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A Review of Human Capital Theory: Microeconomics

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Abstract

With the beginning of the new millennium it has become more and more apparent that education and human capital constitute a key element of modern economies. Despite the important role of human capital in modern societies, there are still many unknowns about the process of educational production as well as individual and collective decisions concerning how much and what kind of education to obtain. This literature review aims at providing a better understanding of the process of human capital formation and educational attainment. Although human capital plays an important role in both microeconomics and macroeconomics, we focus on the former branch of literature in order to analyze the individual incentives to acquire skills.

This review is divided into six parts each of them representing an important stream of human capital literature. First, we introduce the basic concept of human capital that models individuals as investing in skills in response to the expected returns to education. After this, we investigate the different implications of investments in general and specific human capital and then provide an overview of various empirical studies measuring the rate of return to education. Because educational attainment may also be affected by other factors such as school characteristics or family background, we review the literature on educational production functions and discuss the significance of potential inputs into the process of educational production. Subsequently, we refer to models of human capital accumulation over the life-cycle that manage to replicate the empirical life-cycle patterns with respect to the age-earnings profile of individuals. Finally, we analyze the effects of taxation and education subsidies on the formation of human capital.

Keywords

Human Capital, Return to Education, Education Production Function, Life-Cycle of Earnings, Education Subsidies

JEL Classification

H24, H52, I20, I21, I28, J24, J31, J41

1 Introduction

With the beginning of the new millennium it has become more and more apparent that education and human capital constitute a key element of modern economies. While some developing countries succeed in attracting industries of the so-called old economy, developed economies have to concentrate on skill intensive industries in order to defend their leading position. In this context, the change to an information society is occurring rapidly, with information and knowledge the crucial inputs and outputs of nearly all economic processes. Despite the important role of human capital in modern societies, there are still many unknowns about the process of educational production as well as individual and collective decisions concerning how much and what kind of education to obtain.

The contribution of this literature review is to provide a better understanding of the process of human capital formation and educational attainment. Furthermore, we analyze policy instruments and institutional features that may help to increase the aggregate welfare by improving the efficiency of the educational system. In order to structure the vast literature on human capital formation, the paper is divided into six parts. As an introduction to human capital theory, Section 2 introduces the basic concept of human capital that models individuals as investing in skills in response to the expected returns to education.

In Section 3, we distinguish between general and specific human capital and analyze the different implications for human capital investments by workers and firms. In perfect labor markets, all costs and benefits of general training are borne by the workers, while firms and workers share both the costs and the returns of investments in specific training (Becker (1964)). In imperfect labor markets, general training may also be firm-sponsored because the wage structure is compressed, which implies that firms manage to skim labor market rents depending on the amount of training (Acemoglu and Pischke (1998a)).

Section 4 of this review refers to the return to education from the individual's point of view according to Mincer (1974). Although the rate of return to education varies significantly in response to various influencing factors, the average estimate for developed economies generally ranges from 5% to 10% (Wilson (2001)). In Section 5, we review the literature on educational production functions and discuss the significance of potential inputs into the process of educational production. While the empirical evidence concerning the impact of school resources is mixed, there is an unambiguous effect of family and peer groups as well as institutional incentives within the educational system (Hanushek (1997)). Section 6 describes the life-cycle of earnings with endogenous formation of human capital. The two most important approaches by Ben-Porath (1967) and Heckman (1976) manage to replicate the empirical life-cycle patterns with respect to the age-earnings profile of individuals.

Finally, in Section 7, we analyze the effects of taxation and education subsidies on the accumulation of human capital. The marginal effects of proportional and progressive income taxation on human capital formation are generally negative (Heckman, Lochner, and Taber (1999a)). Depending on whether the costs of human capital are direct expenditures or foregone earnings, a "comprehensive income tax" may discriminate either against investments in human or in physical capital. In a nutshell, the incentives for human capital formation depend on the net effective tax rate, which implies that education subsidies

can increase efficiency by offsetting tax-induced distortions (Bovenberg and Jacobs (2005)). Section 8 concludes.

2 The Concept of Human Capital

"Human capital" can be defined as knowledge, skills, attitudes, aptitudes, and other acquired traits contributing to production (Goode (1959)). Skills represent individual capacities contributing to production as an argument in the production function (Bowles, Gintis, and Osborne (2001)). According to Blundell, Dearden, Meghir, and Sianesi (1999), there are two main components of human capital with strong complementarity: early ability (whether acquired or innate) and skills acquired through formal education or training on the job. Human capital differs from other assets because it yields market returns only in proportion to the worker's supply of labor (Hall and Johnson (1980)). Ishikawa and Ryan (2002) suggest that it is the stock of human capital that predominantly determines the earnings of individuals. An extensive review of the theory of human capital is given by Cahuc and Zylberberg (2004).

The first use of the term "human capital" in modern economic literature was by Schultz (1961). He classifies expenditures on human capital as investment rather than consumption.[1] In the same year, Weisbrod (1961) developed a first conceptual framework for estimating the value of assets in the form of human capital. Capital values of people as productive assets are incorporated into an analytical function of sex, age, stock of human capital, etc. The present value of an individual at any given age a is defined as the sum of his discounted expected future earnings Y_t (equal to the value of productivity):

$$V(a) = \sum_{t=a}^{\infty} \frac{P_{at}}{(1+r)^{t-a}} Y_t \tag{1}$$

P_{at} represents the probability of an individual of age a to be alive at age t and r is the discount rate. In general, there are two methods of determining the value of human capital, namely by summing up the costs of production (input-based) and by considering capitalized earnings (output-based) (Kiker (1966)).

The first applications of human capital theory in economics are by Becker and Mincer of the Chicago school. In his original approach, Becker (1964) develops a model of individual investment in human capital. In this view, human capital is similar to "physical means of production". According to Becker (1962), investing in human capital means "all activities that influence future real income through the embedding of resources in people". Human capital investments are expenditures on education, training, health, information, and labor mobility (Weisbrod (1966)).

The accumulation of human capital takes place in three ways: formal schooling (i.e. the individual devotes his whole time to learning), on-the-job training (i.e. post-school training provided by the current employer), and off-the-job training (i.e. post school training provided by "for-profit" proprietary

[1] Shaffer (1961) citicizes the application of capital concepts to individuals for three reasons: educational expenditures may be undertaken for other reasons than the expectation of monetary returns, impossibility to relate a certain return to a certain investment, and undesirable basis for the evaluation of policy actions with respect to social welfare.

institutions) (Lynch (1991)).[2] These investments involve initial costs (direct tuition expenditures, foregone earnings during schooling, and reduced wages during training)[3] in order to gain a return on this investment in the future (Becker (1992)). The return to education is based on two interrelated channels: increased earnings for the worker and higher productivity for the firm as well as increased employment probabilities (Bloch and Smith (1977)).[4] In a nutshell, there are two key determinants of the return to education: the costs of education and the employment opportunities after education (Rephann (2002)).

The key element in the model by Becker (1964) is that education is an investment of time and foregone earnings for higher rates of return in later periods. As with investments in physical capital, a human capital investment is only undertaken by wealth-maximizing individuals or firms if the expected return from the investment (which is equal to the net internal rate of return) is greater than the market rate of interest. Regarding the costs of human capital investments, Perri (2003) remarks that - if the best alternative of an investment in specialized human capital is investing in another specialization of human capital - then the measure of foregone earnings has to cover the complete opportunity costs of specialized education. These opportunity costs describe what could have been earned with the best alternative specialized education.[5]

According to Haley (1973), there are two streams of human capital literature. The first analyzes individual investments in human capital in order to estimate the internal rate of return (based on Becker (1964)). The second stream of literature deals with the life-cycle of earnings. The individual faces a trade-off between producing additional human capital and renting his existing stock of human capital in the labor market (based on Ben-Porath (1967)).

3 General and Specific Human Capital

In his original model, Becker (1964) distinguishes between general and specific human capital. General human capital is defined to be not only useful with the current employer but also with other potential employers. In contrast, specific human capital increases the productivity of the worker only in his current job.[6] Empirically, it is difficult to distinguish between general and specific training. Loewenstein and Spletzer (1999) try to overcome this problem by directly asking employers whether they assess the provided training to be general or specific.

[2] Mincer (1962) notes that more than half of total expenditures on education are investments in on-the-job training.

[3] Parsons (1974) distinguishes these three major components of education costs.

[4] Bloch and Smith (1977) find a positive correlation of human capital and labor market employment. Also Mincer (1989) states that the probability of being unemployed decreases with the amount of education.

[5] Rosen (1983) suggests increasing rates of return in the utilization of human capital due to fixed investment costs independent of the degree of utilization. This induces private incentives for specialization, i.e. to use one type of human capital as intensively as possible. Hence, each individual has a comparative advantage for a certain occupation that uses the accumulated skill most intensively.

[6] Parsons (1974) notes that this firm-specific human capital is analytically equivalent to transfer costs for adjusting a worker to other firms.

3.1 General Human Capital

3.1.1 Investments in General Human Capital: Perfect Labor Markets

In competitive labor markets, where workers receive wages equal to their marginal product, firms cannot recoup investments in general skills, which implies that they refuse to pay for general training (cf. table 1). This "hold-up" problem arises due to incomplete contracts which means that one party (i.e. the employer) pays the costs of the investment in human capital, while another party (i.e. the worker) shares in the return (Acemoglu and Shimer (1999)).

However, workers themselves have the right incentives to invest in general human capital because they are the sole beneficiaries of their increased productivity (either with their current or with future employers).[7] Furthermore, workers can finance such investments quite easily by accepting a wage below their productivity during the period of training (the wage may even be negative) (Becker (1962)). For example, this argument can be applied to apprenticeship systems in earlier centuries, where apprentices often paid fees or worked for very low wages until they mastered a certain grade (Hamilton (1996)). Hence, if workers are not credit constrained, they efficiently invest in the accumulation of general human capital (cf. table 1).

