Measures of Human Capital: A Review of the Literature

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Abstract

Human capital is increasingly believed to play an important role in the growth process, however, adequately measuring its stock remains controversial. This paper identifies three general approaches to human capital measurement; cost-based, income-based and education-based, and presents a critical review of the theories and their applications to data from a range of countries. Emphasis on empirical evidence will be given to the case of New Zealand.

JEL CLASSIFICATION	J24 – Human Capital; Skills; Occupational Choice; Labor Productivity O47 – Measurement of Economic Growth; Aggregate Productivity
KEYWORDS	Human capital, economic growth

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1 Introduction

According to Schultz (1961a), economists have long recognised that people are an important component of the wealth of nations. Schultz cited Smith (1776) who included all acquired and useful abilities of a country's inhabitants as part of capital. Even prior to that, Petty (1690), in an attempt to demonstrate the power of England, estimated the total human capital of that country to be £520 million, or £80 per capita. In a similar exercise, Farr (1853) estimated that the average net human capital of an English agricultural labourer was £150.

Today, with the importance of 'knowledge' in the economy, human capital has increasingly attracted both academic and public interest. Human capital theory suggests that it is human capital – the knowledge and skills embodied in people – rather than physical capital, that is vital to a country's economic prosperity. In practice, private and public investment in human capital, in the form of expenditure in education and training, accounts for over 10 percent of national income in most OECD countries (Healy, 1998). Understanding human capital must therefore be of great interest to politicians, economists, and development strategists.

In the recent economic literature, interest in human capital revolves around economic growth. Traditionally, the focus on creating more economic growth was to give workers access to more physical resources, like land, factories, and machines. But modern theories of economic growth, such as those of Romer (1986), Lucas (1988) and Jones and Manuelli (1990), emphasise human capital in their explanation of growth. According to these theories, human capital can boost growth through stimulating technological creation, invention and innovation, as well as facilitating the uptake and imitation of new technologies. Numerous empirical studies have sought to establish a relationship between human capital and economic growth. Although human capital has been found to enhance growth in some cases, positive results have failed to prevail in others. The hypothesis that human capital plays a significant role in the growth process is therefore not empirically validated.

It has been suggested that a major reason for the mixed evidence is that human capital has been poorly measured (Krueger and Lindahl, 2001). It may be either because the proxies that have been used do not capture key elements of human capital, or because the data on the proxies are erroneous. Consequently, measurement error may account for the somewhat surprising finding that greater investment in human beings does not appear to be associated with faster economic growth. This concern with measurement error therefore brought up a question that has occupied economists in the last several decades – how to measure human capital adequately?

Following the insights of Adam Smith, the creation of specialised labour is seen to require the use of scarce inputs, typically education/learning. This emphasis on 'education' has led to a research agenda where human capital is proxied by some measure of school experience. However, this is only one of several approaches to the measurement of human capital. There are alternative methods which build upon Smith, Ricardo and modern labour economics more generally. In particular, these are measures of human capital which are based on the cost of production or the expected earnings of heterogeneous labour. These approaches have a rich and long intellectual pedigree and the advantages of easily permitting monetary values to be assigned to the stock and thus enabling comparisons with other types of capital.

As can be expected, the impact that human capital has on economic growth is sensitive to the measures or proxies of human capital. It is necessary that there be an accurate and consistent measure of human capital, which will facilitate cross-sectional and temporal comparisons. Only when human capital is adequately and consistently measured can we understand how it affects the growth process and how governments or firms can influence its quantity or quality. The need for a reliable measure of human capital is reinforced by the fact that even in countries where attempts are made to estimate the value of human capital it is not yet standard practice for official statistical agencies to include human capital in their capital stock measures. This is a surprising omission because estimates of the value of human capital, as mentioned above, predate the formal development of National Accounts statistics.

In this paper we identify three general approaches to human capital measurement; cost-based, income-based and education-based, and present a critical review of the theories and their applications to data from a range of countries. Empirical evidence on New Zealand will be treated in greater detail.

The rest of the paper proceeds as follows. Section 2 highlights the public and academic interest in human capital in New Zealand. Section 3 provides some definitions of human capital. The major approaches to human capital measurement will in turn be presented in the next four sections. Section 8 summarises the international literature on human capital measurement while Section 9 concludes with some recent local studies on the subject.[1]

2 The relevance of measuring human capital to New Zealand

Forty years ago when Schultz (1961a) (re)introduced the concept of human capital, it was controversial if humans should be classified as 'capital'. Today, human capital has become a common piece of jargon not only in academic circles but also among politicians, business people and the media.

Many entrepreneurs recognise the importance of human capital in today's business. For example, Chapman (2001) quotes Doug Marsh, president of Business New Zealand and a member of the New Zealand Institute of Management Inc. National Board, who pronounces that "economic growth is driven on achieving higher productivity. That means in part greater investment in human capital." But there is concern that a large amount of New Zealand human capital is wasted through poor management (Anderson, 1998). Indeed, the Watson Wyatt Human Capital Index survey of companies in 12 Asia-Pacific countries reveals that New Zealand firms perform poorly on human capital management, scoring only a B minus on this practice, and Watson Wyatt New Zealand managing director Paul Loof claims that "by improving human capital management, New Zealand firms can improve their bottom line" (Smith, 2002). Apparently, it has been widely accepted that brains are replacing brawn as a strategic resource in New Zealand firms nowadays (Matheson, 2002; Tapsell, 1998). This indicates that traditional accounting methods no longer reflect the true value of a company on the balance sheet. Therefore, according to Tapsell (1998) and Bernacki (1998), measuring the value of human capital to a firm is a growing issue.

Human capital is even more frequently discussed in the policy context. Acemoglu (2001) suggests that rising income inequality in New Zealand is due chiefly to higher skill premia, which are in turn attributable to the uneven distribution of human capital. The author believes that income inequality can be reduced more effectively by human capital policies that seek to close the gaps of skills between the top and the bottom of the income distribution than by those raising the average human capital in the economy without changing its distribution. Specifically, according to Acemoglu, useful policies should aim at improving the quality of secondary schooling, rather than promoting higher college attendance.

Scobie et al (2005), in an analysis of individual net worth in New Zealand, attempt to treat human capital as an asset. The authors reason that since capital acquired from farm and business loans and property mortgages are listed as assets on the balance sheet, human capital – a form

[1] Part of the current paper has been published in Le et al (2003).

of capital usually acquired through student loans – should also be considered an asset. This treatment of human capital obviates recording negative net worth values for recent graduates, who have an outstanding student loan and hardly any financial and physical assets. Scobie et al observe that human capital makes up a significant component of total net worth, amounting up to four times the level of recorded financial and physical assets for a young adult.

Issues on human capital also receive increased attention from politicians. Indeed, former Prime Minister Jenny Shipley believes New Zealand's future to lie in developing human capital (Gawith, 1999). In a Budget speech, Finance Minister Michael Cullen unequivocally asserts that "the single most important prerequisite for lifting our productivity and economic growth rates is increasing human capital" (Cullen, 2001). An important goal which the current government has set out in its three-year programme is to get New Zealand back to the top half of the OECD income rankings (Clark, 2002). This would entail an annual economic growth rate of at least 4 percent (New Zealand Treasury, 2004), and Finance Minister Cullen, again, has been repeatedly quoted to be saying that improving human capital is the top priority to boost the country's economic performance (Laugesen, 2002; Venter, 2002; Weir, 2002). By developing human capital, the government means enabling easier access to tertiary education, improving staff ratios in early childhood education, and expanding numeracy and literacy programmes. These policies are intended to lift the quality of the future workforce, while migrants are needed to fill the current skill gap (Clark, 2002).

The importance of human capital is also understood by official statistical agencies charged with measuring basic economic phenomena:

> Human capital is emerging as a key determinant of international competitiveness and its very long development period makes it necessary to understand the stock of the capital, the influences on it, and the way in which that capital and those influences alter...
>
> (Cook, 2000)

Nevertheless, the role of human capital is not unanimously acknowledged. Some commentators dismiss this term as 'political waffle'. Robertson (2001), for example, criticises the government for overstating the importance of human capital in the growth process. Kerr (2002), executive director of the New Zealand Business Roundtable, believes that New Zealand already has a high level of human capital, in terms of the level of innovation in manufacturing and services sectors and the uptake of technologies, compared with other OECD countries. Kerr also notes that the Soviet Union had excellent scientists and engineers whereas Switzerland has the lowest university attendance and graduation rate in the OECD and argues that the role of human capital in economic success should not be exaggerated at the expense of more critical issues.

How important is human capital to the New Zealand economy? Is the term human capital merely 'waffle', or is the role of human capital not well understood? Does New Zealand already have sufficient human capital, or does it still suffer from a shortage of human capital that needs to be filled by more spending on education and skilled migrants? The contradicting views to these questions can only be resolved when there is a reliable measure of how much human capital New Zealand really has.

3 Definitions of human capital

Schultz (1961a) classified skills and knowledge that people acquire as a form of human capital, and in so doing he sparked the revival of interest in the notion of human capital. Since then, a variety of definitions of human capital have prevailed. For example, the Penguin Dictionary of Economics defines human capital as “the skills, capacities and abilities possessed by an individual which permit him to earn income.” Recently this concept has been extended to incorporate non-market activities, and a broader definition of human capital is “the knowledge, skills, competencies and attributes embodied in individuals that facilitate the creation of personal, social and economic well-being” (OECD, 2001, p18). Laroche et al (1999) further extend the notion to include innate abilities. As it is defined, human capital is a complex concept; it has many dimensions and can be acquired in various ways, including at home, at school, at work, and so on.

It is also clear from the definitions that human capital is *intangible*, the stock of which is not directly observable as that of physical capital; therefore, all estimates of the human capital stock must be constructed indirectly. The common approaches to measuring human capital that have been documented in the literature include the cost-based approach, the income-based approach and the education-based approach.

4 The cost-based approach

A very common approach to measuring the stock of human capital is the cost-of-production method originated by Engel (1883), who estimated human capital based on child rearing costs to their parents. According to Engel, the cost of rearing a person was equal to the summation of costs required to raise him from conception to the age of 25, since the author considered a person to be fully produced by the age of 26. Assuming that the cost of rearing a person aged $x < 26$, belonging the i^{th} class ($i = 1, 2, 3$ for the lower, middle and upper class respectively) consisted of a cost at birth of c_{oi} and annual costs of $c_{oi} + k_i c_{oi}$ a year, Engel arrived at this formula:

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

where it was empirically observed that $c_{01} = 100$, $c_{02} = 200$, $c_{03} = 300$ marks, and $k_i = k = 0.1$.

However, as Dagum and Slottje (2000) point out, this approach should not be taken as an estimation of individual human capital, because it is merely a summation of historical costs which ignores the time value of money and the social costs that are invested in people. More recently, Engel’s approach has been augmented to what is now commonly taken as the cost-based method to human capital measurement. This approach estimates human capital based on the assumption that the depreciated value of the dollar amount spent on those items defined as investments in human capital is equal to the stock of human capital.

Kendrick (1976) and Eisner (1985, 1989) were among the seminal examples of systematically measuring the stock of human capital by a cost-based approach. Kendrick divided human capital investments into tangible and intangible. The tangible component consists of those costs required to produce the physical human being which, by Kendrick’s definition, include child rearing costs to the age of 14. Intangible investments, on the other hand, are the costs to enhance the quality or productivity of labour. These involve expenditures on health and safety, mobility, education and training, plus the opportunity costs of students attending school.

This approach provides an estimate of the resources invested in the education and other human capital related sectors, which can be very useful for cost-benefit analyses. It is also very easy to apply thanks to the ready availability of data on public and private spending.

However, there are several limitations with the method. Firstly, as is well known with evaluating physical capital by costs, there is no necessary relationship between investment and the quality of output: the value of capital is determined by the demand for it, not by the cost of production. This problem is more serious with measuring human capital and thus renders cross-sectional and temporal comparisons less robust. For example, an innately less able and less healthy child is more costly to raise, so the cost-based approach will overestimate his human capital while underestimating well-endowed children who, all else equal, should incur less rearing and educational expenses.

Secondly, the components entering into the production of human capital and their prices are not identified enough for a cost-based estimate of human capital to be useful. In particular, since how increases in each type of spending contribute to change in the human capital stock is not observable, there is a fine line between expenditures classified as investment in human capital and those classified as consumption. For example, Kendrick assumed that all costs of raising children to the age of 14 are human capital investments. His reason was that these expenses, typically on necessities such as food and clothing, compete with other types of investment. This contradicts Bowman (1962) who argued that those costs should not be treated as investment unless the men were slaves. Machlup (1984) concurred with this view, maintaining that basic expenditures should be considered consumption rather than investment. There is a similar problem with determining the marginal contributions to human capital of different types of investments. The lack of empirical evidence means that the researcher may have to allocate household spending quite arbitrarily between investment and consumption. Kendrick, for instance, attributed 50 percent of outlays for health and safety as human capital investment. Since most expenditures on people have both *consumption* effect (satisfying consumer preferences) and *investment* effect (enhancing productivity), cost-based measures are sensitive to the researcher's explicit assumptions about the type of spending and the share of various household and public expenditures that should be regarded as human capital investment. The inseparability of the consumption and investment effects of 'expenditures on man' means that what should be considered human capital investment is controversial.[2]

Thirdly, the depreciation rate matters a great deal to cost-based estimates of human capital stocks. Simple tax accounting rules have typically been chosen. In particular, Kendrick estimated depreciation on human capital by the (modified) double declining balance method. This is because physical capital depreciates faster in early years of life, so the double declining balance schedule is appropriate. To be consistent across different types of capital, Kendrick applied this method to depreciate human capital. By contrast, Eisner simply used the straight-line practice. Appreciation is often ignored, despite empirical evidence that showed human capital appreciating at younger ages then depreciating later in life (Mincer, 1958, 1974). Graham and Webb (1979), who found evidence of human capital appreciation when using the income-based approach to measuring the stock of human capital in the US, criticised Kendrick for underestimating the country's human capital by not accounting for appreciation while over-depreciating it.

Moreover, cost-based estimates of investment in education fail to account for the crucial time dimension of educational investment (Jorgenson and Fraumeni, 1989). Indeed, there is a long lag between the current outlays of educational institutions and the emergence of human capital embodied in their graduates; a large share of educational investments goes to individuals who are still enrolled in school and whose human capital is yet to be realised.

Another limitation, as pointed out by Jorgenson and Fraumeni (1989), is that by evaluating human capital based on costs of education and rearing rather than lifetime labour incomes, the cost-based approach disregards the value of non-market activities. It has been widely recognised that external benefits of education, such as opportunity for self-fulfilment, enjoyment and

[2]See, for example, Schultz (1961a,b) and Shaffer (1961), who discussed the difficulties in distinguishing between consumption and investment expenditures in the formation of human capital.

its development of individual capabilities, are substantial (Haveman and Wolfe, 1984). Furthermore, this method neglects measures of the returns to investment in education or additions to the population.

