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Estimates of Human Capital in Canada: The Lifetime Income Approach

by Wulong Gu and Ambrose Wong

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.	not available for any reference period
..	not available for a specific reference period
…	not applicable
0	true zero or a value rounded to zero
0^s	value rounded to 0 (zero) where there is a meaningful distinction between true zero and the value that was rounded
^{p}	preliminary
^{r}	revised
x	suppressed to meet the confidentiality requirements of the *Statistics Act*
^{E}	use with caution
F	too unreliable to be published

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Abstract

This paper produces an estimate of market-based human capital investment and stock for Canada over the period from 1970 to 2007 based on the lifetime income approach and compares it with that of physical and natural capital investment and stock. It adopts the methodology developed by Jorgenson and Fraumeni, and estimates human capital stock as the expected future lifetime income of all individuals. Human capital investment is estimated as changes in human capital stock due to the addition of new members of the working age population arising from the rearing and education of children and the effect of immigration on human capital.

The main findings are as follows:

1. The volume of aggregate human capital rose at an annual rate of 1.7% in Canada for the period 1970 to 2007, and most of the growth is due to the increase in the number of individuals in the working-age population. The rising education level of the Canadian population is also a significant contributing factor to the growth in human capital.

2. The compositional effects of aging of the Canadian population (a movement to a population that is older on average) reduced human capital growth by 0.6% per year over the period 1980 to 2007, while the rising education level increased human capital growth by 0.7% per year over the period.

3. Human capital stock on a per capita basis increased at 0.9% per year for the period 1970 to 1980, due to the rising education attainment during the period. After 1980, human capital stock per capita was virtually unchanged due to two offsetting factors: rising education level which increased human capital stock and the compositional effects of population aging, which reduced human capital stock.

4. The value of human capital investment and stock exceeds the value of physical capital investment and stock, and the ratio of human capital investment and stock to physical capital investment and stock declined over time. In 2007, human capital stock is about four times as large as physical capital stock while investment in human capital is about two times the magnitude of investment in physical capital.

5. The levels of human capital investment and stock estimates are sensitive to the assumptions made about expected future income growth and the rate used to discount the future income when calculating human capital, but the growth of the quantity and price of human capital investment and stock is not sensitive to the assumptions in these areas.

Executive summary

This paper develops a measure of the human capital derived from the lifetime earnings approach. It provides an estimate of the value of Canada's total wealth associated with the lifetime labour related earnings of individuals that can be compared to the wealth estimates derived from produced physical capital and natural capital.

Investment in human capital is seen to be as important for growth as the expenditures that generate physical capital such as machinery and equipment or natural resources. While measures of the latter have long attracted the interest of the statistical community, measures of human capital are less developed. Recently, member countries of the Organisation of Economic Co-operation and Development have begun to experiment with such measures.

In the late 1990s, the Canadian Productivity Accounts (CPAs) began to assess the contribution of investment in education and training to output growth and productivity growth in Canada. Investment in human capital that has produced a shift in the composition of the workforce towards more educated and more experienced workers has been found to be an important source of productivity growth.

The indices of labour composition constructed by the CPAs of Statistics Canada are an essential first step in incorporating investments in human capital into empirical studies of economic growth and national accounts. This paper is an additional step in this direction.

In the national accounting systems of Canada and other countries, expenditures on human development and related 'intangibles' are all regarded as current expenditures (rather than investment). This, in effect, means that outlays on education, child rearing and training are all classified as consumption expenditures, either intermediate or final. This paper treats human development expenditures as investment (that should be accumulated into human capital stocks) because the benefits of such expenditures accrue to the individual over a lifetime. This paper adopts the income-based approach developed by Jorgenson and Fraumeni and estimates human capital stock as the expected future lifetime income of all individuals. Investment in human capital is estimated as the changes in expected future lifetime income due to the rearing and education of children plus the effect of immigration on human capital accumulation.

The paper focuses on five questions.

1. What are the sources of human capital growth in Canada?

Aggregate human capital stock rose at annual rate of 1.7% in Canada for the period from 1970 to 2007. Most of the growth is due to the increase in the number of individuals in the working-age population aged 15 to 74. The rising education level of the Canadian population is also a significant contributing factor to the growth in human capital. Of the 1.7% growth in human capital in the period from 1970 to 2007, 1.5 percentage points is accounted for by the growth in the working-age population, the remaining 0.2 percentage points is due to the effect of the compositional shift of human capital (i.e.., rising education levels of the Canadian population). For the period 1970 to 2007, the rising education level increased human capital growth by 0.9% per year.

2. What was the compositional effect of the aging of the Canadian population on human capital stock?

The aging of the Canadian population (a shift in the population distribution towards older workers) has a negative effect on the growth of human capital stock as older workers on average have lower human capital stock (measured by remaining lifetime earnings) because of their shorter remaining working life. Our estimates show that the aging of the Canadian population reduced human capital growth by 0.6% per year over the period 1980 to 2007.

3. What was the level of human capital investment and stock relative to physical capital investment and stock?

The value of human capital investment and stock exceeds the value of produced physical capital investment and stock. But the ratio of human capital investment and stock to physical capital investment and stock declined over time. In 2007, human capital stock is about four times as large as produced capital stock, and investment in human capital was about two times as large as investment in produced capital. The difference between human capital and produced capital was higher in the early 1970s. The ratio of human capital stock to produced capital stock was 5.7 to 1 in 1970, and the ratio of investment in human capital to investment in produced capital was also 5.7 to 1 in 1971.

4. What was the growth of human capital investment and stock relative to the growth of physical capital investment and stock?

The growth of human capital investment and stock was slower than the growth of produced capital investment and stock. Over the period from 1970 to 2007, the volume of human capital stock increased 1.7% per year, while produced capital stock rose at 2.8% per year. From 1971 to 2007, human capital investment in constant dollars grew at 0.4% per year, while real investment in produced capital rose at 3.9% per year.

5. Are estimates of the growth and level of human capital investment and stock sensitive to alternative assumptions adopted for the estimation?

The levels of human capital investment and stock estimates are sensitive to the assumptions made about expected future income growth and the rate used to discount the future income when calculating human capital, but the growth of the quantity and price of human capital investment and stock is much less sensitive to the assumptions in these areas.

1 Introduction

This paper develops a measure of the component of total wealth derived from the investments made in human development—commonly referred to as human capital—and provides an estimate of the value and composition of Canada's total wealth that includes produced capital, natural capital and human capital. Each of these produces streams of earning that are available to an economy for personal consumption, further investments and support of government programs.

It is common to measure the capital embedded in physical and natural resource assets and include these in Wealth Accounts. The capital value of an asset and the flow of services at any point in time differ. The net present value of the stream of earnings over a lifetime of an asset such as physical capital represents the 'value' of this capital stock. The net present value of the stream of earnings of resource deposits is taken to be the value of these resources in the Wealth Accounts.

Similarly, each individual has a lifetime earnings profile that can be thought of as the potential amount that can be transformed into consumption, contributions to the government in support of needed programs, and savings that can be transformed into financial wealth to support retirement or contingencies that short-run earnings will not cover. The net present value of these earnings then also can be thought of as the embedded capital of an individual—what is sometimes referred to in the economics literature as human capital.