The empirical evidence of the model by Becker (1964) is mixed. On the one hand, it is supported by the empirical analysis of Veum (1999). By using data from the National Longitudinal Survey of Youth (NLSY), he finds that firm-sponsored training is indeed negatively related to starting wages, but positively related to wage growth. On the other hand, many analyses question the validity of this explanation by showing that there are investments in general human capital which are financed by the employer. For example, by further analyzing data from the NLSY, Loewenstein and Spletzer (1999) find that the larger part of firm-sponsored training is general. Other empirical studies also show that firms bear substantial net costs in providing general training to their apprentices. For example, Ryan (1980) examines welder apprentices in the US and Jones (1986) analyzes apprentices in British manufacturing.

A number of studies also investigate whether workers taking part in general training programs pay for the costs by accepting lower wages. The majority of these studies do not find evidence of lower wages, at least not in an appropriate amount to fully compensate firms for the costs. An overview of these results is provided by Bishop (1997). Hence, in contradiction to the theoretical results of Becker (1964), there is at least some empirical evidence of firm-sponsored investments in the general human capital of their employees.

3.1.2 Investments in General Human Capital: Imperfect Labor Markets

In order to give a theoretical explanation for the empirical evidence with respect to firm-sponsored general training, Acemoglu and Pischke (1998a) develop a model with two periods, a training period where workers have identical productivity zero and may receive an amount of general training t at costs

[7] Already Eckaus (1963) criticizes that this result strictly depends on the assumption of perfect labor markets.

Type of skill	Labor markets	Firms	Workers	Total investment
general	perfect	no	yes	efficient[8]
general	imperfect	yes	yes	generally inefficient
specific	perfect	yes	yes	generally inefficient
specific	imperfect	yes	yes	generally inefficient

Table 1: Investment in Human Capital

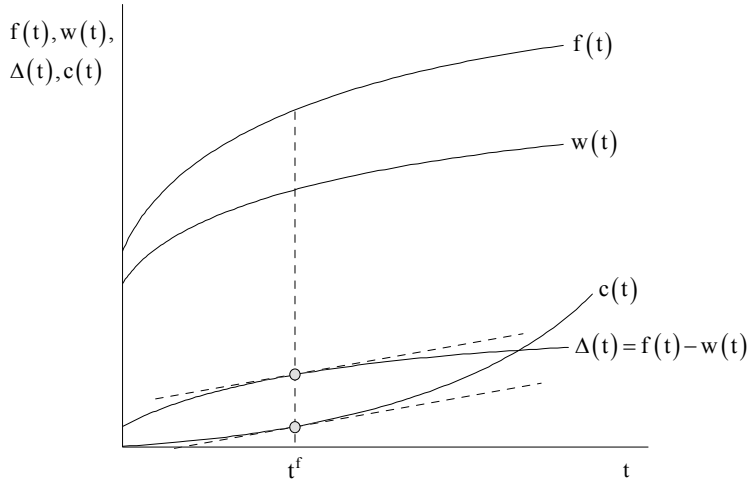

Figure 1: Training with Compressed Wage Structure

$c(t)$, and a second period where workers have an individual productivity $f(t)$ and earn a wage $w(t)$. If the labor market is competitive and workers are not credit constrained, then the results of Becker (1964) hold: firms do not invest in general training and workers invest efficiently by equating marginal returns and marginal costs of their investment:

$$f'(t^*) = c'(t^*) \tag{2}$$

However, if labor markets are not competitive or there are other labor market frictions which generate wage compression, the worker's wage is below his marginal product (Masters (1998)). If the wage structure is compressed, general skills are turned into de facto specific skills and firms manage to skim labor market rents depending on the amount of training. Formally, Acemoglu and Pischke (1999b) express this by assuming $f(t) = w(t) + \triangle(t)$. Hence, the wage function increases with the level of training less steeply than productivity (i.e. the wage structure is compressed), which implies that the firm's profit, equal to the positive gap $\triangle(t)$ between productivity and wage, has a first derivative greater than zero. As a consequence, firms prefer more skilled workers to less skilled ones and invest in general training until the desired level of training satisfies $\triangle'(t^f) = c'(t^f)$ (cf. figure 1). However, this reduction in the hold-up problem of the firms is achieved at the expense of a second hold-up problem in the training decision of the workers, which implies that the total amount of human capital investment is generally inefficient (Roed and Strom (2002)).

Concerning the empirical evidence, Loewenstein and Spletzer (1998) find that general training raises

future wages more for workers who change their job than for workers who remain with the training firm. This result is consistent with workers and employers sharing the returns to general training. Furthermore, Brunello (2002) shows that wage compression and the amount of general training show a positive and significant correlation.

3.1.3 Sources of Labor Market Imperfections

There are several possible sources of labor market imperfections which generate a compressed wage structure. The first one refers to the presence of transaction costs, for example due to matching and search frictions. Search frictions derive from imperfect information about potential contractual partners, heterogeneities, the absence of perfect insurance markets, limited mobility, congestion due to large numbers, and other similar factors (Petrongolo and Pissarides (2001)). In practice, it is difficult for workers to quit their existing jobs and find new suitable employers. Similarly, it is costly for firms to replace their employees. The costs of finding new contractual partners create a bilateral monopoly situation in wage determination so that the match-specific surplus has to be shared by bargaining. If the parameter $0 < \beta < 1$ indicates the bargaining power of the worker, the bargaining process generates profits equal to the Nash bargaining solution $\triangle(t) = (1-\beta) f(t)$ (Acemoglu (1997)).

Furthermore, wage compression may arise due to the interaction of general and specific skills. If general and specific skills are complements in the production of output, the presence of specific skills increases the productivity of general human capital. On the other hand, the value of firm-specific skills increases when general skills are acquired (Acemoglu and Pischke (1999b)). Kessler and Luelfesmann (2002) as well as Balmaceda (2001) extend this idea by designing a model with general and specific skills that constitute strategic complements although returns and costs are technologically disconnected. They find that there is firm-sponsored general training because the hold-up problem of investments in general skills is reduced. According to Bougheas and Georgellis (2004), this interaction of general and specific skills is the main reason for German firms to offer apprenticeship training positions although training is largely general.

A third source of wage compression is the presence of asymmetric information between the current firm and other potential employers. There are two possible types of asymmetric information. The first concerns the amount of training the worker has received and is analyzed by Chang and Wang (1996). If potential employers cannot observe the correct productivity and thus pay a wage below the marginal product, the wage structure is compressed. The second possible asymmetry between the current and potential employers is about the innate ability of the worker (hidden knowledge), i.e. the employer learns about the ability of the worker by providing general training (Acemoglu and Pischke (1998b)).

A fourth reason for wage compression is the presence of asymmetric information between the worker and the current employer concerning the worker's effort (hidden action). Hence, wages must satisfy the incentive compatibility constraints which leads to a compressed wage structure (Acemoglu and Pischke (1999b)). In a similar model, Loewenstein and Spletzer (1998) demonstrate that efficiency wages (that are paid to reduce fluctuations) can also induce firms to pay for general training.

Many authors have investigated similar sources of firm-sponsored general training. For example, Bishop (1997) and Lazear (2003) point out that the firm-specific mixture of general skills makes the labor market non-competitive. Furthermore, wage compression can also be generated by labor market institutions, for example minimum wages (Acemoglu and Pischke (1999a)) and worker unionization (Freeman and Medoff (1984)).

In a nutshell, the reasons for inefficiently low investments in general training are summarized in Malcomson, Maw, and McCormick (2003): (1) imperfect capital markets (i.e. the workers are credit constrained), (2) incomplete contracts (i.e. the desired level of training cannot be specified by a contract), (3) absence of labor market frictions (i.e. the hold-up problem), and (4) positive external effects of human capital investments for potential future employers if there is a positive probability of exogenous separation after the training period.

3.2 Specific Human Capital

3.2.1 Investments in Specific Human Capital: Theory

According to Becker (1964), training in specific human capital is different from general training because workers do not benefit from higher productivity after changing their jobs. Both in perfect and imperfect labor markets, firms can recoup investments in specific skills and thus are willing to share some of the costs of these investments (cf. table 1).

The accumulation of specific human capital leads to lower fluctuations because both firms and workers benefit from keeping their contractual partner (Becker (1962)). In a search model with economic growth and possible accumulation of specific human capital, Higashi (2002) confirms that investments in specific human capital reduce the number of quits. This result can be split into two different effects depending on who pays for the investment. Firm-sponsored specific training reduces layoff rates, while worker-financed specific training leads to lower quit rates (Parsons (1972)). Donaldson and Eaton (1976) stress that firms can manipulate the workers' wage profile by investing in specific skills in order to reduce turnover. Hence, the negative relationship between wages and labor turnover creates incentives for firm-sponsored investments in specific human capital (Rosholm and Svarer (2004)).

According to Becker (1964), many divisions of costs and returns are possible and the optimal sharing rule depends on the correlation between wage and turnover rate. As a corner solution, specific human capital may be no shared investment if the firms manage to keep the whole return (Donaldson and Eaton (1977)). In this context, Prendergast (1993) describes a dual moral hazard problem: first, workers have an incentive not to accumulate specific skills if it is costly for them; and second, firms have an incentive not to reward the accumulated specific skills. As a consequence, the total amount of human capital investment is generally inefficient (cf. table 1). By interpreting investments in specific human capital as application of the Coase theorem, Hashimoto (1981) tries to determine the sharing rule of the return to specific training. The key feature is the existence of transaction costs while the wage is set so as to maximize the expected total surplus.

By using a dynamic model of wage determination in the presence of specific human capital, Felli and Harris (1996) show that the worker receives the full value of the match with an alternative employer. More precisely, there are three components of the wage: the worker's expected productivity in the alternative match, a premium reflecting the accumulation of human capital specific to the alternative match that the worker forgoes by staying with the current employer, and a reduction reflecting the human capital specific to the alternative match that the worker also obtains by staying with the current employer. In a dynamic matching model, Arozamena and Centeno (2006) analyze the interaction of job tenure and external labor market conditions in the wage setting process. As the employment relationship evolves (and more match-specific human capital is accumulated), external labor market conditions (particularly unemployment and real growth) exert less influence on the wage.