On the empirics, there is ample evidence on measures of the stock of human capital by the cost approach, especially for the US. Schultz (1961a), for example, tentatively estimated that the stock of education in the US labour force increased by about eight and a half times over the period 1900-1956 while the stock of reproducible capital grew only half as fast. Kendrick (1976) and Eisner (1985, 1989) provided more comprehensive measures, opening the way to the construction of human capital time series using the perpetual inventory method.

Kendrick estimated the US national wealth and found that during 1929-1969, the stock of human capital often exceeded that of physical capital, making the country's wealth more than double as a result of including human capital in the national accounts. In 1969, for example, the US' non-human capital stock totalled $3,220 billion, whereas human capital was valued at $3,700 billion. In constant prices, the stock of human capital more than tripled over the period 1929-1969, at a growth rate of 6.3 percent a year, and outperformed non-human capital which expanded by only 4.9 percent per year. Education and training accounted for about 40-60 percent of the stock of human capital and this share increased consistently over time.[3]

Eisner (1985) departed from Kendrick's approach by allowing for the value of non-market household contribution to investment in child rearing. Investment in research and development counted as human capital investment in Eisner's estimates. Unlike Kendrick who divided human capital into tangibles and intangibles, Eisner classified all human capital as intangibles. Furthermore, as mentioned earlier, Eisner applied the straight line rule to depreciate all human capital over a 50 year life. His results showed that of the $23,746 billion worth of total capital in 1981, $10,676 billion was human capital. In real terms, human capital grew at 4.4 percent a year from 1945 to 1981 while capital in general increased at a slower rate, 3.9 percent a year. When put in the same price base, Kendrick's and Eisner's estimates are broadly similar, except that Kendrick's estimates of human capital often exceeded those of physical capital stocks, whereas the opposite was true of Eisner's estimates.

5 The income-based approach

5.1 Early studies

The income-based approach to human capital measurement even predates the cost-of-production method described above. Petty (1690) was the first to use this framework to estimate a country's stock of human capital. He calculated the human capital stock of England by capitalising to perpetuity the wage bill, defined as the difference between the estimated national income (£42 million) and property income (£16 million, land and profit combined), at a 5 percent interest rate. This gave a result of £520 million, or £80 per capita. Petty's method was simplistic as it did not account for the heterogeneity of the population. Crude as it was, it raised the issue of estimating the money value of a country's labourers and gave an answer with a meaningful economic and social interpretation.

The first truly scientific model to estimating the money value of a human being, according to Kiker (1966), was that developed by Farr (1853). Farr proposed estimating the earning capacity by calculating the present value of an individual's future earnings net of personal living expenses, adjusted for deaths in accordance with a life table. Using a discount rate of 5 percent, Farr

[3] All figures quoted in this sub-section are net stocks of capital.

estimated the average net human capital of an agricultural labourer to be £150, which is the difference between the average gross value of £349 and the average maintenance cost of £199. Farr's procedure laid a sound base for the income approach to human capital measurement. The underlying principle of this model is to value the human capital embodied in individuals as the total income that could be generated in the labour market over their lifetime.

Dublin and Lotka (1930) followed Farr and devised a formula for estimating the value of an individual at birth, V_0, as:

$$V_0 = \sum_{x=0}^{\infty} \frac{S_{0,x}(W_x Y_x - C_x)}{(1+i)^x} \tag{2}$$

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

As can be seen, equation (2) is a formal statement of Farr's method, except that Dublin and Lotka made allowance for unemployment, rather than assuming full employment. The above formula can be modified to obtain the money value of an individual at a particular age a:

$$V_a = \sum_{x=a}^{\infty} \frac{S_{a,x}(W_x Y_x - C_x)}{(1+i)^{x-a}} \tag{3}$$

Similarly, the net cost of rearing a person up to age a is:

$$C_a = \sum_{x=0}^{a-1} \frac{S_{a,x}(C_x - W_x Y_x)}{(1+i)^{x-a}} \tag{4}$$

Equation (3) can be expanded to:

$$\begin{aligned} V_a &= \sum_{x=a}^{\infty} \frac{S_{a,x}(W_x Y_x - C_x)}{(1+i)^{x-a}} \\ &= \sum_{x=0}^{\infty} \frac{S_{a,x}(W_x Y_x - C_x)}{(1+i)^{x-a}} - \sum_{x=0}^{a-1} \frac{S_{a,x}(W_x Y_x - C_x)}{(1+i)^{x-a}} \\ &= \sum_{x=0}^{\infty} \frac{S_{0,x}(W_x Y_x - C_x)(1+i)^a}{S_{0,a}(1+i)^x} + \sum_{x=0}^{a-1} \frac{S_{a,x}(C_x - W_x Y_x)}{(1+i)^{x-a}} \\ &= \frac{(1+i)^a}{S_{0,a}} \sum_{x=0}^{\infty} \frac{S_{0,x}(W_x Y_x - C_x)}{(1+i)^x} + \sum_{x=0}^{a-1} \frac{S_{a,x}(C_x - W_x Y_x)}{(1+i)^{x-a}} \end{aligned} \tag{5}$$

Combining (5) with (2) and (3), we have:

$$V_a = \frac{(1+i)^a}{S_{0,a}} V_0 + C_a \tag{6}$$

Equivalently,

$$C_a = V_a - \frac{(1+i)^a}{S_{0,a}} V_0 \tag{7}$$

Indeed, this formula has a very intuitive interpretation: the cost of producing an individual up to age a is equal to the difference between his current value and the present value, at age a, of his value at birth, adjusted for his survival probability to age a. The gross human capital value at age a can be obtained by setting maintenance cost C_x to be zero:

$$\text{Gross } V_a = \sum_{x=a}^{\infty} \frac{S_{a,x} W_x Y_x}{(1+i)^{x-a}} \tag{8}$$

Besides Dublin and Lotka, a few other researchers also made important early contributions. Wittstein (1867) combined Engel's cost-of-production approach with Farr's prospective method and developed an interesting procedure to evaluate the human capital of an individual at different ages. However, he was criticised for unjustifiably assuming that lifetime earnings and lifetime maintenance costs of an individual are equal.

Nicholson (1891) derived the value of the stock of human capital for the United Kingdom (UK) by capitalising the wage bill, the earnings of management, the earnings of capitalists, the earnings of salaried government officials, and what he termed "domesticated humanity" (the costs of producing wage earners). He claimed that the value of the UK's stock of living capital was about five times that of the stock of conventional capital. But by combining the prospective and retrospective methods like that, Nicholson was criticised for duplicating values. This is because the costs of producing wage earners, which were already counted in the "domesticated humanity", were also included in the capitalised value of their earnings.

De Foville (1905) believed that the prospective method overestimates human capital by not deducting consumption expenditures from earnings. He therefore estimated the stock of human capital for France by applying Petty's approach to earnings net of maintenance. Another French researcher, Barriol (1910) used Farr's approach to evaluate the "social value" of French male labourers. Assuming that lifetime income equals lifetime expenditures, Barriol computed this value by discounting their future expenditures, adjusted for deaths, at a 3 percent interest rate. This method differed from Farr's in that maintenance costs were not subtracted from earnings. But what made Barriol's work innovative was that he estimated the social value by age group by assuming certain scales. Besides, Barriol used an interesting procedure to obtain the per capita social value of other countries. First, the average social value of the country in question was found by applying the age distribution of its population to the social values of French male labourers. This figure was then adjusted to account for the discrepancy in economic development (particularly the differences in wage levels), and gender differences in wages and labour force participation rates between France and that country.

In the US, experimental studies on this subject date back to the early twentieth century. Fisher (1908) followed Farr's approach and estimated the value of human capital in order to assess the costs of preventable illness and death. Also based on a Farr-type method, Huebner (1914) found the US stock of human capital in 1914 to be six to eight times the value of the stock of conventional capital. Woods and Metzger (1927) used five methods, including those due to Petty and Farr, to tackle this issue. But these analyses, as pointed out by Kiker (1966), contained several erroneous assumptions.

Treadgold (2000) identified Wickens (1924) as a pioneer of measuring human capital. Wickens sought to evaluate the stock of wealth in Australia's population by estimating the total discounted value of all the future streams of services expected to be generated by the country's citizens.

Wickens divided the population into three broad groups: adults of working age (males aged 18-64 and females aged 18-59), juveniles (younger than 18), and the aged. The value of the services a person brings to the society in annual terms was assumed to equal the weighted average annual gross earnings, with no allowance being made for maintenance costs. These figures, corresponding to £133 and £65 for males and females respectively, were estimated from official weekly rates, with four weeks deducted from the working year to account for such factors as unemployment and unpaid holidays. Wickens further postulated that all surviving males would continue to earn £133 a year and females £65 until the retirement age. Combining these figures with the Australian life table and an interest rate of 5 percent, the author computed the present values of earnings that working-age men and women would generate throughout their working life. A similar procedure was applied to the aged, except that old-age pensions were used in place of earnings. The "juveniles" were assumed to render no services before 18 and "adult services" subsequently. Therefore, human wealth values were obtainable for males and females at every age from 0 to 104.

Having human wealth values for males and females at every age, Wickens identified a median age for each of the three new broad age groups (under 15, 15-64, and older than 64) then multiplied the per capita wealth value of the median age in each group by the population size of that group. It was found that in 1915 Australia had a total human capital of £6,211 million, or £1,246 per capita. Besides, the Australian human capital stock was observed to be three times as large as the stock of physical capital. However, the estimate of the human capital stock was questionable, since Wickens used such an unjustified short cut to obtain the aggregate value, not to mention the fact that the present value of individuals in older age groups was not included when estimating the present value of individuals in younger age groups.

5.2 Critique

The income-based approach measures the stock of human capital by summing the total discounted values of all the future income streams that all individuals belonging to the population in question expect to earn throughout their lifetime. This method is said to be 'forward-looking' (prospective) because it focuses on expected returns to investment, as opposed to the 'backward-looking' (retrospective) method whose focus is on the historical costs of production.

While the retrospective method may include expenditures on the individual in addition to those that improve his capabilities, the prospective method seeks to value his earning power. Indeed, the income-based method values human capital at market prices, since the labour market to a certain extent accounts for many factors including ability, effort, productivity, and education, as well as the institutional and technological structures of the economy from the interaction of supply and demand of human capital in the market (Dagum and Slottje, 2000). Also, the income-based approach does not need to assume an arbitrary rate of depreciation because depreciation is already implicitly accounted for. Therefore, this method provides the most meaningful results if the necessary data are available.

Indeed, accurate and timely life tables are readily available, and earnings and (un)employment rates by age and educational level can be easily obtained from relevant surveys. The choice of a discount rate involves some subjective judgment, but this should not be a problem. Above all, since the approach based on income is forward-looking, a dynamic economy interested in evaluating its future productive capacities would be more interested in this approach than the historical cost approach (Graham and Webb, 1979).

But this approach is not free from drawbacks. Most notably, the model rests crucially on the assumption that differences in wages truly reflect differences in productivity. If this assumption fails, the model will collapse. In fact, wages may vary for reasons other than change in productivity. For example, trade unions may be able to command a premium wage for their members, or real wages may fall in economic downturns. In such circumstances, income-based measures of human capital will be biased. Besides, income-based measures of human capital are quite sensitive to the discount rate and the retirement age. This requires analysts to be careful when choosing the figures, or severe biases will result.

Whether maintenance costs should be deducted is open to debate. On the one hand, some authors argue that physical capital estimates are net figures, so to be consistent human capital should also be net of maintenance costs. De Foville (1905) and Eisner (1988), for example, criticised the income-based method for not deducting maintenance costs from gross earnings. Weisbrod (1961) attempted to account for maintenance, but he encountered many difficulties. What types of expenditures should be classified as maintenance, and how to account for economies of scale and 'public' goods when estimating per capita consumption for members in the same household are problems that are not easily resolved. On the other hand, others maintain that consumption is an end, rather than a means, of investment and production, hence gross earnings are a more relevant variable to use when estimating human capital using a lifetime labour income approach. It is argued that net productivity is a more relevant measure of a person's value to others; whereas gross productivity is a superior estimate of his total output to the society (Graham and Webb, 1979).

Another shortcoming of the income-based method is that data on earnings are not as widely available as data on investment. This is especially the case for developing countries, where the wage rate is often not observable. In the early studies reviewed above, the major problem lies in the lack of reliable data on earnings and the unjustified assumption about the flow of future earnings.

5.3 The revived interest in the income-based approach

Despite the merits of the income-based approach, until the mid-twentieth century, the lack of micro data had prevented researchers from exploring this method systematically. While predecessors only had macro data, Weisbrod (1961) was able to draw on cross-sectional data for earnings, employment rates and survival probabilities. He used a slightly modified version of Dublin and Lotka's (1930) formula to estimate human capital:

$$V_a = \sum_{x=a}^{74} \frac{S_{a,x} W_x Y_x}{(1+i)^{x-a}} \tag{9}$$

where V_a is the present value of expected future earnings of a person at age a, $S_{a,x}$ is the probability of a person of age a surviving to age x, W_x and Y_x are respectively the employment rate and average earnings at age x, and i is the discount rate. The retirement age is set at 75, at which earnings are nil.

The use of cross-sectional data necessitates assuming that in n years, those currently aged x would expect to earn an income equal to what people aged $x+n$ now earn. A similar logic applied to employment rates and survival probabilities. The results revealed that in 1950, US males aged 0-74 had a per capita value of human capital of $17 thousand at a discount rate of 10 percent and $33 thousand at 4 percent. Netted of maintenance costs, the corresponding values of human capital would be in excess of $13 thousand and $26 thousand respectively. Apparently, even the lowest estimate of (male) human capital exceeded the stock of non-human assets of $881 billion, consistent with the fact that labour income exceeded property income. Based on his findings, the author claimed that the society was paying too much attention to non-human capital, while it was human capital that was more important and thus deserved more investment.

Weisbrod cautioned that the use of cross-sectional data like that leaves changes in age specific values over time unaccounted for. Since such changes tend to be positive, the estimates of human capital under static age specific conditions are likely to be underestimated. Another source of the underestimation was the fact that median earnings of each age cohort were used, because data on mean earnings were not available. As is well known about the distribution of earnings, the mean is often greater than the median.

Houthakker (1959) and Miller (1965) argued that in a growing economy, every individual should benefit from an expected increase in his earnings on top of the gains in experience, seniority and other factors associated with age. Also using data from the 1950 US Census, Miller demonstrated that by accounting for economic growth, estimates of lifetime income based on cohort analyses well exceeded those based on cross-sectional pattern.