The instantaneous value of flows from an asset and its capital value measure different concepts. An individual near the end of life may have a higher yearly income than someone just starting out their working career as a result of the accumulation of experience or education. But to the extent that they have fewer remaining earning years, the net present value of the remaining earnings and therefore the value of their human capital will be lower. The individual may be just as productive over the course of the year as he has always been but the inexorable passage of time and the finiteness of life mean that his embedded human capital diminishes with age. Just as firms are not sustainable if their assets all are at the end of their working life and no replacement has occurred, if populations consist largely of the elderly, the flow of earnings from that population will not be sustainable as death brings about a decline in population numbers. More recently, birth rates have fallen dramatically in some countries to levels that will eventually lead to decline in their population. For this reason, estimates of human capital are seen to be important indicators of sustainability that complement other statistics that have until now received more attention.

Estimates of the amount of capital, its quality, and its age have been at the heart of investigations into economic growth and sustainability in Canada and in the other member countries of the Organisation for Economic Co-operation and Development (OECD 1998, Skills Research Initiative 2008). Attention originally focused on measures of physical capital. But more recently, experimental estimates have been produced of the amount of human capital.

These estimates require detailed data on labour remuneration across different groups of workers. In the late 1990s, the Canadian Productivity Accounts (CPAs) began to assess the contribution of improvements in education and training to output growth and productivity growth in Canada (Statistics Canada 2002; Gu et al. 2003). The CPAs constructed a measure of labour input and labour composition that focuses on changes in the educational attainment and experiences of the Canadian workforce. Labour input is disaggregated by age, educational

attainment and class of workers (paid and self-employed workers). Changes in the composition of workers towards more educated and more experienced workers are found to be an important source of productivity growth. Over the last 45 years, it accounted for a quarter of the growth in labour productivity in Canada (Baldwin and Gu 2007).

The indices of changes in labour composition, constructed by the CPAs of Statistics Canada, are an essential first step in incorporating more comprehensive measures of human capital using the lifetime earnings approach into empirical studies of Canadian economic growth and the Wealth Accounts produced by the National Accounts. This paper js an additional step towards that objective. It follows similar investigations for the United States (Jorgenson and Fraumeni, 1989).

In the national accounting systems of Canada and other countries, expenditures on human development and related 'intangibles' are all regarded as current expenditures (rather than investment). This, in effect, means that outlays on education, child rearing and training are all classified as current expenditures, either intermediate or final.

The main historical and institutional reasons for this classification decision are:

- The classification follows business accounting conventions.
- Human capital resources cannot be bought and sold on the market in the same way as non-human (physical) capital.
- Certain expenditures, such as child rearing, that are required to sustain population growth are not directly measurable and would have to be imputed.

Yet the concept of human capital has been familiar in economics for the past 40 years (e.g., Schultz 1961a, 1961b; and Becker 1964). The concept is based on an analogy between investments in physical capital and investments made to maintain populations and is motivated by a common economic principle. When an individual (or economic entity) undertakes expenditures, the effects of such outlays can be categorized into one of two types:

- The benefits of the expenditures are realized in the same time period as when the outlays occur (e.g., a period of one year).
- The benefits are realized in future periods and possibly after considerable waiting.

The first type of expenditure is categorized as 'consumption': the second type of expenditure is defined as 'investment.'

This economic principle suggests that expenditures on human development should be classified as investment (and appropriately accumulated into human capital stocks), because the benefits of these expenditures accrue to the individual over a lifetime.

Several different methodologies for measuring human capital have been developed.

Kendrick (1976) used a cost-based approach for the measurement of human capital and estimated human capital as the accumulated value of all expenditures related to human development, such as costs related to the rearing and education of children.

An alternate approach based on lifetime income was developed by Jorgenson and, Fraumeni (1989, 1992a, and 1992b) that treats the net present value of incomes over a lifetime as a proxy for the earnings potential and thus the embedded capital inherent in the individual. The income-based approach has been used to estimate total human capital for Sweden (Ahlroth, Björklund and Forslund 1997), Australia (Wei 2004, 2007, 2008), New Zealand (Le, Gibson and Oxley 2002), for the United Kingdom (O'Mahony and Stevens 2009), and for Norway (Greaker and Liu 2008). This paper contributes to those recent studies on human capital measurement by applying the Jorgenson and Fraumeni income-based approach to measure human capital stock for Canada.

Previous studies have developed a measure of human capital for Canada. Macklem (1997) and Beach et al. (1988) calculated aggregate human wealth as the expected present value of aggregate labour income net of government expenditures. Macklem (1997) found that the value of human wealth was about six times as large as the value of non-human wealth over the period 1963 to 1994. While the concept of human capital in those studies is similar to the one in this paper, those studies adopted a macro approach and failed to take into account the effect on human capital of shifts in the composition of the Canadian population towards older and more educated individuals, as this paper does. Laroche and Mérette (2000) calculated an index of human capital as a weighted sum of the number of workers with different education levels and experience. Unlike this paper, which weights individuals with their lifetime income, Laroche and Mérette weighted the individuals with their current wage income. For the measurement of human capital stock, it is more appropriate to use expected lifetime income as weights. The wage income that a worker receives in one period only represents the flow of services from human capital embodied in the worker at that point in time. Taking a longer time period recognizes that a worker's lifetime income may change because of the lifepath that is taken over a much longer period—caused by life events such as education, training and the overall state of the economy.

The rest of the paper is organized as follows: The next section presents the methodologies for estimating human capital investment and stock. Section 3 presents the construction of data used for estimation. Section 4 presents the results. Section 5 provides a summary of the findings.

2 Methodologies for estimating human capital

In general, capital stock can be valued using two methods:

- It can be valued as the sum of additions, minus the subtractions, made over time to initial stock (cost-based approach).
- Alternatively, capital can be valued as the net present value of the income it is able to produce over time (income-based approach).

The cost-based approach is employed to estimate the value of physical capital stock, while the income-based approach is often used to estimate the value of natural capital. In the former case, the value of physical capital is obtained by summing the value of investments and subtracting the depreciation from initial capital stock. This approach is used because prices for physical investments are available and projections of future profits on physical investments are more difficult to make.

The value of natural resources is often estimated as the net present value of resource rents over an assumed lifetime. This method is adopted because it is sometimes argued that simply summing developmental costs would miss the rents associated with natural resources and thereby underestimate the returns to resources and thus their intrinsic capital value.

In a well-functioning market, where physical assets are bought and sold, the two methods (cost versus earnings) should yield approximately the same results. Otherwise, if the net present value of income exceeds the cost of purchasing the asset, more physical assets are likely to be manufactured and employed thereby reducing returns (under the assumption of diminishing returns) and bringing the future stream of earning into equilibrium with the costs of producing the stream of returns. But in a market, where there is reason to believe that this cannot or does not occur, alternative methods are needed to value an asset. Because of the nature of labour markets (amongst which is the length of childhood before newborns enter the labour market), the ultimate earnings of individuals and the costs of rearing and educating individuals may not equate at the margin.

As a result, Jorgenson and Fraumeni (1989, 1992a and 1992b) estimated the value of human capital directly in terms of lifetime labour income for all individuals. The advantage of this approach is that it directly measures the concept that is being sought—the lifetime earnings associated with labour. Lifetime earnings ultimately measure the potential economic value of the asset.[1] The disadvantage is that it requires projections into the future. Whether this is important is an empirical matter—that can be investigated by examining the impact of alternate assumptions on the estimates of human capital and evaluating the importance of differences that arise from these alternatives.

