section 15.3 describes how the OECD database was constructed. Section 15.4 reports a number of empirical estimates, while section 15.5 concludes and identifies possible directions for future research.

15.2. Methodology

A monetary measure of the total stock of human capital can be derived either directly or indirectly. The indirect approach estimates human capital residually, based on the assumption that the discounted value of the benefits that the capital stock will deliver over its life will be equal, under certain assumptions, to the current monetary value of the capital asset. In the context of discussion on sustainable development, the total capital assets of each country may be thought of as generating a stream of benefits in the form of consumption goods in the future.

Hence, by taking the discounted value of the consumption streams, and subtracting from this amount the monetary value of those capital goods for which monetary estimates of their current stocks are readily available (i.e., financial and produced capital, market value of a range of natural assets), may provide an indirect (i.e., residual) estimate of the value of those capital stocks for which no monetary value can be observed on the market.

The World Bank has pioneered this approach, measuring the total stock of human capital as the difference between the total discounted value of each country's average consumption expenditures into the future (which is taken as a proxy for total wealth) and the sum of the tangible components of that wealth; that is, financial, produced, and natural capital (World Bank 2006a, 2006b, 2011; Ruta and Hamilton 2007). A similar approach has also been applied by Statistics Norway in the case of Norway (Greaker, Lokkevik, and Walle 2005).

While this indirect approach can be applied to a large number of countries based on limited statistical information, it has limits. First, it obviously ignores the nonmarket benefits of the various capital stocks. Second, this measure is affected by measurement errors in all the terms entering the accounting identities, resulting in potential biases in the resulting estimates of human capital. Third, it cannot explain what drives the observed changes of the stock of human capital over time.

Direct approaches derive a measure of the stock of human capital from information on its various components. Within this family of approaches, we can distinguish between parametric methods (which rely on econometric estimation of key parameters and are frequently used in academic research, see, e.g., Kyriacou 1991) and nonparametric methods (which are directly based on the available data and are more akin to the tools typically employed by national statistical offices). Most applications of the direct approach are of the nonparametric type; among these we can further distinguish a cost-based approach, an income-based approach, and an indicators-based approach.

- The cost-based approach measures human capital by looking at the stream of past investments, including investments coming from the individual, the family, employers, and governments (e.g., Schultz 1961; Kendrick 1976; Eisner 1985). This approach relies on information on all the costs that are incurred when producing the human capital. These costs include monetary outlays by each of the agents referred to above, but can also be extended to account for nonmarket expenditures (e.g., imputed values of the time devoted to education by both students and their parents).
- The income-based approach measures human capital by looking at the stream of future earnings that human capital investment generates (e.g., Weisbrod 1961; Graham and Webb 1979; Jorgenson and Fraumeni 1989, 1992a, 1992b). In contrast with the cost-based approach, which focuses on the input side, the income-based approach measures the stock of human capital from the output side.[6]
- The indicators-based approach measures human capital through various types of characteristics in the population such as literacy rates, school enrollment ratios, and average years of schooling (e.g., Ederer, Schuller, and Willms 2007, 2011; various issues of *Education at a Glance*). Unlike others, this approach usually relies on a variety of indicators that, though rich in information, lack a common metric and, as a result, cannot be aggregated into an overall measure. This makes the indicators-based approach less suitable for comprehensive comparisons

6. While the outputs from human capital investment are of many types (i.e., monetary and nonmonetary, private and public), the output measured by the lifetime income approach is limited to the private monetary benefits that accrue to the person investing in human capital. More discussions on this are provided in section 15.2.3 of this chapter.

of the total stock of human capital across countries and over time, and does not allow comparing the relative importance of different types of capital; that is, stocks of financial, produced, natural, and human capital (Stroombergen, Rose, and Nana 2002).

Although all of the approaches mentioned above have advantages and disadvantages, the (income-based) lifetime income approach was selected as the preferred methodology for the OECD Human Capital Project. This choice reflected the specific perspective used in this project, which focused on developing indicators that could be used to assess the intertemporal sustainability of a country's development path. The selection of this approach followed the discussion held at the 2009 OECD CSTAT meeting (OECD/STD/CSTAT(2009)8) and is consistent with the conclusions drawn from literature surveys (e.g., Liu and Greaker 2009; Fraumeni 2008, 2009).

15.2.1 The Lifetime Income Approach

The lifetime income approach, advocated by Jorgenson and Fraumeni (1989, 1992a, 1992b), measures the value of the total stock of human capital embodied in individuals as the total discounted present value of the expected future labor incomes that could be generated over the lifetime of the people currently living.

The choice of the lifetime income approach for measuring the total stock of human capital in the context of the OECD project reflects its advantages in bringing together, through a consistent accounting structure, a broad range of factors that shape the stock of human capital of the population living in a country: these factors include not only the total population and its structure (by age and gender) but also the expected life span of people (a measure that reflects health conditions), their educational attainment, and their labor market experiences (in terms of both their employment probabilities and the earnings they gain).

An additional advantage of the lifetime income approach is that changes in the stock of human capital during each accounting period can be described in terms of investment (such as formal and informal education), depreciation (such as deaths and net emigration), and revaluation (e.g., changes in the labor market premiums of education).[7]

While some of the existing applications of the lifetime income approach have provided estimates of the stock of human capital that include the lifetime income derived from both paid work (i.e., work sold on the labor market) and from nonmarket activities (i.e., household production and leisure time), measured through various imputations (e.g., Jorgenson and Fraumeni 1992b), the approach used in this chapter is limited to market work.

While the fact of providing a comprehensive monetary estimate of

7. One implication of the notion of human capital is that some of the expenditures that are currently classified as "consumption" within the SNA should rather be treated as "investment."

the stock of human capital is the main advantage of the lifetime income approach, this does not imply that the approach is immune from drawbacks, particularly the following:

- First, in order to calculate lifetime incomes, some judgments have to be made about discount rates and the real income growth that people currently living may expect in the future. The nature of these assumptions will obviously affect the final estimates, although their quantitative importance can be assessed through sensitivity analysis (see section 15.4.5).
- Second, there are many reasons to believe that labor markets do not always function in a perfect manner. In these cases, the wage rates by education used in this approach as a proxy for the monetary benefits provided by additional schooling will differ from the marginal productivity of a particular type of worker. Hence, this approach ignores the importance that other factors (such as workers' social background and innate abilities, or the effects of trade unions and industry of employment) may have on shaping wage differentials.[8]
- Third, by relying on observed market wages, the monetary stock of human capital may increase when the composition of employment shifts toward higher paid workers (e.g., from women to men, from migrants to natives, from less-educated to more-educated workers). Other indicators based on the lifetime income approach will, however, capture the effect of these compositional changes (see sections 15.4.3 and 15.4.4).

Despite these conceptual drawbacks, many researchers in this field share the view that compared to other methods, the lifetime income approach provides the most practical way to derive a monetary measure of human capital that is consistent with both economic theory and accounting standards (e.g., Abraham 2010). Further, as described below, the lifetime income approach is also the one that is closer to the assumptions used for measuring conventional economic capital/asset within the SNA (Fraumeni 2009).

15.2.2 Comparisons with the SNA Measures of Economic Capital

Standard investment theory underpins the measurement of both human and conventional economic capital (see Jorgenson 1963, 1967).[9] A single asset, no matter whether it is fixed capital (such as machines, buildings, and infrastructure) or human capital (such as knowledge, skills, and competen-

8. However, literature surveys on the returns to education (e.g., Card 2001) suggest that the ability bias in the cross-sectional relationship between years of school and earnings may not be substantial.

9. The term "economic capital," as compared to "human capital," is used here to refer mainly to produced capital (especially fixed capital) and natural assets that fall within the capital boundary of the SNA. Note that comparisons of the measurement in this section are made at the level of individual asset, i.e., among the single assets; therefore, the corresponding concepts of flow/stock should be understood within this context.

cies), can be used in production over several accounting periods (i.e., for more than one year). The value of the productive service that the asset can generate during each accounting period is a flow concept, while the value of the asset itself is a stock concept.

Both concepts are of significance for economic analysis: the value of the capital stock is a measure of “storage of wealth,” while the value of its productive services is an input into economic production. In a well-functioning market, the stock value of a capital good would be equal to the present value of the productive services that the capital good generates over its lifetime.

In some circumstances, only the stock value (rather than the productive service value) of a capital can be observed from the market; in this case, the challenge for capital measurement might be of deriving an estimate of the corresponding service value from the observed stock value. The measurement of some traditional fixed capital (e.g., some types of machines, equipments, and buildings) corresponds to this situation; as many of these assets are usually sold and bought in markets, their prices (stock values) can be directly observed.

In other cases, however, the stock value of a capital good cannot be observed directly. One case is human capital, for the obvious reason that in modern societies human beings embodied with human capital are not sold and bought in the market. Nonetheless, even if the value of the stock of human capital cannot be directly observed on the market, a long stream of economic theory has argued that labor compensation can be considered as the service value that human capital provides during each accounting period. In these circumstances, the stock value of human capital can be derived by taking the present value of all the labor income streams over people’s lifetime.

A similar reasoning applies to the measurement of many types of natural assets within the SNA. Clearly, the above-mentioned argument suggests that observing the stock value of one type of capital and then deriving its service value (as in the case of some fixed capital) or observing its service value first and then computing its stock value (as in the case of human capital and natural resources) are two sides of one coin. In principle, if capital markets are efficient, both accounting methodologies should be consistent with each other.

In practice, the two approaches face different challenges. To derive the service value from the observed market value of a fixed capital good, assumptions have to be made, for example, about the age-efficiency profile of the good in question (i.e., how fast the productivity of the machine considered will fall as it ages).[10] Similarly, to calculate the stock value of human capital

10. To aggregate the value of single asset across a cohort of assets, more assumptions are needed. For a deeper understanding on this subject, reference should be made to the OECD manual, *Measuring Capital* (OECD 2009a).

from its observed service value, assumptions have to be made about the income growth that each person with a given set of characteristics may expect in the future and on the rate used to discount these future earnings. No matter how these assumptions are made (e.g., either through empirical observations or through theoretical reasoning), they are exogenous in nature. As a consequence, different assumptions will affect estimates in different ways.

To fully develop the accounting structure of human capital estimates, further difficulties should be overcome. For instance, human capital is acquired by learning, studying, and practicing. But these activities cannot be undertaken by anyone else than the person considered. As these activities do not satisfy the "third-party criterion," the acquisition of knowledge cannot be considered as a process of production according to the production boundary of the SNA, even if the services produced by educational institutions are considered as a production activity (SNA 2008, 1.54).

Further difficulties would have to be addressed in order to extend the lifetime income approach to account for nonmarket activities.[11] All these considerations suggest that the construction of a human capital account (even one limited to formal education) should take the form of a satellite account, rather than of full integration in the currently standard SNA accounts.

15.2.3 Scope of the Project

Despite the broad definition of human capital provided above (i.e., "the knowledge, skills, competencies and attributes embodied in individuals that facilitate the creation of personal, social, and economic well-being"), a number of conceptual, methodological, and data limitations have restricted the scope of the project to measuring only *the personal economic well-being generated through market activities*. Such economic well-being is measured by the lifetime labor income that results from human capital investment and that accrues to individual persons themselves. This does not imply neglecting the wider range of benefits from human capital investment that accrue to the society at large, nor other noneconomic benefits that accrue to individuals, but simply recognizes that current valuation methodologies do not allow accounting for these other effects in a proper way.

Beyond the conceptual limitations of the lifetime income approach mentioned in section 15.2.1, some of the practical limitations of the approach implemented here include the following:

- First, while ideally the scope of human capital measurement should cover the whole population, data availability limits the possibility of

11. A first difficulty to extend the lifetime income approach to nonmarket activities is how to impute the value of the time devoted to learning (including both the students' own time as well as parents' and volunteers' time used for helping students). A second difficulty is the availability of detailed information on how individuals use their time.

implementing such a comprehensive approach. Thus, the measures presented here are limited to the population of working age (15 to 64).[12] This implies neglecting both the human capital embodied in children below age 15 and the possibility that elderly people will extend the "service life" of their own skills by staying longer in the labor market. The progressive increase (beyond the age of 65) of elderly people's labor market participation rates, partly due to pension reforms, implies that the monetary estimates of the stock of human capital presented here will be biased downwards.

- Second, the human capital measures presented in this chapter relate to the human resources *in use* (or *realized*) in a given country and year, rather than to the human resources that are *available*. For example, individuals' decisions to withdraw from the labor market, as well as institutional characteristics that affect earnings gaps between men and women, will affect the measures of realized human capital shown here.
- Third, the estimates of human capital shown in this paper, based on the earnings of workers classified by the highest level of education achieved, may confound the effects of different factors impacting on earnings.[13] For example, higher earnings due to better health conditions are indirectly included in the estimates shown in this chapter, whether or not these better health conditions are attributable to investment in education.
- Finally, as already mentioned, the estimates of human capital shown here are limited to market activities. In other terms, the potential effects of education in raising people's productivity in terms of household production (e.g., helping with children's study, making healthier food for family) are ignored.

15.2.4 Estimation Methods

Value of Human Capital

Implementing the lifetime income approach requires three major steps.

- First, a database containing the economic value of labor market activities for various categories of people needs to be compiled. This database should include, at minimum, information on the number of people, their earnings (when employed), as well as their school enrollment rates, employment rates, and survival rates. All these data should, ideally,

12. On the other hand, one may argue that if the research focus is on a country's current economic activities, the working age population (15–64), rather than the total population, might be more relevant, thus deserving a separate treatment.

