COST- AND INCOME-BASED MEASURES OF HUMAN CAPITAL

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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. In this paper three general approaches to measurement are identified; cost-based, income-based and educational stock-based. This survey focuses on the first two approaches and provides a critical review of the theories and their applications to data from a range of countries. Particular emphasis is placed upon the work of Jorgenson and Fraumeni (1989, 1992) and some new results for New Zealand based upon their approach are also presented.

Keywords: Human capital**,** economic growth, monetary value.

1. INTRODUCTION

Economic growth has, once again, taken centre-stage in macroeconomics. Part of the resurgence in interest undoubtedly stems from a number of theoretical developments proposed by for example, Baumol (1990), Romer (1986, 1989), Lucas (1988), Jones and Manuelli (1990), Aghion and Howitt (1998), and Rebelo (1991). Common features of these new developments are the crucial and separate roles for Research and Development (R&D), and human, as distinct from physical capital, in the growth process. Such issues though not new see Ricardo (1951-1973) and Smith (1776), they are in sharp contrast to the traditional features of neoclassical, exogenous technological progress, growth models.

Central to any empirical debate on the role of human capital in the growth process is the issue of how the input is measured. For example, much of the recurring controversy on the magnitude of Total Factor Productivity (TFP) revolves around how factor inputs, particularly human capital, are measured.

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 (possibly weighted) measure of school experience. This approach, popularized by Barro and Lee (1993, 1996, 2001) and Lee and Barro (2001), in its simplest form is measured by "years of schooling". However, this is only one of several approaches to the measurement of human capital see Temple (2000), Pritchett (2001), Krueger and Lindahl (2001), Wolff (2000) and the excellent critical survey by Wößmann (2003), for a thorough discussion of this strand of the human capital literature. Recently, some improvements have been made to this form of human capital measurement, including Oxley *et al*. (1999, 1999-2000), de la Fuente and Doménech (2000), Cohen and Soto (2001), Barro and Lee (2001), and Wößmann (2003), yet they still suffer from drawbacks. In particular, by focusing on education *so far experienced*, these new measures fail to capture the richness of knowledge embodied in humans.

In this paper we concentrate on an alternative approach to measuring the stock of human capital which builds upon Smith, Ricardo and modern labour economics more generally. *In particular we consider measures of human capital which are based on cost- or income-based measures of heterogeneous labour.* This differs from much of the current research agenda on human capital stock measurement which is based upon educational experiences, but has a rich and long intellectual pedigree and the advantage of easily permitting monetary values to be assigned to the stock both at the individual and aggregate level and thus, if one wishes, then comparing its (monetary) value with physical capital.

Shultz (1961a), identifies Smith's (1776) work in this area as a major precursor, however, the origins can be found in Petty (1690), where he estimated the total human capital of this 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.

This 'old' research agenda has been resurrected under the banner of the "knowledge economy" where human capital has increasingly attracted both academic and public interest. Understanding human capital must therefore be of great interest to politicians, economists, and development strategists.

> Enhancing individuals' capacity to succeed in the labour market is a major objective of both families and policy makers, one which in recent years has assumed special urgency with respect to those with low earnings. According to the canonical model, earnings are determined by human capital, which consists of capacities to contribute to production, generically called skills. (Bowles *et al.*, 2001)

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 see Wei, (2001). 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 part because of the deficiencies in the educational stock-based approach, Jorgenson and Fraumeni (1989, 1992) returned to the earlier approaches to valuing human capital, introduced by Farr (1853) and Dublin and Lotka (1930). The basic idea, as will be shown in detail below, is to value the human capital embodied in individuals as the total income that could be generated in the labour market over their lifetime. These expected labour earnings contribute to an extended notion of capital, which Jorgenson and Fraumeni include in a proposed new system of national accounts for the US economy. Outside the United States, this method has been applied to the estimate the human capital stock for Sweden (Ahlroth *et al*, 1997), Australia (Wei, 2001), and New Zealand (Le, Gibson and Oxley, 2002) where, in all cases, the stock of human capital greatly exceeds that of physical capital.

The remainder of this paper is organised as follows. Section 2 outlines the models underpinning the cost- and income-based measures of human capital and critically reviews the empirical results they underpin. Section 3 will present some results for forward-looking measures of human capital in New Zealand and section 4 concludes.

2. MEASURING HUMAN CAPITAL – A REVIEW OF THE LITERATURE

2.1 Definition of human capital

Shultz (1961a) classified *skills and knowledge* that people acquire as a form of human capital, and in so doing revived interest in the notion of human capital. Recently, however, the concept of human capital 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)[1] further extend the notion to also include 'innate abilities'. As 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, hence all estimates of the 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 commonly applied "educational stock-based approach". In this paper we will consider the first two approaches referring interested readers to Wößmann (2003) for an excellent review of the third, educational stock-based approach.

[1] Laroche *et al*. (1999) give a detailed treatment of definition of human capital. Since our study is more concerned with measuring human capital, we do not discuss the definitions at length.

Table 1 in the Appendix, presents a summary of human capital measurement using the cost- , income-based, and integrated approaches and could usefully be referenced while reading Section 2, below.

2.2 The cost-based approach to human capital measurement

This approach has its origins in the cost-of-production method of 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 them from conception to the age of 25, since he 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 $c_{oi} + xc_{oi}k_i$ a year, Engel derived the formula:

$$c_i(x) = c_{oi} + c_{oi}[x + \frac{1}{2}k_i x(x+1)] = c_{oi}[1 + x + \frac{1}{2}k_i x(x+1)] \qquad (1)$$

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

However, as Dagum and Stottje (2000) stress, this approach should not be construed as an estimation of individual human capital as 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, Machlup (1962), and Schultz (1961a), augmented Engel's approach to create what is now commonly taken to be the 'cost-based method' to measuring human capital. 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) are 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 where the tangible components consist of those costs required to produce the physical human including child rearing costs to the age of fourteen. Intangible investments 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 a measure of the current flow of 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 because of the ready availability of data on public and private spending.