The other advantage of using the lifetime earnings approach is that it provides a measure of potential earnings that can be used to characterize an individual's life course that is characterized by a gradual transformation of human capital potential into consumption, investment in upgrading human capital and the transformation of present earnings into financial wealth via savings that is available to support retirement. Descriptions as to how a society prepares for retirement require an understanding of how income potential (as measured by lifetime earnings) is gradually transformed over a lifetime into actual preparedness (through asset acquisition that will support retirement). Human capital accounts provide one of the two main accounts required for this purpose.

Using this income-based approach to measuring human capital, Jorgenson and Fraumeni report that their estimates of human capital were at least 4 times the magnitude of investment in non-human capital in the United States; moreover, the value of human capital stock is over 11 times the value of physical or non-human capital. More recently, the income-based approach was used to estimate human capital for Sweden (Ahlroth, Björklund and Forslund. 1997), Australia (Wei 2004, 2007), New Zealand (Le, Gibson and Oxley 2002) and Norway (Greaker and Liu, 2008). Those studies confirmed the findings for the United States and found that the value of human capital using the income-based approach is significantly greater than the value of non-human capital stock. In a related context, O'Mahony and Stevens (2009) estimated the output of the education sector for the United Kingdom, and Ervik, Holmøy and Hægeland (2003) estimated the output of the education sector for Norway.

Kendrick (1976) and Eisner (1985) use the cost-based approach to estimate investment in human capital. The investment in human capital includes the cost of child rearing and the cost

1. Economic value based on market prices may be quite different from inherent value based on other concepts.

of education, including earning forgone by students. The data on investment in human capital is then aggregated using the perpetual inventory method to derive estimates of human capital stock. More recently, the cost approach was used by Kokkinen (2008) to construct a measure of human capital stock for Finland in an empirical analysis of human capital and economic growth.

In addition to those approaches, previous empirical studies have used a number of proxy measures of human capital, including educational attainment, average years of schooling, and literacy scores (e.g. Barro and Lee 1996; Coulombe and Tremblay 2006; and, for a review, see OECD 1998).

2.1 The income-based approach to human capital measurement

This study adopts a variant of the Jorgenson and Fraumeni (1989, 1992a and 1992b) income-based approach for the measurement of human capital and estimates the value of human capital stock as the expected future lifetime income of an individual.

This approach treats 'individuals' as entities that embody capital with an earning potential that is derived from market activities, and assigns a 'price'[2] to their lifetime labour using their actual earnings profile.[3] As outlined above, the value of an asset can be estimated either from the stream of earnings it produces or the costs of producing or buying it,. For physical capital, the value of the asset is observed directly from market transactions in investment goods. The cost of capital services from the asset is then derived using the user-cost-of-capital equation. For human capital, the value of the asset is not observed from transactions in labour markets; the cost of producing the labour is not directly observed because human trafficking is illegal and therefore the value of lifetime services cannot be observed from market transactions. Therefore, the value of human capital assets is estimated here as the net present value of the wage rates over a lifetime (or lifetime labour income).[4] Labour income is defined as the concept that is used in the National Accounts.[5]

To construct lifetime labour incomes and human capital embodied in the Canadian population, we will exclude the value of non-market activities and focus on the human capital embodied in the working-age population, aged 15 to 74.[6] The extended accounts of Jorgenson and Fraumeni include the value of non-market activities and the value of human capital embodied in all individuals. The value of non-market activities is based on the assumption that individuals allocate time between work and non-market activities so that the marginal value is equalized between the two types of activities. The issue of valuing non-market activities is controversial. Furthermore, it can be argued that human capital embodied in the working-age population is more relevant for measuring the productive capacities of the Canadian population. As such, we will exclude the value of non-market activities in our measure of human capital and focus on the human capital of the working-age population.

2. Assigning a price to human effort as a value accords with the normal practice of the National Accounts which uses the prices of products that are exchanged in markets to value relative worth.
3. Jorgenson and Fraumeni assume that human capital such as skills, knowledge and competencies embodied in an individual with a given gender, education and age group does not change over time. To account for such change in the 'quality' of human capital in an individual would require the use of hedonic methods as in the estimation of price indices for computers and semiconductors (Wei 2008).
4. In this approach, no deduction is made for the maintenance of labour. This allows the income stream derived from labour to be compared to the income stream from other assets like physical and natural capital.
5. For a discussion of this concept, see Gu et al. 2003.
6. The end years are arbitrarly chosen. While the average earnings of 74 year olds are not exactly zero, they are very close to zero and changing the limits will have a very small effect on the estimates produced here.

We estimate market lifetime labour income for all individuals aged 15 to 74 with cross-sectional data benchmarked to National Accounts totals. We assume that expected incomes in future periods are equal to the incomes of individuals of the same gender and education, with the age that the individuals will have in the future time period, adjusted for increases in real income. The lifetime incomes can be calculated by a backward recursion, starting with age 74, which is assumed to be the oldest age before retirement. The expected income for a person of a given age is their current labour income plus their expected lifetime income in the next period multiplied by survival probabilities. For example, the present value of lifetime income of 74-year-olds is their current labour income. The lifetime income of 73-year-olds is equal to their current labour income plus the present value of lifetime income of the 74-year-olds, adjusted for increases in real income. Formally, we use the following equation for estimating average human capital per capita for a cohort of individuals with gender (*s*), age (*a*), and educational attainment (*e*):

$$h_{e,a} = w^{e}_{1,a} y^{e}_{1,a} + w^{e}_{2,a} y^{e}_{2,a} + sr_{a,a+1} h_{e,a+1} (1+g)/(1+r) \qquad (1)$$

where

e = educational attainment levels (1 to 5): 1 = zero to eight years of school, 2 = some or completed high school, 3 = some post-secondary education below bachelor's degree, 4 = bachelor's degree, 5 = master's degree or above;

a = ages: 15 to 74;

$h_{e,a}$ = average human capital or average lifetime labour income per capita for individuals with age (*a*) and education level (*e*);

$w^{e}_{1,a}$ = probability of engaging in paid employment for individuals with age (*a*) and education level (*e*), defined as the number of paid workers over the population for that cohort;

$y^{e}_{1,a}$ = annual labour compensation of paid workers with age (*a*) and education level (*e*);

$w^{e}_{2,a}$ = probability of engaging in self-employment for individuals with age (*a*) and education level (*e*), defined as the number of self-employed workers over the population for that cohort;

$y^{e}_{2,a}$ = annual labour compensation of self-employed workers with age (*a*) and education level (*e*);

$sr_{a,a+1}$ = the probability of surviving one more year from age (*a*); and

g = real income growth rate;

r = discount rate.

This formula is then applied to each generation of individuals at a point in time—assuming that each individual progresses through time using the relative incomes of all succeeding cohorts and the relevant probabilities of moving to different states of education and employment status that are applicable at that point in time.