Recognising the major limitation in Weisbrod (1961), Graham and Webb (1979) adjusted the framework to incorporate economic growth. They also departed from earlier studies by controlling for education. Equation (9) is then modified as follows:

$$V_a^i = \sum_{x=a}^{75} \frac{S_{a,x}^i W_x^i Y_x^i (1+g_k^i)^{x-a}}{(1+i_k^i)^{x-a}} \tag{10}$$

where V_a^i is the present value at age a of an individual having a vector of characteristics i, and i_k^i and g_k^i are respectively the interest rate and the growth rate in earnings that apply to type i individuals at the k^{th} year of life.

So the underlying assumption here is that an individual of age x with a certain vector of identifying characteristics (sex, race, education, occupation, ability, of which only education is accounted for in Graham and Webb) will base his expectation of earnings n years from now on what those who are currently $x + n$ years old and who possess the same basic characteristics are earning.

Applying the model to a sizeable sample of US males aged 14-75, Graham and Webb found that education is strongly positively related to wealth at all ages. Regardless of the level of education, lifetime wealth always has a concave parabola shape, first rising then steadily declining to zero at retirement. Apparently, wealth always peaks well before earnings. It was also observed that higher education does not only increase the steepness of the lifetime wealth profile but also delays the peak in wealth. The parabola shape indicates that human capital appreciates at younger ages followed by straight-line depreciation. In this way the income-based framework implicitly allows for depreciation so there is no need to assume an arbitrary depreciation rate.

In aggregate terms, the stock of capital embodied in US males aged 14-75 in 1969 ranged from $2,910 billion at 20 percent discount rate to $14,395 billion at 2.5 percent discount rate. According to Kendrick's (1976) cost-based method, total human capital in 1969 was estimated to be $3,700 billion. Taking into account the difference in population bases, Graham and Webb claimed that Kendrick's estimate was still comparatively lower than theirs at the highest discount rate of 20 percent. The authors then concluded that the flawed assumption about depreciation had led Kendrick to underestimate the stock of human capital.

5.4 The Jorgenson and Fraumeni method

5.4.1 Model

Graham and Webb's (1979) study was demonstrably far more sophisticated than earlier ones, but it still contained some methodological limitations, not to mention the fact that it covered barely half of the US population. Jorgenson and Fraumeni (1989, 1992) augmented the method in a very comprehensive study of human capital measurement using the income-based approach. The authors proposed a new system of national accounts for the US economy that included both market and non-market economic activities. The model was applied to estimate (along with non-human capital) the human capital of all individuals in the US population classified by the two sexes, 61 age groups, and 18 education groups (0-17+ years of schooling) for a total of 2,196 cohorts.

Recall that the underlying assumption of using the income-based approach on cross-sectional data is that the earnings that a person of age x will receive in n years will be equal to the earnings of a person presently aged $x + n$ of the same sex and education. An important innovation in Jorgenson and Fraumeni's study is that it simplifies the procedure for discounting future income streams to the present value. Specifically, the authors pointed out that the present value of lifetime labour income for an individual of a given age is just their current annual labour income plus the present value of their lifetime income in the next period weighted by survival probabilities. Thus, by backwards recursion it is possible to calculate the present value of lifetime income at each age. For example, Jorgenson and Fraumeni assumed that all individuals retire when they are 75 years old, so for a 74-year-old person, the present value of lifetime labour income is just their current labour income. The lifetime labour income of a 73-year-old individual is equal to their current labour income plus the present value of lifetime labour income of the 74-year-old, and so forth.

Formally, the lifetime income V of a certain individual with sex s, age a, education e at year y is given by:

$$V_{y,s,a,e} = Y_{y+1,s,a,e} + S_{y,s,a+1} V_{y,s,a+1,e}(1 + g)/(1 + i) \qquad (11)$$

where Y is annual earnings and S_{a+1} is the probability that the person will survive another year.

Jorgenson and Fraumeni identified five stages of the life cycle: no school and no work (ages 0-4), school but no work (ages 5-13), school and work (ages 14-34), work but no school (ages 35-74), and no school or work (ages 75 and older). By assumption, the lifetime income for the oldest group is set to be zero, so is the annual income of those in the first stage and the second stage.

Another important contribution of the Jorgenson and Fraumeni method is that it incorporates the potential value created by people who are currently participating in formal education and who anticipate improved income and employment prospects as a result of that extra education. The inclusion of enrolment in the framework affects the lifetime income of those in the second and third stages of the life cycle. For these people, the formula for calculating their lifetime income becomes:

$$\begin{aligned} V_{y,s,a,e} = Y_{y+1,s,a,e} + \{ & E_{y+1,s,a,e} S_{y,s,a+1} V_{y,s,a+1,e+1} \\ & + (1 - E_{y+1,s,a,e}) S_{y,s,a+1} V_{y,s,a+1,e} \}(1 + g)/(1 + i) \end{aligned} \qquad (12)$$

where E indicates the school enrolment rate. Working backward from the lifetime incomes of individuals with the highest level of education enables us to obtain labour income for all individuals who are attending school.

Arguing that human capital is not restricted to market activities, Jorgenson and Fraumeni imputed the value of labour compensation for non-market activities (excluding schooling). They defined full labour income as the sum of market and non-market labour compensation after taxes. The formulae above apply similarly to both market income and non-market income. How income is divided between market and non-market depends on how much time is allocated to 'maintenance'. For example, Jorgenson and Fraumeni assumed 10 hours maintenance a day, so if a person works 40 hours a week for every week, he is said to have $40 \times 52 = 2080$ hours for market activities and $(14 \times 7 - 40) \times 52 = 3016$ hours a year for non-market activities. Annual earnings, market and non-market, are derived from after-tax hourly labour compensation for each sex/education/age cohort.

Jorgenson and Fraumeni (1989) estimated that in 1982 constant dollars the US stock of human capital almost doubled, from $92 trillion in 1949 to $171 trillion in 1984. In the later study (1992), the estimates were about 20 percent higher, due to allowance being made for school enrolment. Population growth accounted for most of the increase, as per capita human capital grew by only 15 percent, from $742 thousand in 1948 to $855 thousand in 1986. Women accounted for about 40 percent of the stock of human capital and this proportion remained fairly stable over the period. The share of human capital based on market labour activities was around 30 percent.

While cost-based studies found the human capital stock to be about the same size of the physical capital stock and earlier income-based studies typically observed the human capital stock to be from three to five times greater than the physical capital stock, Jorgenson and Fraumeni (1989) showed that human capital was from 12 to 16 times more than physical capital in size. For the period 1948-1969, their (1992) estimates of US human capital were from 17.5 to 18.8 times higher than Kendrick's. According to Jorgenson and Fraumeni, the disparity was due to the fact that their estimates include all sources of lifetime labour income, including investment in education, the value of rearing, and the lifetime incomes of individuals added to the population, prior to any investment in education or rearing. On the one hand, Kendrick was criticised for underestimating human capital by over-depreciating it. On the other hand, Jorgenson and Fraumeni have been criticised for overestimating it through the treatment of non-market activities and setting the retirement age too high.

But even when the upward and downward biases are minimised, the difference in the results from the two methods can hardly be avoided. As Graham and Webb (1979) pointed out, in a competitive equilibrium the value of a capital asset can be determined both by summing the costs of production and by discounting future returns. These two methods are equivalent in a world of complete certainty, perfect capital markets and no externalities. Yet in reality estimates from the cost approach and the yield approach can differ markedly since seldom do these conditions prevail.

5.4.2 Critique

The Jorgenson and Fraumeni model is subject to the shortcomings of the income-based approach discussed above. Besides, it has attracted a few other criticisms. Jorgenson and Fraumeni's approach assumes that human capital raises the productivity of time spent at leisure and at work equally, but Rothschild (1992) disproves this assumption. Their way of imputing non-market activities means that unemployment matters to the division of human capital between market and non-market activities but does not affect total human capital. As Conrad (1992) points out, there would be no change in the human capital stock if the population is fully employed or only half employed, since non-work time will be counted to non-market activities and will be fully imputed anyway. Also, average earnings estimated from workers have been used to impute the value of non-market time for non-workers and this creates a sample selection bias problem. Aulin-Ahmavaara (2002) questions the validity of full imputation of non-work time, since at least some leisure time is necessary to prepare for work.

Jorgenson and Fraumeni estimated the returns to one year of schooling as the difference between the present value of lifetime income of an individual with the schooling and without it and in this way their method does not take account of opportunity costs of schooling. Specifically, the value of time spent at school was not imputed, even though schooling is arguably the most productive non-market activity.

Dagum and Slottje (2000) also point out that Jorgenson and Fraumeni's model contains ability bias because it does not allow for the large variations in personal endowment due to nature and nurture among individuals of the same sex and education. This method equalises the returns to all types of education investments of the same length while ignoring informal schooling. It is also well known that school years is a poor measure of productivity. These shortcomings cause biases in estimates of expected future earnings and hence human capital. Furthermore, as mentioned earlier, Jorgenson and Fraumeni set the retirement age too high (Conrad, 1992); overvaluing older people's productivity results in overstating lifetime incomes for all other ages.

5.4.3 Applications to other countries

Wei (2003) adopts Jorgenson and Fraumeni's framework to estimate the stock of human capital in Australia. Since his focus is on the working population (ages 25-65), Wei only distinguishes two life cycle stages: *work and study* (ages 25-34) and *work only*. The author identifies four education levels, based on qualifications, rather than 18 levels based on years of formal schooling as in Jorgenson and Fraumeni. Like Graham and Webb (1979), Wei finds that education and human capital are positively related and that lifetime labour income initially rises then falls for all education levels. In 2001 prices, the stock of Australia's working-age human capital increased from $3.2 trillion in 1981 to $5.6 trillion in 2001. It was observed that the growth in human capital was due mainly to the increasing number of educated individuals. Women accounted for approximately 40 percent of the total stock of human capital. Even for such a small population base, the stock of human capital was found to be larger than that of physical capital in all years, and this ratio has been rising, from 2.8:1 in 1981 to 3.1:1 in 2001.

Ahlroth et al (1997) apply Jorgenson and Fraumeni's model to Swedish data. Interestingly, the authors show that this method works with a typical micro data set of 6,000 individuals like the Swedish Level of Living Surveys. Since there are only 6,000 individuals for 2196 cohorts, most cohorts have few observations and some are even empty. Ahlroth et al resolve this problem by using regression techniques to predict the values of hourly compensation, working hours, school hours, the employment rate and the school enrolment rates. It was found that even the lowest estimates of the human capital stock (after-tax, excluding leisure income) were from six to ten times higher than the stock of physical capital. It should be borne in mind that the studies by Ahlroth et al (1997) and Wei (2003) are also subject to the limitations of the Jorgenson and Fraumeni method.

5.5 The income-based index method

Also using the income-based approach to human capital measurement, some authors seek to obtain an index value rather than a monetary measure. One prominent example of this stream of research is Mulligan and Sala-i-Martin (1997). They measure human capital for a given state in a given year as the total labour income per capita divided by the wage of the uneducated. The rationale for this method is that labour income incorporates not only the worker's skills (human capital) but also the physical capital available to him, such that for a given level of human capital workers in regions with higher physical capital will tend to earn higher wages. Since the human and physical content of education may vary across time and space, a given level of education may attract different wage levels and thus would incorrectly reflect different amounts of human capital. Therefore, the effect of aggregate physical capital on labour income should be netted out by dividing labour income by the wage of a zero-schooling worker.

Formally, the average human capital h of state i at time t is measured as:

$$h_i(t) = \left\{ \int_0^\infty w_i(t,s)\eta_i(t,s)ds \right\} / w_i(t,0) \tag{13}$$

where $w_i(t,s)$ is the wage rate of a person with s years of schooling, $w_i(t,0)$ the wage rate of a zero-schooling worker, and $\eta_i(t,s)$ the fraction of people with s years of schooling. This model specifies that all workers with the same level of education have the same weight that is proportional to their average wage level.

This method implicitly assumes that uneducated workers have the same human capital across time and space, although they do not necessarily earn the same income. According to the authors, if schooling has quality and relevance that vary across states and over time, any amount of schooling will introduce inter-temporal and interregional differences in an individual's level of skills. Hence the only sensible *numeraire* is the uneducated worker. The wage rate of such a worker is estimated by the exponential of the constant term from a Mincer wage regression for each state at each year.

It was observed that the US' stock of human capital shrank substantially between 1940 and 1950, then increased steadily to 1990. This pattern was quite consistent across regions. Interestingly, the aggregate human capital stocks increased by 52 percent between 1980 and 1990, whereas over the four preceding decades it grew by only 17 percent. Mulligan and Sala-i-Martin also find that although their measure of human capital is positively correlated with other measures of human capital like average years of schooling, this correlation is not perfect. Apparently Mulligan and Sala-i-Martin's estimates of human capital grew much faster than schooling which, in the authors' view, was due to the improved quality and relevance of schooling.

Mulligan and Sala-i-Martin's measure clearly has some advantages. First, by netting out the effect of aggregate physical capital on labour income, this measure captures the variation in quality and relevance of schooling across time and space. Second, the elasticity of substitution across workers is allowed to vary in the model. Third, this method does not unrealistically impose equal amounts of skill on workers with equal amounts of schooling. Finally, it does not demand much data. However, like the Jorgenson and Fraumeni (1989, 1992) approach, Mulligan and Sala-i-Martin's cannot control for the fact that wages may vary for reasons other than changes in the marginal value of human capital. Besides, this model relies heavily on the assumptions that zero-schooling workers are identical and that these workers are perfectly substitutable for the rest of the labour force. These assumptions, according to Wachtel (1997), are questionable. Moreover, this method neglects the contribution to human capital by factors other than formal schooling, such as informal schooling, on-the-job training, and health. Jeong (2002) also points out that this approach is not so easy to apply to developing countries, due to the existence of a large informal sector where the wage rate is not observable.

Jeong (2002) modifies Mulligan and Sala-i-Martin's method to measure human capital across 45 countries of diverse income levels. Jeong departs from Mulligan and Sala-i-Martin in that he uses as the *numeraire* the industrial labourer, as classified by the International Labour Office, rather than the worker with no schooling. According to Jeong, industrial labourers, who primarily supply their physical effort with little skill, are more comparable across countries than any other types of workers. Human capital is defined in his study as the ratio of aggregate labour income to the average income of the industrial labourers in that country. Again, the underlying assumptions here are that industrial labourers have the same human capital across countries and that workers' contribution to the country's stock of human capital is proportional to their wage rates. Jeong claims that by not using schooling as a basis for comparing the workers, his method avoids the problems that are inherent in schooling-based measures of human capital, namely mismeasurement of human capital that is acquired outside formal schooling, the failure to account for schooling quality, and the variable returns to a year of schooling at different levels.

Not surprisingly, it was found that poorer countries use less human capital inputs in the production process and that the richest countries have from 2.2 to 2.8 times as much human capital as the poorest countries, depending on whether or not outliers are included. However, these figures pale into insignificance in comparison with the cross-country difference in human capital measures based on years of schooling or with the output difference. Accordingly, Jeong concludes that a large part of output difference between countries is due to factors other than human capital and physical capital.