However, there are several limitations with the method. Firstly, as is well known when evaluating physical capital by costs, there is no necessary relationship between investment and the quality of output: the value of capital is determined by its demand, not by the cost of production. This problem is more serious when 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 fewer rearing and educational expenses. This bias is probably the main reason why Wickens (1924) found the value of the Australian stock of capital to triple when the income-based procedure was used in place of the cost-based procedure.

Secondly, the components entering into the production of human capital and their prices are not well-identified for a cost-based estimate of human capital to be useful. For example, Kendrick assumed that all costs of raising children to the age of fourteen 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* effects (satisfying consumer preferences) and *investment* effects (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 construed 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 the human capital stock. Typically, simple tax accounting rules have 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 and 1970). 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 United States, criticised Kendrick for underestimating the US’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. That is, a large share of educational investment goes to individuals who are still enrolled in school and whose human capital is yet to be realised.

Another limitation, as stressed 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 the external benefits of education, such as opportunity for self-fulfilment, enjoyment and its development of individual capabilities, are substantial (Haveman and Wolf, 1984).

Turning to empirical issues, there are several measures of the stock of human capital based upon the cost approach, though typically for the United States. 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

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

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 United States' national wealth for every year from 1929 to 1969 and found that except in 1929 and 1956, the stock of human capital well exceeded that of physical, making the US's wealth more than double as a result of including human capital in the national accounts. In 1969, for example, the US's 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) followed Kendrick's approach but with some modifications. In particular, Eisner made some allowance for the value of non-market household contributions 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 fifty 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 very 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.[4]

2.3 The income-based approach to human capital measurement

2.3.1 Early studies

Petty (1690) was the first researcher to apply this procedure to estimate a country's stock of human capital. He calculated the human capital stock in England and Wales

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[3] All figures quoted in this part are net stocks of capital.

[4] Many other cost-based type studies allow for human capital formation in estimating the national accounts but do not calculate the human capital stock explicitly. See Ruggles and Ruggles (1970), Nordhaus and Tobin (1972), Eisner (1978), and Zolotas (1981).

by capitalising the wage bill, defined as the difference between the estimated national income (£42 million) and property income (£16 million, for both land and profit), to perpetuity at a five percent interest rate. This gave a result of £520 mill

capita. Petty's method was simple as it did not account for the heterogeneity of the population. Simple as it was, it raised the issue of estimating the monetary value of a country's labourers and provided an answer with a meaningful economic and social interpretation.

The first truly scientific procedure to estimating the money value of a human being, according to Kiker (1966), was that developed by Farr (1853). Farr estimated the capitalised value of 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 five percent, he estimated the average net human capital of an agricultural labourer to be £150, which is the difference between the average salary of £349 and the average maintenance cost of

s approach provided a rigorous standard which has been adhered to by many succeeding researchers. The underlying assumption 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:

$$V_0 = \sum_{x=0}^{\infty} \frac{P_{0,x}(y_x E_x - c_x)}{(1+i)^x} \qquad (2)$$

where i is the interest rate, $P_{0,x}$ is the probability at birth of an individual surviving to age x, y_x is the annual earnings per individual from age x to $x+1$, E_x is the annual employment rate at age x, and c_x is the cost of living for an individual from age x to age $x+1$. As can be seen, equation (2) is a formal statement of Farr's method, except that Dublin and Lotka allow 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:

$$V_a = \sum_{x=a}^{\infty} \frac{P_{a,x}(y_x E_x - c_x)}{(1+i)^{x-a}} \qquad (3)$$

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

$$C_a = \sum_{x=0}^{a-1} \frac{P_{a,x}(c_x - y_x E_x)}{(1+i)^{x-a}} \qquad (4)$$

Equation (3) can be expanded to:

$$\begin{aligned} V_a &= \sum_{x=a}^{\infty} \frac{P_{a,x}(y_x E_x - c_x)}{(1+i)^{x-a}} = \sum_{x=0}^{\infty} \frac{P_{a,x}(y_x E_x - c_x)}{(1+i)^{x-a}} - \sum_{x=0}^{a-1} \frac{P_{a,x}(y_x E_x - c_x)}{(1+i)^{x-a}} \\ &= \sum_{x=0}^{\infty} \frac{P_{0,x}(y_x E_x - c_x)(1+i)^a}{P_{0,a}(1+i)^x} + \sum_{x=0}^{a-1} \frac{P_{a,x}(c_x - y_x E_x)}{(1+i)^{x-a}} \qquad (5) \\ &= \frac{(1+i)^a}{P_{0,a}} \sum_{x=0}^{\infty} \frac{P_{0,x}(y_x E_x - c_x)}{(1+i)^x} + \sum_{x=0}^{a-1} \frac{P_{a,x}(c_x - y_x E_x)}{(1+i)^{x-a}} \end{aligned}$$

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

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

Equivalently,

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

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 value at age *a* 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:

$$GrossV_a = \sum_{x=a}^{\infty} \frac{P_{a,x} y_x E_x}{(1+i)^{x-a}} \qquad (8)$$

Prior to this study, Dublin (1928) estimated the human wealth of the United States in 1922 to be five times that of material wealth, but it is not clear how this figure was obtained (Kiker, 1966).

Wittstein (1867) combined Engel's cost-of-production approach with Farr's prospective method and developed an interesting procedure to estimate the human capital of an individual for different ages. However, he was criticised for the unjustified postulate that lifetime earnings and lifetime maintenance costs are equal.