3.2.2 Investments in Specific Human Capital: Empirical Results

Empirically, Lynch (1991) finds that individuals with on-the-job training are less likely to leave their current employer while individuals with off-the-job training are more likely to quit. Loewenstein and Spletzer (1997) show that individuals with company training are less likely to quit their job, whereas individuals with school training have mobility characteristics similar to those with no training. If on-the-job training is more specific than off-the-job training (as presumed by Lynch (1991)) and company training is more specific than school training (as suggested by Loewenstein and Spletzer (1997)), then the job mobility results are in line with the theoretical predictions of the human capital model (cf. Section 3.2.1). In almost the same manner, Loewenstein and Spletzer (1999) find that specific training and job mobility are negatively correlated.

An empirical study for Switzerland shows that specific training reduces both job search activity and job mobility while general training significantly increases job search (Zweimüller and Winter-Ebmer (2000)). Based on data from the German Socio-Economic Panel (GSOEP), Bougheas and Georgellis (2004) find that labor turnover is negatively correlated with tenure because firm-specific human capital is accumulated during employment.

4 The Rate of Return to Education

The rate of return to education is analyzed by two different branches of human capital literature. According to the micro labor literature, the rate of return to education measures the extra earnings of a worker for an additional year of schooling and training, while the macro growth literature investigates whether the level of education in a cross-section of countries is related to the GDP growth rates (Krueger and Lindahl (2001)). In the following, we focus on the micro literature because it is the rate of return to education that determines the amount of human capital investments at the individual level.

4.1 Theoretical Approach

According to Mincer (1974), if the only costs of an additional year at school are foregone earnings and if the effected proportional income increase is constant over one's lifetime, the logarithm of earnings is linearly dependent on the years of schooling. This yields the following Mincerian wage equation for the individual i:

$$\ln W_i = \beta_0 + \beta_1 S_i + \beta_2 X_i + \beta_3 (X_i)^2 + \varepsilon_i \tag{3}$$

W_i denotes the wage of individual i, S_i represents the years of schooling, X_i is a measure of work experience and ε_i is an individual disturbance term independent of β_0 and S_i. Work experience is included as a quadratic term in order to capture the concavity of the earnings profile. In a nutshell, the parameter β_1 can be interpreted as the rate of return to investments in education. Harmon, Hogan, and Walker (2003) extend this original approach by including dispersion in the return to schooling and thus treating β_1 as a random coefficient. However, empirically they do not find any time trend in mean or variance so that the deterministic Mincerian wage equation can be used quite appropriately.

4.2 Empirical Results

The Mincerian wage equation is a log-linear transformation of an exponential function and can be estimated by OLS. Hence, the coefficients have a semi-elasticity interpretation and measure the percentage change in W_i for absolute variations in the independent variables. By estimating equation (3) on cross-sectional data from the 1960 census for the US, Mincer (1974) finds that an additional year of schooling yields a net increase of 11.5% in annual earnings.[9] Subsequently, the Mincerian wage equation has been estimated for many countries by using OLS. The results generally yield estimates of β_1 between 5% and 15%, with slightly larger estimates for women than men (Psacharopoulos (1994)).

By equating discounted costs and benefits, Becker (1964) estimates an internal rate of return to college and high school education of 13% to 28%. However, Solow (1965) argues that these large estimates are not corrected for correlations between education and ability. In order to solve this problem, Ashenfelter and Krueger (1994) estimate the return to schooling by contrasting wage rates of twins with different levels of educational attainment. They find that an additional year of schooling generates a wage increase of about 12% to 16%. In a similar manner, by analyzing a cross-section of twins, Rouse (1999) concludes that the rate of return to education is about 10% per year of schooling. Furthermore, Arias and McMahon (2001) estimate dynamic and expected dynamic rates of return to college and high school in the US. They find average returns of 13.3% in real terms or 11.7% after correcting for ability, family factors, and measurement errors.

Empirical evidence for developed western economies suggests that the average estimate of the return to an additional year of education ranges from 5% to 10% (Wilson (2001)). For example, for the UK

[9] Mincer (1974) converts his 16.2% gross increase in annual earnings to a net increase of 11.5% by factoring out increased labor force participation associated with an increase in education. In a previous paper, Mincer (1958) uses data from the 1950 census.

Study	Estimate
Becker (1964)	13% - 28%
Mincer (1974)	11.5%
Ashenfelter and Krueger (1994)	12% - 16%
Psacharopoulos (1994)	5% - 15%
Dearden (1998)	5.5% - 9.3%
Ashenfelter, Harmon, and Oosterbeek (1999)	6.6% - 9.3%
Arias and McMahon (2001)	11.7% - 13.3%
Wilson (2001)	5% - 10%

Table 2: The Rate of Return to Education

Dearden (1998) finds that the average annual return to an additional year of full-time education is 5.5% for men and 9.3% for women. Comparisons with less-developed countries show that the rate of return to education tends to be higher in latter countries (Acemoglu (2002)). However, at least some of these countries show estimated returns to human capital investments of nearly the same magnitude, for example Belarus with 10.1% (Pastore and Verashchagina (2006)). In a meta-analysis of the literature on returns to education, Ashenfelter, Harmon, and Oosterbeek (1999) review 96 estimates from 27 studies regarding 9 different countries. They find that the average OLS estimate of the return to schooling is 6.6%, whereas the average IV estimate is 9.3%.[10] Even after adjusting for a possible publication bias (because the probability of being published is higher for statistically significant results), the average IV estimate is 8.1% and still exceeds the average OLS estimate.

In a nutshell, the most important empirical findings with respect to the rate of return to education are summarized in table 2. In the following subsections, we refer to some important influencing factors that may have an impact on the magnitude of the return to education.

4.2.1 The Rate of Return Depending on Type of Skill

The figures above are only averages for the population as a whole and the returns to education vary significantly, for example by the type of acquired skill. According to Wasmer (2006), specific human capital yields a higher return than general human capital investments if the job-finding rate is low. By using data from the Displaced Worker Surveys, Neal (1995) empirically investigates skills that are neither completely general nor fully specific but rather common to firms operating in relatively homogenous economic activities. Because industry-switchers suffer significant wage losses, he suggests that wages strongly reflect industry-specific human capital. In contrast to this result, Cingano (2003) estimates returns to skills by using a special identification strategy and concludes that there are no returns to skills for industrial districts but high returns to firm-specific skills.

Important differences in rate of return to education have been found for different subjects taken in higher education. In the UK, men with chemistry or biology degrees have returns below average while women with education, economics, accountancy or law have significantly higher returns compared to

[10] IV estimates are identified by variability in schooling associated with quarter-of-birth. Individuals who are born early in the year tend to earn less. Krueger and Lindahl (2001) discuss the validity of these instruments.

other subjects (Blundell, Dearden, Goodman, and Reed (1997)). In a dynamic model of college and major choice, Arcidiacono (2004) estimates the returns to different majors in order to find reasons for ability sorting across majors.

Furthermore, individuals who completed schooling with some formal qualification have significantly larger returns than individuals with the same amount of schooling but without any formal qualification (Dearden (1998)). Concerning the level of qualification, Blundell, Dearden, Meghir, and Sianesi (1999) report that the average annual return to an O level qualification exceeds the average annual return to an A level or higher education qualification. Evidence from the US also suggests that there are decreasing returns to successive investments in human capital, i.e. the rate of return to education declines with the level of education (Hanoch (1967)). Early US studies as well as studies from developing countries find that the return to education is largest for investments in primary education (Psacharopoulos (1994)). With respect to basic skills, Tyler (2004) estimates a model relating cognitive skills (measured by a post-schooling math test), schooling, and earnings. He concludes that basic cognitive skills matter for earnings of young dropouts. Increasing their basic skills by one standard deviation leads to 6.5% higher earnings within the next three years.

Finally, Rubb (2003) investigates the effects of overeducation (o), required education (r) and undereducation (u) by estimating the following log-linear wage equation for individual i:[11]

$$\ln W_i = \alpha + \beta_r S_{ir} + \beta_o S_{io} + \beta_u S_{iu} + \delta\Phi_i + \varepsilon_i \tag{4}$$

with

$$S_{io} = S_{ia} - S_{ir} \tag{5}$$

$$S_{iu} = S_{ir} - S_{ia} \tag{6}$$

W_i represents the wage of individual i, S_r is the required years of schooling, S_a describes the actual years of schooling and Φ is a vector of other control variables including work experience. Rubb (2003) finds that the premium for overeducation is about the same magnitude as the penalty for undereducation but lower than the reward for required education, i.e. $\beta_r > \beta_o \approx |\beta_u|$. By using the same econometric specification, Bauer (2002) confirms these results for Germany.

4.2.2 The Rate of Return Depending on Gender

In the UK, the average annual return to a first degree in terms of hourly wages (compared to just A levels) is in the range of 5% to 8% for men and 10% to 13% for women (Blundell, Dearden, Meghir, and Sianesi (1999)). Studies from other countries also find that investments in women's education tend

[11] This econometric specification is due to Verdugo and Verdugo (1989). The distinction between received level of education and required education is made by Duncan and Hoffman (1981). In a matching model with ex-post wage bargaining, Charlot, Decreuse, and Granier (2005) demonstrate that both over- and under-education may take place in equilibrium, depending on the relationship between private and social returns to education.

to yield higher rates of return than investments in men's education. For example, Butcher and Case (1994) find higher returns for women in the US. In this context, Mincer and Opek (1982) suggest that the restoration of human capital - after labor market interruptions associated with the depreciation of human capital - is more efficient than the accumulation of new human capital by men who stay inside the labor market the whole time.