13. Although formal education is the most important type of human capital investment, other factors (such as early parenting, on-the-job training, etc.) will affect individuals' earnings (Rosen 1989; Abraham 2010). However, distinguishing the effect from various factors would require econometric estimates drawn from earnings equations at the individual level.

be cross-classified by gender, age, and the highest level of educational attainment achieved.[14]

- Second, an algorithm needs to be constructed for calculating the lifetime income for a representative individual in each category in the database. The fundamental assumption applied here is that an individual of a given age, gender, and educational level will have in year $t + 1$ the same labor income (adjusted by the real income growth rate expected in the future and by the survival rate of each person) and other characteristics (e.g., school enrollment rate, employment rate and survival rate, etc.) of a person who, in year t, is one year older but has otherwise the same characteristics (e.g., gender and educational level). This assumption, which is unlikely to hold in practice,[15] simply reflects the nature of data used in this project, that is, cross-sectional data for different cohorts rather than longitudinal data following the same people over time.[16] Appendix A provides a more complete specification of the methodological assumptions and relevant equations used to estimate lifetime labor income for a representative individual in each category in the database.
- Third, the measures of lifetime labor income per capita estimated (through equations [A1] and [A2] as shown in appendix A) need to be applied to all individuals in each age/gender/education category to compute the human capital stock for that category. Summing up the stocks of human capital across all categories yields an estimate of the aggregate value of the human capital stock for each country.

Volume of Human Capital

Estimates of human capital values based on the methodology just outlined are in current prices. To monitor the evolution of human capital within a country, values in current prices are not enough, as changes of human capital values may be driven by changes in both human capital volumes and in price between two periods in time. Similarly, the difference of human capital value at one point in time between two countries may reflect both differences of human capital volumes and differences of the price levels in the two countries.

To compare human capital either across countries or over time, as required

14. In practice, most data on survival rates do not distinguish between different categories of educational attainment (i.e., survival rates differ only according to the age and gender of each person).

15. In other terms, the methodology used here ignores "cohort effects"; for example, there exists the possibility that a person born in the twenty-first century may expect different income flows in the future than a person born in the 1990s.

16. A natural modification of this approach would be to use not only cross-sectional but also time-series information in order to estimate the future earnings of various groups of people. For example, to smooth the short-term business cycle effects that cannot be removed by applying the original Jorgenson-Fraumeni approach (which relies on current cross-sectional information only), Wei (2008) relies on a cohort-based estimation method of future earnings.

in analyses of economic growth, productivity, and inflation, one needs to derive estimates of human capital *volumes* from the estimated human capital values, that is, to decompose changes of human capital at current prices into changes of price levels between two periods (or two countries) and changes of human capital volumes. Since there are two dimensions for comparisons (across countries and over time), two types of human capital indices (i.e., spatial volume and temporal volume indices) have been constructed.

Given the three terms of *value*, *volume*, and *price*, in principle any one can be derived from the other two. In practice, there are two approaches to deriving volume indexes. The first, which is more frequently applied, derives *volume* estimates by dividing *value* by a *price deflator*. The second directly constructs *volume* estimates and then derives *price* by dividing the *value* by such constructed *volume index*. This chapter applies the first approach for constructing human capital spatial volume index,[17] and the second one for constructing human capital temporal volume index.

Spatial Volume Index. The purpose of constructing spatial human capital volume index is to compare human capital in real terms between different countries at one point in time, since price levels for the same set of goods and services in different countries can differ. The approach used here is to simply divide estimated human capital values by the purchasing power parities (PPPs) for each country.

The OECD statistical system provides three types of estimates for purchasing power parities: (1) PPPs for GDP; (2) PPPs for private consumption; and (3) PPPs for actual individual consumption (which includes prices for the in-kind individual goods/services provided by governments and NPISHs [nonprofit institutions serving households] to households). Arguably, since incomes generated through human capital investment will flow to final consumption in the end, the PPPs used in this project are those for private consumption.

Depending on the purpose of the exercise, other PPPs could be applied. For instance, when evaluating human capital from an individual's perspective, the lifetime income they can earn should include not only wages and salaries after taxes, but also other payments and transfers (either in cash or in kind) flowing to them from other sources (e.g., employer's contribution to social security, government transfer); in this case, the relevant deflator may be the PPPs for actual individual consumption.

The income concept applied in this project is that of "wages and salaries" as defined in the SNA; this includes worker's own contributions to social security, but not those paid by employers. In part due to this, the PPPs for private consumption are used for constructing the spatial volume index.

17. To be more precise, the spatial index calculated as such is human capital *in real terms* across countries.

Ideally, the construction of spatial volume index needs to use as deflators the specific PPPs for *human capital* rather than the PPPs for *private consumption* as used in this chapter. Due to data constraint, the choice of the latter is just an approximation, which will lead to some biases when making country comparisons. However, it is challenging to make any judgments at this stage on whether the resulting biases are upwards or downwards for each project participating country. But this issue should be further investigated in the future.

Temporal Volume Index. To compare stocks of human capital in real terms over time, a temporal volume index needs to be constructed. This project relies on the Tornqvist index method,[18] whose methodology is outlined in Jorgenson, Ho, and Stiroh (2005) and has been applied in several national studies on human capital measurement (e.g., Gu and Wong 2010; Li et al. 2010).

According to this methodology, the growth rate of the temporal volume index of human capital is calculated as the weighted sum of the growth rates of the number of individuals in different categories of the population (such as age, gender, and educational attainment), using their shares of the nominal value of human capital as corresponding weights. In other terms:

$$(1) \qquad \Delta \ln HCI = \sum_{age}\sum_{edu}\sum_{gender} \overline{VSH}_{age,gender}^{edu} \Delta \ln NUM_{age,gender}^{edu},$$

where HCI stands for the temporal human capital volume index, $NUM_{age,gender}^{edu}$ is the number of persons in the corresponding age/gender/education category, and Δ is the first difference operation between two periods of time, t and $t - 1$.

Further, the weights in equation (1) are given by the share of each category of population in the total value of human capital averaged across the two periods, that is:

$$(2) \qquad \overline{VSH}_{age,gender}^{edu} = \frac{1}{2}\{VSH_{age,gender}^{edu}(t) + VSH_{age,gender}^{edu}(t-1)\}, \text{ and}$$

$$(3) \qquad VSH_{age,gender}^{edu} = \frac{LIN_{age,gender}^{edu} NUM_{age,gender}^{edu}}{\sum_{age}\sum_{edu}\sum_{gender} LIN_{age,gender}^{edu} NUM_{age,gender}^{edu}},$$

where $LIN_{age,gender}^{edu}$ refers to the lifetime income of a representative individual classified by age, gender, and educational level and is calculated by using equations (A1) and/or (A2) as shown in appendix A.

In principal, the more detailed the categories of population, the more accurate the volume index will be. At one extreme end, one could argue that

18. The Tornqvist index is a discrete approximation to a continuous Divisia index and has been shown to be an exact superlative index number (Diewert 1976).

each person should be treated differently from anyone else and thus be classified as a unique category; in practice, the data requirements to implement this approach are daunting, so that the approach is not practically feasible.

Despite this consideration, as long as data allows, the population should be classified with as much detailed category as possible. In this project, the working age population has been classified by three characteristics: age, gender, and educational level. With richer data, the classification might be extended to include more characteristics such as occupation, industry of employment, and so forth, as all these characteristics have important bearings in determining individuals' wages.

Equation (1) shows that the temporal volume index will increase if the composition of population shifts toward those categories of people having higher lifetime incomes. This may occur, for example, when more people attend higher education (which is generally associated with higher lifetime income) or when the composition of the working age population shifts toward younger people (because younger people have more remaining working years and so higher lifetime income, even if they usually have lower annual income at the time they enter into the labor market).

For some purposes, such as implementing sustainability assessment, more interest will be put on monitoring changes of human capital *per capita*. According to the notion of "weak sustainability," a necessary condition for a country to follow a sustainable path is that its total capital stock per capita does not decrease over time (UNECE 2009). The growth rate of human capital per capita is just the difference between the growth rate of the human capital volume (HCI) and that of population (NUM).

To account for the contribution of different characteristics (e.g., age, gender, and educational level) to the real growth of human capital per capita, first-order partial Tornqvist indices for each characteristic were derived. For instance, a first-order partial index for gender is defined as:

$$(4) \qquad \Delta \ln HCI_{gender} = \sum_{gender} \overline{VSH}_{gender} \Delta \ln \left(\sum_{age} \sum_{edu} NUM^{edu}_{age,gender} \right), \text{ where}$$

$$(5) \qquad \overline{VSH}_{gender} = \frac{1}{2} \{ VSH_{gender}(t) + VSH_{gender}(t-1) \}, \text{ and}$$

$$(6) \qquad VSH_{gender} = \sum_{age} \sum_{edu} VSH^{edu}_{age,gender}.$$

The first-order partial volume index for gender as shown in equation (4) captures the shift of the population structure between men and women, while ignoring other shifts among age groups and educational categories within each gender. Similarly, the first-order partial volume indices for age (or educational attainment categories) measure the shift between age groups only (or between educational categories only).

In this approach, the contribution of each characteristic to the real growth of human capital per capita is defined as the difference between the growth of the first-order partial indices of human capital for each characteristic (age, gender, and educational level) and the growth of the number of individuals in the population.

It should be noted that the sum of these contributions across characteristics will differ from the overall growth of human capital per capita, as the sum of the contribution of the different characteristics represents only the first-order approximation to the growth of human capital per capita.[19]

15.3 Database Construction

Although the original lifetime income approach requires information by single year of age, all the data relevant for the implementation of this approach that are available within the OECD statistics system, as well as most data available to researchers in individual countries, refer to categorical data (i.e., data for people classified by either five-year or ten-year age groups).[20]

To develop a database suitable for this exercise, the OECD project has relied on a number of practical assumptions and imputation methods to generate data by single year of age. For example, data on the number of students by single year of age were estimated based on information on the average enrollment rate of a given age group, and on the number of people of each age. These assumptions and imputations obviously affect the quality of the estimates presented in this chapter.

A further factor shaping the estimates of the stock of human capital presented here is the quality of the underlying data in the various years. In general, the quality of the OECD Education Database, the principal data source for this project, is lower for the years preceding the mid-1990s, particularly in the following ways:

- School enrollment data for most countries are of better quality starting from 1998, partly reflecting changes in the International Standard Classification of Education (from ISCED 67 to ISCED 97) implemented around that year.
- Data on annual earnings by educational attainment categories are only available since 1997 for most countries participating in the project.
- Similarly, the OECD Education Database contains two educational attainment data sets: the first, with more detailed categories, starts for

19. Higher order partial volume indices and their corresponding contributions to the growth of human capital per capita have not been calculated in this study. For an example of such applications, see Jorgenson, Ho, and Stiroh (2005) and Fraumeni (2011).

20. In an effort to extend the 1992 Jorgenson-Fraumeni approach to measuring human capital and investments in education, Fraumeni (2008) proposed a streamlined approach that relied on a more limited database than the one used in the original 1992 study, combining categorical data and detailed data by single year of age.

most countries from the 1990s; and the second, with more aggregated categories, provides time series going back longer in time.

Because of these factors, it was decided that estimation of the stock of human capital would start from around 1997 for most countries, and that the project would use the educational attainment data set with more detailed categories.

For most of the countries participating in the OECD project, a database was established for each country.[21] This database for each country consists of the five data sets described below, covering the various elements that enter the estimation of the monetary value of the human capital stock based on the chosen lifetime income methodology.[22]

15.3.1 Survival Rates

The survival rate is the conditional probability that a person who is alive in year t will also be living in year $t + 1$. Information on survival rates, by gender and individual year of age, was mainly derived from country life tables published in the Human Mortality Database (http://www.mortality.org/). For a few countries that are not included in this database, data on survival rates were obtained through bilateral contacts with country correspondents.

Several studies show that people with higher educational attainment also have longer life-expectancy rates and higher survival rates. This may reflect a range of factors, such as having a healthier lifestyle (e.g., doing more exercise, having a healthier diet), having better working and living conditions, and having greater access to quality health care (e.g., OECD 2010a). Despite this evidence, it is difficult to find comparative data on the extent to which higher educational attainment improves survival rates in each country. For this reason, this project relies on the same survival rate for all people of a given age and gender. The use of differential survival rates by educational levels could be addressed in future research.

15.3.2 Educational Attainment

Educational attainment in each country participating in the project was based on the categories defined in the International Standard Classification of Education (ISCED 97) developed by UNESCO (2006) as shown in appendix B. It should be mentioned, however, that no country adheres exactly to this classification, and almost every country relied on detailed

21. Due to data constraints for Mexico and Russian Federation, the OECD Human Capital Project has so far only constructed databases for sixteen participating countries (Australia, Canada, Denmark, France, Israel, Japan, Italy, Korea, the Netherlands, New Zealand, Norway, Poland, Romania, Spain, the United Kingdom, and the United States). For the detailed information on the country databases, please refer to http://www.oecd.org/std/publications documents/workingpapers/.

22. More detailed and technical information on the construction of the five data sets are presented in Liu (2013).

codes that differed, to some extent, from those used by others: some codes were missing in many countries, and some countries combined two or more codes together. Furthermore, a few countries have detailed codes that are not specified in appendix B. In these cases, judgments have been used to translate the national classifications into the codes shown in appendix B.