In a study on Austria and Germany, Koman and Marin (1999) construct an aggregate measure of human capital stock by weighting workers of different schooling levels with their wage income. First, based on a perpetual inventory method, the number of individuals aged i whose highest level of schooling at time t is j is computed as:

$$H_{i,j,t} = H_{i-1,j,t-1}(1-\delta_{i,t}) + H^{+}_{i,j,t} - H^{-}_{i,j,t} \tag{14}$$

where $H^{+}_{i,j,t}$ is the number of people aged i who completed the education level j at time t, $H^{-}_{i,j,t}$ is the number of individuals aged i whose highest level of education was j in time $t-1$ and who completed a higher schooling level in time t, and $\delta_{i,t}$ is the probability that those aged $i-1$ in time $t-1$ died before reaching age i. After converting each schooling level j into years of schooling, the authors use a Cobb-Douglas aggregator to relate workers with different educational attainment to human capital h:

$$h = \ln\left(\frac{H}{L}\right) = \sum_{s} \omega_s \ln(\rho(s)) \tag{15}$$

where $\rho(s) = \frac{L(s)}{L}$ is the share of working-age individuals with s years of schooling; $\omega_s = \frac{e^{\gamma s}L(s)}{\sum_s e^{\gamma s}L(s)}$, the share of the wage income of workers with s years of schooling in the total wage bill of the economy, is the efficiency parameter of a worker with s years of schooling; and γ's, the slope coefficients that capture the effect of schooling on earnings, are obtained from a Mincer wage regression.

Koman and Marin's estimate of human capital measures workers' productivity by their wage income. Similar to Mulligan and Sala-i-Martin's (1997) approach, Koman and Marin's efficiency parameter ω_s nets out the effect of physical capital on wages (and hence on human capital).

The use of a non-linear aggregator also avoids assuming that different educational levels are perfectly substitutable. A serious limitation, however, is that the model assumes that one year of schooling yields the same amount of skills over time. Koman and Marin find that their measure of human capital grew faster than average years of schooling and that the time-series evidence is not consistent with a human capital augmented Solow model. Remarkably, with the inclusion of human capital in the model, factor accumulation is less able to explain cross-country growth performance of Austria and Germany.

Laroche and Mérette (2000) adopt Koman and Marin's model but depart from their predecessors by taking into account working experience in addition to formal schooling. They find that in terms of average years of schooling, Canada's human capital per capita increased by 15 percent between 1976 and 1996. The growth is even higher, by over 33 percent, when human capital is measured using Koman and Marin's income-based approach, as higher education levels command an increasing premium. Furthermore, when experience is accounted for, average human capital increased by up to 45 percent over the period. Interestingly, while the two human capital measures (including and excluding experience) were virtually the same from 1976 to 1981, the two measures began to diverge since. According to Laroche and Mérette, this is because before 1981 schooling contributed more to human capital than working experience whereas after that the reverse is true. This pattern is reinforced by the fact that the Canadian population has grown older and as this greying trend is expected to persist, the difference between the two measures is likely to widen.

5.6 Other income-based methods

Also income-based, Macklem's (1997) measure of human wealth takes a more macro approach by calculating the expected present value of aggregate labour income net of government expenditures, based on an estimated bivariate vector autoregressive model. According to the author, this method has at least two important merits. First, it is simpler. The macro focus is less data demanding, making it easily applicable to other countries. Second, this approach permits greater recognition of the joint statistical properties of innovations in income and interest rates. These advantages are, however, counteracted by the less disaggregated information.

Macklem finds that in per capita terms, human wealth in Canada rose steeply from 1963 to 1973, then decreased well into the mid 1980s, but has picked up since. Despite the fluctuations, per capita human wealth has changed very little since the mid-1970s. First, this was due to the fact that the real interest rate was very low in the mid-1970s and high in the 1980s, since a higher interest rate lowers the cumulative growth factor and thus human wealth. Second, net income in the early 1980s was lowered by both the increases in government expenditures and the drop in labour income as a result of the recession in the same period. Third, in the second half of the 1980s real interest rates were falling while net income was growing strongly, reversing the earlier downward trend in human wealth. Clearly, since this human wealth (capital) measure is income-based, it has a pro-cyclical pattern with economic downturns. While human wealth fluctuated considerably, non-human wealth increased rather consistently over the period (1963-1994). Therefore, the ratio of human wealth to non-human wealth fell from 8 to 1 in the early 1960s to about 3 to 1 in the 1990s.

Dagum and Slottje (2000) criticise Macklem's estimation for containing large, unacceptable and unsubstantiated fluctuations, in a period when Canada experienced steady economic growth. In the critics' view, this paradox is due to the limitations in the exogenous variables specified in the bivariate autoregressive model.[4]

[4] A summary of studies that use cost-based, income-based and integrated approaches to human capital measurement is provided in Appendix Table 1.

6 The education-based approach

Unlike the ‘conventional’ approaches which measure capital by cost or by yield, the education-based approach estimates human capital by measuring such education output indicators as literacy rates, enrolment rates, dropout rates, repetition rates, average years of schooling in the population, and test scores. The rationale for this method is that these indicators are closely related to investment in education and that (investment in) education is a key element in human capital formation. Educational measures are therefore proxies for, not direct measures of, human capital. Of course, human capital encompasses more dimensions, but education is arguably the most important component. Indeed, for individuals, education can enhance well-being not only by opening up broader economic opportunities but also through non-market benefits such as improvements in health, nutrition, fertility, upbringing of children, opportunity for self-fulfilment, enjoyment and development of individual capabilities (Haveman and Wolfe, 1984). At the macro level, education plays a central role in economic, institutional and social development and technological progress.

6.1 Adult literacy rates

Typically defined as the proportion of the population aged 15 and older who are able to “read and write a simple statement on his or her everyday life” (UNESCO, 1993, p24),[5] adult literacy rates convey meaningful information about a country’s general educational status. This indicator has been used in early empirical studies that control for human capital in growth equations, including Romer (1989) and Azariadis and Drazen (1990).

Not surprisingly, the so defined human capital variable has shown limited explanatory power in cross-country growth regressions. One, perhaps minor, reason lies in the fact that literacy is not objectively and consistently defined across countries and thus creates biases in international comparisons. A more important reason is, despite reflecting a fundamental component of human capital, adult literacy rates miss out most of the human capital elements that extend beyond that elementary level, including numeracy, logical and analytical reasoning and scientific and technological knowledge. The use of adult literacy as a proxy for human capital thus ignores the contribution of the more advanced skills and knowledge to productivity. As Judson (2002) assesses, literacy rates might be a good proxy for human capital accumulation in countries where the populace has little education, but not for those with universal primary education.

6.2 School enrolment rates

School enrolment rates measure the number of students enrolled at a given level relative to the population of the age group who, according to national regulation or custom, should be attending school at that level. Net and gross enrolment rates are distinguished by the numerator of the ratio. Specifically, gross enrolment rates take as the numerator the total number of students, regardless of age, enrolled at the given level, whereas net enrolment rates only count those students belonging to the designated age group.

Studies that treat school enrolment rates as proxies for human capital in augmented growth models include Barro (1991), Mankiw et al (1992), Levine and Renelt (1992) and Gemmell (1996). The use of enrolment rates as a human capital variable is justified by the notion that the enrolled

[5] This is a rather ‘narrow’ definition of literacy; various definitions of literacy are discussed in Chowdhury (1995).

population represents the flow that adds to the existing stock of education to establish the subsequent stocks. That is, enrolment rates measure the current investment in human capital that will be reflected in the stock of human capital sometime in the future.

However, enrolment rates prove poor proxies for the present stock of human capital. First, being measures of flows of investments in human capital rather than its stock, school enrolment rates only capture part of the continuous accumulation of the stock of human capital. Second, as Psacharopoulos and Arriagada (1986) noted, there is a long time lag between investment in education and additions to the human capital stock; hence, current enrolment rates are not indicators of the schooling level of the current labour force but of the future labour force. Third, the critics also showed that the education of current students may not be fully added to the (future) productive human capital stock because graduates may not partake in the labour force and because investment may partially be wasted through grade repetition and dropouts. Indeed, the measurement error due to repetition and dropouts arises because gross enrolment ratios are typically used, due to data availability, even though net enrolment ratios should be more appropriate. Fourth, change in the stock of (productive) human capital is the difference between the human capital embodied in those who enter and those who withdraw from the labour force, but school enrolment rates take no account of the human capital of the latter. Therefore, school enrolment rates do not even accurately reflect future flows of the human capital stock, let alone current flows or the current stock itself.

Moreover, data on school enrolment in developing countries often lack reliability. According to Barro and Lee (1993), UNESCO enrolment data primarily come from annual surveys of educational institutions in each country and the reporters of these data often overstate enrolment figures for the sake of their institutions. Another source of bias is that there could be a reverse causality between enrolment rates and productivity growth – high enrolment may result from high productivity growth, rather than vice versa (Wolff, 2000).

In view of the pros and cons, school enrolment rates can be at best satisfactory proxies for human capital in some countries but not in others. Judson (2002) argues that secondary enrolment rates will only be good proxies for human capital accumulation in countries where secondary education is expanding the most rapidly. Indeed, this author observes positive correlations between growth and human capital accumulation at the primary level for poor countries, at the secondary level for middle-income countries, and at the higher levels for rich countries, but no relationship between growth and human capital is found for the pooled sample.

6.3 Average years of schooling

The numerous deficiencies of adult literacy rates and enrolment ratios as proxies for human capital stocks have motivated researchers to look for a more powerful indicator, namely the average years of schooling of the labour force. This measure quantifies the accumulated educational investment in the current labour force and assumes that the human capital embodied in the workers are proportional to the years of schooling that they have attained.

The number of average years of schooling has several advantages over adult literacy rates and school enrolment ratios. First, it is a valid stock measure. Second, by taking into account the total amount of formal education acquired by the labour force, years of schooling captures the effective human capital available for economic production. Wachtel (1997) shows that under some reasonable assumptions, the number of schooling years is an exact measure of educational human capital using the cost-based approach to capital measurement.

Since primary data on years of schooling are not typically available at the country aggregate level, researchers have to construct the data set they want using several techniques. Typically, UNESCO data on enrolment and attainment levels are used to obtain years of schooling through a perpetual inventory method or some other procedure. The studies that have attempted to develop data series on years of schooling can be conveniently divided into three groups based on the method they employ: the census/survey-based estimation method, the projection method, and the perpetual inventory method.[6]

6.3.1 The census/survey-based estimation method

Psacharopoulos and Arriagada (1986, 1992) were the first to compile data on mean years of schooling at the country level. The authors estimated the mean years of schooling $\overline{S}$ for the labour force for 99 countries as:

$$\overline{S} = \sum L_i D_i \tag{16}$$

where L_i is the proportion of labour force participants with the i^{th} level of schooling, D_i is the duration in years of the i^{th} level of schooling, and i includes illiteracy, incomplete primary, completed primary, incomplete secondary, completed secondary and university education.

An advantage of this method is that data on L_i was available directly from national censuses and surveys for 66 countries. For the remaining 33 countries, the corresponding statistics had to be derived from information on the educational composition of the general population classified by sex and age.

It was evident that the average educational attainment of the labour force varied widely across countries, ranging from a low of 0.5 for Mali (1976) to a high of 12.6 for the US (1981). In addition to Mali, labour force participants in Nigeria (1967) and Maldives (1977) had also attained on average less than one year of schooling. Mali and Nigeria, indeed, belonged to the region (West Africa) where workers were the least educated, having only 1.8 years of schooling on average. By contrast, workers in Eastern European countries and developed countries were very well educated, with a mean of over 10 years of schooling per worker. With 11.7 years per person in the labour force, New Zealand (1981) ranked third, next to the US (12.6 years) and East Germany (11.9).

One problem with this data set, however, is that for those who do not complete each schooling level, it is not known how many years of schooling they have finished and the authors were forced to assume that these individuals have attended half of the duration of the corresponding level. This arbitrary assumption is a potential source of measurement error, since dropout rates tend to vary considerably across countries. Another drawback is that of the 99 countries covered, only for 34 countries were more than one observation available. Cross-country comparisons are further hampered by the fact that the year of observation varies greatly from country to country, extending from 1960 to 1983 and that labour force is defined differently across countries.

6.3.2 The projection method

The use of years of schooling as a human capital variable in growth equations had been impeded by the limited coverage in Psacharopoulos and Arriagada's (1986) data. Kyriacou (1991) therefore sought to overcome this problem by using a projection method. First, he regressed the years of schooling data available from Psacharopoulos and Arriagada (1986) for 42 countries in the mid

[6] This classification is similar to that of Wößmann (2003).

1970s (from 1974 to 1977) on lagged gross enrolment ratios obtained from UNESCO Statistical Yearbook:

$$S_{1975} = \beta_1 + \beta_2 Prim_{1960} + \beta_3 Sec_{1970} + \beta_4 High_{1970} \tag{17}$$

where S is the average school years in the labour force, $Prim$, Sec and $High$ respectively stand for enrolment ratios for primary, secondary and higher education. Observing that the relationship between years of schooling and lagged enrolment ratios was quite strong ($R^2 = 0.82$), Kyriacou used the estimated coefficients to predict the average years of schooling in the labour force for other years (1965, 1970, 1980, 1985) and other countries. In that way, five observations were obtainable for most of the 113 countries covered. The dispersion in schooling attainment across countries in this data set seems even larger than in Psacharopoulos and Arriagada's, ranging from 0.15 for Chad in the mid 1960s to 12.09 for the US in the mid 1980s. For New Zealand, the mean years of schooling for the labour force increased from 7.97 to 9.28 over the period studied, and this latter figure places the country at 12th place only.

It should be noted, however, that the richness of Kyriacou's data set comes at the expense of substantial measurement error. By using the regression method, Kyriacou had to assume that the relationship between lagged enrolment ratios and years of schooling was stable over time and across countries when in practice it never was UNESCO (1978). Similarities in the length of each schooling level, dropout rates and repetition rates were also assumed. These inadequate assumptions explain why the estimates and the original data are well correlated for the mid 1970s but greatly differ for other time periods.

6.3.3 The perpetual inventory method

Lau et al (1991) constructed time series of educational stocks in 58 developing countries from 1965 to 1985. The authors defined educational stock as the total person-school years of the working-age population, which can be divided by the population size to obtain the average years of schooling per person. Their study used a perpetual inventory method, which computes the total stock of education S at year T by summing the enrolments E at all grade levels g for all age cohorts:

$$S_T = \sum_{T-a_{max}+6}^{T-a_{min}+6} \sum_{g=1}^{g_{max}} E_{g,t}\theta_{g,t} \tag{18}$$

where $\theta_{g,t}$ is the probability that an enrolee in grade g at time t will survive to the year T, $a_{min} = 15$ and $a_{max} = 64$ are respectively the youngest and oldest working ages. Setting the age of school entry at six, we have $T - 64 + 6$ as the year when the oldest cohort entered school, whereas the youngest cohort started school in year $T - 15 + 6$.