Nicholson (1891) computed the value of the stock of human capital for Great Britain by capitalizing the wage bill, the earnings of management, the earnings of capitalists, the earnings of salaried government officials, and adding these up with what he termed "domesticated humanity" (the costs of producing wage earners). He claimed that the value of the United Kingdom's stock of living capital was about five times that of the stock of conventional capital. But by combining the prospective and retrospective methods, 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. By applying Petty's approach to labour earnings net of maintenance, he obtained the net stock of human capital, which was more comparable to conventional capital (i.e. physical capital) than other income-based measures of human capital.

Barriol (1910) used Farr's approach to evaluate the "social value" of male French labourers. Assuming that lifetime income equals lifetime expenditures, Barriol computed this value by discounting their future expenditures, adjusted for deaths, at a three percent interest rate. This estimate differed from Farr's in that maintenance costs were not subtracted from earnings, but what made Barriol's method innovative was that he estimated the social value by age groups by assuming certain scales. In addition, Barriol used an interesting procedure to obtain the per capita social value of other countries. First, the weighted per capita average social value of the country in calculated by applying the age distribution of its population to the social values of male French labourers. This figure was then adjusted to account for the discrepancy in economic development (particularly the differences in wage levels), and gender differences in wage and labour force participation rates between France and that country. Although these figures were questionable, Barriol's adjusting procedure was interesting and indeed was followed by many subsequent analysts.

In the United States, early estimates date back to Fisher (1908) who followed Farr's approach and estimated the value of human capital in order to assess the costs of preventable illness. Also based on a Farr-type method, Huebner (1914) calculated 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 address this issue, but as Kiker (1966) stresses, these analyses contained several erroneous assumptions.

Treadgold (2000) identified Wickens (1924) as a pioneer in the field of human capital measurement. Applying the capitalization of earnings method, Wickens sought to evaluate the stock of wealth in Australia by estimating the total discounted value of all 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 be equal to 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 fours 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 five 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 instead of earnings. The "juveniles" were assigned a "pure endowment" of £2,245 for males and £1,082 for females, which was equal to the "wealth" value just computed for those aged 18. 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 from 0 to 104, 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 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 (£1,923 for males and £928 for females). In addition, the Australian human capital stock was observed to be three times as large as the physical capital stock. However, the estimate of the human capital stock was questionable, since Wickens used such an unjustified short-cut to obtain the aggregate value.

2.3.2 Assessment of the income-based method

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 their capabilities, the prospective method seeks to value their earning power. Indeed, the income-based method values human capital at market prices, since the labour market to a certain extent account for the many factors including ability, effort, drive, and professional qualifications, as well as the institutional and technological structures of the economy in an interactive framework of human capital supply and demand (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 in the model. Therefore, this method provides the most reliable results if 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 computed 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).

However, 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. 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. In addition, income-based measures of human capital are quite sensitive to the discount rate and the retirement age[5]. This requires analysts to be careful when using the results, 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 by 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. Alternatively, 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.

2.3.3 The revived interest in the income-based approach to measuring human capital

Despite the merits of the income-based approach, until recently the lack of data at micro level had prevented researchers from exploring this method systematically.

Weisbrod (1961) used a modified version of Dublin and Lotka's (1930) formula to estimate human capital:

$$V_a = \sum_{x=a}^{74} \frac{Y_x W_x P_{a,x}}{(1+r)^{n-a}} \qquad \text{(9) c.f. equation (3)}$$

[5] In New Zealand compulsory retirement ages have been abolished.

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

While precursors only had macro data to use, Weisbrod drew on cross-sectional data for earnings, employment rates and survival probabilities. It was implicitly assumed that in n years, those currently aged x would expect to earn an income equal to what those aged $x+n$ now earn, adjusted for survival probabilities and the discount rate. A similar logic applied to employment rates and survival probabilities. The results revealed that in 1950, US males aged 0-74 had a total gross value of human capital of $1,335 billion at a discount rate of ten percent and $2,752 billion at four percent. Nett of maintenance costs, the corresponding values of human capital would be $1,055 billion and $2,218 billion respectively. Apparently, even the lowest estimate value of (male) human capital exceeded the stock of non-human assets of $881 billion.

Weisbrod cautioned that the use of cross-sectional data do not account for changes in age specific values over time, which given that such changes tend to be positive mean that the estimates of human capital under static age specific conditions are likely to be an underestimation. Another source of the underestimation is 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) asserted that in a growing economy, every individual should benefit from an expected increase in his earning 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 including education in the model. Equation (9) is then modified as follows:

$$PV_x^i = \sum_{x=a}^{75} \frac{Y_x^i W_x^i P_{xt}^i (1+g_k^i)}{(1+r_k^i)^{x-a}} \qquad (10)$$

where PV_x^i is the present value of an individual aged x having a vector of characteristics i, and r_k^i and x_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 well into 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. Graham and Webb maintained that the flawed assumption about depreciation had led Kendrick to underestimate the stock of human capital.

2.3.4 The Jorgenson and Fraumeni approach

Graham and Webb's (1979) study was more sophisticated than earlier approaches, however it still contained a number of methodological limitations and covered only half the US population.

Jorgenson and Fraumeni (1989, 1992) augmented their method and presented the most comprehensive study to date using the income-based approach to measuring human capital. The authors proposed a new system of national accounts for the US economy that included market and non-market economic activities, as well as attempting to assess the impact of human capital on economic growth. The model was applied to estimate the human capital (along with non-human capital) for all individuals in the US population classified by the two sexes, 61 age groups, and 18 education groups[6] for a total of 2196 cohorts.

Recall the underlying assumption of Graham and Webb (1979), is that the earnings of a person aged *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, adjusted for real income growth and the probability of survival. An important innovation in the Jorgenson and Fraumeni's approach is that they simplified the procedure for discounting future income streams to the present value. Specifically, the authors showed 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 employment and survival probabilities. Thus, by backward 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 the present value of lifetime labour income of the 74-year-old plus their current labour income, etc.