The equation is estimated separately for males and females. This formula requires estimates of the future growth rate of real income. Here it is assumed to equal labour productivity growth in the Canadian business sector, which was 1.7% per year for our estimation period of 1970 to 2007. Real income growth in the past followed the growth in productivity very closely over long

periods of time (Statistics Canada, 2007). We will set the real discount rate equal to 5.1%, which is the weighted average of real rates of return to equity and debt (Baldwin and Gu 2007).[7]

During their working life, individuals may pursue further studies to increase their earnings. To incorporate the extra human capital of those individuals, the formula for backward recursion in (1) is modified (Jorgenson and Fraumeni 1989, 1992a, 1992b; Le, Gibson and Oxley 2002; Wei 2004):

$$h_{e,a} = w^e_{1,a} y^e_{1,a} + w^e_{2,a} y^e_{2,a} + (1 - senr^e_a) sr_{a,a+1} h_{e,a+1} (1+g)/(1+r) + \sum_{m=1}^{M_e} \left(senr^e_a / M_e \right) sr_{a,a+m} h_{e+1,a+m} (1+g)^m / (1+r)^m \quad (2)$$

where

$senr^e_a$ = school enrolment rate, which is defined as the proportion of individuals with education level (*e*) who are studying for a higher education level (*e*+1);

M_e = number of years that the individuals with education level (*e*) spend to complete a higher education level (*e*+1).

When individuals pursue further studies, they face two possible earnings streams: one with the current education level (*e*), and the other with the higher education level (*e*+1) with a delay because of schooling. Average human capital per capita among a cohort of the individuals is a weighted sum of these two earnings streams, with weights being the probability of school enrolment.

In Equation (2), we make the assumption that students enrolled in an education level are evenly distributed across different study years, except for certain young ages. For example, 22 year-old students with a bachelor's degree studying for master's degree are assumed to be in their first year.[8]

To estimate human capital for Canada, we have classified individuals in the Canadian population into five education levels: zero to eight years of schooling, some or completed high school, some post-secondary school below bachelor's degree, bachelor's degree and master's degree or above. We will assume that individuals with zero to eight years of schooling take three years to complete the next education level (some or completed high school); that individuals with some or completed high school take two years to complete some post-secondary education; that individuals with some post-secondary education take two years to

7. Schreyer (2001) provided a detailed discussion about the conceptual issues of discount rate.
8. Specifically, we made the following assumptions about school enrolment:
   For an individual with education level 4 and enrolled in school, he or she is assumed to be in the first year of study if he or she is less than or equal to 22 years of age, in the second year if he or she is 23, and in the first and second year with equal probability if he or she is 24 or older.
   For an individual with education level 3 (some post-secondary education) and enrolled in school for bachelor's degree, he or she is assumed to be in the first year of study if he or she is less than or equal to 20 years of age, in the second year if he or she is 21, and in the first, and second years with equal probability if he or she is 22 or older.
   For an individual with education level 2 and enrolled in school, he or she is assumed to be in the first year of study if he or she is 15, and in the first and second year with equal probability if he or she is 16 or older.
   For an individual with education level 1 and enrolled in school, he or she is assumed to be in the first, second and third years of study with equal probability. In our empirical analysis, we find that this change to the assumption of even distribution of students across different school years has little effect on the estimated stock of human capital for Canada.

complete a bachelor's degree and that individuals with a bachelor's degree take two years to complete a master's degree or above.

The total value of human capital is just the sum across all individuals in the population being counted (in our case, 15-74 year olds). For a given population, the value of human capital will be smaller if there is a larger proportion of the population at an older age since this group has a smaller proportion of their earning years before them. While the latter may seem counterintuitive since the flow of services from the stock of the human capital may be no different in two countries that differ only in terms of the age composition of their population, the value of the human capital is indeed lower in the latter situation since its population has a lower remaining lifetime. An analogy can be found in comparison of physical capital stocks derived from one-hoss shay type assets—that is, where the asset yields a more or less constant flow of services over a lifetime but dies suddenly at the end of its physical life. Two companies that possess the same physical units of this type of asset but that differ in terms of the age structure of the asset (one say owning n units with 20 years remaining life and the other possessing n units with only 1 year left) will differ in terms of their sustainability. The former will be able to continue to produce for 20 years without further investment but the other is going to have to make major investments or go out of business within 2 years. A comparison of flows derived from human capital in these two situations would conclude that the two countries are equally well off when, in reality, the production volume of one is much less sustainable than other. It is for this reason that students of sustainability argue that measure of human capital are needed to supplement flow measures that are traditionally used to study economic growth—especially in an era where birth rates have fallen in many countries to levels that will not sustain the present population.

Differences in human capital per capita across countries arise from the same sources that determine differences in wages rates across individual workers. Higher incomes may be related to greater experience or higher levels of education or superior abilities. Differences are also a function of the amount of capital intensity of a country or its natural resource endowment.

For many purposes, values of changes in human capital rather than levels of human capital are required. And changes can occur either because of movements in prices or volumes. A volume estimate provides a measure that abstracts from changing prices—that is changing relative lifetime earnings across individuals.

A measure of the change in the volume of human capital is obtained using the Tornqvist aggregation method.[9] The growth rate of the volume index of aggregate human capital stock is calculated as the weighted sum of the growth rates of the number of individuals across different categories of the population (gender, age and education) using their share of the nominal value of human capital stock as weights:

$$\Delta \ln K = \sum_{s} \sum_{e} \sum_{a} \overline{v}_{s,e,a} \Delta \ln L_{s,e,a} \qquad (3)$$

where *K* denotes the volume indices of aggregate human capital stock, $L_{s,e,a}$ the number of individuals with gender (*s*), age (*a*), and education level (*e*), and Δ denotes a first difference, or change between two consecutive periods, for example:

9. Diewert (1976) shows that the Tornqvist index is an exact superlative index number.

$$\Delta \ln K = \ln K(t) - \ln K(t-1) \tag{4}$$

The weights are given by the average human capital share of each category of population in the nominal value of aggregate human capital stock:

$$\overline{v}_{s,e,a} = \frac{1}{2}\left[v_{s,e,a}(t) + v_{s,e,a}(t-1) \right], v_{s,e,a} = \frac{h_{s,e,a} L_{s,e,a}}{\sum_s \sum_e \sum_a h_{s,e,a} L_{s,e,a}} \tag{5}$$

where $\{h_{s,e,a}\}$ is the set of average lifetime labour income of different types of individuals, cross-classified by gender, age and education, calculated using Equation (2).

Ceteris paribus, this index will increase if the number of individuals increases over time. Concomitantly, countries with declining populations will experience declines in this index. Alternately, populations with changes in composition towards those that have increasingly large remaining lifetime earnings will experience increases in the volume index. This may occur if growth in the population occurs in those who have greater lifetime earnings because they are at an early stage of their career path or in those who have more earning power because of increases due to education or experience.

The difference between the growth of this weighted population counts and the growth of unweighted population counts measures the growth of human capital per capita. The growth in human capital per capita reflects the effect of demographic changes in population such as aging compositional effects and rising education levels. Human capital per capita will increase if there is a shift in the composition of the population toward younger or more educated individuals with higher expected lifetime income. Formally, aggregate human capital per capita is defined as:

$$CK = K / L \tag{6}$$

where *L* is the number of individuals in the population.

The evolution of human capital per capita is sometimes used as an indicator of whether an economy is on a path of sustainable development. According to some, an economy is on a sustainable development path if total capital (including produced capital, natural capital and human capital) per capita does not decline (Arrow et al, 2007; UNECE, 2009).