As can be seen, this method is very data demanding. Estimating the total schooling years embodied in the population aged 15-64 during 1965-1985 requires data series on school enrolment and mortality probabilities that go as far back as 1907. Lau et al used age-specific survival rates constructed for a 'representative' country in each world region, although this should not be a significant concern. But substantial measurement error is likely, because pre-1950 and post-1980 data on enrolment were not available and thus needed to be extrapolated, and data gaps needed to be filled by interpolation. The heavy reliance on 'fabricated' statistics and the lack of benchmarking against census data is probably the major reason why Lau et al's estimates are poorly correlated with those from Psacharopoulos and Arriagada (1986). More biases could also result from ignoring dropouts, grade repetition and migration.

Nehru et al (1995) modified Lau et al's method to correct for dropouts and repetition:

$$S_T = \sum_{T-a_{max}+6}^{T-a_{min}+6} \sum_{g=1}^{g_{max}} E_{g,t}(1 - r_{g,t} - d_{g,t})\theta_{g,t} \tag{19}$$

where $r_{g,t}$ and $d_{g,t}$ are respectively the repetition rates and dropout rates, which are assumed to be constant over time and across grade levels, due to data constraints.

Another merit of Nehru et al's paper is that they collected enrolment data that go as far back as 1930 for most countries and in some cases to 1902, thereby reducing the measurement bias due to backward extrapolation.

From a sample of 85 countries, Nehru et al found that workers in sub-Saharan Africa were the least educated, having acquired only 2.54 years of schooling per person by 1987. Along with East Asia, sub-Saharan Africa experienced the fastest growth in schooling, averaging 4.2 percent per annum during 1960-1987. By contrast, industrial countries grew by only 0.3 percent in terms of schooling per person during the same period. This is because workers in these countries had received as many as ten years of schooling per person. New Zealand performed somewhat below the industrial countries' average, with mean years of schooling of only 8.85 per worker in 1987.

A limitation in their results was that Nehru et al chose to ignore census data on attainment levels because, the authors reasoned, most countries in their sample have more than one census data observation in the period covered and they could not determine what data point to benchmark their estimates to. Moreover, they argued that census-based estimates are not necessarily superior to those estimates based on a perpetual inventory method. As a result, their study has been criticised by De la Fuente and Doménech (2000), who claim that disregarding the only direct information available on the variables of interest is hardly justifiable.

6.3.4 The Barro and Lee studies

Barro and Lee (1993) used some combination of all the three methods to develop a data set on educational attainment for 129 countries over five-year periods from 1960 to 1985. The authors applied essentially the same approach as Psacharopoulos and Arriagada's (1986; 1992); the departure in Barro and Lee's study is on how missing data are filled.

Since census and survey data on educational attainment levels are available for only 40 percent of the observations, data gaps needed to be closed using information from other sources. First, observing the high correlation (0.95) between adult illiteracy rates and the share of uneducated individuals for the 158 available observations, Barro and Lee used them to fill missing data on no schooling. This exercise provided another 16 percent of the observations. Next, to fill in the missing data at the other broad categories (first level total, second level total and higher) the authors used a perpetual inventory method which involves using census/survey data on attainment rates as benchmarks and estimating changes from these benchmarks on the basis of school enrolment ratios and data on the age structure of the population. Estimates for the sub-categories (incomplete/complete) of each level (primary, secondary and higher) were next obtained by regressing the observed completion ratios on five- and ten-year lagged values or lead values and on regional dummies. Incompletion ratios were eventually determined using various ways.

With sufficient information on attainment rates, average years of schooling $\overline{S}$ can then be computed using a similar formula as in Psacharopoulos and Arriagada (1986, 1992):

$$\begin{aligned}\overline{S} =& D_p(\frac{1}{2}h_{ip} + h_{cp}) + (D_p + D_{s1})h_{is} + (D_p + D_{s1} + D_{s2})h_{cs} \\ &+ (D_p + D_{s1} + D_{s2} + \frac{1}{2}D_h)h_{ih} + (D_p + D_{s1} + D_{s2} + D_h)h_{ch}\end{aligned} \tag{20}$$

where h_j denotes the share of the adult population with the highest level of schooling j: $j = ip$ for incomplete primary, cp for complete primary, is for first cycle secondary, cs for second cycle secondary, ih for incomplete higher, and ch for complete higher. D indicates the duration in years of the i^{th} level of schooling, and i refers to primary (p), first cycle secondary ($s1$), second cycle secondary ($s2$) and higher education (h).

In a background paper for World Development Report 1995, Ahuja and Filmer (1995) developed estimates of educational attainment for the population aged 6-60 in 81 developing countries. This study especially focuses on gender inequality in developing countries, whereas Barro and Lee's data set misses out an important part of the population in these countries by only covering ages 25 and above, and Nehru et al's data (1995), despite the broader age coverage, are not disaggregated by gender. Ahuja and Filmer built on Barro and Lee's (1993) data but used a different method to fill in missing data on enrolment and departed from their predecessors by also correcting enrolment rates for repetition and dropouts. For 1985, their estimates of mean years of schooling show high correlation, ranging from 0.88 to 0.95, with those from Kyriacou (1991), Barro and Lee (1993) and Nehru et al (1995). Their projections on educational attainment levels suggest that the strongest growth in human capital will be seen in the Middle East and North Africa, whereas sub-Saharan Africa, already the least educated region, will still experience the lowest growth.

In a subsequent paper, Barro and Lee (1996) updated their estimates to 1990. This study also overcomes several shortcomings in their previous work. Following Nehru et al (1995), they extended their coverage to ages 15-24 as well as using net enrolment ratios to avoid overstating enrolments. In the most recent revision (Barro and Lee, 2001), gross enrolment ratios adjusted for repetition are used, so that children who enter school earlier or later are not incorrectly missed out. Allowance is also made for variations in the duration of schooling levels over time within a country.

It was observed from the Barro and Lee studies that South Asia did not only have the lowest average years of schooling but also the highest gender inequality in education. In 1960 females in this region received 28 percent as much schooling as males, rising to 48 percent in 1985. This sharply contrasts with the case of OECD countries, where the gender ratio has stabilised around 94 percent. Interestingly, while New Zealand never got to the top ten in Kyriacou's (1991) and Nehru et al's 1995 data sets, it frequently tops Barro and Lee's lists. Besides, Barro and Lee's (1993) estimates of average schooling for some countries (Portugal, Spain and Turkey) appear substantially lower than the corresponding estimates from Kyriacou which, according to Wolff (2000), is too large to be attributable to the difference in population bases alone. However, Wolff observes that Barro and Lee's data show much greater internal consistency over time than Kyriacou's. This view is shared by De la Fuente and Doménech (2000), who assess that Barro and Lee's procedure should be theoretically superior to Kyriacou's because it utilises more information and avoids making strong implicit assumptions.

But De la Fuente and Doménech (2000) point out that the widely used Barro and Lee data still contain a lot of noise, leading to unjustifiable inconsistencies in country rankings across data sets and to implausible jumps and breaks in the time-series patterns. To make their case, the critics draw on attainment data from previously unexploited sources to revise Barro and Lee's (1996) data set for OECD countries. They use interpolation and extrapolation techniques, rather than the perpetual inventory method, to estimate missing observations. De la Fuente and Doménech rely on subjective judgment to obtain the most 'plausible' figure in the presence of multiple observations or sharp breaks. According to their estimates, New Zealanders aged 25 and above in 1990 had on average 12.11 years of schooling, rather than 11.18 as in Barro and Lee's (1996) data, yet the country's ranking in the OECD went from third place down to sixth place.

The most interesting point from De la Fuente and Doménech's study is that their estimates outperform those developed by Barro and Lee (1996) or Nehru et al (1995) in a number of growth specifications. Although De la Fuente and Doménech's method involves considerable guesswork and lacks scientific underpinning, their results lend support to the argument that poor data quality is a principal cause behind the 'growth puzzle' – the lack of relationship between economic growth and human capital formation – in the recent literature.

Cohen and Soto (2001) also criticise Barro and Lee's estimates, but use a different approach. They seek to obtain as much observable data as possible to minimise potential error. Missing data are filled in based on the assumption that the school attainment of the population aged T in one census is equal to the school attainment of the population aged $T - n$ in the census conducted n years earlier or, when this information is not available, the school attainment of the population aged $T + m$ in the census conducted m years later. Only in the absence of relevant census information do Cohen and Soto resort to enrolment data and the perpetual inventory method to fill in missing observations based on a perpetual inventory method.

Cohen and Soto's estimates are found to be highly (about 90 percent) correlated with Barro and Lee's (2001), but the correlation drops down to less than 10 percent in first differences. The authors maintain that this disagreement is largely because Barro and Lee's estimates are plagued with measurement error, which is most visible from the several 'implausible' figures. Furthermore, Cohen and Soto also believe that while Barro and Lee's estimates are biased downwards, De la Fuente and Doménech's (2000) are biased in the opposite direction, even though very high correlation (a coefficient of 0.938) is observed between the latter and their estimates.

6.3.5 Summary

The sound theoretical grounds and the reasonable availability of data are major reasons why years of schooling has been so widely used in human capital studies, at both micro and macro levels. Years of schooling has become the most common proxy for human capital stocks in cross-country growth models, which can be found in such studies as Benhabib and Spiegel (1994), Barro and Sala-i-Martin (1995), Islam (1995), Barro (1997, 1999), Temple (1999), Wolff (2000) and Krueger and Lindahl (2001). However, the use of years of schooling as a human capital variable does not seem to improve the explanatory power of cross-country growth regressions. Such a disappointing outcome is often attributable to the many imperfections inherent in this indicator.

First, years of schooling fails to account for the fact that the costs and returns of a year of education vary considerably from level to level. Using years of schooling as a measure of human capital stocks incorrectly assumes that one year of schooling always raises human capital by an equal amount. For example, a worker with 10 years of schooling is assumed to have 10 times as much human capital as a worker with one year of schooling. This assumption is at odds with the empirical literature which has typically documented diminishing returns to education (Psacharopoulos, 1994).

Second, no allowance is made for the difference in quality of education over time and across countries. Behrman and Birdsall (1983) in a study using data from Brazil found that neglecting quality of schooling had created misleading results on returns to (years of) schooling. Since the quality of schooling varies more considerably across countries than within one country, the biases from emphasising quantity while overlooking quality is potentially a more severe problem.

Third, as noted by Mulligan and Sala-i-Martin (1997), this measure of human capital unrealistically assumes that workers of different education categories are perfect substitutes for each other. For example, a receptionist who holds two Bachelors degrees and a medical doctor are treated alike, regardless of their productivity, as long as they have equal years of schooling. Speaking of these problems, Judson (2002) claims that using years of schooling as a human capital stock measure is analogous to estimating the physical stock by counting the number of buildings, rather than valuing different kinds of buildings differently.

Fourth, it is debatable whether or not schooling raises productivity. Starting from Arrow (1973), there has been evidence that schooling does more to 'signal' abilities to employers than to truly enhance productivity. If this was the case, years of schooling may increase even when the true (but unobservable) human capital remains the same. In reality, the effect of schooling may be less extreme, but to the extent that schooling has a 'signalling' effect, rather than purely improving skills, years of schooling will be a biased measure of human capital.

Moreover, average years of schooling completely ignores all the human capital elements other than formal schooling, including health, on-the-job training, informal schooling and work experience. A clear example is that this measure treats uneducated individuals as having no human capital, even though in practice they are economically valuable as long as they participate in economic production.

Data quality introduces a further source of measurement error in the years of schooling variable. As reviewed earlier, the methods that have been used to construct series of schooling years are more or less flawed. Many authors, including De la Fuente and Doménech (2000), Krueger and Lindahl (2001) and Cohen and Soto (2001), argue that it is the lack of good data on years of schooling, rather than the characteristics of the variable itself, that has rendered years of schooling a poor proxy for human capital in growth models. This is quite clear from the discrepancies in New Zealand's rankings across data sets, ranging from the top positions in Barro and Lee (1993, 1996, 2001) to 21st place in Nehru et al (1995).

According to Krueger and Lindahl (2001), until recently, the macro literature had not paid adequate attention to potential problems caused by measurement error in education, even though average years of schooling has been poorly measured across countries. These authors show that the reliability of country-level schooling data is no higher than had been found for micro data. For example, the correlation between schooling data from Barro and Lee (1993) and Kyriacou's (1991) in 1985 is 0.86, dropping down to as low as 0.34 for change in schooling between 1965 and 1985. Additional estimates of the reliability of country-level schooling data further confirm their belief that measurement error in education severely distorts results from growth equations that control for human capital (Krueger and Lindahl, 2001).[7]

6.4 Quality of schooling

According to Hanushek and Kimko (2000), quality issues have been overlooked in growth models because it is taken for granted that variations in quality of human capital are of much less

[7]Appendix Tables 2-3 contain a summary of studies that measure the stock of human capital in terms of average years of schooling.

importance than variations in pure quantity of human capital. Such an omission has proved a big mistake as far as the growth empirics is concerned.

Recognising the limitations that contaminate measures of quantity of schooling, Barro and Lee (1996) and Lee and Barro (2001) seek to allow for the quality dimension of schooling. They consider such input measures as public educational spending per student, pupil-teacher ratios, estimated salaries of teachers and length of the school year, and such outcome measures as repetition and dropout rates. These measures are actually more or less a version of the cost-based approach to human capital evaluation.

As reported in Appendix Table 4, not only does New Zealand lag behind the OECD average but it also ranks very low by international standards, especially on pupil-teacher ratios at secondary level, ratios of government educational spending per pupil to GDP per capita and ratios of primary school teachers' salaries to GDP per capita. However, the country performs much better on the outcome measures (repetition rates and dropout rates). It is interesting to note that while New Zealand's performance, relative to other countries, on the input indicators has improved over time, its performance on the outcome measures has worsened.

Barro and Lee (2001) introduce more 'quality' measures of human capital, including international test scores of high school students and of adults. In theory, test scores have appealing features of a good human capital indicator because they measures educational outcome, cognitive skills, and they ensure international comparability. Until the early 1990s, New Zealand students achieved good test scores in mathematics, science and reading. Yet their performance is much more disappointing in the most recent test (the Third International Mathematics and Science Study, TIMSS, 1994-1995), where New Zealand ranked 23rd out of the 37 participating countries (see Appendix Table 5).