When considering the transitions between educational levels, further information is needed both on the transition patterns from lower to higher education and on school duration (the length of school course) within each educational level. The transition patterns are displayed in appendix C. Country-specific information on school duration for each educational level is collected by the UNESCO's Institute for Statistics, the OECD, and Eurostat over sixty countries worldwide.[23]

This database provides information on school duration from 2000 to 2007, although data are not always available for all years. For missing years as well as for years before 2000, estimates were based on the assumption that school duration in each country was the same as that in the closest available year in the period of 2000 to 2007.

Information on the number of people by the highest educational attainment completed is available in the OECD Education Database. These data are mostly based on national Labor Force Surveys and are available by gender, educational level, and five-year (for most countries) or ten-year (for Japan) age groups; in addition, they typically refer to people between age 15 and 64.

Two adjustments to the data on number of people by educational attainment were applied. First, data on the working age population by educational attainment were benchmarked to the levels (by gender and five-year age groups) available within the OECD Demographic Database. This adjustment (which was small in most cases) was performed in order to assure the coherence between the educational and demographic information used in the project. Second, in order to obtain data by individual year of age from the available data referring to five-year or ten-year age groups, national data on the population by gender and individual year of age were used to interpolate across different educational categories.

Without additional information, it is difficult to fully assess the size of possible biases due to these adjustments. Collecting information on educational attainment by single year of age will be a natural way forward for future research.

15.3.3 Employment Rates

OECD data on employment rates by gender and educational level are based on the same source (national Labor Force Surveys) that was used for educational attainment data. Employment rates were calculated as the ratio

23. For methodological issues please refer to *2004 Data Collection on Education Systems—UOE Data Collection Manual* (OECD 2004).

of the number of employed persons to that of total population in each group classified by gender, age group, and educational attainment.

In the case of missing data on employment for some age groups, it was assumed that the corresponding employment rates were equal to 100 percent. Since missing data on employment rates occurred for very few and usually young age groups (in most cases, the age group of 15 to 19), while annual earnings for these groups are usually low, the assumption of full employment in early age will not affect substantially the accumulation of income over the rest of their lifetimes; as a result, the upward bias due to this assumption on the estimated value of the stock of human capital results is unlikely to be significant.[24]

Data on employment rates by five-year (for most countries) or ten-year (for Japan) age groups were broken down into data by individual years of age based on the assumption that the employment rate for each group applied equally to each single year within the corresponding age group.

15.3.4 School Enrollment Rates

Information on the number of students by gender and age (by single year of age up to 29, by five-year of age for the groups 30–34 and 35–39, and by one group for all people aged 40 and above) enrolled in different educational levels, classified according to ISCED 97 categories, is available in the OECD online databank (http://dotstat.oecd.org/wbos/Index.aspx).

Data on the number of students in each educational category, combined with data on the number of people by their highest educational attainment, allow computing school enrollment rates as needed for the purposes of this project; these are defined as the share of people who, having completed a given level of education, then enrolled in the level above. For simplicity, these school enrollment rates were computed only up to age 40. For people aged 30 and above, the assumption made to obtain data by individual year of age is that the enrollment rate for each single year within the age groups 30 to 34 and 35 to 39 is the same as that for the corresponding age groups.

In general, the quality of data on the number of students enrolled in different educational levels (as available in OECD.stat) varies across countries and over years. For instance, time series on enrolled students is shorter than the educational attainment data for Canada; as a result, for subsequent years, enrollment rates were held constant at the level of the last available observation. Similarly, in the case of Japan, no data on the number of students enrolled at above level 3 (upper secondary education) by age are available after 2000; consequently, other information has been used to make estimation of school enrollment rates for Japan.

24. The alternative option is to assume the employment rates for these age groups are zero, which will lead to downward bias. However, given that annual earnings for these groups are low, the resulted bias would not be significant either.

As many country-specific assumptions were used for constructing the data set of school enrollment rate, the potential biases due to the use of this data set should be kept in mind. Sensitivity analysis with respect to different assumptions for the construction of the data set of school enrollment rates could be conducted in the future.

15.3.5 Annual Earnings

Data on annual earnings by gender, age groups, and educational attainment are available through the OECD Education Database. The original sources of these data vary across countries (Labor Force Surveys, household income surveys, and other sources). Partially for this reason, the earnings concept used and the reference period for the earnings paid (i.e., annual, monthly, and weekly) may differ across countries. For example, while some countries provide estimates of annual earnings (based on the weekly and monthly data included in the original sources), other countries only provide monthly or weekly earnings data, as available in national sources.

The earnings data in the OECD Education Database may also reflect differences in how part-time and full-time workers (as well as students holding a paid job) were treated by the national correspondents providing these earnings estimates to the OECD. A more detailed assessment of these country differences in earnings' definitions (e.g., whether they include employers' social security contributions) is needed.

The data available in the OECD Education Database refer to both the number of "income earners" and the "total earnings" of each category of workers, classified by gender, age group (15–24, 25–29, 30–34, 35–44, 45–54, 55–64), and educational levels. This information is available for all countries participating in the project except Japan. For the latter country, information of annual earnings by gender, age group, and educational attainment was derived from national sources, and the way it was derived differs slightly from that used for other countries.

Because of differences in the exact definition of earnings used in the OECD Education Database, earnings data by educational attainment were benchmarked on the series "wages and salaries" per employee as available from the OECD annual national accounts. This implies that ratios between the earnings for different educational categories (from the OECD Education Database) were applied to the national account series of "wages and salaries" per employee. This procedure allowed deriving estimates of the value of annual earnings by gender, age, and educational levels that are consistent with the SNA totals.[25]

Two additional adjustments were then applied to the "benchmarked"

25. A similar adjustment method has been applied to align the earnings data from INES Network collection to those of national accounts (see "A proposal for indicators linking education to economic growth," OECD document, INES-LSO-WG-ECO (2011)1).

earnings data described above. First, in order to obtain earnings by single year of age, a parabolic curve was fitted through the observations of annual earnings by six age groups (15–24, 25–29, 30–34, 35–44, 45–54, 55–64) for most countries, and by nine age groups (20–24, 25–29, 30–34, 35–39, 40–44, 45–49, 50–54, 55–59, and 60–64) for Japan. Second, as the educational categories in the OECD annual earnings data sets do not always match those in the educational attainments data sets, imputations were used to generate annual earnings consistent with the educational levels shown in the educational attainment data sets.

15.4 Empirical Results

This section describes quantitative estimates from the project as they pertain to overall values of the stock of human capital, their distribution between people with various characteristics, and volume comparisons both across countries and over time. Due to data limitation, monetary estimates of the stock of human capital have been computed only for fifteen OECD countries (Australia, Canada, Denmark, France, Israel, Italy, Japan, Korea, the Netherlands, New Zealand, Norway, Poland, Spain, the United Kingdom, and the United States), and one nonmember country (Romania).[26] These estimates refer to the years for which data are available, as detailed in table 15.1.

The available years for most of the countries participating in the project are typically from around 1997 to around 2007, with a few countries missing specific years over this period. Other countries only have data covering a shorter time span. For country comparisons, the year 2006 has been chosen as benchmark since this is the year where country coverage is the most comprehensive.

Measuring the stock of human capital in each country based on the retained approach requires making assumptions on future earnings growth and discount rates. In this chapter, the annual discount rate was set at 4.58 percent for all countries (the same value used by Jorgenson and Fraumeni for the United States in their 1992 study).

Conversely, country-specific assumptions on real earnings growth in the future were based on the OECD medium-term baseline. This baseline is prepared by the OECD Economics Directorate based on historical data and short-term projections, and extended to the medium term based on

26. The estimated values of human capital for fifteen participating countries (Australia, Canada, Denmark, France, Israel, Italy, Korea, the Netherlands, New Zealand, Norway, Poland, Romania, Spain, the United Kingdom, and the United States) over the observed years (as shown in table 15.1) were first presented in Liu (2011). In 2012, estimates were also made for Japan over the period of 2002 to 2007. All the relevant estimates are available online at http://www.oecd.org/std/publicationsdocuments/workingpapers/.

Table 15.1 Data availability for countries covered in the project

Country	Data availability
Australia (AUS)	1997, 1999, 2001
Canada (CAN)	1997–1999, 2003–2006
Denmark (DNK)	1998–1999, 2001–2002
France (FRA)	1998–1999, 2002–2007
Israel (ISR)	2002–2007
Italy (ITA)	1998, 2000, 2002, 2004, 2006
Japan (JPN)	2002–2007
Korea (KOR)	1998–2007
Mexico (MEX)	No data
Netherlands (NLD)	2002, 2006
New Zealand (NZL)	1997–2007
Norway (NOR)	1997–1999, 2001–2006
Poland (POL)	1999, 2001–2002, 2004, 2006
Romania (ROU)	2002, 2006
Russian Federation (RUS)	No data
Spain (ESP)	2001–2002, 2004, 2006
United Kingdom (GBR)	1997–2001, 2003–2007
United States (USA)	1997–2000, 2002–2007

Source: OECD Human Capital Project.

assumptions about the growth of potential output in each country. This medium-term baseline is used by the OECD for much of its policy analysis (e.g., OECD 2009b).[27]

Using data from this medium-term scenario, the annual real income growth rate was computed as the geometric mean of real wages and salaries per employee for the total economy (including government workers) over the period 1960 to 2017 (as presented in figure 15.1). Due to lack of information on Israel and Romania in the OECD medium-term baseline, this parameter for these two countries was set at the level of 1.32 percent (the rate used by Jorgenson and Fraumeni for the United States in their 1992 study).[28]

27. Earlier estimates from this project relied on common assumptions for all participating countries, that is, an annual real income growth of 1.32 percent and an annual discount rate of 4.58 percent. These two values were those used by Jorgenson and Yun (1990) and Jorgenson and Fraumeni (1992b) in their estimations for the United States, and corresponded to their estimates of the annual growth rate of (Harrod neutral) productivity and of the long-run rate of return for the private sector of the economy. The choice of common assumptions for these two parameters was mainly based on the need of simplicity. Based on such simplified assumptions, preliminary estimates were presented in a "Project Progress Report" and in a paper presented at the CSTAT meeting of June 2010 (OECD/STD/CSTAT/RD(2010)3) and at the thirty-first IARIW conference (OECD 2010b), respectively.

28. The two decimals in the values of chosen parameters are not meant to suggest a high degree of precision in the estimates shown in this chapter; rather, they are just to show the consistency with the source data. For instance, the values of 1.32 percent and 4.58 percent were originally used by Jorgenson and Fraumeni (1992b).

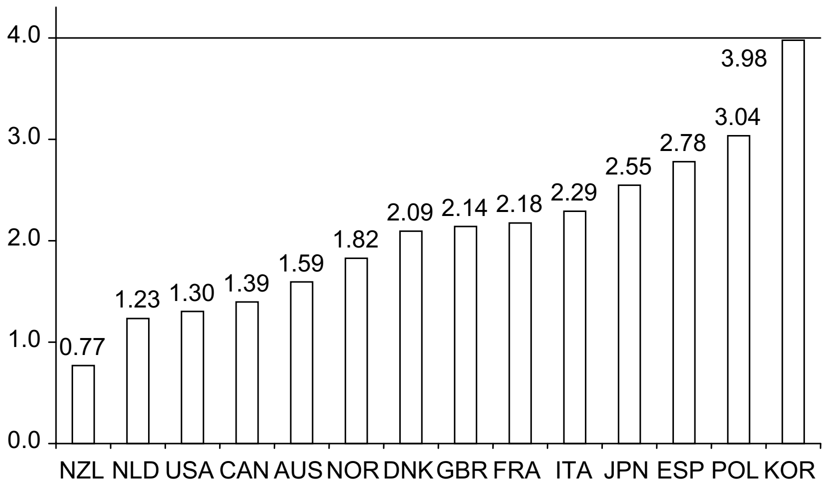

Fig. 15.1 Annual real income growth rates used in human capital estimation (%)
Source: OECD medium-term baseline.

15.4.1 Employment Rates and Survival Rates

A first set of estimates from the project relates to observations of country-specific employment rates and survival rates. These are shown here as they critically influence the human capital estimates reported later. Figure 15.2, which shows results for Canada in 2006, highlights patterns that hold for all countries covered in the project and that are in line with those reported in several national studies (e.g., Liu and Greaker 2009; Gu and Wong 2010), especially the following patterns:

- The higher the educational level, the higher the employment rate of each group; this pattern holds for both men and women, and for most age groups.
- The difference of employment rate between adjacent educational levels becomes smaller as the educational level increases.
- The employment rate is lowest at the two ends of working life. For women, and especially for those with lower education, a typical "M" shape pattern can be observed, with the lower employment rates at the bottom attained around age 25 to 39; that is, the age range where most women become mothers.
- Regardless of their educational levels, employment rates are higher for men than for women, except at some young ages. These gender differences are largest for people with less than upper secondary education (level 0/1 and level 2), and for younger cohorts (left lower panel in figure 15.2).