Formally, the lifetime income of a certain individual with sex *s*, age *a*, education *e* at year *y*, $i_{y,s,a,}$, is given by:

$$i_{y,s,a,e} = yi_{y+1,s,a} + sr_{y,s,a+1} * i_{y,s,a+1,e} * (1+g)/(1+i) \qquad (11)$$

[6] Education levels range from no schooling at all to 17 years of schooling.

where $yi_{y+1,s,a}$ is the annual earnings at year y of a person with sex *s*, age *a* and education *e*, and $sr_{y,s,a+1}$ 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 (aged 0-4), school but no work (aged 5-13), school and work (aged 14-34), work but no school (aged 35-74), and no school or work (aged 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 by Jorgenson and Fraumeni is that they incorporate 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 second and third stages of the life cycle. For these people, the formula for calculating their lifetime income becomes:

$$i_{y,s,a,e} = yi_{y+1,s,a,e} + [senr_{y+1,s,a,e} * sr_{y,s,a+1} * i_{y,s,a+1,e+1} + (1- senr_{y+1,s,a,e}) * sr_{y,s,a+1} * i_{y,s,a+1,e}]*(1+g)/(1+i) \qquad (12)$$

where *senr* 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 attending school.

Arguing that human capital is not restricted to market activities, Jorgenson and Fraumeni also 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 ten hours maintenance a day, so if a person works 40 hours a week for every week, they are said to have 40*52=2080 hours for market activities and (14*7-40)*52=3016 hours a year for non-market activities. Annual earnings, market and non-market, are derived from after-taxes hourly labour compensation for each sex/education/age cohort.

Jorgenson and Fraumeni (1989) obtained the value of US human capital for every year from 1948 to 1984. In 1982 constant dollars the 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 contributed about 40 percent in 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, Jorgenson and Fraumeni's (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 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.

2.3.4.1 Assessment of the Jorgenson and Fraumeni model

The Jorgenson and Fraumeni model is subject to the general criticisms of the income-based approach discussed above and also the following.

According to Rothschild (1992), Jorgenson and Fraumeni's approach assumes that human capital raises the productivity of time spent at leisure by the same amount that it does time spent at work. Rothschild shows that the choice of hours worked is not independent of the level of human capital when the consumer gets utility from non-labour income and that full income (or the value of human capital) is not a linear function of the wage rate. Therefore, full income is not a reasonable measure of welfare.

Jorgenson and Fraumeni's 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) notes, 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 as 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. Ahmavaara (2002) questions the validity of full imputation of non-work time, since at least some leisure time is necessary to prepare for work.

Ahlroth *et al*. (1997) and Dagum and Slottje (2000) also stress that the Jorgenson and Fraumeni model contains ability bias because it does not allow for the large variations of 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). It is clear from the framework that overvaluing people's productivity in old age results in overestimation of their lifetime labour income.

2.3.4.2 Some applications of the Jorgenson and Fraumeni method

Wei (2001) adopts Jorgenson and Fraumeni's framework and estimates the stock of human capital in Australia. Since his focus is on the working population, defined as all individuals aged 25-65, Wei only distinguishes two life cycle stages: *work and study* (aged 25-34) and *work only*. The author classifies education by five levels, depending on qualifications, rather than 18 levels based on years of formal schooling like in Jorgenson and Fraumeni.

Wei's results show a strong positive relationship between human capital and education. Like Graham and Webb (1979), Wei finds that lifetime labour income initially rises then fall for all education levels and that over the period examined (1981-1996) the age at which lifetime income peaked was increasing. In 1996 prices, the stock of Australia's working age human capital increased from \$1.7 trillion in 1981 to \$2.1 trillion in 1996, but there was a sharp drop in 1991 such that human capital in that year was the lowest. However, it was observed that the growth in human capital was accounted for by the increase in "quality". Even in 1991 when total human capital was decreasing, degree-qualified capital was still rising and the quality components of women’s capital grew faster than men’s. Women accounted for approximately 40 percent of the total stock of human capital. Even for such as small population base and based mostly on market activities, the stock of human capital was found to be larger than that of physical in all years, although this ratio has been declining, from 2:1 in 1981 to 1.6:1 in 1996.

However, Wei’s estimates are misleading as he appears to use the wrong version of the relevant formula.[7] Furthermore, the results appear overstated by assuming that those who ‘choose’ to be out of the labour force will have the same employment and earnings pattern as those with similar characteristics to those in the labour force. Since Wei’s focus is on market labour activities, the value of human capital of non-participants should not be imputed. By applying the expected lifetime labour income of the labour force to the entire working age population, the author did account for non-market effects of human capital, although not as fully as Jorgenson and Fraumeni (1989 and 1992) and Ahlroth et al. (1997).

Ahlroth *et al*. (1997) apply Jorgenson and Fraumeni’s method to Swedish data. Interestingly, the authors show that this method is still workable 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 noted that the studies by Ahlroth *et al*. (1997) and Wei (2001) are also subject to the limitations of the Jorgenson and Fraumeni method.

[7] The basic equation that he used was [illegible] (page 13), whereas the correct one should be [illegible]. A similar correction should be made for formulae that incorporate the effect of enrolment. Double counting unemployment explained why Australia’s human capital stock sharply decreased in 1991 when unemployment averaged 11%.

2.3.5 The Mulligan and Sala-i-Martin method

Mulligan and Sala-i-Martin (1997) develop a labour income-based measure of human capital (LIHK) which seeks to obtain an index value, rather than a monetary value, of human capital. 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 total labour income incorporates not only the worker's skills (human capital) but also the physical capital available to them, 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 wrongly 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. 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 always and everywhere. According to the authors, if schooling has quality and relevance that varies 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.