This gender difference in the returns to education arises because the earnings of women are considerably lower than those of men (Blundell, Dearden, Meghir, and Sianesi (1999)). The gender wage gap can be decomposed into three different parts: gender differences in human capital accumulation, occupational sex segregation[12], and discrimination[13] (as residuum) (Kanazawa (2005)). According to Winter-Ebmer and Zweimüller (1992), occupational sex segregation can have three different reasons: different preferences for various occupations, crowding (i.e. disadvantages in "male jobs" leading to oversupply in the more "female jobs"), and human capital theory. With respect to human capital theory, Blackburn (2004) empirically finds that men perform better in math-oriented tests and women better on speed-oriented tests. However, he argues that test score differences explain only a small part of the gender wage gap.

Another explanation for the gender wage gap my be the fertility decision of women which leads to labor market interruptions. This gives rise to gender differences in the turnover rate and thus in employment and wages (Erosa, Fuster, and Restuccia (2002)). Polachek (1981) extends this argument to a rationale for occupational sex segregation and suggests that women tend to choose jobs with low penalties for intermittent employment. Although this reasoning is rejected by England (1982), Schumann, Ahlburg, and Mahoney (1994) find that the male-female wage differential can be partially attributed to job characteristics. In an empirical study for apprentices in West Germany, Kunze (2005) verifies a gender wage differential of about 25% that is attributed to occupational segregation. However, Blau (1998) suggests that the convergence in male and female college majors may be responsible for a reduction in the gender wage gap during the 1980s.

4.2.3 The Rate of Return Depending on Time

In his empirical analysis for Thailand, Hawley (2004) finds increasing returns to education over time which are fluctuating depending on gender and the type of skill. The general trend of rising returns to human capital in the 20th century is analyzed in a theoretical model by Acemoglu (2002). He suggests that the increasing supply of skills leads to skill-biased technological change. As a consequence, the demand for skills rises and thus the returns to skill and wage inequality increase. In a nutshell, the individual returns to education change over time due to the increased interaction between demand for and supply of workers at each qualification level. Individuals working in an industry with rapid technological change have above-average returns to education, which can be attributed to the positive correlation of education and adaptability to new technologies in high-tech firms (Lillard and Tan (1992)).

[12] If different occupations require different skills and people are differently equipped with these skills, individuals have comparative advantages for one occupation leading to self-selection into different occupations (Paglin and Rufolo (1990)). Another explanation for the development of comparative advantages is given by Rosen (1983).

[13] Bloch and Smith (1977) and Bloch and Smith (1979) find sex discrimination much more important than race discrimination.

According to Juhn, Murphy, and Pierce (1993), rising wage inequality stems from two dimensions of inequality which have been growing over time: the return to education and within-group inequality. However, Mincer (1997) suggests that (log) wages are an increasingly convex function of years of schooling, which implies that growing wage inequality is essentially concentrated at the top of the wage distribution. By analyzing the distribution of taxable earnings, Piketty and Saez (2003) also find that relative wage gains are disproportionately concentrated in the top end of the wage distribution. Lemieux (forthcoming) and Autor, Katz, and Kearney (2005) show that within-group inequality has grown substantially among college graduates but has changed little for most other groups. This unbalanced development of the variation in wages points at a rising trend in the return to postsecondary education (Lemieux (2006)).

4.2.4 The Rate of Return Depending on Family and School Quality

Empirical research has also highlighted the importance of other factors in affecting the return to education. These factors are for example innate ability (Dearden (1998)), family income, parental education, and the number of siblings (Butcher and Case (1994)) as well as school quality and the proximity to a college (Card and Krueger (1992)). For example, Lam and Schoeni (1993) show that in Brazil the estimated returns to schooling decrease by about 30% if parental schooling is added as a family background variable to the wage equation.

Card and Krueger (1992) use state-level data to estimate the effect of school quality on the return to education for men born between 1920 and 1949. They find that men educated in states with lower student/teacher ratios, longer average term length, and higher-paid teachers have higher rates of return. By using individual-level data, Altonji and Dunn (1996) estimate the effect of parental education and school quality on educational returns. In most of their specifications, having a more educated parent is associated with a higher return to education while school expenditures per student do not have a positive effect.

In these studies, family and school effects are analyzed with respect to their impact on the return to education but they are not allowed to directly affect the process of human capital formation. The importance of this shortcoming will become more evident when contrasted with the concept of education production functions. This stream of literature takes the opposite position and assumes that the schooling environment directly affects the decision how much education to obtain (cf. Section 5). For example, Wilson (2001) estimates a model that allows family, neighborhood, and school characteristics to affect educational attainment both indirectly through the expected return to education and directly as inputs into the educational production process. She finds that background characteristics predominantly work directly and not through their impact on returns to education.

4.3 Problems of the Empirical Analysis

There are several problems in empirically estimating the true causal effect of education on individual earnings. The most discussed of them is whether higher observed earnings for better-educated workers

are caused by their higher education or whether individuals with greater innate ability and thus higher earning capacity choose to acquire more education. If econometric specifications omit the direct influence of ability, the estimated return to education is biased upward, which is referred to as ability bias due to the positive correlation of ability and education. However, even with ability as an independent variable empirical estimates will be biased (sorting bias) because they are unable to separate the contribution of ability from that of education (Heckman and Vytlacil (2000)). In this context, Murnane, Willet, Duhaldeborde, and Tyler (2000) argues that at least 50% of the full return to higher achievement can be attributed to individual ability.

A further problem with the Mincerian approach is the endogeneity of schooling. IV studies that use exogenous variations in the schooling decision indicate that the estimated OLS values are too small, i.e. the OLS estimates are biased downward. The magnitude of this endogeneity bias is controversial in the literature. While Angrist and Krueger (1991) suggest a limited impact of endogeneity, Harmon and Walker (1995) find a rather large effect.

Finally, Lindsay (1971) notes that a correct measure of returns to education would consist in the wealth effect of increased wages due to human capital investment, but not in the simple income difference. With increasing wages leisure is substituted for hours worked (if the substitution effect of labor supply is larger than the income effect), which generates an upward bias in the estimated return to education that is positively related to the size of the investment.

4.4 Human Capital Theory versus Signaling

As shown in Section 4.2, empirical results suggest that education provides significant wage increases to individuals. But the positive impact of schooling on earnings could have two different explanations: (1) human capital theory (i.e. education as productivity-enhancing activity), and (2) signaling (i.e. education as indication of innate ability) (Kroch and Sjoblom (1994)).[14] It is important to differentiate between these two concepts because their implications for the optimal amount of education are completely different.

Kroch and Sjoblom (1994) empirically compare the two competing theories by estimating earnings equations that include both absolute (i.e. years) and relative (i.e. percentile) measures of education. They find that only years of schooling affect earnings, which provides evidence for human capital theory. Groot and Oosterbeek (1994) test human capital theory by distinguishing between actual and effective years of schooling with respect to the Dutch educational system. Because earnings are related negatively to class-skipping, positively to dropout years, and neutrally to repeated years, the results of Groot and Oosterbeek (1994) strongly support human capital theory.

Furthermore, Black and Lynch (1996) empirically analyze whether education is positively correlated with productivity as suggested by human capital theory. They find that a 10% increase in average education leads to a productivity-enhancement of 8.5% in manufacturing and 12.7% in non-manufacturing,

[14] The concept of signaling is based on Spence (1973).

respectively. By using international data on test scores and wages for eleven countries and two birth cohorts, Bedard and Ferrall (2003) show that test score dispersion and wage dispersion are positively related.

5 The Education Production Function

According to Hanushek (1971), the severest problem in educational research is the complexity of the educational process. Hence, there is considerable confusion about how empirical studies should be conducted and interpreted (Hanushek (1979)). Unlike common assumptions concerning the production in firms, the educational process is characterized by two special features: first, inputs may not be converted efficiently to outputs, and second, simple school expenditures may not measure accurately the amount of all inputs (Hanushek (1996a)). There are two kinds of potential inefficiencies in the allocation of school resources: the misallocation of resources between different units (although the resources may be used efficiently in each unit) and the inefficient use of given resources (although they may be allocated efficiently) (Bishop and Woessmann (2002)).

Many studies focus on the effects of school characteristics on educational attainment within the framework of education production functions. The educational production process is modeled as in the theory of the firm but with a modified interpretation of economic efficiency (Hanushek (1986)). The relationship between inputs and educational output is assumed to be deterministic and depends on the technology of the education production function.

5.1 Inputs in Educational Production

The measurement of school inputs and outputs varies from study to study, but most studies measure inputs as expenditures per student, student-teacher ratios, teacher salaries, class size, family background, peer groups, and individual ability. For about two thirds of the studies, the output of educational production is measured by test scores.[15] The other one third focuses on quantity of schooling achieved, such as high-school graduation or college attendance (Bishop and Woessmann (2002)).

5.1.1 The Level of Resources

The relationship between school expenditures and educational outcome reached a lot of public awareness with the so-called Coleman Report that analyzes the equality of educational opportunities. It suggests that resources have only little impact on educational attainment (Coleman (1966)). Subsequently, various studies have presented mixed conclusions concerning the dependency of student achievement on public expenditures.

[15] We do not address the question whether test scores are adequate for measuring educational output. Using data from the National Education Longitudinal Study of 1988, Rose (2006) suggests that, at least for women, test score gains effect both the status of employment and earnings. Also Murnane, Willet, Duhaldeborde, and Tyler (2000) find that one standard deviation increase in mathematics performance at the end of high school translates into 12% higher annual earnings.

In his influential work, Hanushek (1986) reviews 147 regressions (taken from 33 separate published studies) regarding the effects of school characteristics on educational attainment. According to Hanushek, Rivkin, and Taylor (1996), the separate studies are different along two dimensions: the level of data aggregation (in many studies data are aggregated at state level) and the degree of control for other variables that potentially influence educational performance (for example family background). In a nutshell, Hanushek (1986) compares the sign and the significance of the estimated effects of school inputs. Due to a lack of consistent findings, he concludes that "there appears to be no strong or systematic relationship between school expenditures and student performance", at least after variations in family inputs are taken into account.