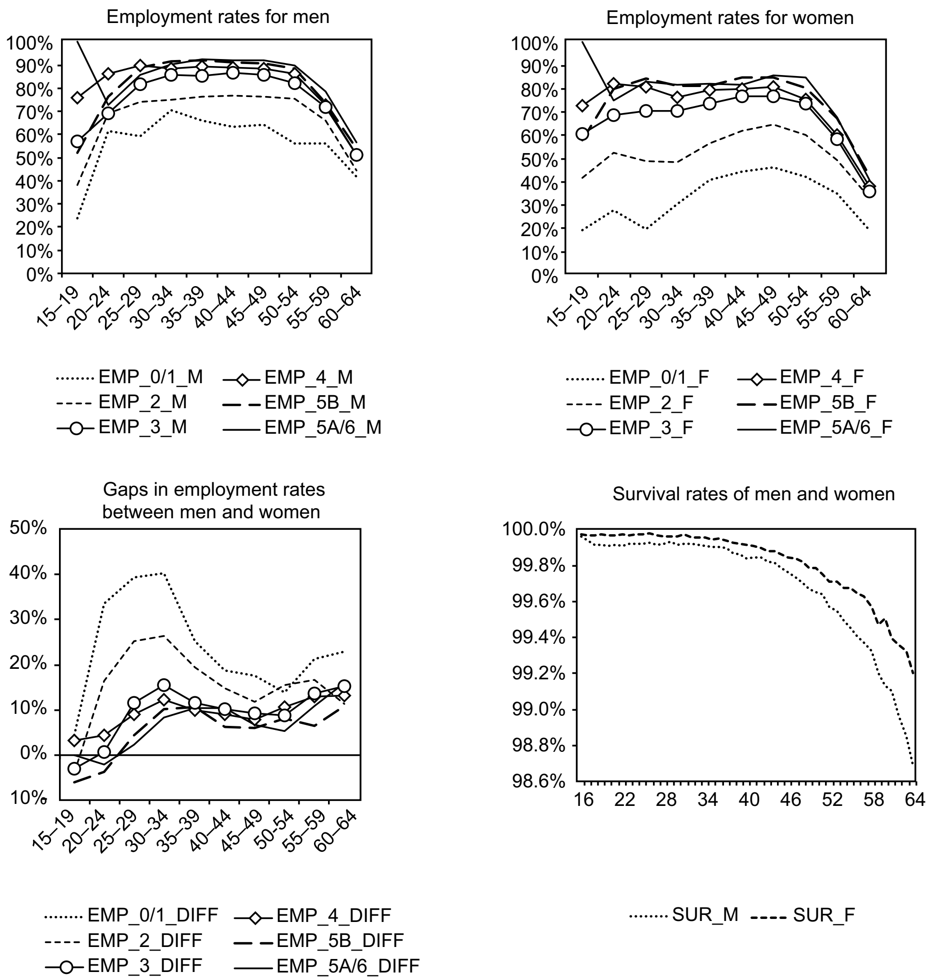

Fig. 15.2 Employment rates and survival rates for Canada in 2006
Source: OECD Human Capital Project.

- Survival rates decline with age, especially in older ages, for both men and women. At all ages, women have a higher survival rate than men (right lower panel in figure 15.2).

15.4.2 Annual Incomes and Lifetime Incomes

Earnings profiles by age and educational attainment have been computed separately for men and women, and are based on the two concepts of annual income and lifetime income, respectively. Figure 15.3 presents estimates for Canada in 2006; the upper panels refer to annual incomes and the lower pan-

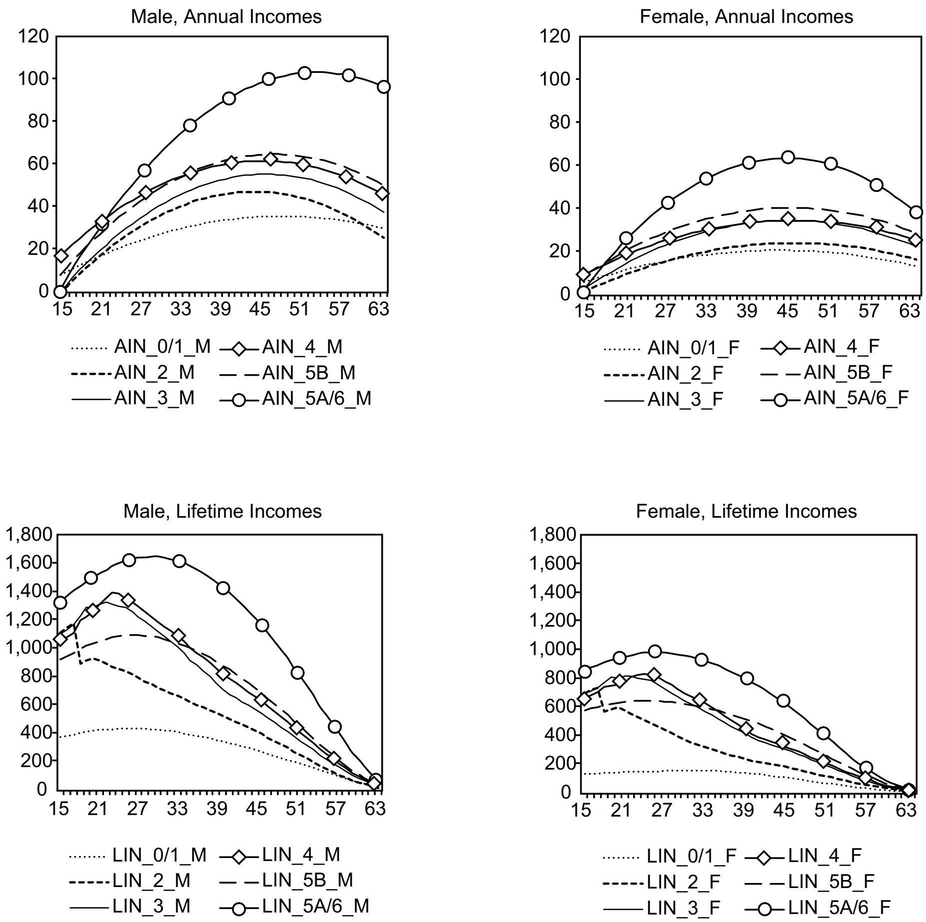

Fig. 15.3 Earnings profile for Canada in 2006 (current prices, in thousands Canadian dollars)

Source: OECD Human Capital Project.

els to lifetime incomes. These age-earnings profiles for Canada are similar to those prevailing in other countries covered by the project and to those highlighted in a range of national studies (e.g., Le, Gibson, and Oxley 2006; Liu and Greaker 2009; Wei 2004, 2007), particularly in the following ways:

- Both annual and lifetime incomes rise with age and then gradually decline, a pattern that holds for all educational levels. The peaks occur at younger ages for lifetime income than for annual income.
- Both annual and lifetime incomes are higher for people with higher levels of educational attainment.

- Both annual and lifetime incomes are higher for males than for females, at all levels of educational attainment.

15.4.3 Value of Human Capital

Level

To give an indication of the magnitude of the stock of human capital estimated by using the lifetime income approach, panel a of figure 15.4 shows the ratios between the value of the total stock of human capital and nominal GDP in 2006.[29] The ratios range between 8.3 in the Netherlands and 16.3 in Korea, with an average value of around 10.6. Cross-country differences are smaller when ignoring the four countries at both ends of the distribution (i.e., the Netherlands and Italy, at the lower end; and Poland and Korea, at the higher end), ranging between 9 and 11.

A second important feature highlighted by panel b of figure 15.4 is that the monetary value of the stock of human capital based on the lifetime income methodology is typically several times larger than that of produced capital in all countries for which relevant estimates of the latter are available.[30] The data shown in figure 15.4 indicate that ratios between human and produced capital range between 3.6 in the Netherlands and Italy and 7.0 in the United Kingdom, with a mean value of 4.7.

For some countries, the estimates of the stock of human capital based on the lifetime income approach described in this chapter can be compared with estimates derived from national studies that used a similar methodology. To allow more meaningful comparisons, the project estimates provided below have been based on assumptions that are as close as possible to those used by the selected national studies. For instance, comparisons are based on the same values for annual real income growth rate and discount rate as those used in the corresponding national studies.

- In the case of Norway, the differences between the estimates computed for this project and those presented in Liu and Greaker (2009) range between 1 percent (in 2001 and 2006) and 21 percent in 2003, with an average difference (across the period) of 8 percent.

29. For Norway, GDP data shown in figure 15.4 (as well as per capita GDP in figures 15.8 and 15.9) refers to "GDP Mainland Norway"; that is, GDP exclusive the oil and ocean transport industries.

30. The estimates of produced capital stock are drawn from OECD calculations based on investments data from member countries' national accounts data. These estimates are net figures as opposed to the *gross* estimates of human capital reported in this project, that is, living or human maintenance costs have not been deducted. There exist different views on whether these costs should be netted out from the gross estimates of human capital (e.g., Graham and Webb 1979; Conrad 1992). Another closely linked but different concern is that the gross estimates of human capital do not take into account the depreciation of human capital, such as deterioration in health and obsolescence of knowledge and skills (Conrad 1992); however, one may argue that these factors are implicitly reflected in the wage rates paid to individuals used in this approach.

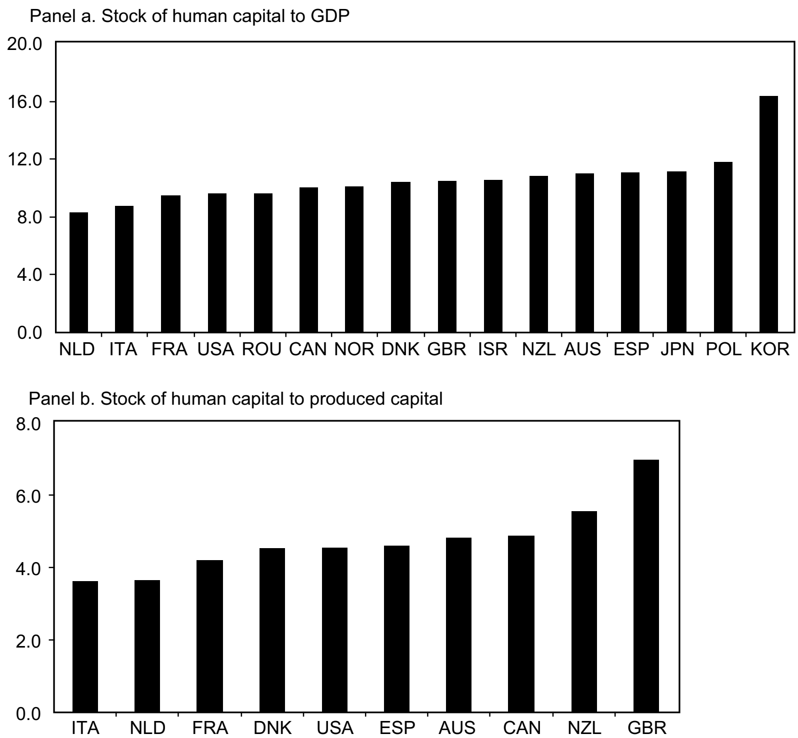

Fig. 15.4 Stock of human capital relative to GDP and to the stock of produced capital, 2006

Source: OECD Human Capital Project.

Note: Estimates for Australia refer to 2001; those for Denmark, to 2002.

- In the case of Australia, the difference relative to the results shown in Wei (2004) is about –2 percent (in 2001).
- In the case of New Zealand, the difference relative to the results shown in Le, Gibson, and Oxley (2006) is higher, at about 30 percent for 2001.
- In the case of the United States, Christian (2010) shows human capital values (limited to market earnings) for the whole population (age 0–80) in 2006 of USD 212 trillion. The estimate presented in this chapter, limited to the working-age population (age 15–64), is USD 153 trillion, implying a ratio between the two estimates of around 72 percent; this difference is fairly close to the ratio of the working-age population to the entire US population (67 percent).[31]

31. Based on own human capital data set and program for the United States, and by setting the income growth rate to 1.32 percent and the discount rate to 4.58 percent, and only including lifetime incomes of people aged 15 to 64, Michael Christian found that the estimated market

- In the case of Canada, estimates of human capital per capita for the total population, for men and for women reported by Gu and Wong (2009) for 2007 are C$ 653,000, 795,000, and 511,000. These values compare to estimates in this project of C$ 627,000, 799,000, and 453,000 in 2006, suggesting differences of –4 percent, 0.5 percent, and –11 percent, respectively.

To sum up, almost all national studies that have applied the lifetime income approach to measuring human capital share the same findings that the stock value of human capital is substantially larger than that of conventional economic capital, such as produced capital. The estimates produced as part of the OECD project, which are based on less detailed data than those typically available in the case of country-specific studies, are also broadly comparable to those produced by national research in the subject (with the partial exception of New Zealand).[32] Detailed differences between project and national estimates could be further investigated in the future.

Distribution

The estimates of the stock of human capital based on the lifetime income approach can also be compared across different groups of people within each country. The distribution of human capital across people classified by different dimensions within each country provides useful information for addressing issues related to inequality, poverty, and social cohesion. Taking 2006 as an example, this section describes the distribution of human capital between men and women (figure 15.5), among people with different educational attainment (figure 15.6), as well as among different age groups (figure 15.7) for the countries participating in the project.

To facilitate cross-country comparisons, the detailed (but differentiated) educational categories available for each country have been reclassified into three main groups; that is, "below upper secondary education" (denoted as EDU_0/1/2), "upper secondary education" (EDU_3/4), and "tertiary education" (EDU_5/6).[33] Data on individuals by single year of age have also been reclassified into three age groups; that is, young people (those aged 15 to 34, AGE_I), prime-age people (those aged 35 to 54, AGE_II), and older people (those aged 55–64, AGE_III).

component of the stock of human capital in the United States in 2006 is USD 116 trillion; while our calculation based on the OECD project database and with the same assumptions is USD 129 trillion, 10 percent higher.

32. In addition to these countries, unpublished estimates of the stock of human capital for Israel (based on monthly income across four educational levels for the years 1997–2007), elaborated by the national statistical office of that country, are also similar to our estimates presented in this chapter.