They observed that on the whole, the stock of human capital shrank substantially between 1940 and 1950, and then increased steadily to 1990. This pattern was quite consistent across regions. Interestingly, aggregate human capital stocks increased by 52 percent between 1980 and 1990, whereas over the four earlier decades human capital 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' LIHK 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. In addition, the model relies heavily on the assumptions that zero-schooling workers are identical always and everywhere and that workers with different levels of schooling are perfectly substitutes. 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 observed.

Jeong (2002) modifies the Mulligan and Sala-i-Martin's method and applies it to measure human capital across 45 countries of diverse income levels. Jeong departs from Mulligan and Sala-i-Martin in that he uses the industrial labourer, as classified by the International Labour Office, rather than the worker with no schooling, as the *numeraire*. 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 varied 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 outliers are included or not. 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 believes 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 (1997) 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:

$$H_{j,j,t} = H_{i-1,j,t-1} * (1 - d_{i,t}) + H^{+}_{i,j,t} - H^{-}_{i,j,t} \qquad (13)$$

where $H^{+}_{i,j,t}$ is the number of individuals 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 schooling was *j* in year *t-1* and who completed a higher educational level in year *t*, and $d_{i,t}$ is the probability that those aged *i-1* in year *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 schooling levels to human capital:

$$\ln\left(\frac{H}{L}\right) = \sum_{s} w_s \ln(r(s)) \qquad (14)$$

where $w_s = \frac{e^{gs} L(s)}{\sum_{s} e^{gs} L(s)}$

$r(s) = \frac{L(s)}{L}$ is the share of working age individuals with *s* years of schooling,

w_s, defined as 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 g 's the slope coefficients that capture the effect of schooling on earnings, are obtained from a Mincer-type wage regression.

Koman and Marin's estimate of human capital measures workers' productivity by their wage income. As with Mulligan and Sala-i-Martin (1997), the efficiency parameter $\grave{u}_s$ nets out the effect of physical capital on wages (and hence on human capital). A serious limitation, however, is that one year of schooling yields the same amount of skills over time. The authors find that their measure of human capital grew faster than average years of schooling in the populace and that the time-series evidence is not consistent with a human capital augmented Solow model. Apparently, 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 with some modifications to suit Canada's complicated education system. Laroche and Mérette also depart from Koman and Marin by taking into account working experience in addition to formal schooling. In terms of average years of schooling, Canada's human capital per capita increased 15 percent between 1976 and 1996. The increase 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. Also, when experience is accounted for, Canada's average human capital increased by up to 45 percent over the period. Interestingly enough, 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 keep widening over time.

In aggregate terms, the Canada's stock of human capital increased in all dimensions. From 1976 to 1996, Canada's working age population grew by 33 percent and total years of education grew by a further 12 percent, however, the greatest growth was seen in labour income-based measures of human capital with and without working experience, which increased by 73 percent and 89 percent respectively. Laroche and Mérette also propose a measure of the so-called *active* human capital stock which is based on the labour force. In the authors' opinion, this measure gives better insight about the human capital stock available for market production purposes. In average terms, Canada's active human capital (measured using the labour-income based) also increased by 45 percent between 1976 and 1996, whereas the aggregate active human capital stock increased much faster, more than doubling over the same period.

2.3.6 Other income-based measures of human capital

Like Beach *et al*., (1988), Macklem (1997) estimates the stock of human wealth in Canada, where human wealth is computed as the expected present value of aggregate labour income net of government expenditures based on an estimated bivariate vector autoregressive (VAR) model for the real interest rate and the growth rate of labour income net of government expenditures. Since the present value formula is non-linear, the estimated VAR is approximated as a discreet value finite-state Markov chain, which allows expectations to be calculated as a weighted sum over possible outcomes instead of an intractable integral.

Although also income-based, Macklem's measure of human wealth takes a more macro approach which, according to the author, has at least two important merits. First, it is much simpler. The macro focus requires much less onerous data, 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, which improves understanding of household behaviour regarding consumption and savings. 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 these complicated fluctuations, per capita human wealth has changed very little since the mid-1970s. First, this was due to the fact that real interest rates were 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 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 like that, 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 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.

2.4 Integrated approaches to human capital measurement

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

2.4.1 Tao and Stinson (1997)

Tao and Stinson (1997) develop an integrated approach to estimating the stock of human capital in the United States which resolves some well known problems inherent in both 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. In turn, human capital determines earnings for individuals through the income-based approach.

First, the authors specify a fundamental earning function, which establishes the relationship between human capital $h_{i,j}^{s}$ and earnings $E_{i,j}^{s}$, as:

$$E_{i,j}^{s} = w_t h_{i,j}^{s} \qquad (21)$$

where *s*, *i*, and *j* indicate the sex, age, and educational level respectively 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 the two variables must be standardised. Tao and Stinson choose to standardise the human capital stock of the base entrants. This group is selected because they enter the labour force after leaving high school and thus no account needs to be taken of how experience, on-the-job training and the cost of training affect their human capital. In addition, the ability of these base entrants can be determined from the SAT (Scholastic Aptitude Test) scores. This test provides a consistent measure of the ability of high school graduates and SAT results are available for a number of years.[8] The human capital stock can then be identified by exploiting its relationship with human capital 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 in their general education (through high school graduation). Once the human capital of these individuals is defined, the human capital rate *w* can then be easily estimated by applying earnings data to equation (21) above. That rental rate, which is assumed to be constant across cohorts, can then be applied together with earnings to equation (21) to derive the human capital stock for cohorts other than the base entrants.

The total human capital stock is obtained by aggregating the human capital from all cohorts in the population. It was found that the human capital stock embodied in employed individuals[9] expanded by six times between 1963 and 1988. When differences in the abilities of base entrants were considered, specifically, when the SAT scores of base entrants and entry level wages set by employers are assumed to be closely connected, the increase was less than 100 percent over the period. Effective human capital increased more for females (135 percent) than for males (75 percent), largely due to the increased participation of females in the labour force.