Hedges, Laine, and Greenwald (1994) reexamine the same studies like Hanushek (1986) but draw a much different conclusion by summarizing that expenditures are positively related to school outcomes. While Hanushek (1986) uses a "vote counting" selection rule of weighting the separate studies (i.e. the results of each regression receive one vote), Hedges, Laine, and Greenwald (1994) use a more sophisticated method accounting for the size of the estimate, the expected correlation in the error terms from regressions estimated over the same sample, and the potential influence of outliers.

By applying more explicitly defined search criteria to the selection of relevant studies, Greenwald, Hedges, and Laine (1996a) again conclude that educational resources are positively related to student achievement. Hanushek (1996b) criticizes this "specialized meta-analytic approach" by pointing out systematic distortions towards the desired conclusions. Greenwald, Hedges, and Laine (1996b) reject this reproach by explaining their different understanding of "statistical independence". In a further approach, Hanushek (1997) reviews about 400 studies in order to investigate the relationship between student performance and school resources. He finds that most estimates are not simultaneously positive and significant.

Unfortunately, also more recent studies are not able to resolve whether the level of resources is a significant determinant of educational attainment (cf. table 3). On the one hand, Wilson (2002) uses US data to examine the impact of school expenditures on earnings. By controlling for extensive measures of family background and neighborhood, she finds that school expenditures positively affect both earnings and returns to education. Furthermore, Winter-Ebmer and Wirz (2002) estimate that raising educational expenditures by 1% leads to an increase in the college enrollment rate by 1%. On the other hand, by using data from the Third International Mathematics and Science Study (TIMSS), Hanushek and Luque (2003) compare the performance in different schooling systems and different countries. They find evidence of inefficient input-based schooling policies, independent of the income level of the country and the resource level of the school.

5.1.2 Class Size

In line with Greenwald, Hedges, and Laine (1996b), Krueger (2003) criticizes the conclusions of Hanushek (1986) and proposes a different selection rule, namely "equal weight to every study". With this method class size becomes a significant determinant of student achievement. Also Tennessee's Project STAR, a

Input	Empirical evidence
level of resources	ambiguous
class size	weak
school competition	weak
private schools	ambiguous
teacher quality	strong
teacher incentives	strong
early education	strong
individual ability	strong
parental education	strong
family income	weak
neighborhood	weak
peer groups	strong
segregation	ambiguous

Table 3: Inputs in Educational Production

random-assignment experiment, seems to prove empirically the performance-enhancing effect of class size reductions. However, Hanushek (1999) argues that there are several experimental features biasing upward the estimates of Project STAR. His objections are in detail: (1) design and implementation issues, (2) the estimated effect is only valid if students are very young, (3) the estimated effect is only valid for very large reductions in class size, (4) teacher quality is much more important than class size reductions, and (5) the costs of such class size reductions have to be considered. Furthermore, Heckman, Layne-Farrar, and Todd (1996) find only little empirical evidence for the connection between class size and earnings.

However, Dustmann, Rajah, and Soest (2003) draw a different conclusion in their analysis of class size, education, and wages. They suggest that lowering the pupil-teacher ratio (as measure for class size) causes an increase in the wage rate. This effect is generated by two channels: a direct effect of reduced class size on wages and an indirect effect by increased probability of staying in school at age 16. With respect to the analysis of different school resources by Hanushek (1997), Hanushek, Leung, and Yilmaz (2003) agree that class size constitutes the most validated input factor of all school resources. In an empirical study for Italy, Brunello and Checchi (2005) analyze the dependency of educational attainment on school quality (measured by the pupil-teacher ratio) and family background (measured by parental education). They conclude that school quality and family background both positively affect educational achievement and constitute complements in the production of human capital.

Altogether, the empirical evidence of class size reductions is weak but generally positive (cf. table 3). Starting from these empirical findings, Lazear (2001) develops a "disruption model" with class size as the main determinant of educational production (cf. Section 5.1.8).

5.1.3 Institutional Incentives

Instead of additional school expenditures, Hanushek (1997) proposes institutional incentive structures (i.e. output-based schooling policies) to recognize differences of students, teachers, and schools. In a nutshell, Hanushek (1997) suggests three types of efficiency-enhancing incentive schemes: merit pay for

teachers and schools, acceptance of private schools, and increased competition between schools (Hanushek, Leung, and Yilmaz (2003)). In this context, Bishop and Woessmann (2002) refer to six institutional features affecting the educational production process. These are the degree of centralization of the examination system, the degree of centralization of school organization, the degree of teacher unionization (as measure of teachers' influence), parental influence (for example in choosing which school their children should attend), the degree of competition between schools, and the distribution of responsibilities between different administration levels.

In the empirical literature, it is controversial whether there is a difference between private and public education on the student achievement and whether private school competition improves the outcome of public schools. In this context, school vouchers may be an important instrument to allocate monetary stipends so that parents can send their children to the schools (either public or private) they find the most suitable.

While Rouse (1998) finds substantial benefits of school vouchers with respect to the Mikwaukee voucher experiment, Witte (2000) does not. Furthermore, Evans and Schwab (1995) conclude that private schools outperform public schools, but Goldhaber (1996) does not confirm this empirical result. In their empirical analysis concerning undergraduate students at Ball State University, Horowitz and Spector (2005) suggest that religious private schools perform slightly better than others, but this influence is small and seems to disappear in later years. By evaluating the effectiveness of private education across countries with data from the PISA 2000 study, Vandenberghe and Robin (2004) conclude that private education does not generate systematic benefits.

Finally, Hoxby (2002b) suggests that private school competition leads to a better performance of public schools, but Arum (1996) argues that this result may be only due to increased funding for public schools rather than due to the competition itself. Hence, while competition among schools seems to have a positive effect of educational production, the empirical evidence concerning the promotion of private schools is mixed (cf. table 3).

5.1.4 Teacher Quality and Incentives

According to Hanushek (1989), differences in school quality are generated by "teacher skills" that are not strongly related to teacher education, teaching experience, and class size.[16] By using student-level data, Hanushek, Kain, and Rivkin (1998) suggest that at least 7.5% of the total variation in student achievement can be explained by teacher fixed effects. Hence, educational reforms should focus on improving the quality of the teacher force (cf. table 3). This requires a new set of incentives by introducing selective hiring, retention, and pay (Hanushek (2006)).

Teachers in public schools face weak performance incentives because tenure is granted and the wage is generally independent from effort and outcome. Ballou and Podgursky (1998) and Ballou (1999) investigate the causes and consequences of weak incentives among public school teachers. Relative to public

[16] These teacher skills "cannot be described correctly, but possibly can be observed directly" (Hanushek (1986)).

schools, private schools adopt hiring and pay practices which favor teachers with better overall academic ability. Hence, school vouchers and competition between public and private schools may generate changes in hiring and pay practices that attract more talented individuals into the teaching profession (Hoxby (2002a)).

In a nutshell, it not only the teacher quality but also the teacher incentives that significantly affect the educational outcome. For this reason, Hanushek (1989) and Hanushek (1997) propose merit pay for teachers and schools in order to provide better institutional incentive structures. In this context, the role of economic incentives at universities is empirically analyzed by Lach and Schankerman (2003). They find that increasing the share of license royalties received by academic inventors (i.e. the share not passed on the general university budget) enhances research activity by two channels, namely by increasing the research effort and by sorting (i.e. attraction of better researchers). This effect is much stronger for private universities.

In general, Lazear (2000) analyzes existing compensation schemes that are either input-based, output-based, or a combination of them and can be summarized by the following pay structure:

$$w_i = \alpha q_i + \beta \{q_i > q_{\min}\} + \gamma e_i + \delta \{e_i > e_{\min}\} \tag{7}$$

w_i represents the wage of teacher i, q_i is a measure of output and e_i describes the teacher's effort. β and δ are dummies equal to one if a certain minimum output $q_{\min}$ or a minimum effort $e_{\min}$ are exceeded, respectively. In a nutshell, α and β are parameters related to an output-based compensation scheme, while γ and δ are related to an input-oriented pay structure. Furthermore, the dummies represent compensation in discrete steps, while α and γ stand for continuously paid wages.

If α is the only parameter different from zero, then the pay structure is said to produce "high-powered incentives". Concerning merit pay for teachers, the optimal compensation scheme depends on the observability of output and the heterogeneity of teachers (Lazear (1986)). Compared to input-based wages, output-based compensation schemes lead to strong sorting of teachers according to their productivity (Lazear (2000)).

5.1.5 Early Education

Ritzen and Winkler (1977) and Psacharopoulos (1994) propose to promote very young and high-ability children because their returns to education exceed those of older and less able students, respectively. According to Heckman and Masterov (2004), the main mechanisms through which early education affects productivity is through its impact on cognitive and non-cognitive skills. Furthermore, the impact of peer abilities appears to be large for the skill development of very young children in preschool (Henry and Rickman (forthcoming)).

Early education may be more effective than offering costly training for those experiencing difficulties graduating from high school (Heckman (2000)). This result is empirically confirmed by Temple and Reynolds (forthcoming) who show that there are consistently positive economic returns of preschool

programs that exceed most other educational interventions, especially later programs such as class size reductions and youth job training (cf. table 3).[17]

5.1.6 Family Background and Neighborhood Effects

Haveman and Wolfe (1995) provide an overview of empirical estimates concerning the influence of family and neighborhood variables. The strong effect of parental education on children's educational success stands out in this research. The economic status of the family (measured by total family income) also tends to be positively correlated with educational attainment. For example, by estimating the influence of maternal education on the human capital of their children, Rosenzweig and Wolpin (1994) find that each additional year of schooling increases the children's test scores significantly by 2.4%. Furthermore, Loury (2006) suggests that also older extended family members (i.e. aunts, uncles, and grandparents) independently affect the schooling of same-gender children.

Concerning the students' choice of alternative programs of study during high school, Zietz and Joshi (2005) suggest that family background and peer pressure constitute the most important determinants of the program choice. Students from families with higher level of education and higher income are more likely to pursue the college program. According to Astone and McLanahan (1991), growing up in an intact family is associated with substantially higher educational achievement. Hanushek (1992) finds that family size negatively affects educational outcome. He attributes this effect to the parental trade-off between number of children and their schooling performance.