33. This classification holds for all participating countries except for Japan and Korea. For Japan, EDU_0/1/2 refers to levels 1, 2, and 3 combined, and EDU_3/4 corresponds to level 5B; while for Korea, EDU_3/4 refers to level 3 only and EDU_5/6 actually includes level 4.

For each figure, the upper panel on the left shows the distribution of the population among the various groups, while the upper panel on the right shows the share of human capital accruing to the groups considered. The lower panel on the left shows the ratios between the shares of human capital accruing to each group and their corresponding population share (with ratios larger than 1 implying that the group considered is "rich" in human capital, and with higher ratios indicating that the more better off the corresponding group is in terms of its holdings of human capital). Finally, proxy estimates of the Gini coefficient based on grouped data (computed on the basis of Lorentz curves plotting shares of the population against shares of their human capital) are reported in the lower panel on the right of each figure.[34]

Figure 15.5 provides information on the distribution of human capital between men and women in 2006. Although the population shares for men and women are in general very similar to each other (marginally higher in some countries and marginally lower for others, upper panel on the left), men dominate women in terms of their human capital holdings in all countries. This pattern is also confirmed by a visual inspection of the lower panel on the left of figure 15.5.

In almost all countries, men account for more than 60 percent of the total value of the human capital stock, with Korea, Italy, Japan, and the Netherlands recording values close to, or higher than, 70 percent. The exceptions are Romania and Poland, where men account for marginally less than 60 percent of human capital. Estimates of the Gini coefficient by gender vary between less than 0.10 to above 0.20 in Korea.

These gender differences in the distribution of human capital reflect a combination of lower labor force participation, lower employment, and lower wages for women than for men. As women usually do more housework than men, these gender differences in human capital would be lower if human capital estimates were to be extended to include nonmarket activities.

Figure 15.6 provides information on the distribution of human capital among people in the three main educational categories. In general, the higher the educational attainment of each person is, the higher will be their earnings and probability of having a job, and thus their measured human capital. However, because marginal returns to higher education (from EDU_0/1/2 to EDU_3/4 and from EDU_3/4 to EDU_5/6) vary across countries, human capital distribution by education varies as well. For instance, compared with other countries, the share of human capital held by more educated people

34. The Gini coefficient is a measure ranging between 0 (in the case of perfect equality; that is, the share of human capital accruing to each group is equal to its population share) and 1 (in the case of maximum inequality, e.g., all the human capital accrue to the richest group). While the Gini coefficient is generally based on individual records (with each person ranked according to their income or wealth level), the values shown here are based on broad categories that ignore within-group inequality.

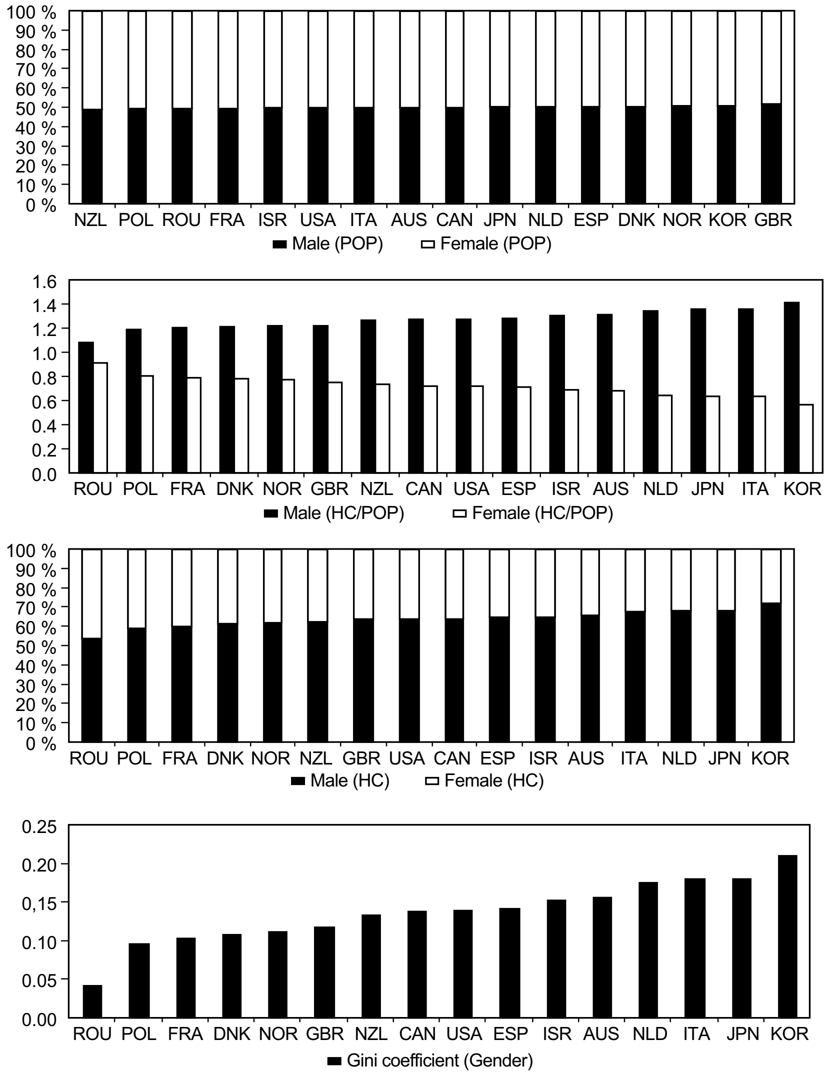

Fig. 15.5 Distribution of human capital by gender in 2006
Source: OECD Human Capital Project.
Note: Estimates for Australia refer to 2001; those for Denmark, to 2002.

is relatively low in Denmark and New Zealand, while it is relatively high in Italy and Spain. Estimates of the Gini coefficient by educational level range between less than 0.10 in Denmark, New Zealand, Poland, and Canada, and above 0.20 in Italy.

In theory, higher marginal returns from higher education are desirable

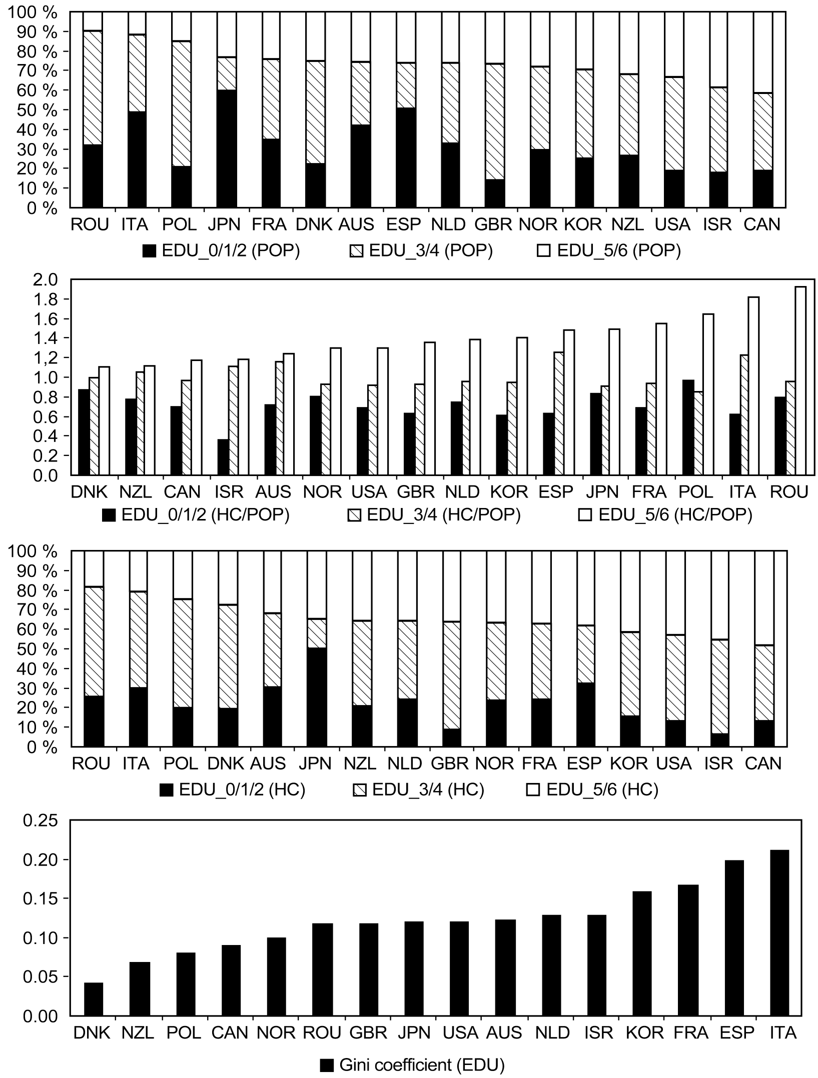

Fig. 15.6 Distribution of human capital by educational level in 2006

Source: OECD Human Capital Project.

Note: Estimates for Australia refer to 2001; those for Denmark, to 2002.

since they provide incentives for people to augment their investments in human capital. In this sense, larger Gini coefficients may imply that investment in human capital is encouraged. But higher Gini coefficients by educational attainment may also signal constraints in the possibility to access or complete higher education, which would point to the need for remedial policies in this field.

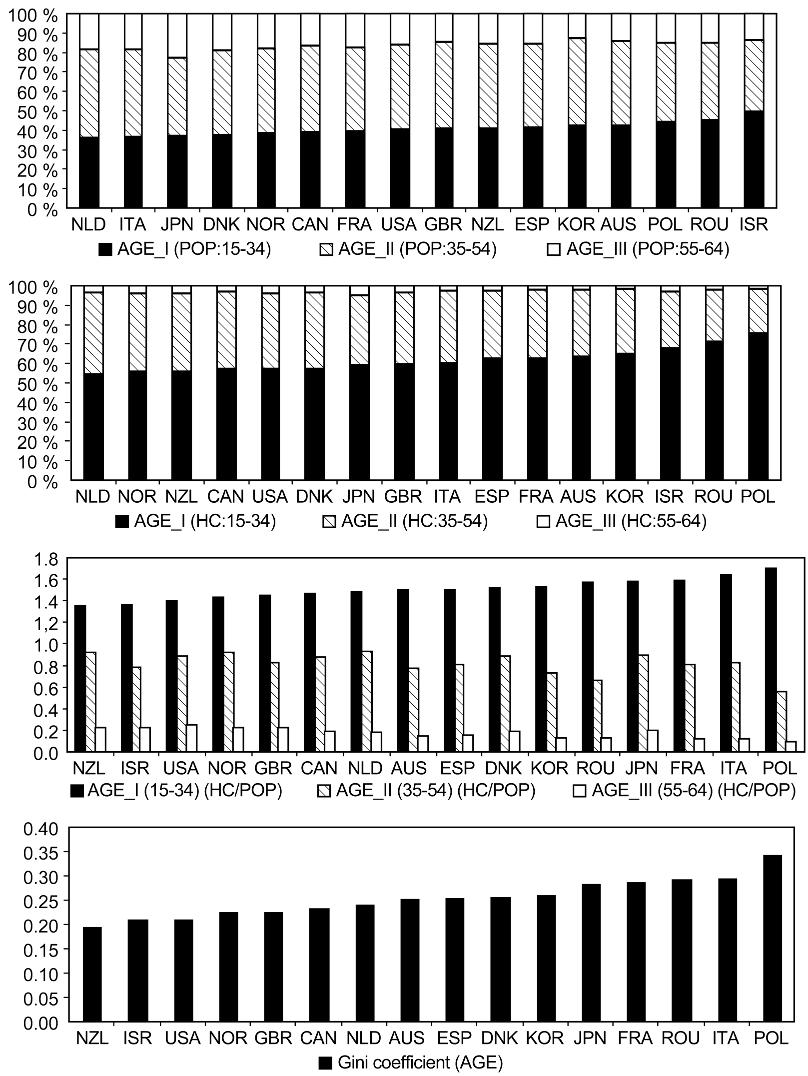

Fig. 15.7 Distribution of human capital by age group in 2006

Source: OECD Human Capital Project.

Note: Estimates for Australia refer to 2001; those for Denmark, to 2002.

Finally, figure 15.7 shows the distribution of human capital by age groups. The methodology used in this chapter implies that the younger people are, the more human capital they hold. The reason is that younger people have a longer remaining lifetime than their older counterparts, an effect that more than offsets their lower annual income compared to seniors. Conversely, higher unemployment rates for youths tend to lower the chance of their human capital to be employed in economic activities, implying that reducing youth unemployment rates is important not only to improve the current situation of youths but also to increase a country's (realized) human capital stock.[35]

One obvious limit of the methodology used in this chapter is that youths, as they age, are assumed to achieve the same earnings and employment probabilities of today's prime-age workers. To the extent that this assumption does not hold true (i.e., that today's youths could earn less as they age than prime-age workers earn today), the human capital holdings of young people will turn out to be much worse than depicted here.

15.4.4 Volume Measures of the Stock of Human Capital

Spatial Volume Index

County comparison based on the total value of human capital may be misleading due to two factors: first, because countries have different population sizes; and second, because countries may differ in terms of the purchasing power of people's earnings. Figure 15.8 addresses these two factors by showing information on countries' human capital values per capita in 2006. To take into account differences in price levels across countries, the estimates shown here are based on purchasing power parities (PPPs) for private consumption in each country, and expressed in terms of USD.

Based on the assumptions made here on the annual real income growth rate and discount rate, the estimates shown in figure 15.8 indicate that the values of human capital per capita range between USD 79,000 in Romania and USD 641,000 in the United States. Excluding the two ends of the distribution (Romania and Poland at the lower end, and the United Kingdom and the United States at the higher end), the differences of human capital per capita among other countries are, however, relatively small, comprised in a range between around USD 400,000 and USD 550,000.