Tao and Stinson assert that their new framework demonstrates many advantages over existing approaches. First, by using the cost method to derive only the human capital stock of the average base entrants and estimating the human capital stock of other cohorts based on the human capital stock of this group, this method avoids the problem of what defines an investment in human capital. The authors believe that it is appropriate to consider only educational expenditures as human capital investments in base entrants. Since medical spending, for example, is already reflected in improved health and thus earnings, adding medical costs to the base entrants' human capital would be double counting. Additionally 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 provides more explanatory power than hours of labour.

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[8] The SAT data suffer from a self-selection bias, since students have the choice to take the test. Tao and Stinson have, however, corrected this problem.

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

However, a few problems persist. For example, 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 a wage based on the abilities as measured by the SAT score, but the SAT score may not be a good measure of ability. Nevertheless, Tao and Stinson show that their measure enhances the explanatory power of the Cobb-Douglas production function for the US economy over the period studied.

2.4.2 Dagum and Slottje (2000)

Dagum and Slottje also combine various methods to develop an integrated measure of human capital. Their approach estimates personal human capital, its size distribution, the average level of human capital by age, and the average level of human capital in the population. From this a specific monetary value of the stock of human capital can be computed.

Personal human capital is construed as a dimensionless latent endogenous variable. From p indicators of human capital chosen from the sample survey database, a linear function of human capital is specified as:

$$z = L(x_1, x_2, x_1, \ldots, x_p) \qquad (22)$$

where z refers to the standardised (zero mean and unit variance) human capital latent variable, and $x_1, x_2, x_1, \ldots, x_p$ are p standardised indicators of human capital. An accounting monetary value of human capital for the i^{th} economic unit, $h(i)$, can then be computed based on the following formula:

$$h(i) = exp(z_i) \qquad (23)$$

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

$$h(x) = \sum_{n=0}^{70-x} \frac{y(x+n)\,p(x,x+n)(1+r)^n}{(1+i)^n} \qquad (24)$$

where $p(x,x+n)$ is the probability that a person aged x will survive another n years, i is the discount rate, r is the economic growth rate, and the highest working age is set at 70.

The weighted average value of the transformation in equation (23), $Av(h)$, and the weighted average of the population human capital given in equation (24), $AvHC(h)$, can be easily derived. The monetary value of the human capital of the i^{th} sample observation is then given as:

$$HC(i) = h(i)\frac{AvHC(h)}{Av(h)}, \qquad i=1, 2, \ldots, n. \quad (25)$$

Intuitively, the monetary value of a person's human capita is equal to the average lifetime earnings of the population, weighted by the level of human capital that he/she has relative to the average human capital of the population.

Using data from 4,103 household observations from the 1983 US Federal Reserve Board sample survey on income and wealth distributions, Dagum and Slottje estimated that in 1982 the US per capita human capital ranged from $239,000 to $365,000, depending on whether the discount rate was six percent or eight percent and whether economic growth rate was zero or positive. Their lowest estimate of US human capital was still twice Kendrick's estimate of per capita human capital in 1969 real terms. Not surprisingly, these figures are only a fraction of those obtained by Jorgenson and Fraumeni (1989, 1992) as the latter incorporates non-market human capital. Dagum and Slottje's estimates compare very unfavourably with the results for Canada in 1982 estimated by Macklem (1997). However, as discussed earlier, Dagum and Slottje question the reliability of Macklem's results.

Dagum and Slottje believe that by combining the estimation of human capital as a latent variable with a macroeconomic estimation of the average human capital of a population of economic units, their method provides a robust statistical support to the estimation of human capital. Most notably, the use of the latent variable approach is intended to remove the omitted variable bias that plagues the income-based method to measuring human capital. However, the data used in Dagum and Slottje's study does not contain any measure of intelligence, ability or any other indicators of genetic endowment, which renders the estimated *h(i)* a less powerful indicator of human capital.

3. Some recent applications to New Zealand

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 Treasury (2001).

However, in New Zealand attention is now switching to directly valuing human capital. Hendy, Hyslop and Maré (2002), in work that is still in progress, 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.

Oxley and Zhu (2002) follow the approach of Dagum and Slottje (2000) and use Census data in five-year age bands are used to estimate expected lifetime income, with different rates of productivity growth over the lifecycle. 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 NZ$282,000 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 results when using the considerably more complex methods of our current study.

Here we present some results, derived from Le, Gibson and Oxley (2003), where full details of the model and data can be found, based upon a modified Jorgenson and Fraumeni (1989, 1992) and Wei (2001) approach. These new results place a value on the stock of human capital of the employed work force, or the *effective* human capital stock, for New Zealand.[10] We focus only on those individuals in employment, since these people are directly participating in economic production and so their human capital is arguably a better measure of the country's productive capacity.

The estimates presented below, are based on the discounted present value of expected lifetime labour market incomes. The results allow for the possibility of future further educational experiences with individuals trying to move onto a higher age-earnings profile. Similar to Wei (2001), we assume that the potential working life is from age 21 to 65. A work-study phase occurs from 21-34, a work-only phase occurs from age 35. We initially followed Wei and specify five groups defined by their highest qualification: higher degree, Bachelors degree, diploma, skilled labour, and unqualified although it is apparent that in New Zealand there is not much difference between the annual labour incomes of people in the diploma group and those in the skilled labour group such that we aggregated diploma and skilled to give four categories. Extensions including a work-study phase and varying enrolment rates were used to provide for robustness analysis.