As shown in table 3, neighborhood effects tend to be small relative to the influence of parental education. Nevertheless, the estimated effects are often statistically significant, even when controlling for an extensive number of family characteristics. For example, Brooks-Gunn, Duncan, Klebanov, and Sealand (1993) estimate that the fraction of families with high and low incomes affect educational attainment. Furthermore, Datcher (1982) uses ZIP code-level data and concludes that the racial composition of the neighborhood is not significantly correlated with educational attainment. In a similar setup, Corcoran, Gordon, Laren, and Solon (1992) find that living in a neighborhood with more mother-only families and more people on public assistance reduces educational attainment, but that median income and male unemployment do not have significant effects.

5.1.7 Peer Effects

Peer effects describe the external effects by some students to others. According to Epple and Romano (1998), peer effects can be defined as the influence of students' mean ability on school quality. Hoxby (2000) concretizes this expression by specifying knowledge spillover, influence on classroom standard, and individual behavior (i.e. self-discipline and disruption). Most empirical studies focus on socioeconomic status indicators of peer quality, such as average income or the percentage of people with college graduation. Some studies also concentrate on the composition of peer groups, for example the proportion of

[17] However, the estimated effects on early human capital formation may be only short-lived as suggested by DeCicca (forthcoming) in his empirical analysis of full-day kindergarten.

different ethnic groups. In this context, the Coleman report concludes that peer effects in public schools contribute to differences in the educational achievement of black and white students (Coleman (1966)).

According to Manski (1993) and Rivkin (2001), there are three problems in estimating peer effects: (1) endogeneity (i.e. self-selection due to family income or educational preferences), (2) the simultaneous interaction of students' mutual influence, and (3) the difficulty to distinguish between peer effects by individual background and peer effects by individual behavior. A number of studies attempts to solve the endogeneity problem, but so far no clear consensus exists regarding its severity.

Evans, Oates, and Schwab (1992) find that there are no peer effects once endogeneity is controlled for by estimating simultaneous equations. By using fixed-effects models that rely on peer variation between siblings and controlling for parental characteristics, Aaronson (1998) find significant peer effects while Plotnick and Hoffman (1999) do not. In order to solve the problem of self-selection, Sacerdote (2001) uses a sample of the Dartmouth College with random assignment of roommates. He finds that - at room level as well as at dormitory level - peers indeed exert significant influence on the Grade Point Average (GPA). In contrast, Arcidiacono and Nicholson (2005) investigate the effect of peer groups with respect to a non-random category of students, namely medical students who graduated from US medical schools between 1996 and 1998. They find that the peer effects disappear if school fixed effects are included in order to control for endogeneity.

Hoxby (2000) uses some idiosyncratic variation of students in order to estimate peer effects with an endogeneity bias as small as possible. She concludes that augmenting the reading scores of the peer group by one point leads to an increase in the individual test score by about 0.15 to 0.4 points. Another approach is pursued by Lefgren (2004) who compares the academic achievement of high-ability students in segregated and integrated schools. He finds that peer effects are small but generally positive and significant.

By taking data from the PISA 2000 study, Fertig (2003) analyzes the influence of achievement heterogeneity in a peer group (measured by the variation coefficient) on the individual educational attainment. In order to circumvent the endogeneity problem, he uses an IV approach to estimate the following equation:[18]

$$y_{ijs} = \alpha + \beta' z_i + \gamma C_j^{-i} + \delta' \bar{z}_j^{-i} + \lambda' z_s + \varepsilon_i \tag{8}$$

z_i is a vector of individual characteristics, $\bar{z}_j^{-i}$ is a vector of the corresponding peer group characteristics, C_j^{-i} represents the variation coefficient, z_s is a vector of school characteristics, and ε_i is an unobserved error term. In this context, γ measures the endogenous part of the peer effect (i.e. the direct impact of group achievement), while δ describes the exogenous or contextual effects (i.e. the indirect impact of other peer characteristics, for example group composition).

In a nutshell, Fertig (2003) obtains the following empirical result: the higher the heterogeneity of the

[18] The variation coefficient is defined as standard deviation devided by mean.
PISA is the abbreviation for "Program for International Student Assessment". The PISA 2000 data contain test scores in reading, mathematics, and science literacy of representative samples of 15-year old students across OECD and non-OECD countries. Furthermore, they provide a rich set of background information about students and schools. For the empirical analysis on hand, Fertig (2003) only uses the reading scores for US students.

peer group, the lower is individual educational outcome. As a consequence, the aggregate educational output should be maximized if schools exhibit perfect homogeneity of students. However, Fertig (2003) admits that the explanatory power of the endogenous variable declines substantially when exogenous effects are controlled for.

5.1.8 Segregation

As illustrated in the previous subsection, the presence of peer effects gives rise to the idea of an efficient sorting of students according to their innate ability (Epple and Romano (1998)). In general, there are two possibilities of putting together students with different individual abilities: integration (i.e. randomized mixing) and segregation (i.e. sorting according to the students' abilities).

Segregation implies that classes are completely homogenous and theoretically, the individual deviation from mean ability is zero. For example, the educational system of Germany is one of the most segregated among industrialized countries. Depending on the student's ability, there are four types of German secondary schools: lower (*Hauptschule*), middle (*Realschule*), upper (*Gymnasium*), and mixed (*Gesamtschule*) (Cooke (2003)).

Lazear (2001) makes an important attempt to analyze the effects of segregation in a model based on microeconomic considerations. In his "disruption model", m_j represents class size (i.e. the number of students in class j) and p is the probability that a student behaves so that lessons can be given without disruption. The total amount of learning (L_j) in class j is defined by the following education production function:

$$L_j\left(m_j, p\right) = m_j p^{m_j} \tag{9}$$

If there are different ability-types of students with different disruption probabilities, the aggregate educational output is generally larger with segregation than with integration. Hence, in line with Fertig (2003), the aggregate educational output is maximized if schools exhibit perfect homogeneity of students. However, Lazear (2001) also refers to one important exception from this conclusion: if students with low-ability can be transformed into high-ability students by undergoing social contact with these better behaving students, then mixed classes may yield higher educational outcomes than segregation. Altogether, the effect of segregation on the educational achievement of students is ambiguous (cf. table 3).

5.2 Models of Educational Production

Nechyba (1996) incorporates peer effects into the following education production function that describes the educational achievement (y_{ij}) of individual i in peer group j:

$$y_{ij} = \left(\bar{y}_j\right)^{\rho} \left(e_j\right)^{1-\rho} \tag{10}$$

with ρ measuring the strength of the peer effect. In this production function, e_j describes the expenditures per student in group j, and $\bar{y}_j$ is the average educational outcome of peer group j.

If the educational system allows for private schools in combination with private school vouchers, then there is endogenous ability-based segregation so that each private school is completely homogenous in ability. This is shown by Nechyba (1996) who undertakes general-equilibrium simulations within the framework of his education production function (10). In a theoretical model with public schools (financed by taxes and without tuition) and private schools (completely financed by tuition), Epple and Romano (1998) draw a similar conclusion. They demonstrate that there is a strict hierarchy of school qualities and a two-dimensional student sorting according to ability and income. Quite intuitively, the implementation of tuition vouchers benefits high-ability students relative to students with low ability.

Caucutt (2002) expands on Nechyba (1996) by considering different ability levels θ_k (with n_{kj} as the fraction of ability type k in peer group j):

$$y_{ij} = \alpha \left(\theta_i\right)^{\beta_1} \left(\sum_k n_{kj}\theta_k\right)^{\beta_2} \left(e_j\right)^{\beta_3} \tag{11}$$

Based on this education production function (11), Caucutt (2001) and Caucutt (2002) develop a general-equilibrium model (with schools interpreted as clubs) where the change from a public school system (with endogenous number of private schools) to a completely private system of schools with vouchers yields several mixed schools with sorting according to ability and tuition fees.

6 Human Capital and the Life-Cycle of Earnings

6.1 The Accumulation of Human Capital over the Life-Cycle

An important stream of human capital literature deals with the life-cycle of earnings. Mincer (1958) points out that the difference between normally distributed abilities and the positively skewed distribution of incomes must be due to investments in human capital over the life-cycle.[19] Becker (1964) suggests that earnings increase with age but at a declining rate. In a nutshell, Mincer (1970) and Mincer (1997) summarize the empirical evidence concerning the age-earnings profile of individuals. Earnings (E_t) positively depend on the stock of human capital (H_t) at date t; the age-earnings profile is concave and at least for a long time upward-sloping. If human capital investment increases, the age-earnings profile becomes steeper and has its maximum later. These empirical findings are illustrated in figure 2.

Becker (1962) notes that human capital investment decreases with age. Intuitively, this is because younger workers receive the returns to education over a longer period and the investment risk increases with age (which implies that older workers discount future earnings more heavily) (Zucker (1967)). In a nutshell, decreasing marginal returns and increasing marginal costs lead to an optimal amount of human

[19] The normal distribution of abilities is also assumed by Becker (1964).

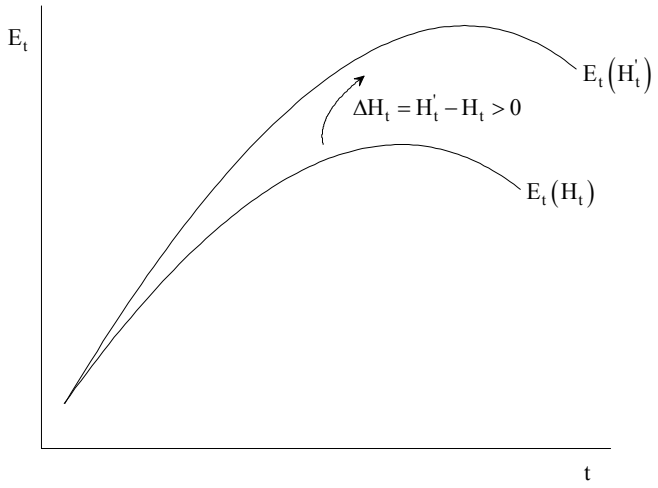

Figure 2: Human Capital and the Life-Cycle of Earnings

capital investment that negatively depends on age (Mincer (1970)). However, human capital investment may not monotonically decline with age if the accumulated human capital is rather specific than general. While the profitability of general skills depends on the length of working life, the profitability of specific skills only depends on the expected duration of the current job (Bartel and Borjas (1977)).