The changes in human capital per capita can be traced to demographic changes in population such as compositional aging effects and rising education levels in population. To examine the effect of the demographic changes on changes in human capital per capita, we construct the partial indices of aggregate human capital stock corresponding to population characteristics such as gender, age and education separately. For example, a partial index of the volume of aggregate human capital stock corresponding to gender is defined as follows:

$$\begin{aligned} \Delta \ln K^{sex} &= \sum_s \overline{v}_s \Delta \ln L_s \\ &= \sum_s \overline{v}_s \Delta \ln \left(\sum_e \sum_a L_{s,e,a} \right) \end{aligned} \tag{7}$$

where

$$\bar{v}_s = \frac{1}{2}\left[v_s(t) + v_s(t-1)\right]$$

$$v_s = \sum_e \sum_a v_{s,e,a}$$

The partial volume index corresponding to gender captures the shift of the population distribution between the two genders alone. Similarly, the partial volume indices for education and age measure the shift between age groups or between education levels.

The difference between the growth of the partial indices of aggregate human capital for each characteristic (gender, age and education) and the growth of the number of individuals in the population measures the contribution of that characteristic to the change in human capital stock per capita. The sum of the contribution that each characteristic makes to the change in human capital stock per capita will differ from the overall change in human capital stock per capita, as the sum of the contribution of characteristics represents the first-order approximation to the index of human capital stock per capita.

To examine the evolution of human capital stock over time and present an accumulation account of human capital, we will decompose the changes in human capital stock into three components: investment in human capital, depreciation on human capital and revaluation of human capital. The methodology for decomposing the change in human capital stock is similar to the one for decomposing the change in non-human capital stock and was developed by Jorgenson and Fraumeni (1989). For a comparison, we will first present the method for decomposing the change in non-human capital stock (Christensen and Jorgenson 1973).

For a single capital good, the value of stock is the sum of values of investment goods of each vintage, summed over all vintages:

$$W_t = \sum_{v=0}^{\infty} p_{t,v} A_{t-v} \tag{8}$$

where $p_{t,v}$ is the price of the investment good of vintage v in period t. $A_{t\text{-}v}$ is the quantity of the investment good of vintage v in period t.

The change in the nominal value of capital stock from period to period may be written as:

$$\begin{aligned} W_t - W_{t-1} &= \sum_{v=0}^{\infty} p_{t,v} A_{t-v} - \sum_{v=0}^{\infty} p_{t-1,v} A_{t-1-v} \\ &= p_{t,0} A_t + \sum_{v=0}^{\infty} p_{t,v+1} A_{t-v-1} - \sum_{v=0}^{\infty} p_{t-1,v} A_{t-1-v} \\ &= p_{t,0} A_t - \sum_{v=0}^{\infty} (p_{t-1,v} - p_{t-1,v+1}) A_{t-1-v} + \sum_{v=0}^{\infty} \left(p_{t,v+1} - p_{t-1,v+1}\right) A_{t-v-1} \end{aligned} \tag{9}$$

The first term in the last expression is gross capital formation. The second term is the depreciation on capital goods of all vintages, which represents the change in the value of an asset associated with the aging of the asset and the resulting decline in its efficiency. The third term is the revaluation of assets of all vintages, which represents the change in the value of an asset associated with everything other than aging, including pure inflation, obsolescence and any other impact on the value of an asset that is not associated with aging (Fraumeni 1997; Diewert 2005; Schreyer 2001).

According to Equation (9), the change in the nominal value of capital stock is the sum of net capital formation (gross capital formation minus depreciation) and asset revaluation.

The methodology for decomposing the change in the value of non-human capital stock (Equation [9]) can be used to decompose the change in the value of human capital stock. Similar to non-human capital stock, the change in human capital stock can be decomposed into three components: investment in human capital, depreciation on human capital and revaluation for human capital (Jorgenson and Fraumeni 1989). Human capital investment reflects the increase in human capital stock arising from the rearing of children, formal education, vocational and on-the-job training, health and migration. For this paper, our measure of human capital investment reflects additions to the working age population due to the rearing of children (the arrival of new members of the native born population into the workforce), formal education (skills upgrading from schooling post high school) and migration (new members of the population from outside Canada). This is estimated as the sum of changes in lifetime incomes arising from formal education, lifetime incomes of all individuals who reached working age and changes in human capital due to immigration.

The second component of the change in human capital arises from depreciation of human capital, which is the change in human capital stock because of aging, death and emigration. It is calculated as the sum of changes in lifetime labour incomes associated with aging for all individuals who remain in the working-age population and lifetime labour incomes of all individuals who die or emigrate. Recall that the human capital of everyone in the population will suffer a reduction in their total lifetime stream of earnings each year that they live because they have fewer earning years left in their life—due to the finite nature of human working life.

The third component of the change in human capital is the revaluation of human capital, which represents the change in human capital over time for individuals with a given set of demographic characteristics—gender, education and age. It is calculated as the sum of changes in lifetime labour incomes from period to period for individuals with a given set of demographic characteristics. These changes can occur for many reasons. Economic business cycles may cause a reduction in earnings during downturns. Or generational effects may suddenly affect new labour force entrants. An example of such change is provided by Picot and Heisz (2000) who document a decline in participation rates and slow growth in worker earnings in Canada during the early 1990s, particularly for the younger male cohort. This will give rise to a small or negative revaluation term for human capital in that period, particularly for the younger male cohort. Whether these changes are only temporary or are long-lived is an empirical matter that will be investigated later.

To derive the equation for decomposing the change in human capital stock, we start with the definition of human capital stock. Human capital stock in current dollars in period *t* is the sum of discounted lifetime labour incomes for all individuals in the working-age population:

$$P_K^t K^t = \sum_{s,e,a} h_{s,e,a}^t L_{s,e,a}^t \qquad (10)$$

where P_K^t is the price index of aggregate human capital stock, K^t is the volume index of aggregate human capital stock.

The change in the value of human capital stock from period *t*-1 to period *t* may be written as:

$$
\begin{aligned}
P_K^t K^t - P_K^{t-1} K^{t-1} &= \sum_{s,e,a} h_{s,e,a}^t L_{s,e,a}^t - \sum_{s,e,a} h_{s,e,a}^{t-1} L_{s,e,a}^{t-1} \\
&= \sum_{s,e,a} h_{s,e,a}^t L_{s,e,a}^t - \sum_{s,e,a} h_{s,e,a}^t L_{s,e,a}^{t-1} + \sum_{s,e,a} (h_{s,e,a}^t - h_{s,e,a}^{t-1}) L_{s,e,a}^{t-1} \\
&= \left(\sum_{s,e,a} h_{s,e,a}^t L_{s,e,a}^t - \sum_{s,e,a} h_{s,e,a+1}^t sr_{a,a+1}^{t-1} L_{s,e,a}^{t-1} \right) - \left(\sum_{s,e,a} h_{s,e,a}^t L_{s,e,a}^{t-1} - \sum_{s,e,a} h_{s,e,a+1}^t sr_{a,a+1}^{t-1} L_{s,e,a}^{t-1} \right) \\
&\quad + \sum_{s,e,a} (h_{s,e,a}^t - h_{s,e,a}^{t-1}) L_{s,e,a}^{t-1}
\end{aligned}
\tag{11}
$$

The first term in the last expression is investment in human capital in current prices. The second term is the depreciation of human capital. The third term is the revaluation of human capital stock, which is the sum of changes in lifetime labour incomes from period to period for individuals with a given set of demographic characteristics—gender, education and age.

According to Equation (11), the change in human capital is the sum of gross investment in human capital net of depreciation and the revaluation of human capital.