A selection of results based on data obtained from each New Zealand Census of Population from 1981 to 2001, are presented as Table 2, below. The data used were in the form of population counts within homogeneous cells defined by age, gender, educational level, employment status, and income bracket. Depending on the particular census, the number of cells approached 100,000, but for most of the analysis we formed the data into 360 cohorts defined by 45 ages (21-65), two genders,

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[10] This term is adopted from Tao and Stinson (1997). Hendy *et al*., (2002) also focus on the same part of the population.

and four educational levels.[11] The last variable needed to calculate the expected value of lifetime income is survival rates, which were obtained from *New Zealand Life Tables*. Since survival rates are classified by gender and age only, we assume that the probabilities of surviving do not vary with the level of education. Survival rates were unavailable for 2001, so we use estimates for 1998-2000 from *Demographic Trends*, which are in five-year age intervals rather than by each specific age as used with the other census years.

The average per capita lifetime labour incomes (in 2001 NZ dollars) are reported in Table 2, below. These figures are weighted averages of the lifetime income profiles, where the weights are the number of people at each year of age. Consistent with the time trend for annual incomes, average lifetime incomes declined in real terms during 1981-1991 and started to increase since. Although average annual income in 2001 is nine percent higher than in 1981, average lifetime incomes grew by less than two percent over the period. The major cause of this fall is the decrease in employment rates over the years. In particular, compared with 1981, both employment and real annual income in 1986 were lower, which explains the lower average lifetime income. Annual income rose slightly in the next inter-censual period, but employment declined dramatically, especially for the less educated, who make up the majority of the population. As a result, expected annual income and lifetime income increased only marginally. In the last ten years since 1991, both employment and real annual income have risen over time, improving average lifetime income consequently. These temporal patterns do not seem to be affected by the particular deflator used, and if anything the decline from 1981 is even greater if a price index (rather than a wage index) is used.

The contribution to the stock of New Zealand human capital by each education and gender group is presented as Table 3, below. The share of “unqualified” people in the stock of human capital has declined from one-half of the male total in 1981 to just one-third in 2001, while the proportionate decline is even greater for women. By contrast, the human capital contributed by university degree holders has risen, in both relative and absolute terms. Indeed, this is to be expected, from what was observed

[11] Cell counts were randomly rounded to base 3 to protect confidentiality, which could lead to errors in our results, because our data are broken down to such a detailed level. However, since the rounding is only at random, we believe that the effect it has on our results, if any, is insignificant.

earlier that annual incomes of these people have improved relatively the most and that their shares of the population have also expanded.

Table 2: Average Lifetime Labour Income Per Capita (NZ$2001)

	1981	1986	1991	1996	2001
Males					
Unqualified	500,558	479,910	456,012	480,015	455,641
Skilled	678,840	633,728	633,625	677,056	701,763
Bachelors	938,104	956,174	985,915	1,009,189	997,022
Higher	991,535	953,096	988,319	1,055,101	1,022,189
Weighted average	**588,742**	**588,451**	**596,444**	**638,471**	**631,766**
Females					
Unqualified	343,374	277,427	290,192	308,373	299,945
Skilled	478,039	399,872	422,376	448,494	470,244
Bachelors	675,291	564,624	632,443	640,275	674,362
Higher	726,225	602,110	670,562	710,553	758,011
Weighted average	**400,420**	**342,272**	**379,348**	**409,976**	**429,034**
Overall average	**527,573**	**488,791**	**503,803**	**535,607**	**537,081**
Change from last Census		**-7.35%**	**3.07%**	**6.31%**	**0.28%**

Source: Authors calculation from New Zealand Census of Population, 1981, 1986, 1991, 1996, 2001. Adjusted to 2001 dollars using the Prevailing Weekly Wage Index PWIQ.S4329 and All Salary & Wage Rates LCIQ.SA53Z9.

Table 3: Aggregate Value of Human Capital in New Zealand (NZ$2001 billion)

	1981	1986	1991	1996	2001
Males					
Unqualified	215.5	181.1	144.2	163.3	177.6
Skilled	161.4	220.3	235.0	242.1	227.0
Bachelors	28.4	40.0	49.3	68.4	81.3
Higher	14.7	25.7	28.1	38.0	42.5
Subtotal	**420.0**	**467.2**	**456.6**	**511.8**	**528.4**
Females					
Unqualified	76.0	84.4	77.4	91.6	99.2
Skilled	51.0	80.6	107.7	126.8	135.6
Bachelors	7.9	12.2	20.1	33.6	53.9
Higher	2.5	7.6	11.0	17.1	25.8
Subtotal	**137.4**	**184.8**	**216.2**	**269.1**	**314.5**
Total	**557.4**	**652.1**	**672.8**	**780.8**	**842.9**
Change from last Census		**16.98%**	**3.18%**	**16.06%**	**7.95%**

Source: Authors calculation from New Zealand Census of Population, 1981, 1986, 1991, 1996, 2001. Adjusted to 2001 dollars using the Prevailing Weekly Wage Index PWIQ.S4329 and All Salary & Wage Rates LCIQ.SA53Z9.

For example, in 1991, when the total human capital stock increased by a mere three percent from 1986, the capital accounted for by the university educated grew by 27 percent. While total human capital increased by half, university degree holders’ capital almost quadrupled over the last twenty years. Most of the growth in total human capital comes from the additions to the labour force, since expected annual labour income in 2001 is marginally higher than in 1981.

4. Conclusions

In this paper we have concentrated on reviewing the cost- and income-based approaches to measuring human capital, in part, because it is a relatively neglected field in the area of human capital measurement and also due to the existence of other excellent surveys of the educational experience approach. However, the three approaches are clearly related. Inputs into the human capital production process, including, for example, the costs of rearing and educating people, form the basis for the cost-based approach to human capital valuation. The income-based approach to measuring human capital uses an individual's earnings which are assumed to be influenced by acquired skills and education. Human capital measures based upon literacy rates, school enrolment rates, and mean years of schooling, which have been widely used in their own right as educational stock-based measures of human capital, potentially form an input into such income-based measures.