Unlike the tests for students, the International Adult Literacy Test (IALS) directly measures the capital embodied in the labour force, and, unlike other schooling indicators, this test captures the knowledge that is gained after formal schooling. Therefore, IALS test scores have attracted considerable interest, as well as criticism, in human capital measurement. New Zealand does not perform well on this test, ranking from seventh on prose literacy to 13th on quantitative literacy out of a sample of 20 countries. These results put New Zealand on par with Australia and the US but well below the best performers (Sweden, Norway, Finland and Denmark). Overall, there is huge variation in human capital across OECD countries, despite the similarity in mean years of schooling in their labour force. Barro and Lee (2001) also note that there is a large discrepancy in achievement between students and adults. For example, the correlation between the TIMSS mathematics score for 7th grade students and the IALS quantitative literacy score for adults, in the common sample of 17 countries, is only 0.32. The biggest limitation with test scores is that data on these measures are often restricted to certain countries and certain points in time.

The existence of so many 'quality' measures, most of which are poorly correlated with each other and with quantity measures of schooling, seems to create confusion rather than to resolve the human capital measurement puzzle. It is striking to note that those education-based measures of human capital, the most widely used measures of this variable, produce results that are often at odds with each other. The case of New Zealand gives a telling example of this argument; ranking for this country varies wildly not only across indicators, from first to 117th, but also across different data sets of the same indicator, from first to 20th (see Appendix Tables 3-6).

To settle this problem, Hanushek and Kimko (2000) develop a single measure of labour force quality by combining all of the available information on international mathematics and science test scores. Data are available for 26 performance series for different ages, sub-test scores, and various years from 1965 to 1991. For their first measure (QL1), data on each of the series are transformed to having a world mean of 50. The second measure (QL2) adjusts all scores according to the US international performance modified for the national temporal pattern of scores provided by the National Assessment of Educational Progress (NAEP). To be more specific, these national tests serve as an absolute benchmark of performance to which the US scores on international tests can be keyed, whereby the mean of each international test series is allowed to drift in reference to US NAEP score drift and the mean US performance on each international comparison. Measures of schooling quality for each country are then constructed by averaging all available transformed test scores, weighted by the normalised inverse of the country-specific standard error for each test.

Hanushek and Kimko's measure has the advantage of combining various indicators of schooling quality in one index, but it can be misleading because test scores do not just reflect schooling quality – they may also pick up such unobserved variables as innate abilities. Moreover, a measure of schooling quality is not necessarily a good measure of labour force quality since the quality of past and current students may diverge greatly from the quality of the current labour force. Moreover, since data on internationally comparable test scores are limited, Hanushek and Kimko are forced to impute missing values based on a regression method and in that way can not escape from the second type of measurement error, namely low data quality.

Wößmann (2003) makes further improvements by incorporating Hanushek and Kimko's measure of educational quality into measures of the stock of human capital. First, the author expresses Hanushek and Kimko's measure of schooling quality for each country as a ratio to the measure for the US. This measure of relative quality can then be used as quality weights for a year of schooling in a country, with the weight for the US being unity. World average rates of return to education at different levels are finally integrated to arrive at a quality-adjusted measure of human capital stock:

$$h_i^Q = e^{\sum_a r_a Q_i s_{ai}} \tag{21}$$

where r_a denotes the world average rate of return to education at level a, Q_i indicates Hanushek and Kimko's educational quality index for country i relative to the US value, and s_{ai} is mean years of schooling at level a in country i.

Employing data from Barro and Lee (2001) for mean years of schooling, from Psacharopoulos (1994) for world average rate of return to education, and from Hanushek and Kimko (2000) for the aggregate measure of schooling quality, Wößmann shows that New Zealand is the richest country in the world in terms of human capital, having 2.5 times as much per capita human capital as the US. Other countries in the top five include Norway, Poland, Hong Kong and Australia (see Appendix Table 6).

Wößmann argues that one virtue of his measure is that it allows human capital to rise continually and without an upper bound, just like physical capital, in contrast to the conventional measure of pure quality of human capital which has an upper limit. Moreover, Wößmann's measure is comprehensive because it accounts for quantity as well as several dimensions of quality of schooling in one single measure. However, this method is very data demanding, and to the extent that the estimates reported in Barro and Lee (2001), Psacharopoulos (1994), Hanushek and Kimko (2000) are biased by mismeasurement, Wößmann's measure of human capital will also be biased.

6.5 Summary of education-based measures

The education-based measures of human capital, including literacy rates, school enrolment rates and average years of schooling, clearly have the merits of being easy to quantify and of good international data coverage. These measures give a rough idea of how much human capital a country has. However, they have been criticised for not adequately reflecting key aspects of human capital, as they largely emphasise quantity at the expense of quality. By being based upon some crude proxy for education so far experienced, these measures neither capture the richness of knowledge embodied in humans nor quantify the flow of future benefits of the knowledge accrued. Indeed, they have been found to be at best relevant to one group of countries but not to another group which is at a different stage of development. The use of these indicators has also been hampered by the deficiencies in the data. Recently, ample evidence has been gathered which shows that it is how these indicators are measured, rather than what the indicators measure, that renders these indicators poor proxies for the true stock of human capital.

Although Barro and Lee (1996, 2001) and Lee and Barro (2001) account for quality of schooling, their allowance for quality has complicated the matter. The reason is, since quality is multidimensional many indicators of quality have to be taken into account, but estimates across indicators are very poorly correlated. Hanushek and Kimko (2000) combine several test scores in one single index of schooling quality and Wößmann (2003) incorporates this indicator, together with world average rates of returns to education at each level, in a comprehensive quality-adjusted measure of human capital. However, as with pure quantity measures of schooling, errors in recording data and estimating missing data on the quality indicators of schooling are also a potential source of bias. Since the data used in his analysis are of dubious quality, the reliability of Wößmann's estimates of human capital is questionable.

7 The integrated approach

Recognising that no single approach to human capital measurement is free from limitations, some authors have attempted to combine different methods in order to exploit their strengths while neutralising their weaknesses.

Tao and Stinson (1997) develop an integrated approach which resolves the well-known problems inherent in the cost- and income-based methods. The authors note that investments in human capital determine the human capital stock, which can be established by the cost-based method. Human capital in turn determines earnings for individuals through the income-based approach. They specify an earnings function between human capital h and earnings Y:

$$Y_{s,a,e} = w_t h_{s,a,e} \tag{22}$$

where s, a, and e denote the sex, age and educational level of an individual, and w_t is the human capital rental rate in year t.

Since both of the right-hand side variables are unobservable, one of them must be standardised. Tao and Stinson choose to standardise the human capital stock of base entrants. This group is selected because they enter the labour force straight after leaving high school, thus no allowance needs to be made for the impact that experience, on-the-job training and the cost of training have on their human capital. Besides, the ability of these base entrants can be determined from the Scholastic Aptitude Test (SAT) scores. This test provides a consistent measure of the ability of high school graduates and SAT results are available for many years.[8]

[8]The SAT data suffer from a self-selection bias, since students have the choice whether or not to take the test. Tao and Stinson have, however, corrected for this problem.

Human capital can be identified by exploiting its relationship with investments based on the cost method. The human capital stock of base entrants in this study is assumed to be equal to the accumulated real expenditures on their general education (until high school graduation). Once the human capital of these individuals is defined, the human capital rental rate w can be estimated by applying earnings data to equation (22). That rental rate, which is assumed to be constant across cohorts, can then be plugged into equation (22), together with earnings, to derive the human capital stock for cohorts other than the base entrants.

It is found that the US effective human capital stock[9] expanded by six times between 1963 and 1988. When differences in the abilities of base entrants are considered, specifically, when entry-level wages are assumed to match the SAT scores of base entrants, the growth dropped down to less than 100 percent. The expansion was greater for females (135 percent) than for males (75 percent), largely due to the increased labour force participation by the former.

Tao and Stinson claim that their framework demonstrates many advantages over existing approaches. First, by using the cost method to derive only the human capital stock of base entrants and using this human capital stock to estimate that of other cohorts, this method avoids the problem of what constitutes an investment in human capital. The authors believe that it is appropriate to only consider educational expenditures as human capital investments in base entrants. For instance, medical spending, according to Tao and Stinson, is already reflected in improved health and thus earnings; adding medical costs to the base entrants' human capital would be double counting. Besides, this approach does not require any assumption about depreciation or appreciation in human capital. Tao and Stinson also show that when used to estimate a Cobb-Douglas production function, their measure of human capital provides more explanatory power than hours of labour.

However, a few problems persist. Rearing costs are classified as consumption and thus not included in human capital investments for base entrants. As discussed above, whether rearing costs should be considered consumption or investment is controversial. Another problem is more related to the income-based method. This model assumes that base entrants are paid according to their ability as measured by the SAT score, but whether or not SAT scores are a good measure of ability is open to question.

Dagum and Slottje (2000) also combine various methods to develop an integrated measure of human capital. They define personal human capital as a dimensionless latent endogenous variable:

$$z = L(x_1, x_2, x_3, \ldots, x_p) \tag{23}$$

where z is a standardised (zero mean and unit variance) human capital latent variable, and x_1, x_2, x_3, …, x_p are p standardised indicators of human capital. An accounting monetary value of human capital for the i^{th} economic unit can then be computed as:

$$h_i = e^{z_i} \tag{24}$$

Dagum and Slottje adopt an assumption that is commonly used in the income method, namely the average earnings n years from now of an economic unit currently at age x will be the same as the average earnings of the economic units currently aged $x + n$, adjusted for real income growth. Accordingly, the human capital of the average economic unit of age x can be estimated as:

[9]Tao and Stinson call the human capital stock of the employed work force *effective* human capital.

$$H_x = \sum_{n=0}^{70-x} \frac{Y_{x+n} S_{x,x+n} (1+g)^n}{(1+i)^n} \tag{25}$$

where $S_{x,x+n}$ is the probability that a person aged x will survive another n years, i is the discount rate, g is the economic growth rate, and the highest working age is set at 70. The monetary value of human capital of the i^{th} sample observation is then given as:

$$H_i = h_i \frac{\overline{H}}{\overline{h}}, \ i = 1, 2, \ldots, n \tag{26}$$

where $\overline{h}$ and $\overline{H}$ are respectively the average values of the transformation in equations (24) and (25). Intuitively, the monetary value of a person's human capital is equal to the average lifetime earnings of the population, weighted by the level of human capital that he has relative to the average human capital of the population.

Dagum and Slottje estimate that in 1982, US per capita human capital ranged from $239 thousand to $365 thousand, depending on whether the discount rate is 6 percent or 8 percent and whether economic growth rate is zero or positive. In real terms, their lowest estimate is still twice Kendrick's 1976 estimate for 1969. Not surprisingly, these figures are only a fraction of those obtained by Jorgenson and Fraumeni (1989, 1992) because the latter incorporate non-market human capital.

Unlike previous studies which could only estimate the average human capital of cohorts, Dagum and Slottje are able to estimate human capital of individuals. Theoretically, the latent variable approach should remove the omitted variable bias inherent in the income-based method. However, this innovation is empirically hampered by the fact that the data used in their study does not contain any measure of intelligence, ability, or hard work. Besides, their model assumes a standardised normal distribution of human capital; whether or not human capital is normally distributed has not been documented in the literature. Furthermore, as with the income-based method, the results obtained from this integrated framework are very sensitive to the assumptions regarding the retirement age, discount rate and real income growth rate.

8 Summary of approaches to human capital measurement

Different as they may seem, the cost-, income- and education-based approaches to human capital measurement are not independent of each other. Figure 1 shows how these models are related. In words, the inputs in the human capital production process, including the costs of rearing and educating people, form the basis for the cost method. The income method builds on individuals' earnings, whereas such indicators as literacy rates, school enrolment rates, and mean years of schooling have been widely used as education-based measures of human capital.

It is interesting to note that there has been a radical change in the motivation behind human capital valuation. Early measures of human capital were more concerned with demonstrating the power of a nation, with estimating, in monetary terms, human loss from wars and plagues, and with developing accurate estimates of human wealth in national accounts. Recently the focus has been switched to using human capital as a tool to explain economic growth across countries. Human capital is believed to play a critical role in the growth process, as well as producing positive external effects such as enhanced self-fulfilment, enjoyment and development of individual capabilities, reduction in poverty and delinquency, and increased participation in community and social and political affairs.

However, the impact of human capital on economic growth has not been empirically validated. The lack of empirical consensus is, it is believed, because those approaches to human capital valuation are based on sound theoretical underpinning yet none of them is free from shortcomings. Each approach is more or less subject to two types of measurement error: the measure does not adequately reflect key elements of human capital, and data on the measure are of poor quality. Therefore, properly measuring human capital in general, and for New Zealand in particular, remains a challenge.

9 Recent New Zealand studies

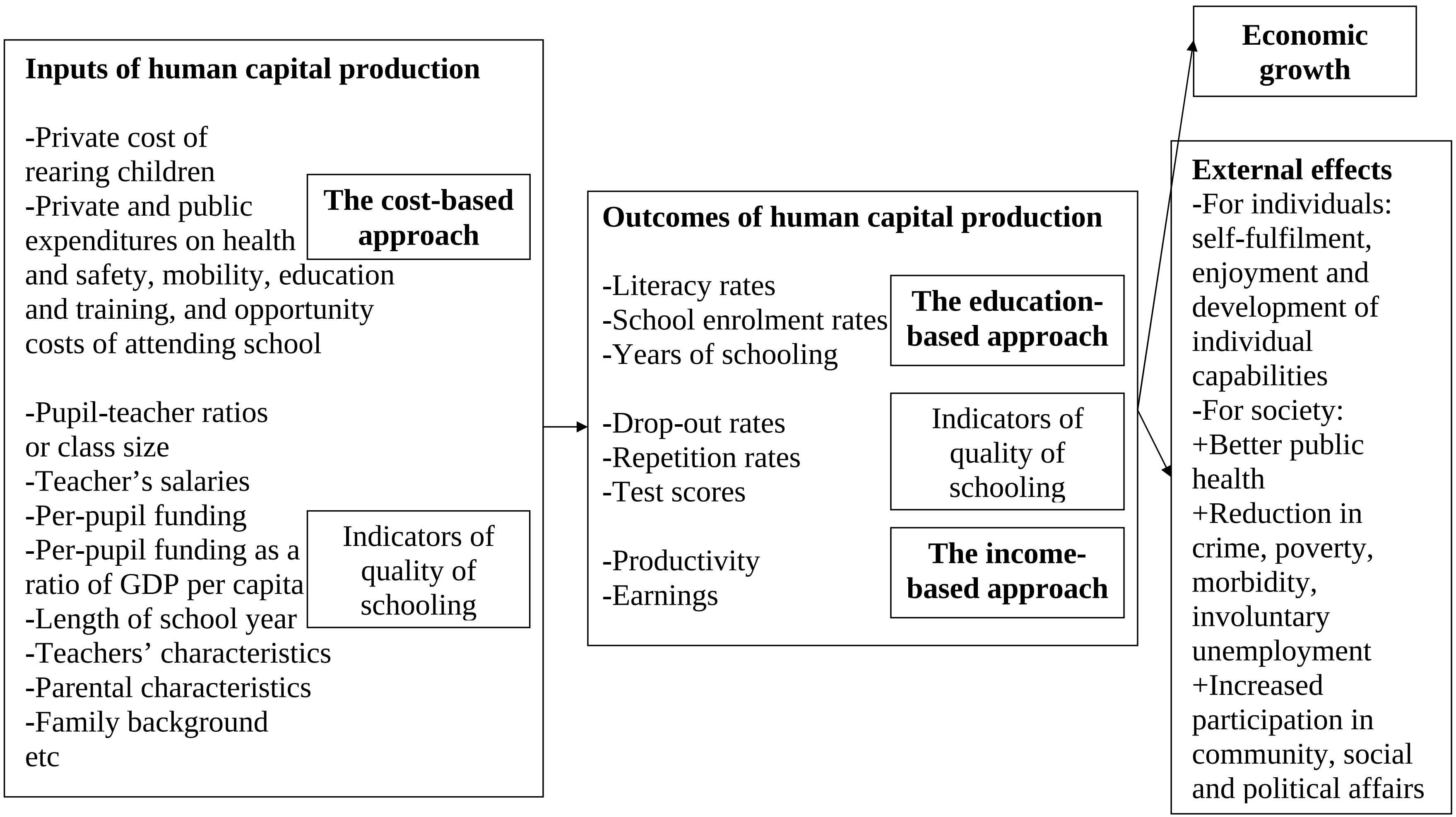
Most published research on human capital in New Zealand has dealt with either changing prices – the returns to particular educational qualifications (Maani, 1999) – or changing quantities, such as the compositional shift implied by the rising importance of the 'information workforce' (Engelbrecht, 2000). There are also many studies that use proxy indicators within the educational stock approach, such as New Zealand Treasury (2001).