To interpret the term for investment in human capital, we rewrite it as:

$$
\begin{aligned}
&\sum_{s,e,a} h_{s,e,a}^t L_{s,e,a}^t - \sum_{s,e,a} h_{s,e,a+1}^t sr_{a,a+1}^{t-1} L_{s,e,a}^{t-1} \\
&\qquad = \sum_{s,e,a \subset \{15\}} h_{s,e,a}^t L_{s,e,a}^t + \sum_{s,e,a \not\subset \{15\}} h_{s,e,a}^t (L_{s,e,a}^t - sr_{a-1,a}^{t-1} L_{s,e,a-1}^{t-1})
\end{aligned}
\tag{12}
$$

Investment in human capital in a period can be calculated as the sum of the changes in lifetime incomes because of education, lifetime incomes for all individuals who reached working age in the period and the effect of immigration. The first term on the right side of the equation is lifetime incomes of all individuals who reached working age (15 years of age). It captures the effect on human capital investment of the rearing and education of children up to age 15. The second term is the addition to human capital stock due to increases in education and immigration. This is estimated as the average lifetime labour income of individuals multiplied by the change in the number of graduates at a given education level and immigration to Canada.[10]

The term for the depreciation in human capital may be written as:

$$
\begin{aligned}
&\sum_{s,e,a} h_{s,e,a}^t L_{s,e,a}^{t-1} - \sum_{s,e,a} h_{s,e,a+1}^t sr_{a,a+1}^{t-1} L_{s,e,a}^{t-1} \\
&\qquad = \sum_{s,e,a} \left(h_{s,e,a}^t - h_{s,e,a+1}^t \right) sr_{a,a+1}^{t-1} L_{s,e,a}^{t-1} + \sum_{s,e,a} h_{s,e,a}^t \left(L_{s,e,a}^{t-1} - sr_{a,a+1}^{t-1} L_{s,e,a}^{t-1} \right)
\end{aligned}
\tag{13}
$$

The depreciation on human capital is estimated as the sum of two terms. The first term is the change in lifetime labour incomes that occurs with aging for all individuals who remain in the working-age population. The second term is the lifetime labour incomes of all individuals who die, emigrate or reach the age of 75.

10. We did not collect data on immigration for this paper and will not estimate the separate effect of immigration and education on human capital investment.

The nominal value of investment in human capital, depreciation and revaluation of human capital can be separated into two components associated with price and quantity indices. Treating average lifetime labour income $h^t_{s,e,a}$ as the price component of investment in human capital and the terms associated with population counts $L^t_{s,e,14}$ and $(L^t_{s,e,a} - sr^{t-1}_{a-1,a} L^{t-1}_{s,e,a-1})$ as the quantity component of investment in human capital in Equation (12), we can apply the Tornqvist aggregation formula to data on individuals to obtain the price and quantity index for investment in human capital. To obtain the price and quantity index for depreciation, we treat terms associated with lifetime incomes $\left(h^t_{s,e,a+1} - h^t_{s,e,a},\quad h^t_{s,e,a}\right)$ as the price component, and the terms associated with population counts as the quantity component. Similarly, treating the changes in average lifetime labour income of individuals across time periods $(h^t_{s,e,a} - h^{t-1}_{s,e,a})$ as the price component of revaluation and the number of individuals $(L^{t-1}_{s,e,a})$ as the quantity component, we obtain the price and quantity index of revaluation for all individuals in the working-age population.

The measure of investment in human capital in this paper excludes the effect of on-the-job training and health on human capital investment because of a lack of consistent time series data on training and health. The importance of training for human capital investments was discussed in Becker (1964) and Mincer (1962, 1989). Mincer (1989) provided a survey on the incidence and impact of on-the-job training. Rosen (1989) noted that investment in training is included in the depreciation estimates for the Jorgenson and Fraumeni method for human capital measurement. Hui Wei (2008) made the same point and estimated the component of the depreciation term that is associated with the effect of work experience on human capital investments for Australia. Abraham and Mackie (2005, editors, Chapter 6) discussed health care (such as exercise, diet and medical care) as a form of human capital investment.

2.2 The cost-based approach to human capital measurement

The cost-based approach to estimating human capital stocks and flows is similar to that often used to estimate physical capital stocks and flows. The approach estimates the stock of human capital as the accumulated value of the expenditures spent on those items defined as investment in human capital.

The cost-based approach was used by Kendrick (1976) and Eisner (1985) to estimate human capital stock for the United States. Kendrick (1976) included in investments in human capital the following items: the costs of rearing children, expenditure on health and safety, mobility, education and training, and earnings forgone by students attending school.

It is relatively easy to measure adequately most forms of investment in human capital using various data sources at Statistics Canada. Public and private spending on formal education is relatively well-documented. Spending by enterprises on job-related training programmes may also be quantified.

The work of Mincer (1962) shows that informal, on-the-job training contains an implicit investment aspect, as workers accept lower wages to gain working experience. Indeed, education results not only from schooling and training, but also from general experience both at work and in leisure-time activities. But the expenditures related to informal on-the-job training are not readily available.

The cost-based approach to measuring human capital is useful for cost-benefit analysis of human capital expenditures (e.g., Stager 1996; Vaillancourt 1995). This approach provides a measure of flow of investments in human capital. When combined with the income-based measure of human capital, the cost-based approach provides a measure of a rate of return to investment in human capital. However, there are several challenges this approach has to overcome.

The first challenge concerns the decision criteria used to split human resource expenditures into a consumption-flow component and an investment-flow component. For example, Kendrick (1976) assumed that all costs of raising children to the age of 14 are human capital investments. But Bowman (1962) argued that those costs should not be treated as investments unless men are considered slaves. There is a similar problem with determining the contributions to human capital of different types of investments. The lack of empirical evidence led Kendrick to attribute 50% of household expenditures on health and safety as human capital investment and attribute the other 50% to consumption.

The second challenge of the cost-based approach relates to the choice of depreciation rates for human capital. The choice of depreciation for measuring human capital is essentially arbitrary because of a lack of empirical evidence. Kendrick used the modified double declining-balance method. In contrast, Eisner used straight-line depreciation to estimate human capital stock.

Finally, there is the choice of deflators that can be used to deflate expenditures related to human capital investment.

For the rest of the paper, we will apply the income-based approach to estimate human capital stock and investment in Canada.

3 Data sources and data construction

To construct aggregate human capital in Canada, we cross-classify individuals in the working-age population by the 2 genders, 60 ages (15 to 74) and 5 education levels (primary, secondary, some post-secondary, bachelor's degree, and master's degree or above), for a total of 600 groups of individuals. We develop a database on labour market activities and school enrolment for those individuals. The database includes population counts, paid employment, self-employment, school enrolment and annual labour compensation of paid workers.

The data on labour market activities and school enrolment are derived from the monthly Labour Force Survey (LFS) from 1976 to 2007 and the Census of Population for the years 1971, 1981, 1986, 1991, 1996, 2001 and 2006.

The data on the number of individuals, paid employment, self-employment[11] and school enrolment are obtained from the LFS for the period from 1976 to 2007, and obtained from the Census of Population for 1970.

The data on the annual earnings of paid workers are obtained from the LFS for the period 1997 to 2007, as the LFS started to collect data on hourly earnings of paid workers beginning in 1997.