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, by estimating, in monetary terms, human loss from wars and plagues, and with developing accurate estimates of human wealth in national accounts. Now the focus has been switched to using the human capital variable as an input to explain economic growth and a potential policy instrument. 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 is not unambiguous. The lack of empirical consensus is, in part, due to alternative approaches to measuring human capital where each approach subject to two types of measurement error: the measure does not adequately reflect key elements of human capital, and data on the measure is of poor quality. Hence, measuring human capital remains a significant research challenge.

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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/Comments
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, 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)		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, 1907	To estimate the cost of preventable illness	The stock of human capital exceeded all other wealth.
Barriol (1910)	Income-based (Farr's approach)	France and other selected countries		
Huebner (1914)	Income-based (Farr's approach)	United States, 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		Human capital of £6,211 million (or £1,246 per capita, £1,923 for males and £928 for females) was about 3 times as large as the physical capital stock.
Woods and Metzger (1927)	5 different methods, including -Farr's approach -Petty's approach	United States, 1920	To show the importance of the nation's population	
Dublin (1928)	Unknown	United States, 1922		The stock of human wealth was approximately 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 economic costs of preventable disease and premature death	
Schultz (1961)	Cost-based	United States, 1900-1956	Economic growth, productivity	The stock of human capital grew twice as fast as that of physical capital during 1900-1956.
Weisbrod (1961)	Income-based	United States, 1950, males aged 0-74	To estimate the value of the human capital stock	-Gross: $1,335b at r=10%, $2,752b at r=4% -Net (of consumption): $1,055b and $2,218b respectively -Compared with non-human assets of $881b
Kendrick (1976)	Cost-based	United States, 1929-1969	To develop national wealth estimates to complement estimates of the physical stock.	The stock of human capital was often greater and grew faster than that of physical capital.
Eisner (1985)	Cost-based	United States, 1929-1969	As above	The stock of human capital was almost as large as that of physical capital.
Graham and Webb (1979)	Income-based	United States, 1969, males aged 14-75	As above	The stock of human capital embodied in US males aged 14-75 in 1969 ranged from $2,910 billion at 20% discount rate or $14,395 billion at 2.5% discount rate. This contrasted with an estimate of $3,700 billion obtained by Kendrick's (1976).

Jorgensen and Fraumeni (1989, 1992)	Income-based (Improvement on Dublin and Lotka, 1930)	United States, 1948-1986	-To present a new system of national accounts for the US economy -To measure the impact of investment in education on economic growth	Stock of real human capital almost doubled, from $92 trillion in 1949 to $171 trillion in 1984. Estimates in the later study (1992), were about 20% higher, due to allowance being made for school enrolment. Per capita human capital grew by 15%, from $742,000 in 1948 to $855,000 in 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, Jorgensen and Fraumeni's (1992) estimates of US human capital was from 17.5 to 18.8 times higher than Kendrick's.
Ahlroth et al. (1997)	Income-based (Jorgensen and Fraumeni method)	Sweden, 1968, 1974, 1981 and 1991	To compute the aggregate measures of the output of the Swedish education sector.	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.
Wei (2001)	Income-based (JF method)	Australia, 1981-1996 quinquennially	To develop measures of human capital that could serve as useful counterparts to measures of physical capital.	In 1996 prices, the stock of Australia's working age human capital increased from $1.7 trillion in 1981 to $2.1 trillion in 1996, but there was a sharp drop in 1991. The stock of human capital was larger than that of physical capital, although the ratio has been declining over time.
Macklem (1997)	Income-based (macro focussed)	Canada, 1963-1994, quarterly		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. 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)		On the whole, the stock of human capital shrank substantially between 1940 and 1950, before increasing steadily to 1990. Aggregate human capital stocks increased by 52% between 1980 and 1990.

Koman and Marin (1997)	Income-based	Austria and Germany, aged 15 and over, in 1980, 1985, 1990, and 1992		Human capital grew faster than average years of schooling in the populace and that the time-series evidence was not consistent with a human capital augmented Solow model.
Jeong (2002)	Income-based Mulligan and Sala-i-Martin's 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, depending on whether or not outliers are included. Although this figure is considerable, it is small in comparison with the cross-country difference in human capital measures based on years of schooling or with the output difference.
Laroche and Mérette (2000)	Income-based (Koman and Marin's (1997) method)	Canada, aged 15-64, 1971 to 1996		*In per capital terms: -years of schooling increased 15% between 1976 and 1996 -human capital measured using Koman and Marin's income-based approach increased by over 33%, and by 45% when working experience is accounted for. *In aggregate terms: -working age population grew by 33% -total years of education grew by a further 12% -labour income-based measures of human capital with and without working experience increased by 73% and 89% respectively. *For the labour force only: in average terms, Canada's active human capital (measured using the labour income-based approach) also increased by 45% between 1976 and 1996, whereas the aggregate active human capital stock increased much faster, more than doubling over the same period.

Tao and Stinson (1997)	Integrated	United States, 1963-1988, the employed		The effective human capital stock expanded by 6 times between 1963 and 1988. When differences in the abilities of base entrants were considered, the increase was less than 100% over the period. Effective human capital increased more for females (135%) than for males (75%), largely due to the increased participation of females in the labour force.
Dagum and Slottje (2000)	Integrated	United States, 1982		In 1982 the US per capita human capital was estimated to range from \$239,000 to \$365,000, depending on whether the discount rate was 6% or 8% and whether economic growth rate was zero or positive. The lowest figure was still twice Kendrick's estimate of per capita human capital 1969 in real terms. Not surprisingly, these figures are only a fraction of those obtained by Jorgensen and Fraumeni (1989, 1992) because the latter incorporate non-market human capital as well.