Recently there has been considerable interest in directly valuing human capital. Hendy et al (2002) examine how the value of human capital changed between 1986 and 1996. Whilst their method is also based on an expected income concept, it does not take into account enrolment in further education and survival probabilities and is not calculated on a lifetime income basis. Their study shows that the real value of the human capital of the employed New Zealand workforce rose by 11.7 percent between 1991 and 1996, after falling by one percent in the previous five years. Overall, employment growth produced 7.3 of the 10.6 percent increase in human capital over the period 1986-1996, which was then offset by a drop in productivity of 0.4 percentage points. The remaining 3.7 percentage points were attributed to relative quantity and relative price effects.

In a related paper, Hyslop et al (2003) find that the value of human capital rose by about 20 percent between 1986 and 2001. Around 75 percent of this growth is due to general increases in incomes across qualifications at constant qualification shares, the effects of upskilling at constant incomes account for some 15-20 percent, and 8 percent is left to be explained by the interaction of upskilling and rising incomes. Evidence at the individual qualification level suggests that the upskilling seems to have been driven by the increase in demand for skills. As with Hendy et al (2002), Hyslop et al's measure can be seen as a measure of the current 'flow' (based on average annual earnings), rather than 'stock' (based on lifetime earnings), of human capital.

Oxley and Zhu (2002) approach the question with a lifetime income method. Census data in five-year age bands are used to estimate expected lifetime income, with different rates of productivity growth over the life cycle. However, there is no differentiation amongst workers according to their educational attainment and the study extends only from 1986-1996. Oxley and Zhu find that in 1996, the human capital embodied in New Zealanders aged 15 and above averaged $282 thousand per person. This figure reflected an increase of 7.7 percent from 1986, most of which (6.3 percent) occurred between 1986 and 1991. Some degree of catching-up by females is also evident, although women still have no more than 60 percent as much human capital as men do. These estimates can serve as a benchmark to see how much change in this stock value will result when using more complex methods and disaggregated data.

Figure 1: Human capital production and common approaches to human capital measurement



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Appendix Table 1 – Summary of studies on measuring human capital using cost-based, income-based, and integrated approaches

Source	Method	Country, time	Motivation	Results
Petty (1690)	Income-based	England and Wales	-Interest in public finance -To evaluate the power of England, the economic effects of migration, the loss caused by a plague or by men killed in war	Aggregate stock was about £520 million, or £80 per capita.
Farr (1853)	Income-based	England	Interest in public finance: taxing human capital	Per capita net human capital value was about £150.
Engel (1883)	Cost-based	Germany		
Wittstein (1867)	Income-based (Farr's approach), combined with cost-based (Engel's approach)	Germany	To determine a guide to be based on for claims for compensation from loss of life	
Nicholson (1891, 1896)	Income-based, combined with cost-based	United Kingdom, 1891	To estimate the stock of "living" capital	The stock of living capital was about 5 times that of conventional capital.
De Foville (1905)	Income-based (Petty's approach)	France, around 1900		
Fisher (1908)	Income-based (Farr's approach)	United States (US), 1907	To estimate the cost of preventable illness and death	The stock of human capital exceeded all other wealth.
Barriol (1910)	Income-based (Farr's approach)	France and other selected countries	To estimate the social value of an individual	
Huebner (1914)	Income-based (Farr's approach)	US, around 1914		The stock of human capital was from 6 to 8 times that of conventional capital.
Wickens (1924)	Income-based (Farr's approach)	Australia, 1915		The human capital of £6,211 million (or £1,246 per capita) was about 3 times as large as the physical capital stock.

Source	Method	Country, time	Motivation	Results
Woods and Metzger (1927)	5 different methods, including -Farr's approach -Petty's approach	US, 1920	To show the importance of the nation's population	
Dublin (1928)	Unknown	US, 1922		The stock of human wealth was about 5 times that of material wealth.
Dublin and Lotka (1930)	Income-based (improvement on Farr, 1853)		-To estimate how much life insurance a man should carry -To estimate the economic costs of preventable disease and premature death	
Schultz (1961a)	Cost-based	US, 1900-1956	Economic growth, productivity	The stock of human capital grew twice as fast as that of physical capital.
Weisbrod (1961)	Income-based	US, 1950, males aged 0-74	To estimate the value of the human capital stock	-Gross: $1,335b at $i = 10\%$, $2,752b at $i = 4\%$ -Net (of consumption): $1,055b and $2,218b respectively -Compared with non-human assets of $881b
Kendrick (1976)	Cost-based	US, 1929-1969	To develop national wealth estimates to complement estimates of the physical stock in the national accounts	The stock of human capital was often greater and grew faster than that of physical capital.
Graham and Webb (1979)	Income-based	US, 1969, males aged 14-75	National accounts	The stock of human capital ranged from $2,910 billion at 20% discount rate $14,395 billion at 2.5% discount rate. This contrasted with an estimate of $3,700 billion that Kendrick's (1976) obtained based on the cost method.
Eisner (1985)	Cost-based	US, 1945-1981 (selected years)	To implement the total incomes system of accounts	The stock of human capital was almost as large as that of physical capital.

Source	Method	Country, time	Motivation	Results
Jorgenson and Fraumeni (1989, 1992)	Income-based	US, 1947-1986	-To present a new system of national accounts for the US economy -To measure the output of the education sector	The stock of human capital almost doubled between 1949-1984. Per capita human capital grew by only 15% during 1947-1986. Women's share was around 40%. The share of human capital based on market labour activities was around 30%. Human capital was from 12 to 16 times greater than physical capital in size. For the period 1948-1969, their (1992) estimates of US human capital was from 17.5 to 18.8 times higher than Kendrick's (1976).
Ahlroth et al (1997)	Income-based (Jorgenson and Fraumeni method)	Sweden, 1968, 1974, 1981 and 1991	To derive the aggregate measures of the output of the Swedish education sector that can serve as alternatives to the input-based measures that are traditionally used in the national accounts	Even the lowest estimates of the human capital stock (after tax, excluding leisure income) were from 6 to 10 times higher than the stock of physical capital.
Macklem (1997)	Income-based (macro focussed)	Canada, 1963-1994, quarterly	To provide a comprehensive measure of aggregate private sector wealth that includes both human and non-human components	In per capita terms, human wealth rose steeply from 1963 to 1973, then decreased well into the mid 1980s, but has picked up since. The ratio of human wealth to non-human wealth fell from 8:1 in the early 1960s to about 3:1 in the 1990s.
Mulligan and Sala-i-Martin (1997)	Income-based	48 US continental states, 6 census years (1940, 1950, 1960, 1970, 1980, 1990)	To provide an alternative measure of human capital	The stock of human capital shrank substantially between 1940 and 1950, then increased steadily to 1990. Aggregate human capital stocks increased by 52% between 1980 and 1990, whereas over the 4 earlier decades human capital grew by only 17%.

Source	Method	Country, time	Motivation	Results
Tao and Stinson (1997)	Integrated	US, 1963-1988, employed work force	To provide an alternative approach to human capital measurement which circumvents the problems of the cost- and income-based approaches	The effective human capital stock expanded by 6 times. When differences in the abilities of base entrants are considered, the growth dropped down to less than 100%. The expansion was greater for females (135%) than for males (75%), largely due to the increased labour force participation by the former.
Koman and Marin (1999)	Income-based	Austria and Germany, aged 15 and over, 1960-1997	To assess the impact of human capital on economic growth	Human capital grew over twice as fast as average years of schooling in both countries.
Dagum and Slottje (2000)	Integrated	US, 1982	To estimate the monetary value of personal human capital and to examine its size distribution	Average human capital is estimated to range from $239,000 to $365,000. In real terms, their lowest estimate is still twice Kendrick's (1976) estimate for 1969, but well below those obtained by Jorgenson and Fraumeni (1989, 1992) and Macklem (1997).
Laroche and Mérette (2000)	Income-based (Koman and Marin's (1999) method)	Canada, aged 15-64, 1976 to 1996	To provide an alternative measure of human capital	In terms of average years of schooling, human capital per capita increased by 15%. The growth is even higher, by over 33%, when human capital is measured using Koman and Marin's income-based approach. When experience is accounted for, average human capital increased by up to 45% over the period.
Jeong (2002)	Income-based (Mulligan and Sala-i-Martin's (1997) method)	45 countries	To compare human capital inputs for countries of diverse output levels	Poorer countries use less human capital inputs in the production process and the richest countries have from 2.2 to 2.8 times as much human capital as the poorest countries.
Wei (2003)	Income-based (Jorgenson and Fraumeni method)	Australia, aged 25-65, 1981-2001 quinquennially	To present systematic estimates of the stock of human capital for Australia	The stock of human capital increased by 75%. Women's share was approximately 40%. The stock of human capital was found to be 3 times as large that of physical and this ratio has been rising.

Appendix Table 2 – Summary of studies on measuring human capital using an education stock-based approach

Source	Data coverage	Population base	Method of constructing mean years of schooling	Highlighted results
Psacharopoulos and Arriagada (1986)	99 countries, various years from 1960 to 1983	Labour force	$\overline{S} = [(L_{p1} \times D_p/2) + (L_{p2} \times D_p) + (L_{s1} \times (D_p + D_s/2)) + L_{s2} \times (D_p + D_s)) + L_h \times (D_p + D_s + D_h))]/100$ where $\overline{S}$ = mean number of years of schooling, $L_{p1}, L_{p2}, L_{s1}, L_{s2}, L_h$ are respectively proportions of the labour force with incomplete primary schooling, completed primary schooling, incomplete secondary schooling, completed secondary schooling, incomplete and completed higher education, D_p, D_s, D_h are respectively duration in years of primary, secondary, and higher education cycles	Top 5 countries: US 12.6 D R Germany 11.9 Canada 11.7 **New Zealand** 11.7 Czechoslovakia 11.5
Kyriacou (1991)	113 countries, for 1965, 1970, 1975, 1980, 1985	Labour force	$S_{1975} = \beta_1 + \beta_2 \times Prim_{1960} + \beta_3 \times Sec_{1970} + \beta_4 \times High_{1970}$ where S = average school years, $Prim, Sec, High$ = enrolment ratios for primary, secondary, and higher education respectively, $\beta_1 = 0.052$, $\beta_2 = 4.439$, $\beta_3 = 2.665$, $\beta_4 = 8.092$	Top 5 countries in 1985: US 12.09 Finland 10.83 Germany 10.33 Israel 10.03 Canada 9.98
Lau et al (1991)	58 developing countries, 1965-1985	Working-age population (15-64)	$S_T = \sum_{T-a_{max}+6}^{T-a_{min}+6} \sum_{g=1}^{g_{max}} E_{g,t}\theta_{g,t}$ where S_T = total stock of education at year T E = enrolment number of grade g at time t $\theta_{g,t}$ = probability that an enrolee will survive to year T a_{min} = 15, youngest working age a_{max} = 64, oldest working age 6 = school entry age	

Source	Coverage	Population	Method	Highlights
Barro and Lee (1993)[a]	129 countries, 5-yearly periods from 1960 to 1985	Population aged 25 and over	$\bar{S} = D_p(\frac{1}{2}h_{ip} + h_{cp}) + (D_p + D_{s1})h_{is} + (D_p + D_{s1} + D_{s2})h_{cs} + (D_p + D_{s1} + D_{s2} + \frac{1}{2}D_h)h_{ih} + (D_p + D_{s1} + D_{s2} + D_h)h_{ch}$ where h_j = share of the adult population with the highest level of schooling j, $j = ip$ for incomplete primary, cp for complete primary, is for first cycle secondary, cs for second cycle secondary, ih for incomplete higher, and ch for complete higher, D = duration in years of the i^{th} level of schooling, and i refers to primary (p), first cycle secondary $(s1)$, second cycle secondary $(s2)$, and higher education (h)	Top 5 countries in 1985: **New Zealand** 12.04 US 11.79 Hungary 10.75 Norway 10.38 Canada 10.37
Nehru et al (1995)[b]	85 countries, 1960-1987	Working-age population (15-64)	$S_T = \sum_{T-a_{max}+6}^{T-a_{min}+6} \sum_{g=1}^{g_{max}} E_{g,t}(1 - r_{g,t} - d_{g,t})\theta_{g,t}$ where $r_{g,t}$ = repetition rates $d_{g,t}$ = dropout rates r and d are assumed to be constant over time and across grade levels, due to data constraint.	Top 5 countries in 1987: Israel 12.58 US 11.62 Japan 10.99 Great Britain 10.21 Canada 10.01
Ahuja and Filmer (1995)	81 developing countries, for 1985, 1990, 1995	Population aged 6-60		In 1995: High: 6.9 (East Asia and the Pacific Low: 4.0 (Sub-Saharan Africa)
Barro and Lee (1996)[c]	126 countries, 5-yearly periods from 1960 to 1990	Population aged 15 and over	Revised from Barro and Lee's (1993) data set	Top 5 countries in 1990: US 11.74 **New Zealand** 11.25 Denmark 10.70 USSR 10.50 Australia 10.39