Models of (general) human capital accumulation over the life-cycle can be attributed to two different branches: earnings maximizing models and utility maximizing models. Earnings maximizing models abstract from the labor-leisure choice problem and only analyze the trade-off between investment and income. At the intensive margin, the individual faces a trade-off between producing additional human capital and renting his existing stock of human capital in the labor market. Utility maximizing models also incorporate the labor-leisure choice so that labor supply becomes endogenous to the model. The difference between these two types of models is illustrated by Snow and Warren (1990) who explain that the income effect of higher wages (due to investments in human capital) on future labor supply may reduce realized future earnings. However, there are efforts to integrate these two branches, for example by Blinder and Weiss (1976). Weiss (1986) provides a review of the theoretical literature.

Ben-Porath (1967) develops an earnings maximizing model of human capital accumulation and gives a productivity-based explanation of earnings growing with age. He emphasizes the process by which additions to the individual stock of human capital are produced. The model is similar to Becker (1964) in the sense that each individual is presumed to combine market goods (D_t) with some portion (s_t) of his own human capital (H_t) to produce new human capital (Q_t) in period t according to the following production function:

$$Q_t = f(s_t, H_t, D_t) = \beta_0 (s_t H_t)^{\beta_1} (D_t)^{\beta_2} \tag{12}$$

The rate of change of the stock of human capital is equal to

$$\dot{H}_t = Q_t - \sigma H_t \tag{13}$$

where σ represents the depreciation rate of human capital. The individual maximizes the sum of all future disposable earnings discounted over the life-cycle. The individual decision problem consists in choosing that portion of the existing stock of human capital to be used as input in the production of further human capital. This choice is made by comparing the costs of producing an additional unit of human capital to the marginal benefits. The whole decision problem can be divided into two separate parts: first, the trade-off between income and human capital formation, and second, the timing of consumption.

Heckman (1976) designs a utility maximizing model with endogenous labor supply, income, human capital accumulation, consumption, and non-monetary utility of education, which contains the original model of Ben-Porath (1967) as a special case. Human capital accumulation takes place according to the following relationship:

$$\dot{H}_t = f\left(I_t H_t, D_t\right) - \sigma H_t \tag{14}$$

H_t represents the stock of human capital at date t, I_t is the time devoted to human capital production, D_t stands for the direct costs, and σ is the depreciation rate of human capital.

Even the basic model by Ben-Porath (1967) manages to replicate the most important qualitative characteristics of the empirical life-cycle patterns. According to Ben-Porath (1967), there are three different phases of human capital accumulation: an initial phase with no earnings (i.e. full-time human capital production, interpreted as "formal schooling"), a long phase with part-time human capital production, and a third phase with no training.[20] The second phase is characterized by earnings increasing at a declining rate (and eventually decreasing). At any point in time, individuals with more schooling or greater ability invest more in on-the-job training.

A serious problem of the empirical application of human capital theory to life-cycle differences in earnings is that post-school investments are not directly observable. As a consequence, measurement problems arise because a wide range of activities might be viewed as on-the-job training (Hanushek and Quigley (1985)). By using data from the NLLS, Haley (1976) empirically estimates the model by Ben-Porath (1967) and concludes that it fits the data quite well. In contrast, Brown (1976) finds only a poor performance of the model. However, Heckman (1976) finds that his model fits the data well and even better than Ben-Porath (1967).

The hypothesis that earnings profiles are driven by human capital investment is further analyzed by Mincer (1997). For the US, he confirms that post-school investment in human capital is indeed the primary factor underlying the wage profiles. He also finds empirical support for the implications by Ben-Porath (1967) concerning the positive relationship between ability, schooling, and on-the-job training.

Besides this vast literature on life-cycle human capital investment, there is a strand of literature concentrating on the extensive margin. The extensive education decision divides the workforce into different skill groups such as low-skilled and high-skilled workers. This mostly empirical literature analyzes self-selection of students into skill groups according to ability types which affects estimates of occupational choice and thus the distribution of earnings.[21] For example, Willis and Rosen (1979) as well as

[20] Wallace and Ihnen (1975) develop a model to describe endogenously the "formal schooling" period and the end of this phase depending on the parameters of the model. They suggest a longer "formal schooling" period than Ben-Porath (1967).

[21] The first source is Roy (1951), which has received subsequent elaboration, for example by Heckman and Honoré (1990).

Heckman, Lochner, and Taber (1998a) derive a theoretical model of the demand for college attendance and empirically show that expected lifetime earnings differentials indeed influence the college attendance choice.

6.2 Implications of Pension Systems for Human Capital Formation

According to Echevarría (2003), the return to human capital investments is affected by the pension system if finite horizon economies are considered. With a tax-benefit link, the return to education is not restricted to increased labor incomes, but also extends to pensions during retirement. Hence, if workers decide on the optimal amount of human capital investments, they take into account not only the effect on future labor incomes but also on future retirement benefits (Echevarría and Iza (2005)).

Lau and Poutvaara (2001a) and Lau and Poutvaara (2001b) study the impact of social security incentives on human capital formation, arguing that actuarial fairness and a tight tax-benefit link increase human capital along with an increase in the retirement age. This is a common result in most theoretical analyses because postponed retirement lengthens the time period at the extensive margin over which individuals can appropriate the benefits from human capital investments, which translates into higher returns to education (Trostel (1993)). Hence, the return to education positively depends on the remaining active years. In a nutshell, postponed retirement raises aggregate human capital because higher returns to education are associated with increased human capital investments (Echevarría (2003)).

In their analysis of demographic transition and economic growth, Kalemli-Ozcan, Ryder, and Weil (2000) show in an OLG framework that augmented life expectancy gives rise to increased human capital formation. In a similar setup, de la Croix and Licandro (1999) investigate an economy where the workers accumulate human capital as a function of their optimal schooling period. The effect of lower mortality rates on human capital formation is positive because the increased expected flow of future incomes will increase human capital per capita. The same result is obtained by Boucekkine, de la Croix, and Licandro (2002) under a setting with uncertain lifetime horizon and endogenous retirement age. Echevarría (2003) argues that an increase in life expectancy translates into higher growth rates by increased human capital formation only if demographic change is accompanied by simultaneous increments in the length of the working life. Hence, if there is a positive correlation between life expectancy and retirement age, an increase in life expectancy will foster the formation of human capital. For the UK, this result is empirically confirmed by Kalemli-Ozcan, Ryder, and Weil (2000).

In a nutshell, because the PAYG pension system generates distortions in labor supply and thus provides incentives for early retirement, aggregate human capital is lower than with a capital funded system of old-age provision. The reason is that the PAYG system discourages human capital formation both directly and indirectly via the retirement age (Echevarría and Iza (2005)). Moving the pension system from PAYG towards capital funding eliminates the distortions in the labor market and thus increases the workers' retirement age and the investment in human capital (Feldstein (2005)).

Furthermore, the positive relationship between retirement age and human capital accumulation also holds in the opposite direction. According to Hernoes, Sollie, and Strom (2000), education is an important

determinant of the retirement age. A higher stock of human capital increases the retirement age because the worker's higher productivity implies increased labor incomes and makes labor supply more worthwhile compared to retirement. Hence, while early retirement is low among high-skilled workers, low-skilled workers may take the opportunity to retire at the lowest possible date.

7 Fiscal Policy and Human Capital Formation

Weisbrod (1966) assigns to the government the role of using its limited resources for the economic well-being of its people. Hence, it is important to investigate tax and expenditure issues in an integrated analysis because they constitute "Siamese twins" concerning the maximization of aggregate welfare (Bovenberg and Jacobs (2005)). For example, with respect to the optimal level of education subsidies, social welfare is maximized subject to the public budget constraint (Steuerle (1996)).

However, the design of tax and education policies must also consider the special characteristics of human capital (Anderberg and Andersson (2003)). In this context, Eaton and Rosen (1980) suggest that the efficient tax rate may be greater than zero in order to provide insurance against the riskiness of human capital investments.

7.1 The Effects of Taxation on Human Capital Formation

An ideal income tax should define income uniformly as the sum of earnings from all possible sources. Hence, human capital should be taxed like physical or financial assets (Kaplow (1994)). Theoretically, this implies that human capital should be taxed in three ways: at birth (i.e. the present value of expected future earnings net of costs should be taxed immediately), over time (reflecting the difference between earnings and depreciation of human capital), and at all moments when uncertainty is resolved (Kaplow (1996)).

Because the ideal income tax is not feasible in reality, we analyze the effects of taxing labor and capital income within a prevalent fiscal system. Due to the special characteristics of human capital there are great differences in the taxation of human and physical capital, which leads to radically different tax burdens (Ill (1984)). In the context of his life-cycle model, Heckman (1976) shows that differences in the tax treatment of human and physical capital may induce the substitution of human capital for physical capital investment.

In the absence of direct costs of education, there is no direct effect of a proportional income tax on the accumulation of human capital because both marginal returns and marginal costs are scaled down in the same proportion. With direct costs of education, an increase in the tax rate decreases human capital investment if the net financial benefit before taxes is positive (Heckman, Lochner, and Taber (1999a)). In a nutshell, the marginal effects of proportional income taxation on human capital formation may be significantly negative for three reasons. First, some direct inputs into the process of human capital production are not tax-deductible (in contrast to foregone earnings). Second, the negative effect

of taxation on labor supply reduces the return to education. And finally, the negative effect of taxation on savings reduces the amount of physical capital and thus - by general-equilibrium effects on interest rates and wages - human capital investments (Trostel (1993)).