For the purpose of country comparisons, values of GDP per capita in USD are also presented in the left upper panel of figure 15.8. Broadly speaking, countries with a higher GDP per capita also display a higher value of human capital per capita, but there are exceptions. For instance, despite relatively high GDP per capita in Italy and the Netherlands, their human capital per capita is relatively low. Conversely, Korea combines comparatively low GDP per capita and higher human capital per capita than most other countries.

Holdings of human capital per capita by gender, by educational level, and by age groups are also shown in upper-right, lower-left, and lower-right panels of figure 15.8, respectively. Country rankings in these panels are broadly

35. Given its importance, the youth employment rate is selected among the four human capital leading indicators by The Lisbon Council (Ederer, Schuller, and Willms 2011).

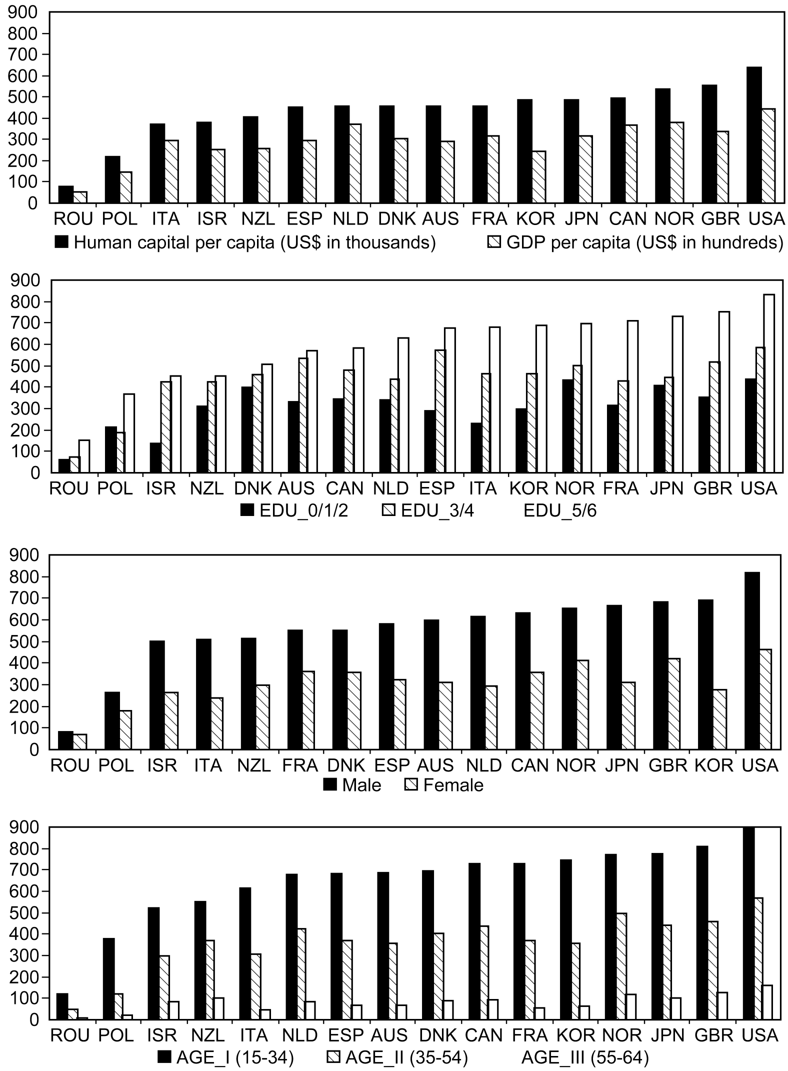

Fig. 15.8 Real human capital per capita in 2006 (in thousands US dollars)

Source: OECD Human Capital Project.

Note: Estimates for Australia refer to 2001; those for Denmark, to 2002.

similar to those shown for human capital per capita in the upper-left panel in the same figure. Nevertheless, due to differences in how human capital is distributed in various countries, the rankings are not exactly the same.

An alternative way of presenting the same type of information is conveyed by figure 15.9, which shows country human capital per capita in real terms

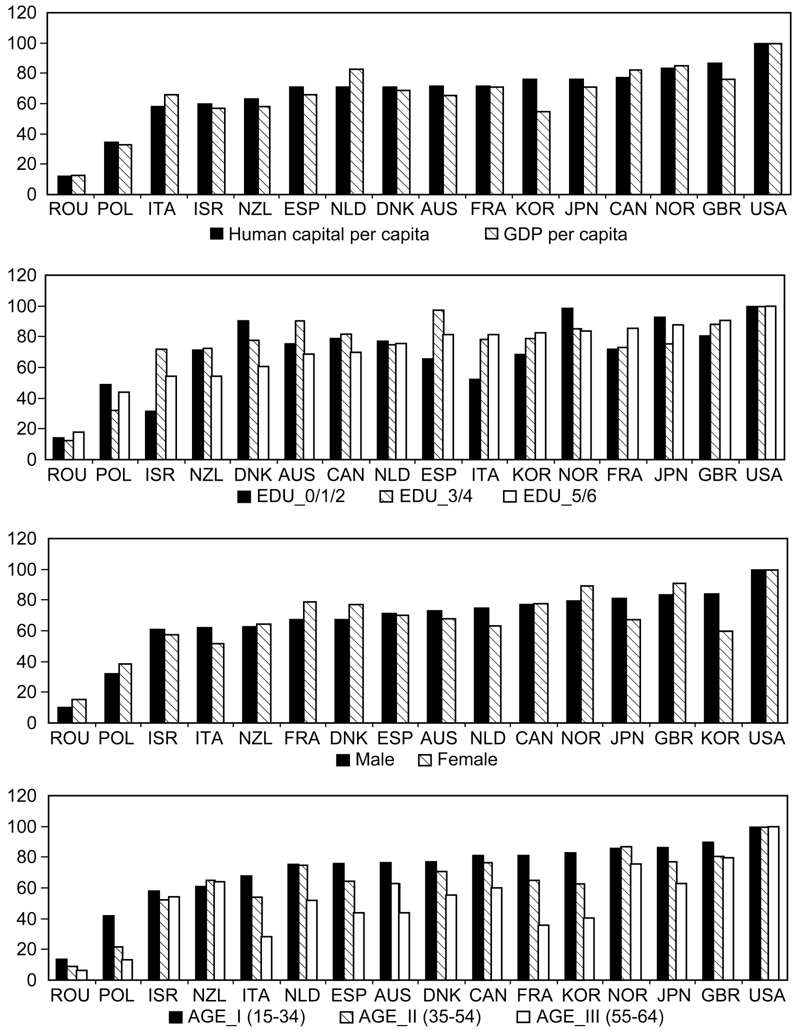

Fig. 15.9 Human capital spatial volume indices in 2006 (US levels equal to 100)

Source: OECD Human Capital Project.

Note: Estimates for Australia refer to 2001; those for Denmark, to 2002.

in 2006 relative to the level observed in the United States (set equal to 100). The upper left panel of figure 15.9 shows that the volume index of human capital per capita is only 12 for Romania and 38 for Poland, and over 60 for most other countries. This means that human capital per capita is larger in the United States than in any other participating countries. The same conclusion can be drawn from the other panels in figure 15.9 when looking at various population groups.

Temporal Volume Index

Information on how the stock of human capital in volume terms evolves in a country is of critical importance for policy decisions. In particular, from the perspective of assessing sustainability, a necessary condition for a country to grow along a sustainable path is that the volume of its total capital stock in per capita terms should not decline over time (UNECE 2009). While this argument underscores the importance of having a single measure of how the total capital stock of each country evolves over time (in real terms), information on the volume change in each capital stock of different types of capital is also important.

Though the observation of declining levels of human capital per capita would not necessarily imply that the development path for the country in question is "unsustainable," since this decline in human capital could be offset by raising stocks of other types of capital (as implied by the "weak sustainability" criterion, according to which different types of capital are assumed to be substitutable for each other; Pearce and Atkinson 1993), nonetheless, a decline in the real stock of human capital per capita will warrant policy attention.

Moreover, this argument is even more justified when applying the "strong sustainability" criterion, according to which critical capitals should not be allowed to fall below some minimum levels (Pearce and Atkinson 1993).

Figure 15.10 displays information on human capital temporal volume indices (denoted as "VOL"), population indices ("POP"), and human capital per capita indices ("HCPERCAPITA") for participating countries during their corresponding observation years.[36] For each country, the volume of human capital and the population in the base year were set as equal to 100.

Compared with the starting year, the total stock of human capital in real terms has increased for all countries except for Japan, though there were ups and downs for a few countries throughout the observation period. Even for countries that experienced increasing human capital volumes throughout the period, however, the rate of increase varied significantly across these countries.

The situation is strikingly different when looking at changes in the volume of human capital *per capita*. With the exception of Italy and Japan,[37] all countries experienced growing population during the period. The difference of the growth rate of human capital volumes index and that of population is the growth rate of human capital per capita. Relative to its starting year, three patterns are in evidence:

36. Due to data constraint, figure 15.10 shows human capital temporal volume indices only for thirteen OECD countries.

37. The working age population in Italy dipped around 2002 and picked up again since then; while that of Japan shrank monotonously during the observed period (2002–2007).

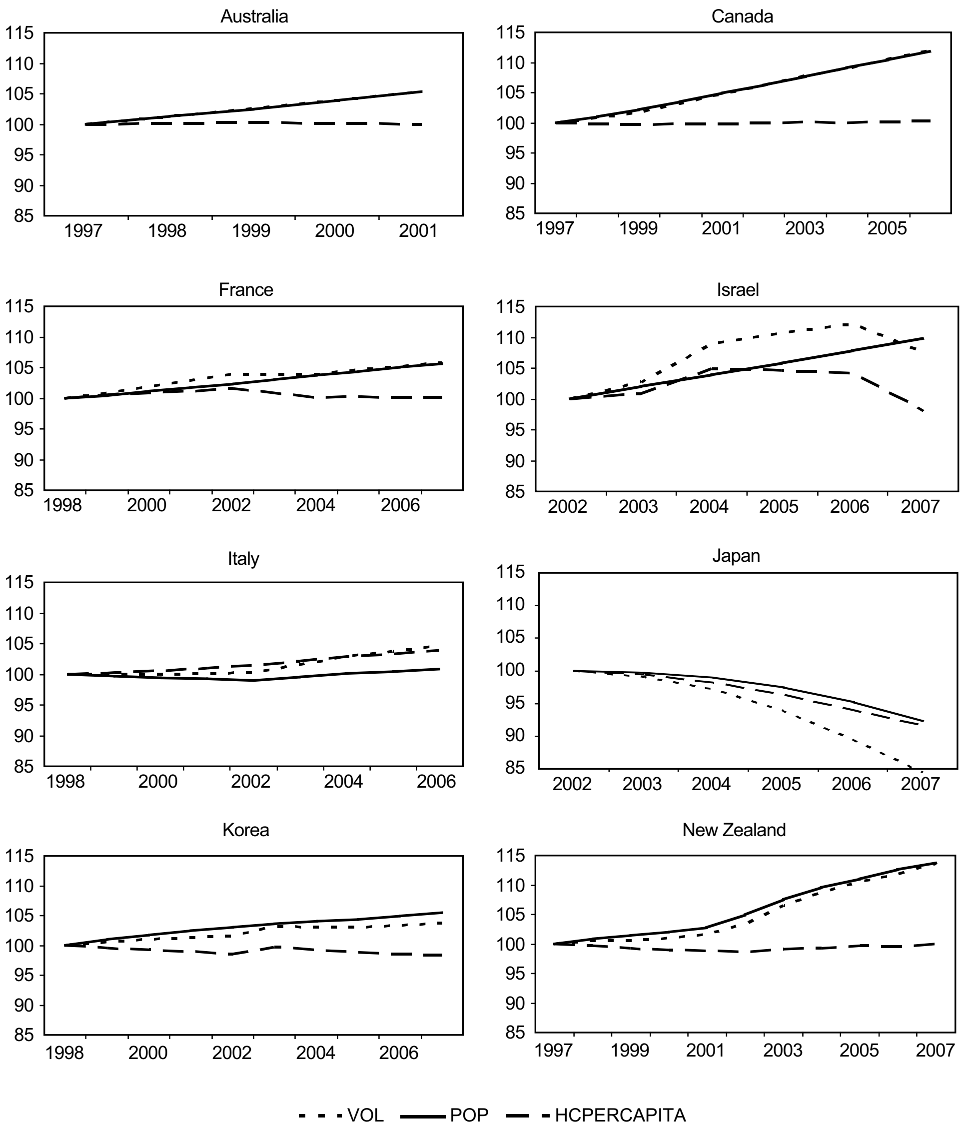

Fig. 15.10 Human capital temporal volume indices

Source: OECD Human Capital Project.

Note: The abrupt fall of human capital volume from 2006 to 2007 in Israel reflects a change of educational categories.