Source	Coverage	Population	Method	Highlights
De la Fuente and Doménech (2000)	21 OECD countries, 5-yearly periods from 1960 to 1990	Population aged 25 and over	Revised from Barro and Lee's (1996) data set	Top 5 countries in 1990: Germany 12.99 US 12.91 Canada 12.80 Switzerland 12.53 Australia 12.28
Cohen and Soto (2001)[d]	95 countries, 10-year intervals from 1960 to 2010	Population aged 15-64		Top 5 countries in 2000: UK 13.12 Australia 13.09 Canada 13.07 Germany 12.95 Switzerland 12.73
Barro and Lee (2001)[e]	142 economies, 5-yearly periods from 1960 to 2000	Population aged 15 and over	Revised from Barro and Lee's (1996) data set	Top 5 countries in 2000: US 12.05 Norway 11.85 **New Zealand** 11.52 Canada 11.62 Sweden 11.41
Krueger and Lindahl (2001)	34 countries, mostly surveyed in 1990	Labour force	Derived from The World Values Survey	Top 5 countries: Norway 13.43 US 13.26 Sweden 12.79 Finland 12.61 Canada 12.6

Sources: [a]*Barro-Lee Data Set: Educational Attainment Data, 1960-1985, International Comparisons of Educational Attainment*, http://www.worldbank.org/research/growth/ddbarlee.htm

[b]*Nehru and Dhareshwa Data Set*, http://www.worldbank.org/research/growth/ddnehdha.htm

[c]*Barro-Lee Data Set, International Measures of Schooling Years and Schooling Quality*, http://www.worldbank.org/research/growth/ddbarle2.htm

[d]Data available at http://www.oecd.org/dataoecd/33/13/2669521.xls

[e]Data available at http://www.cid.harvard.edu/ciddata/Appendix%20Data%20Tables%20-%20in%20Panel%20Set%20format.xls

Appendix Table 3 – Average years of schooling:
New Zealand in comparison with Australia and the United States

Source	Year	Countries	New Zealand		Australia		United States	
Psacharopoulos and Arriagada (1986)	1981*	99	11.7	3	11.1	8	12.6	1
Kyriacou (1991)	1965	80	7.97	5	6.91	8	9.82	1
	1970	89	7.94	6	7.39	10	10.40	1
	1975	109	8.31	9	7.81	15	11.95	1
	1980	109	8.79	11	8.26	15	12.02	1
	1985	113	9.28	12	8.72	18	12.09	1
Barro and Lee (1993)	1960	101	9.61	1	8.93	3	8.67	4
	1965	98	9.54	1	8.94	4	9.36	3
	1970	102	9.69	3	10.09	2	10.14	1
	1975	108	11.16	1	10.01	4	10.77	2
	1980	110	12.14	1	10.08	7	11.89	2
	1985	106	12.04	1	10.24	7	11.79	2
Nehru et al (1995)	1960	83 each year	5.70	21	6.00	19	10.73	2
	1961		5.76	21	5.98	19	10.72	2
	1962		5.82	21	5.97	19	10.70	2
	1963		5.89	21	5.96	20	10.68	2
	1964		5.96	21	5.96	20	10.67	2
	1965		6.03	20	5.97	22	10.66	2
	1966		6.14	21	5.99	22	10.67	2
	1967		6.26	21	6.03	22	10.68	2
	1968		6.38	21	6.07	22	10.69	2
	1969		6.46	20	6.12	22	10.70	2
	1970		6.55	20	6.16	22	10.71	2
	1971		6.66	20	6.24	22	10.74	2
	1972		6.76	20	6.31	21	10.75	2
	1973		6.88	20	6.39	21	10.77	2
	1974		6.99	19	6.46	21	10.78	2
	1975		7.11	19	6.54	21	10.80	2
	1976		7.24	17	6.63	21	10.84	2
	1977		7.38	17	6.72	21	10.88	3
	1978		7.53	17	6.81	21	10.92	2
	1979		7.68	17	6.91	21	10.96	2
	1980		7.82	17	6.98	22	10.98	2
	1981		7.97	17	7.08	22	11.09	2
	1982		8.11	16	7.16	22	11.19	2
	1983		8.24	14	7.24	23	11.28	2
	1984		8.38	13	7.32	24	11.35	2
	1985		8.51	13	7.40	24	11.41	2
	1986		8.68	11	7.50	24	11.52	2
	1987		8.85	11	7.60	25	11.61	2
Barro and Lee (1996) (Population aged 25+)	1960	107	9.55	2	9.03	3	8.66	5
	1965	107	9.42	2	8.94	4	9.25	3
	1970	109	9.37	4	10.09	1	9.79	3
	1975	114	11.00	1	9.81	4	10.01	3
	1980	113	11.94	1	10.02	6	11.91	2
	1985	113	11.88	1	10.06	5	11.71	2
	1990	112	11.18	3	10.12	8	12.00	1

Source	Year	Countries	New Zealand		Australia		United States	
Barro and Lee (1996) (Population aged 15+)	1960	107	9.70	3	9.28	4	8.49	5
	1965	107	9.74	2	9.18	4	9.09	5
	1970	109	9.72	3	10.24	1	9.56	5
	1975	114	11.27	1	10.14	2	9.69	6
	1980	114	11.94	1	10.29	4	11.86	2
	1985	114	11.91	1	10.32	4	11.56	2
	1990	113	11.25	2	10.39	5	11.74	1
De la Fuente and Doménech (2000)	1960	21 each year	10.46	3	10.15	4	11.44	2
	1965		10.72	3	10.67	4	11.69	2
	1970		10.98	4	11.15	3	11.93	2
	1975		11.30	4	11.43	3	12.24	1
	1980		11.60	5	11.71	3	12.53	2
	1985		11.86	6	12.00	4	12.74	1
	1990		12.11	6	12.28	5	12.91	2
Barro and Lee (2001) (Population age 25+)	1960	99	9.55	1	9.43	2	8.66	4
	1965	99	9.42	1	9.30	2	9.25	3
	1970	101	9.36	3	10.09	1	9.79	2
	1975	106	11.00	1	9.81	3	10.01	2
	1980	105	11.43	2	10.02	5	11.91	1
	1985	105	11.43	2	10.06	4	11.71	1
	1990	107	11.18	2	10.12	6	12.00	1
	1995	104	11.31	3	10.31	6	12.18	1
	2000	104	11.52	3	10.57	6	12.25	1
Barro and Lee (2001) (Population age 15+)	1960	99	9.70	2	9.73	1	8.49	5
	1965	99	9.74	1	9.57	2	9.09	3
	1970	101	9.72	2	10.24	1	9.53	4
	1975	106	11.27	1	10.14	2	9.69	4
	1980	106	11.47	2	10.29	5	11.87	1
	1985	107	11.50	2	10.32	4	11.57	1
	1990	109	11.25	3	10.38	5	11.74	1
	1995	105	11.49	3	10.67	6	11.89	1
	2000	105	11.74	3	10.92	6	12.05	1
Cohen and Soto (2001)	1960	95 each year	8.98	10	9.82	3	10.18	2
	1970		9.87	11	11.04	4	11.27	2
	1980		10.72	11	12.20	3	12.19	4
	1990		11.02	11	12.76	3	12.62	4
	2000		12.09	11	13.09	2	12.63	6
	2010		12.48	10	13.25	4	13.24	5

Note: Entries for each country are respectively average years of schooling and ranking for the applicable year. *1981 for these 3 countries, but other years may apply to others.

Appendix Table 4 – Lee and Barro's data on indicators of schooling inputs and outcomes

Indicator	1960		1965		1970		1975		1980		1985		1990	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
No. of sch. days per year (Primary)	200 (44)	195	(in general, not indicative of year 1960)											
No. of sch. hours per year (Prim.)	1000 (30)	980												
Pupil/Teacher ratio (Prim.)	30.9 (38)	29.3	25.2 (25)	25.8	21.3 (14)	24.1	18.5 (11)	21.1	16.7 (13)	19.0	19.9 (30)	17.5	18 (28)	15.7
Pupil/Teacher ratio (Secondary)	19.4 (67)	18.2	25.2 (113)	17.2	24.4 (107)	16.2	29.1 (117)	16.2	26.3 (104)	15.2	18.8 (61)	13.6	17.2 (52)	12.7
Govt Edu Exp per pupil (Prim.) (1)	407 (10)	546	747 (15)	1,010	1,031 (10)	1,180	1,359 (14)	1,687	1,680 (10)	2,239	1,730 (15)	2,472	1,894 (16)	2,796
Govt Edu Exp per pupil (Sec.) (2)	743 (24)	757	648 (43)	1,287	810 (42)	1,515	1,025 (29)	1,885	1,490 (23)	2,277	1,243 (27)	2,485	1,665 (22)	2,697
(1) to GPD per capita (%)	5.1 (58)	9.22	8.2 (73)	13.2	11 (45)	13.2	13 (40)	17.1	16.4 (28)	19.9	15.3 (30)	20.0	16.5 (15)	20.1
(2) to GPD per capita (%)	9.4 (62)	12.9	7.2 (83)	17.9	8.7 (86)	17.8	9.8 (81)	19.2	14.5 (67)	20.6	11 (69)	20.7	14.5 (58)	20.2
Avg real salary of teachers (Prim.) (3)	8,676 (15)	10,428	13,921 (14)	17,873	16,461 (16)	19,811	21,813 (12)	25,922	24,327 (10)	25,725	25,903 (12)	28,821	18,279 (25)	28,372
(3) to GDP per capita (%)	1.09 (65)	1.89	1.54 (82)	2.48	1.76 (79)	2.31	2.08 (65)	2.73	2.37 (50)	2.44	2.29 (53)	2.51	1.59 (57)	2.10
Repetition rate (Prim.) (%)	.	.	0 (1)	5.65	0 (1)	5.48	0 (1)	4.26	4 (35)	3.91	3 (30)	3.77	3 (28)	3.14
Repetition rate (Sec.) (%)	.	.	.	.	3 (9)	8.31	.	9.50	3 (16)	9.28	2 (10)	12.1	2 (13)	11.3
Dropout rate (Prim.) (%)	.	.	.	.	3 (17)	3.58	3 (18)	3.37	3 (19)	3.36	3 (20)	3.33	3 (21)	2.95

Source: Lee and Barro (2001) and *Barro-Lee Data Set, International Measures of Schooling Years and Schooling Quality*, http://www.worldbank.org/research/growth/ddbarle2.htm

Note: (a) New Zealand, (b) OECD average. Overall sample size is 145 countries, but data on the indicators are not always available for all countries. OECD averages are unweighted averages over 23 OECD countries. Numbers in brackets under New Zealand estimates are ranking for New Zealand; the lower the rank, the better New Zealand performs relatively to other countries. Statistics in (1), (2), and (3) are in 1985 US dollars adjusted for PPP.

Appendix Table 5 – Barro and Lee's data on test scores

Test	Test participants	Top 5 countries	Results for NZ	
			Test score	Rank[a]
Mathematics (1982-83)	13 year-old students	Japan, Netherlands, Hungary, France, Belgium	46.4	10/17
Mathematics (1982-83)	FS students[b]	Hong Kong, Japan, Finland, Sweden, New Zealand	49.8	5/12
Mathematics (1993-98)	13 year-old students	Singapore, Korea, Japan, Hong Kong, Belgium	47.2	23/37
Science (1970-72)	14 year-old students	Japan, Hungary, Australia, New Zealand, Germany	30.3	4/16
Science (1970-72)	FS students	New Zealand, Germany, Australia, Netherlands, UK	48.3	1/16
Science (1993-98)	13 year-old students	Czech, Bulgaria, Singapore, Slovak, Russia	48.1	26/37
Reading (1990-91)	9 year-old students	Finland, US, Sweden, France, Italy	52.8	6/26
Reading (1990-91)	13 year-old students	Finland, France, Sweden, New Zealand, Switzerland	54.5	4/30
TIMSS[c] (1994-95): Math	7th grade students	Singapore, Korea, Japan, Hong Kong, Czech	472	23/37
TIMSS: Science	(as above)	Singapore, Korea, Czech, Japan, Bulgaria	481	23/37
IALS: Prose	Adults aged 16-65[d]	Sweden, Finland, Norway, Netherlands, Canada	275.2	7/20
IALS: Document	(as above)	Sweden, Norway, Denmark, Finland, Netherlands	269.1	12/20
IALS: Quantitative	(as above)	Sweden, France, Denmark, Norway, Germany	270.7	13/20

Source: Barro-Lee Data Set, International Measures of Schooling Years and Schooling Quality, http://www.worldbank.org/research/growth/ddbarle2.htm, and Barro and Lee (2001), Table 6.

Note: Overall sample size is 58 countries, but data on the tests are not always available for all countries. Scales: TIMSS: 0-1000, IALS: 500, others: 0-100.

[a] New Zealand's rank out of participating countries. [b] FS denotes final year of secondary schooling. [c] Third International Mathematics and Science Study.

[d] Several countries have a higher upper age limit.

Appendix Table 6 – Quality-adjusted measure of human capital

Source	Construction method	Coverage	Top 5 countries
Hanushek and Kimko (2000)[a]	For **QL1**, data on each of the series are transformed to having a world mean of 50. **QL2** adjusts all scores according to the US international performance modified for the national temporal pattern of scores provided by the National Assessment of Educational Progress. QL1 and QL2 are then constructed by averaging all available transformed test scores, weighted by the normalised inverse of the country-specific standard error for each test.	Including 37 countries participating in at least one international test during 1961-1965, but test scores can be imputed using a regression method for another 49 countries (QL1) or 52 countries (QL2).	Score **QL1** Japan 60.7 China 59.3 West Germany 59.0 Hong Kong 65.9 Netherlands 56.8 **QL2** Singapore 72.1 Hong Kong 71.9 **New Zealand** 67.1 Japan 65.5 Norway 64.6
Wößmann (2003)	$h_i^Q = e^{\sum_a r_a Q_i s_{ai}}$ where $r_a =$ world average rate of return to education at level a, 20% for primary level, 13.5% for secondary level, 10.7% for higher level, from Psacharopoulos (1994) $Qi =$ QL2 from Hanushek and Kimko (2000) $s_{ai} =$ mean years of schooling for population aged 15 and over, from Barro and Lee's (2001) estimates for 1990	151 countries, missing data imputed	Score **New Zealand** 2.47[b] Norway 2.23 Poland 1.67 Hong Kong 1.56 Australia 1.43

Note: [a]The 6 tests used were: IEA Math 1964-1966, IEA Science 1966-1973, IEA Math 1980-1982, IEA Science 1983-1986, IAEP 1988, and IAEP 1991, where IEA refers to the tests administered by the International Association for the Evaluation of Educational Achievement, and IAEP to International Assessment of Educational Progress. [b]These figures refer to the country's estimate relative to the US' value.