A progressive income tax strengthens the negative effects of taxation on human capital formation of workers because marginal returns on future earnings are reduced more than marginal costs of schooling by foregone earnings (Heckman, Lochner, and Taber (1999a)). However, higher tax progression my increase the firms' investments in human capital if the degree of tax progression changes the distribution of the surplus between the worker and the firm and thus increases the compression of the wage structure (cf. Section 3.1.2). Hence, if labor markets are imperfect and both the worker and the firm can invest in human capital, higher tax progression increases human capital formation if the positive effect on the firms outweighs the negative effect on the workers (Hungerbühler (forthcoming)). Furthermore, the progressivity of the tax system affects the job mobility of workers. On-the-job search (i.e. the probability of turnover) decreases both with the level of tax rates and with the convexity of the tax system (as measure of progressivity) (Gentry and Hubbard (2002)).

If there is only unskilled labor and physical capital, a "comprehensive income tax" (i.e. the same taxation of labor and capital income) generates two distortionary effects on resource allocation, namely on the intratemporal leisure-consumption trade-off (due to the taxation of labor) and on the intertemporal saving-consumption trade-off (due to the taxation of capital). However, in the presence of skilled labor and human capital, the "comprehensive income tax" generates two additional distortions. On the one hand, it discriminates against physical capital because the capital income tax does not apply to investments in human capital. On the other hand, it discriminates against human capital because the labor income tax reduces the return to education. While the net effect of these two distortions is ambiguous in general, the "comprehensive income tax" discriminates against human capital if there are only direct costs of education and the government does not use the tax revenues to subsidize the human capital formation (Nerlove, Razin, Sadka, and Weizsäcker (1993)).

In contrast, if the only costs of education are foregone earnings, Nielsen and Sorensen (1997) suggest that the "comprehensive income tax" leads to a discrimination against investments in physical capital. Hence, they propose a "dual income tax"[22] (i.e. the combination of a proportional tax on capital income with a progressive tax on labor income) on pure efficiency grounds (and not on the basis of redistribution or insurance arguments) because the progressivity of the labor income tax reduces the return to education.

7.2 The Effects of Tax Reforms on Human Capital Formation

The first attempt to quantify the importance of human capital formation for the comparative efficiency costs of alternative tax bases is due to Driffill and Rosen (1983). In a partial-equilibrium life-cycle model, they conclude that income taxation according to the "comprehensive income tax" can be dramatically more distortionary than the taxation of consumption. As suggested by Perroni (1995), switching from

[22] Nielsen and Sorensen (1997) refer to it as the "Nordic system of dual income taxation" because it was implemented in all four Nordic countries.

income to revenue-neutral consumption taxation provides large welfare gains. In this context, endogenous human capital has only little effects because the substitutability between labor supply and human capital is limited by downward rigidities in the stock of human capital (i.e. the stock of human capital can decrease at most with its rate of depreciation). However, Judd (1998) shows that consumption taxes are generally biased against investment in human capital.

There are several approaches to analyze the welfare consequences of alternative tax policies in a general-equilibrium framework with endogenous human capital formation. Starting point of various numerical simulations is the current US tax system approximated by a proportional tax on capital income and a progressive tax on labor income (Heckman, Lochner, and Taber (1999b)). In a general-equilibrium growth model with OLG and perfect foresight, Perroni (1995) shows that the welfare gains from switching to a revenue-neutral consumption tax are much lower than in a partial-equilibrium setting because prices adjust in response to quantities.

Furthermore, in an OLG dynamic general-equilibrium model with endogenous human capital formation and heterogenous agents, Heckman, Lochner, and Taber (1998b) investigate the consequences of two revenue-neutral tax reforms, namely a flat income tax (i.e. a proportional tax on both labor and capital income) and a flat consumption tax. Analytically, each individual solves a two-step decision problem: first, he determines the optimal paths of consumption and post-school human capital investment conditional on the level of schooling, and second, he chooses that level of schooling which maximizes his aggregate welfare over the life-cycle (Heckman, Lochner, and Taber (1998b)). In a nutshell, switching to a flat income tax fosters the accumulation of human capital at the cost of reduced investment in physical capital, while a flat consumption tax is more pro-capital and less favorable to human capital. Similar to Perroni (1995), general-equilibrium effects of these tax reforms are much weaker than partial-equilibrium effects (Heckman, Lochner, and Taber (1999b)).

7.3 The Effects of Education Subsidies on Human Capital Formation

According to Bovenberg and Jacobs (2005), optimal education subsidies can increase efficiency in human capital formation by offsetting tax-induced distortions. For example, with respect to the negative effects of taxation on human capital formation by workers (cf. Section 7.1), education subsidies can correct for the hold-up problem in imperfect labor markets (Boone and de Mooij (2003)).

Collins and Davies (2003) conclude that the incentives for human capital accumulation depend on the net effective tax rate ($NETR$), i.e. the difference between the effective tax rate (ETR) and the effective subsidy rate (ESR). This concept is based on the internal rate of return that is determined by comparing the sum of discounted earnings with and without taxation and subsidies, respectively:

$$NETR = ETR - ESR \tag{15}$$

$$ETR = \frac{r_g - r_n}{r_g} \tag{16}$$

$$ESR = \frac{r_g - r_p}{r_g} \tag{17}$$

ETR, ESR and $NETR$ are calculated by considering the relationship between the gross rate of return (r_g), the net rate of return (r_n), and the public rate of return (r_p). In their empirical analysis for Canada, Collins and Davies (2003) find that the net effective tax rate is smaller than zero.

In a nutshell, Dur and Teulings (2003) favor the implementation of education subsidies for three reasons: (1) redistribution, (2) positive externalities of education, and (3) credit constraints due to capital market imperfections.[23] However, positive external effects of higher education are difficult to establish empirically (for example Krueger and Lindahl (2002)) and also the empirical findings with respect to capital market imperfections are controversial in the literature (for example Shea (2000)).

As a further argument for education subsidies, Bénabou (2002) points out the insurance effect because subsidies to higher education make college attendance more attractive by reducing both the direct costs and the risk, particularly for students with low wealth endowment. If investments in human capital are risky and uninsurable, even small initial changes in college investment may generate large changes in college attendance (Ljungqvist (1995)). In a theoretical model, Akyol and Athreya (2005) suggest large welfare gains of education subsidies relative to the fully decentralized outcome because subsidies lead to nearly mean preserving reductions in college failure risk. Furthermore, if the variance of wages decreases with the level of education, education per se produces an insurance effect (Anderberg and Andersson (2003)). In this context, Bénabou (2002) develops a risk-adjusted, distribution-free measure of general efficiency. By simulating his model with empirical parameter estimates, he shows that the optimal education subsidy should be combined with a tax on consumption.

However, education subsidies also lead to adverse selection (i.e. more low-ability students attend college) and may generate a deadweight loss if they are financed by distortionary taxation. Hence, the optimal level of education subsidies has to maximize social welfare subject to this trade-off (Dur and Teulings (2003)).

7.4 Fiscal Policy in the Context of Factor Mobility

According to Boadway (1996), mandatory education and the public provision of education can be explained as second-best policies in order to circumvent the hold-up problem of time-consistent optimal taxation, i.e. the problem of underinvestment in human capital because workers anticipate the excessive taxation of their labor incomes in the future. However, globalization and increased mobility of high-skilled workers reduce this time-consistency problem because the government's ex post incentives to tax human capital are decreased.

The effects of proceeding globalization on taxation and education policy are analyzed by Andersson and Konrad (2001) and Andersson and Konrad (2003). Compared to the closed-economy benchmark case, globalization increases the aggregate welfare if optimal education subsidies are completely directed to immobile low-skilled workers (Andersson and Konrad (2001)).

[23] Capital market imperfections imply that workers may be prevented from investing efficiently in their stock of (general) human capital (cf. Section 3.1).

However, in the presence of "Leviathan governments", the full mobility of high-skilled workers generates welfare losses because the tax competing governments raises taxes on education in order to broaden their tax base which only comprises the immobile low-skilled workers (Andersson and Konrad (2003)). With respect time-consistent optimal taxation, Konrad (2001) suggests another solution to the problem of underinvestment in human capital. If the government has only limited information about the effort of workers, then this may work as Pareto-improving commitment mechanism to time-consistent taxation and thus reduces the hold-up problem.

In a similar model with education subsidies financed by labor income taxation and possible migration of high-skilled workers, Poutvaara (2001) analyzes the effects of tax competition between countries in a federation. He concludes that this tax competition may lead to inefficiently low taxes and subsidies. In a nutshell, the problem of underinvestment in human capital can be solved by a fiscal system such that taxes are paid to the country of education and not to the country of residence.

8 Conclusion

The contribution of this paper is to provide a better understanding of the process of human capital formation and educational attainment. Furthermore, we analyze policy instruments and institutional features that may help to increase the aggregate welfare by improving the efficiency of the educational system. Although this literature review does not provide a final word on incentive schemes in the process of educational production, it points out some important issues of human capital formation that may shape future research and policy discussions.

In order to structure the vast literature on human capital formation, the review is divided into six parts. Historically, there have been two different ways of conceptualizing educational attainment. First, human capital theory models individuals as investing in human capital in response to the expected returns to education. A second branch of literature focuses on the empirical effects of school characteristics on educational attainment. These studies model education production functions where the educational output is determined as a function of production technology and the amount of inputs. These two concepts of educational attainment - including theoretical analyses as well as empirical estimates - are presented in Sections 2 and 5 of this paper.

According to Haley (1973), human capital theory is further divided into literature estimating the rate of return to education (cf. Section 4) and a second stream of literature modeling the life-cycle of earnings with endogenous accumulation of human capital (cf. Section 6). The third section of this review refers to the distinction between general and specific human capital and the different implications for human capital formation. In Section 7, we analyze the effects of taxation and education subsidies on the accumulation of human capital.

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