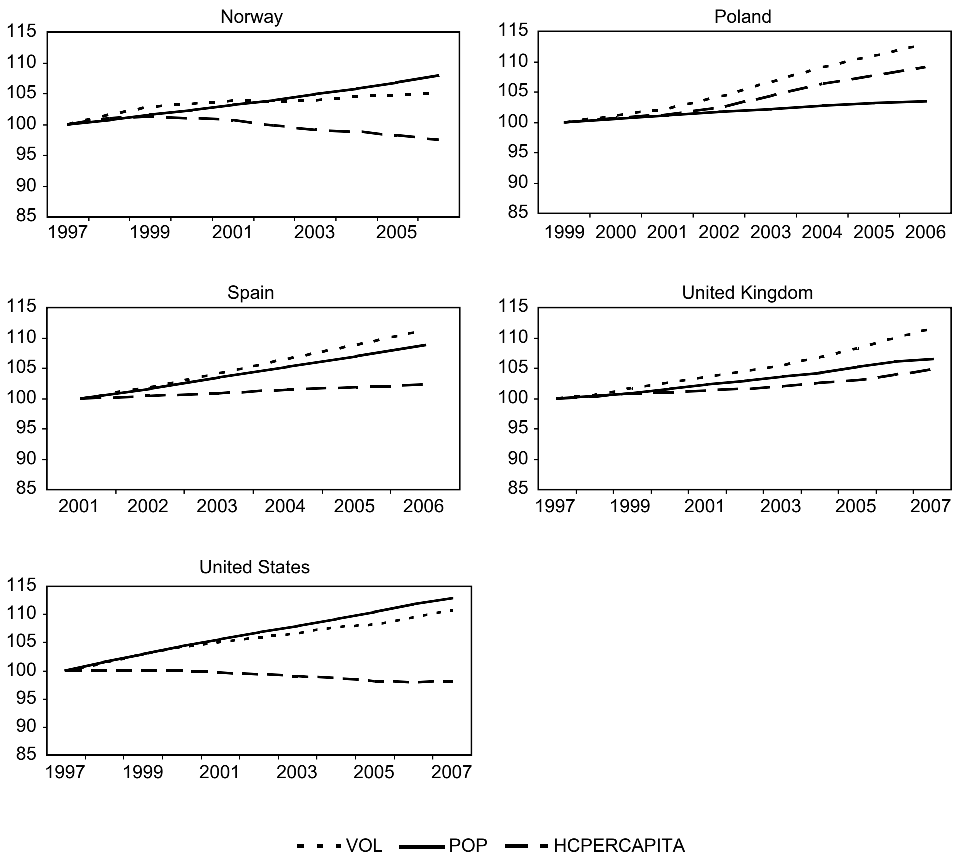

Fig. 15.10 (cont.)

- higher human capital volumes per capita in Italy, Poland, Spain, and the United Kingdom;
- broadly stable human capital volumes per capita in Australia, Canada, France, and New Zealand; and
- lower human capital volumes per capita in Israel, Japan, Korea, Norway, and the United States.

To explore why human capital volume per capita increased in some countries and declined in others, decomposition analyses can be used. Partial volume indices allow assessing the relative importance of the various factors at work. As outlined in section 15.2.4, these partial volume indices refer to the main population characteristics (i.e., age, gender, and educational attainment) and allow examining the contribution of these characteristics to the real growth of human capital per capita.

Figure 15.11 provides information on average annual growth rate of human capital per capita for each country throughout the observation period available (shown as "diamonds" in the figure). Contributions from first-order partial indices with respect to age, gender, and educational level are reported in the form of stacked bars: as mentioned already, the sum of the contribution that each characteristic makes to the growth of human capital per capita will not equal the overall growth in human capital per capita, as these contributions represent only first-order approximations.

Figure 15.11 indicates that, compared with the contributions from other two characteristics, the contribution of shifts of the population between gender was very small (positive for Israel, Italy, Japan, Korea, Poland, Spain, the United Kingdom, and the United States; negative for Australia, Canada, France, New Zealand, and Norway) and almost negligible for all countries. This means that during the observation period shift of population composition between men and women had little effect on the change of human capital per capita for all countries.

Similarly, for all countries the contribution from educational level was positive while that from age was negative. The former effect suggests that, during the period, more people attained higher levels of education, while the latter signals that all countries were experiencing population aging (since

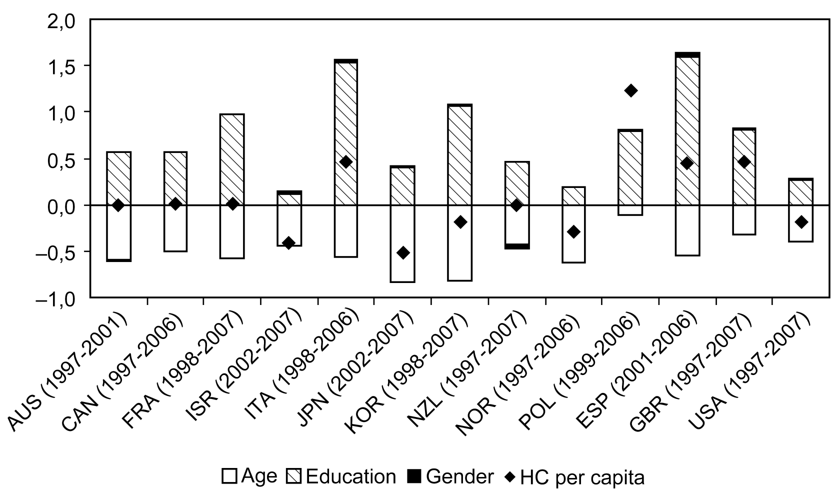

Fig. 15.11 Decomposition of average annual growth of human capital volume per capita due to age, gender, and educational attainment (first-order partial volume index, %)

Source: OECD Human Capital Project.

Note: For many countries, the contribution from gender is too small to be discernible in the figure.

older people have fewer remaining working years and thus lower lifetime incomes).[38]

The magnitude of these two opposite effects varied across countries. For countries that experienced increased volumes of human capital per capita (Italy, Poland, Spain, and the United Kingdom), the positive contribution from education was larger than the negative effect from population aging. For countries that experienced broadly stable volumes of human capital per capita (Australia, Canada, France, and New Zealand), these two effects almost cancelled out each other. Finally, for countries that experienced decreased volumes of human capital per capita (Israel, Japan, Korea, Norway, and the United States), the contribution from age exceeded that from education.[39]

One obvious policy implication that can be drawn from these patterns is that some countries are not investing enough in education to offset the negative effect of population aging.

15.4.5 Sensitivity Analysis

The estimates of human capital presented in this project are subject to a number of assumptions, in particular assumptions about two key parameters, that is, the annual growth rate of real income of each age/gender/education categories in the future; and that on the discount rate. A number of national studies have shown that human capital estimates based on the lifetime income approach are sensitive to the choice of these two parameters (e.g., Wei 2004; Gu and Wong 2008, 2009; Liu and Greaker 2009; Fraumeni 2011).

In this project, sensitivity analysis has been implemented with respect to these two parameters. Taking the United States as an example, table 15.2 shows results of sensitivity analyses on human capital stock value and its distribution in 2006. In table 15.2, the baseline scenario is one where the annual real income growth rate is set at 1.30 percent and the discount rate is 4.58 percent, the values used for generating the estimates of human capital for the United States that have been shown above.

Since income growth rate and discount rate enter the estimation of the stock of human capital in multiplicative forms (see equations (A1) and (A2) in appendix A), what matters is the ratio between the two parameters; that

38. Recall that the focus of the current study is the working age (15–64) population. An aging working age population implies that the share of elderly people is increasing relative to that of younger people. This could happen when more prime age people (35–54) become older (55–64) and/or when less younger people (aged less than 15 years) enter the working age population.

39. Korea, a country where the contribution from education was larger than that from age, is an exception. This might reflect the fact that Korea is the only country that combines educational level 4 with level 5B in the original data source. As a result, the tertiary educational level (EDU_5/6) used for Korea in this project includes level 4; one consequence is that the contribution from first-order volume index with respect to education might be exaggerated.

Table 15.2 **Sensitivity analysis on human capital stock value and distribution for the United States in 2006**

			Distribution (%)							
		Level (trillions)	Gender		Education			Age		
Fixed annual discount rate (4.58%)	Annual income growth rate (%)	Total stock	Males	Females	EDU_0/1/2	EDU_3/4	EDU_5/6	AGE_I	AGE_II	AGE_III
Baseline	1.30	128,235	63.8	36.2	13.4	43.7	42.9	57.6	38.5	3.9
Scenario A	–2.10	86,131	63.7	36.3	11.2	42.4	46.4	50.6	44.1	5.3
		(–32.8)	(–0.2)	(0.3)	(–16.4)	(–3.0)	(8.2)	(–12.2)	(14.5)	(35.9)
Scenario B	1.11	125,009	63.8	36.2	13.3	43.6	43.2	57.2	38.8	4.0
		(–2.4)	(0.0)	(0.0)	(–0.7)	(–0.2)	(0.7)	(–0.7)	(0.8)	(2.6)
Scenario C	1.50	131,673	63.8	36.2	13.5	43.8	42.7	58.1	38.1	3.8
		(2.7)	(0.0)	(0.0)	(0.7)	(0.2)	(–0.5)	(0.9)	(–1.0)	(–2.6)
Scenario D	3.96	188,188	63.8	36.2	15.8	44.7	39.6	64.1	33.0	2.9
		(46.8)	(0.0)	(0.0)	(17.9)	(2.3)	(–7.7)	(11.3)	(–14.3)	(–25.6)

Source: OECD Human Capital Project.

Note: Changes (in percentages) relative to baseline scenario are shown in parentheses.

is, $\{(1 + r)/(1 + \delta)\}$. For this reason, the four scenarios shown in table 15.2 rely on the same annual discount rate (4.58 percent for all scenarios) while differing in terms of the real income growth rate that they use (–2.1% in scenario A, 1.11% in scenario B, 1.50% in scenario C, and 3.96% in scenario D), respectively; this implies setting the values of the parameter $\{(1 + r)/(1 + \delta)\}$ at 96.86%, 93.62%, 96.68%, 97.05%, and 99.41%, respectively.

Table 15.2 shows that the estimates of the total value of the stock of human capital are sensitive to the choice of the two parameters. Nonetheless, the distribution of human capital between men and women, among educational groups, and among age groups are relatively less sensitive.

Likewise, the growth of the volume of human capital is not very sensitive to the choice of the two parameters. As shown in figure 15.12, the curves of human capital volume for scenarios baseline B and C are almost identical; the same applies to the curves of human capital per capita.

One interesting pattern from figure 15.12 is that the curve referring to the volume of human capital in scenario A, which relies on a lower income growth rate than in the baseline, lies above that for the baseline scenario; conversely, in scenario D, which uses a higher income growth rate than in the baseline, the curve for the volume of human capital is below that of the baseline scenario. These counterintuitive results reflect the nature of the method used to estimate lifetime income in this chapter.

In terms of equations (1), (2), and (3) in section 15.2.4, the higher-than-baseline income growth rate (as in the case of scenario D) implies a higher share for the value of human capital held by younger people than for their older counterparts. Due to the population aging observed in the United States (and given that the sum of the value shares must equal one), the higher growth in the older population combined with a lower share of human capital held by this group, together with the lower growth in younger population weighted by a higher share of their human capital, lead to a growth of human capital volume that is smaller than in the baseline.

In addition, although the *level* of human capital volume is increasing due to higher income growth rate, the curve of human capital volume will be shifted down in order to keep the volume level at the starting year (1997) fixed at 100.

Therefore, in scenarios that have higher income growth rate than in the baseline, the lower growth rate of human capital volume, combined with the fixed starting value, will lead to curves of human capital volume that lie below the curve for the baseline. The opposite holds true for scenarios that have lower income growth rate (e.g., scenario A) than in the baseline.

While these paradoxical results stem from equations (1), (2), and (3), together with the population aging that is observed in the United States, it may also reflect a more fundamental constraint imposed by the basic assumptions made in this approach; that is, that annual real income growth

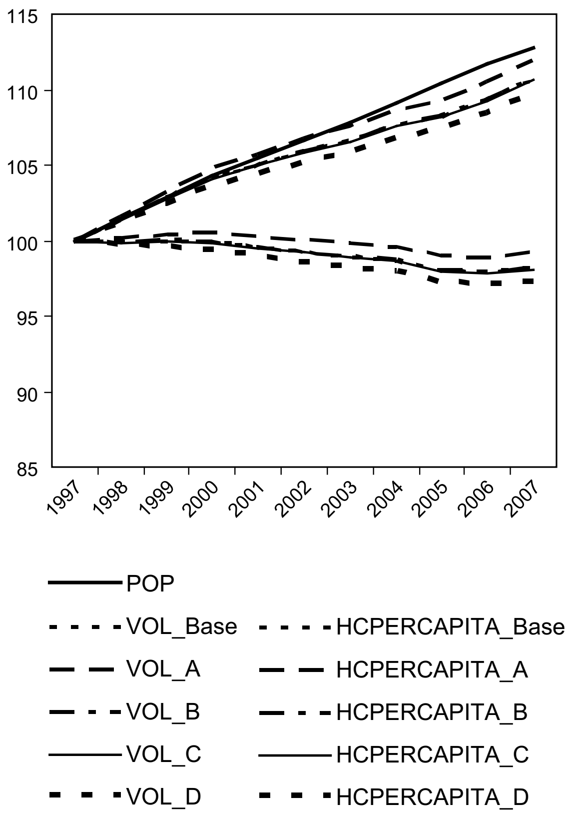

Fig. 15.12 Sensitivity analysis on human capital temporal volume index for the United States
Source: OECD Human Capital Project.

rate is exogenously given rather than derived from the model. The implications of this assumption can be gleaned when considering that, in a country experiencing aging population, its long-term economic growth would be affected since human capital, a critical asset for economic growth, is declining. This causal link from aging population to future income growth rate is neglected in the model for human capital measurement used in this project. Exploring how population aging will affect real income growth rate in the future is beyond the scope of this project.