11. In keeping with the National Accounts, only unincorporated self employed are considered in this category.

For the years before 1997, the hourly earnings are derived from a linear interpolation of the two adjacent censuses.

The earnings of self-employed workers are not available from the LFS and censuses.[12] To estimate the annual earnings of self-employed workers, we assume that the hourly earnings of self-employed workers are equal to those of paid workers with the same level of education and experience.

The data on annual earnings of paid workers and self-employed workers are all benchmarked to annual labour compensation in the Canadian Productivity Accounts of Statistics Canada.[13] The data reflect the annual labour compensation of paid workers and self-employed workers.

In January 1990, the LFS revised the questions related to the educational attainment of respondents. From 1976 to 1989, post-secondary education was limited to education that normally required high-school graduation. After 1990, post-secondary education included any education that could be counted towards a degree, certificate or diploma from educational institutions. The change caused a reallocation of respondents from secondary to post-secondary education. To ensure the data were consistent over time, we combined secondary education and post-secondary education into one category for the pre-1990 LFS data and used the information on secondary and post-secondary education from the censuses to split the LFS data for that period.

The data on survival rates are obtained from *Life Tables, Canada, Provinces and Territories* published by Statistics Canada. While education tends to increase survival rates, no such data exist for Canada. We assume the survival rates do not vary across education levels and depend on age and gender only.

4 Empirical results

In this section, we first present the data that are used for calculating lifetime incomes and aggregate human capital investment and stock. We then present our estimates of human capital investment and stock and compare it with non-human capital investment and stock.

4.1 Summary of the data

Table 1 presents the distribution of the working-age population, aged 15 to 74, across different individual characteristics (gender, age, and education) for the selected years 1970, 1980, 1990, 2000, and 2007.

12. Censuses provide data on mixed income of self-employed workers that include both labour income and capital income.
13. Labour compensation, as defined for the productivity program, includes all payments in cash or in kind that Canadian producers make to workers in return for their services. It includes labour income such as wages and salaries (including bonuses, tips, taxable allowances and back pay), supplementary income of paid workers (various employer contributions) and the implicit labour income of self-employed workers.

Table 1
Share of the working-age population

	1970	1980	1990	2000	2007
			percent		
Gender					
Male	49.3	49.8	49.7	49.9	49.8
Female	50.7	50.2	50.3	50.1	50.2
Educational attainment					
Primary education	35.0	20.9	13.0	8.5	5.8
Secondary education	39.4	44.6	44.2	37.6	34.2
Post-secondary education	20.4	26.0	31.5	37.8	39.8
Bachelor's degree	4.1	5.9	7.8	10.9	14.1
Master's degree or above	1.1	2.6	3.5	5.2	6.1
Age group					
Young, 15 to 34 years	49.0	50.2	44.0	36.7	35.4
Prime age, 35 to 54 years	32.8	30.2	35.2	41.9	40.2
Older, 55 to 74 years	18.2	19.6	20.8	21.4	24.4

The share of women in the working-age population was virtually unchanged over the period from 1970 to 2007. Over the period, the share of women was slightly larger than that of men.

Levels of education in the Canadian population have risen steadily since the 1970s. The share of the working-age population with a post-secondary education rose, from 20.4% in 1970, to 39.8% in 2007. Over the same period, the share of individuals with a bachelor's degree climbed from 4.1% to 14.1%, and the share of individuals with a master's degree or above increased from 1.1% to 6.1%.

The share of the Canadian population in various age groups has changed substantially since 1970. The 1970-to-1980 period was characterized by the entry of younger cohorts—the post-war baby boomers to the Canadian population. The trend towards a younger population reversed itself in the early 1980s, when the baby boomers entered the 35-to-44 age group. From 1980 to 2007, the share of the population in the 15-to-34 age group dropped from 50.2% to 35.4%. Over the same period, the share of the population in the 35-to-54 group increased from 30.2% to 40.2%, and in the 55-to-74 group, from 19.6% to 24.4%.

Table 2
Probabilities of paid employment

	1970	1980	1990	2000	2007
			percent		
All individuals	**48.8**	**54.6**	**56.7**	**56.3**	**58.9**
Gender					
Male	65.5	66.0	63.0	60.7	62.3
Female	32.5	43.3	50.5	51.8	55.6
Educational attainment					
Primary education	39.5	35.2	28.6	21.6	23.2
Secondary education	48.3	53.4	53.8	51.1	53.1
Post-secondary education	59.6	65.6	66.2	63.7	64.4
Bachelor's degree	70.3	73.6	74.0	70.0	69.0
Master's degree or above	76.9	78.2	73.7	67.5	66.4
Age group					
Young, 15 to 34 years	50.7	60.3	63.5	61.3	63.2
Prime age, 35 to 54 years	55.4	62.3	67.8	68.5	71.3
Older, 55 to 74 years	31.6	28.0	23.4	23.8	32.3

Note: The results show the number of paid employees as a percentage of the working-age population.

Table 3
Probabilities of self-employment

	1970	1980	1990	2000	2007
			percent		
All individuals	**6.1**	**5.2**	**5.6**	**6.2**	**5.6**
Gender					
Male	7.7	6.8	7.1	7.4	6.7
Female	4.5	3.6	4.1	5.0	4.6
Educational attainment					
Primary education	8.0	6.8	5.7	4.8	4.3
Secondary education	5.7	4.8	5.4	5.7	4.9
Post-secondary education	4.1	4.6	5.4	6.3	5.8
Bachelor's degree	3.5	4.6	5.8	6.4	6.2
Master's degree or above	8.6	7.6	9.9	10.4	8.9
Age group					
Young, 15 to 34 years	4.3	4.0	4.3	4.1	3.4
Prime age, 35 to 54 years	8.4	7.3	7.5	8.3	7.5
Older, 55 to 74 years	6.9	5.1	5.0	5.6	5.9

Note: The results show the number of self-employed workers as a percentage of the working-age population.

Tables 2 and 3 present the rates of paid employment and self-employment, defined as the number of people employed as a percentage of the working-age population. The rate of paid employment as a share of the working-age population increased from 48.8% to 56.7% over the period from 1970 to 1990 and remained unchanged after 1990. The rise in the rate of paid employment over time was due to the large increase in the employment rate for women. The employment rate for men declined slightly over the period.

For the entire period, the employment rate was higher among more educated invidividuals and, in general, it increased with education levels. The rate of paid employment declined for all education groups after 1990. However, the overall rate of paid employment did not decline

during that period. This is a result of shifts towards more educated individuals with higher employment rates.

The rate of paid employment rose for people with secondary or post-secondary education for the period from 1970 to 2007. It declined greatly for people with less than a high school education, reflecting the deteriorating labour market condition for the less-educated population. The rate of paid employment for people with a bachelor's degree experienced little change, and the rate of paid employment for people with a master's degree or above declined over the period.

The changes in paid employment rates differ across age groups. The rate of paid employment rose for the younger and prime-age population over time. For the older population, the employment rate declined before 2000 and increased thereafter.

Table 3 presents the share of the working-age population who are self-employed. The share of those self-employed changed little over the period from 1970 to 2007 for men and women. However, the self-employment rate was higher for men than for women. In the post-1990 period, self-employment rates tend to be higher among more educated individuals. For the 1970s and 1980s, the self-employment rate was highest for people with the least education and the highest educational attainment.