15.5 Conclusions and Future Plan

Human capital is of significant importance for policymakers to address various issues such as economic growth, quality of life, social cohesion, and sustainable development. The OECD Human Capital Project is among the first attempts to measure human capital for comparisons both across countries and over time. To that end, an OECD database has been constructed for most of the project participating countries, containing information on the various elements that enter the human capital estimation, based on the lifetime income approach.

The results contained in the chapter show the feasibility of applying the lifetime income approach to measuring human capital for comparative analysis. They also highlight the feasibility of applying the methodology to categorical data (e.g., by five-year or ten-year age group) that are typically available within the OECD statistics system, rather than to more demanding detailed data that would be required by the original Jorgenson-Fraumeni methodology. The main results are the following:

- Despite of some differences, most of the estimates in this chapter are in line with those reported in national studies. In terms of the level of human capital value, almost all studies share the conclusion that, even when estimates are restricted to market activities, the value of human capital is substantially larger than that of conventional produced capital and is much larger than GDP (by a factor ranging from around eight to over ten times in this study).
- Within countries, the stock of human capital is not uniformly distributed across different groups of the population. The distributions of human capital indicate that men have a higher human capital than women. In addition, people with higher education are better off than those with lower education, and the same is true for younger people compared to their older counterparts, although the detailed patterns vary across countries.
- Adjusting for changes in price levels in each country shows that human capital volume increased for all countries (except for Japan) during the observed period. However, in some countries, the volume of human capital in per capita terms fell.
- Decomposition analysis of human capital volume indices shows that changes in the structure of the population between men and women had little effect on the change of human capital per capita in all countries. While more people attaining higher levels of education contributed positively to the change of human capital per capita in each country, in all countries population aging contributed negatively to this change over the observed years.
- The magnitude of these two opposite effects varied across countries. In Italy, Poland, Spain, and the United Kingdom, the positive contribution from higher educational attainment exceeded the negative effect of population aging, while the opposite was true in Israel, Japan, Korea, Norway, and the United States. it may imply that, when facing popu-

lation aging, countries can invest more into education so as to offset this negative demographic effect.

- Finally, the sensitivity analysis confirms that estimates of the values of human capital are sensitive to the choice of the two key parameters in the estimation; that is, the annual real income growth rate and the discount rate. But within-country distribution of human capital and trends in human capital volume index in each country are less sensitive.

Country-specific assumptions of real income growth rates and a common discount rate have been used in this project to estimate human capital based on the lifetime income approach. Although there are reasonable arguments for these choices, there are also reasons in favor of different assumptions. This issue will have to be addressed in future research.[40]

In conclusion, it seems that, despite some deficiencies in the methodology used, the lifetime income approach, by bringing together the influence of a broad range of factors (demography, mortality, and educational attainment, as well as labor market aspects) allows comparing the relative importance of these factors and drawing useful policy implications from the estimates.

In the near term, the project could be expanded in two main directions: (1) improving the underlying statistical information (e.g., by using information from other sources to improve current data on school enrollment rates, by improving the comparability of educational categories, by improving the earnings concept used in the OECD database); and (2) extending the work to additional countries and years.

In the longer term, the OECD work on human capital based on the lifetime income approach could explore a number of more fundamental issues, including the following:

- Running simulations of future stocks of human capital, based on existing demographic projections.
- Constructing human capital accumulation accounts that will help explain changes in the stock of human capital over time in terms of investment, depreciation, and revaluation.
- Using the human capital estimates to construct an education satellite account, combining various inputs and outputs data on education.
- Extending the scope of the current accounting exercise to include children (below age 15), the elderly (above 65), and nonmarket activities.
- Examining how results on adults' competencies from PIAAC (the OECD Programme for the International Assessment of Adult Competencies) might be integrated into human capital accounting so as to produce "quality-adjusted" estimates.
- Identifying and reinforcing the structural links between human capital accounting and other economic entities in the SNA.

40. For more discussions on this issue, see Abraham (2010), Fraumeni (2011), and Liu (2013).

- Investigating potential possibilities for addressing more policy issues based on the human capital accounting exercise.

Appendix A

Methodological Assumptions and Relevant Equations Used for Estimating Lifetime Income

The OECD Human Capital Project distinguishes between three stages in the life cycle of an individual of working age (i.e., between 15 and 64 years of age): (1) "study-and-work" (15–40);[41] (2) "work-only" (41–64); and (3) "retirement only" (65 and above). Based on this assumption, the lifetime labor income of an individual can be computed using the following:

- For persons aged 65 and over (i.e., "retirement only" stage), their lifetime labor income is zero since, by assumption, these persons will not receive earnings after withdrawing from the labor market.
- For persons aged 41 to 64 (i.e., "work-only" stage), their lifetime labor income is estimated using the following:

$$(A1)\quad LIN_{age}^{edu} = EMR_{age}^{edu}AIN_{age}^{edu} + SUR_{age+1}LIN_{age+1}^{edu}\{(1 + r)/(1 + \delta)\},$$

where LIN_{age}^{edu} is the present value of lifetime labor income for a representative individual with educational level of "*edu*" at the age of "*age*"; EMR_{age}^{edu} is the employment rate for this individual; AIN_{age}^{edu} is his/her current annual labor income, if employed; SUR_{age} is the probability of surviving one more year given that this individual is at the age of "*age*"; r is the annual growth rate of the labor income (in real terms) of a person of these characteristics in the future; δ is the annual discount rate.

The lifetime income of a representative individual during the "work-only" stage is therefore estimated as the sum of two parts: the first part is the current labor income, adjusted by employment rate (the first term in equation [A1]); the second part is the lifetime income in the next year, adjusted by the corresponding survival rate, income growth rate, and discount rate (the second term in equation [A1]).

For persons aged 15 to 40 (i.e., "study-and-work" stage), their lifetime labor income is estimated using the following:

41. The cut-off at age 40 for the upper bound of the "study-and-work" stage is due to the fact that information on the number of students enrolled in different educational levels from the OECD database is available until age 40. Many countries have witnessed in recent years a quite significant increase in the number of adults (more than 40 years old) attending schools for further education (http://dotstat.oecd.org/wbos/Index.aspx).

$$\text{(A2)}\quad LIN_{age}^{edu} = EMR_{age}^{edu} AIN_{age}^{edu} + \left\{1 - \sum_{\overline{edu}} ENR_{age}^{edu-\overline{edu}}\right\} SUR_{age+1} LIN_{age+1}^{edu} \cdot \{(1+r)/(1+\delta)\} + \sum_{\overline{edu}} ENR_{age}^{edu-\overline{edu}} \cdot \left\{\left(\sum_{t=1}^{t_{edu-\overline{edu}}} SUR_{age+t} LIN_{age+t}^{\overline{edu}} \{(1+r)/(1+\delta)\}^{t}\right) / t_{edu-\overline{edu}}\right\},$$

where $ENR_{age}^{edu-\overline{edu}}$ is the school enrollment rate for a representative individual with educational level of "*edu*" pursuing studies into a higher educational level of "$\overline{edu}$"; $t_{edu-\overline{edu}}$ is the school duration for this individual with educational level of "*edu*" to complete a higher educational level of "$\overline{edu}$".

During the "study-and-work" stage, a representative individual in the next year will be confronted to two courses of action: the first is to continue his/her school and (after completing study and having gained a higher educational level) to receive income as $\{\sum_{t=1}^{t_{edu-\overline{edu}}}(SUR_{age+t} LIN_{age+t}^{\overline{edu}}\{(1+r)/(1+\delta)\}^{t})/t_{edu-\overline{edu}}\}$, with the probability of $\sum_{\overline{edu}} ENR_{age}^{edu-\overline{edu}}$; the second is to start working (holding the same educational level as before) and earn income as $SUR_{age+1} LIN_{age+1}^{edu}\{(1+r)/(1+\delta)\}$, with the probability of $\{1-\sum_{\overline{edu}} ENR_{age}^{edu-\overline{edu}}\}$. Therefore, his/her lifetime income in the next year is the expected value of the outcomes of these two courses of action (i.e., the sum of the second and the third terms in equation [A2]).

The empirical implementation of equations (A1) and (A2) is based on backwards recursion. With this approach, the lifetime labor income of a person aged 64 (i.e., one year before retirement) is simply his/her current labor income (the first term in equations [A1] and [A2]) because his/her lifetime labor income at 65 is zero by construction. Similarly, the lifetime labor income of a person aged 63 is equal to his current labor income plus the present value of the lifetime labor income of a person aged 64, and so forth.

In estimating lifetime labor income by using equations (A1) and (A2), several practical assumptions are made, some of which are used as well by other studies in the field (e.g., Gu and Wong 2008; Le, Gibson, and Oxley 2006; Liu and Greaker 2009; Wei 2004, 2007). The most important of these assumptions are the following:

- Individuals can only enroll in a higher educational level than the one they have already completed.
- No further enrollment is allowed for people having already achieved the highest educational level.
- Students enrolled in educational institutions requiring more than one year to complete are assumed to be evenly distributed across the total study period (school duration). This is equivalent to saying that, during each school year, the same proportion of all students will complete the study.

- No delaying, quitting, or skipping is allowed during the whole study period.

In formal terms, the total stock of human capital (HCV) is computed as:

(A3) $$HCV = \sum_{age}\sum_{edu} LIN_{age}^{edu} NUM_{age}^{edu},$$

where NUM_{age}^{edu} is the number of persons in the corresponding age/education category. It should be noted that equations (A1), (A2), and (A3) are applied separately to both men and women; this allows computing the stock of human capital by gender.

Appendix B

Classification of Educational Levels in ISCED 97

The International Standard Classification of Education (ISCED) developed by UNESCO is based on standard concepts, definitions, and classifications, and aims to provide a tool suitable for assembling, compiling, and presenting comparable statistics on education both within countries and internationally. ISCED 97 covers primarily two cross-classification variables: (1) the level of education; and (2) the field of education. Due to data constraint, the OECD Human Capital Project only relied on the classification of educational levels, based on the following main categories:

- level 0: preprimary education
- level 1: primary education or first stage of basic education
- level 2: lower secondary or second stage of basic education
- level 3: upper secondary education
- level 4: postsecondary nontertiary education
- level 5: first stage of tertiary education
- level 6: second stage of tertiary education

Except for levels 0 and 1, the above-defined categories can be further subclassified according to the destination for which the programs have been designated, resulting in more detailed classifications. This information is used to determine the detailed transition patterns from lower to higher educational levels shown in figure 15A.1. In particular, the following should be noted:

- Level 2 encompasses sublevels 2A (designed to provide direct access to level 3 in a sequence that would ultimately lead to tertiary education, i.e., entrance to 3A or 3B); 2B (designed to provide direct access to 3C); and 2C (primarily designed to lead to direct access to labor market at the end of this level).

- Level 3 consists of sublevels 3A (designed to provide direct access to 5A); 3B (designed to provide direct access to 5B); and 3C (designed to lead directly to labor market or to level 4 or other level 3 programs).
- Level 4 consists of sublevels 4A (prepared for entry to level 5); and 4B (primarily designed for direct labor market entry).
- Level 5 includes sublevels 5A (theoretically based research and preparatory courses of history, philosophy, mathematics, etc., or giving access to professions with high skills requirements such as medicine, dentistry, architecture, etc.); and 5B (programs that are practical/technical/occupationally specific).

Appendix C

Transition Pattern in ISCED 97

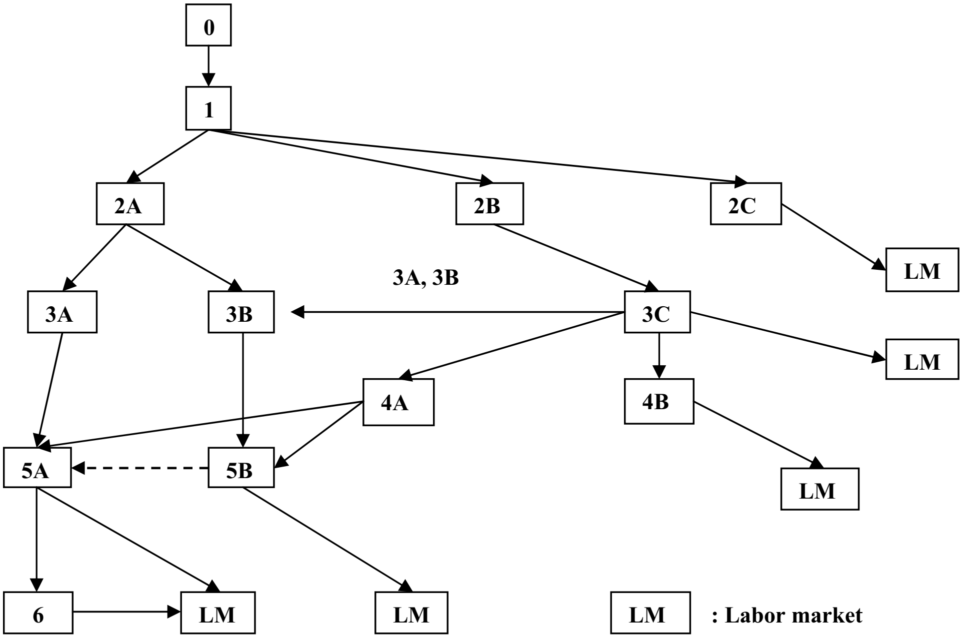

Fig. 15C.1 Labor market

Source: International Standard Classification of Education (ISCED) 97 (UNESCO 2006).

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