The estimation of lifetime income and aggregate human capital requires data on enrolment for formal schooling by gender, age and education. A summary of the enrolment rates, defined as the share of people who attended an educational institution, is presented in Table 4. We include enrolment in both full-time and part-time studies in the estimation.

Over the period from 1970 to 2007, the share of people aged 15 to 74 who enrolled in an educational institution showed a slight change, which was the net result of rising enrolment rates for women and declining enrolment rates for men. The enrolment rate increased across all age groups. Over the period from 1970 to 2007, the enrolment rate increased from 30.5% to 35.7% for the younger population, and it increased from 1.7% to 3.4% for the prime-age population. The number of older people, aged 55 and over, who attended school was very small, but it increased over time.

Table 4
Enrollment rates

	1970	1980	1990	2000	2007
			percent		
All individuals	**15.4**	**13.1**	**13.6**	**14.1**	**14.1**
Gender					
Male	16.9	13.5	13.2	13.5	13.4
Female	13.8	12.7	13.9	14.7	14.8
Educational attainment					
Primary education	5.2	3.7	4.5	6.2	8.4
Secondary education	24.7	17.2	15.9	18.2	19.4
Post-secondary education	15.5	14.4	15.4	14.0	12.8
Bachelor's degree	15.1	12.5	10.8	9.3	9.7
Master's degree or above	10.2	7.2	7.1	7.8	8.6
Age group					
Young, 15 to 34 years	30.5	24.8	27.7	34.3	35.7
Prime age, 35 to 54 years	1.7	2.0	3.7	3.3	3.4
Older, 55 to 74 years	0.2	0.2	0.3	0.5	0.6

Note: The results show the share of people who attended an educational institution, both full time and part time.

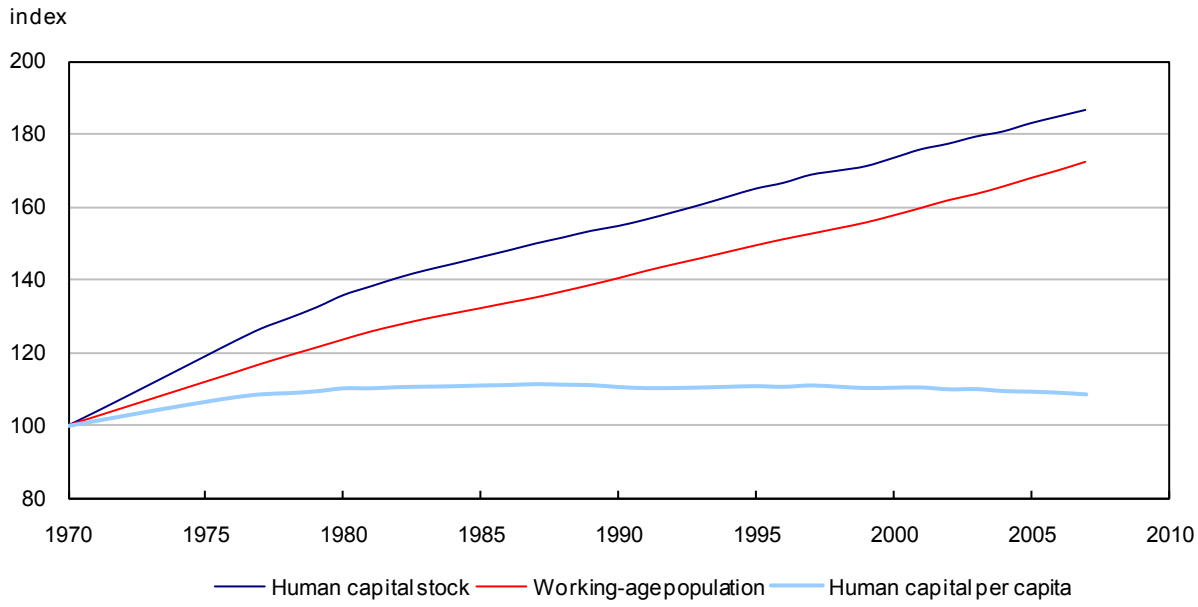
4.2 Human capital stock

Table 5 presents annual growth rates of aggregate human capital stock estimated using the Jorgenson and Fraumeni methodology. Chart 1 plots the indices of human capital stock, working-age population counts, and human capital per capita.

Table 5
Average annual growth in human capital and working-age population

	1970 to 2007	1970 to 1980	1980 to 2000	2000 to 2007
		percent		
Human capital stock	**1.7**	**3.0**	**1.2**	**1.1**
Working-age population	1.5	2.1	1.2	1.3
Human capital per capita	0.2	0.9	0.0	-0.2
First-order indices of human capital per capita				
Gender	0.0	0.0	0.0	0.0
Education	0.9	1.4	0.8	0.5
Age	-0.4	-0.1	-0.5	-0.6

Chart 1
Indices of human capital and working-age population in Canada



Over the period from 1970 to 2007, aggregate human capital rose at an annual rate of 1.7% in Canada. Most of the growth in human capital was due to the increase in the number of individuals in the working-age population. Of the 1.7% growth in human capital, 1.5 percentage points were due to the growth in the working-age population, and the remaining 0.2 percentage point was due to the effect of the compositional shift or the growth in human capital per capita.

The growth of aggregate human capital was the highest in the 1970s, a period that coincided with the entry of baby boomers to the working-age population and a rapid increase in the education levels of the Canadian population. The growth of aggregate human capital was lower after 1980 because of the slower growth and the compositional effects of aging of the working-age population. The compositional effects of aging of the working-age population had a negative effect on the growth of human capital per capita as a result of a shift of the population towards older individuals with lower lifetime income because of fewer remaining years of work.

The growth of human capital stock per capita can be decomposed into the contributions of changes in population characteristics such as age, gender and education. The relative effect of age, gender and education on the growth of human capital per capita is presented in the bottom half of Table 5. Rising educational attainment in the Canadian population makes a positive contribution to the growth in aggregate human capital. It adds 0.9% to annual growth in human capital stock over the period from 1970 to 2007. It adds 1.4% per year to human capital growth in the 1970 to 1980 period and 0.7% per year to human capital growth in the 1980 to 2007 period.

The compositional effects of aging of the Canadian population after the early 1980s made a negative contribution to the growth in human capital stock, and it lowered the annual growth in human capital by 0.5% in the 1980-to-2000 period, and by 0.6% in the 2000-to-2007 period.[14]

14. Boothby et al. (2003) discussed the effect of the aging of the Canadian population on the skill level of the working-age population in Canada.

Over the period 1980 to 2007, the aging of the Canadian population reduced human capital growth by 0.6% per year.

There was only a slight change in the share of women in the working-age population over time. As such, gender had little effect on the growth in the composition of human capital stock. This occurred despite large increases in labour force participation rates of women and increases in the discounted lifetime labour income of women.

4.3 Investment and change in human capital stock

The change in aggregate human capital stock can be broken into investment in human capital, depreciation and revaluation using Equation (11). Investment in human capital in a period is the sum of changes in lifetime incomes because of education, lifetime incomes for the individuals who reached working age and immigration to Canada. Depreciation of human capital is the sum of changes in lifetime labour incomes because of aging for all individuals who remain in the working age population and lifetime labour incomes of all individuals who die or emigrate. Revaluation of human capital is the sum of changes in lifetime labour incomes from period to period for individuals with a given set of demographic characteristics—gender, education and age.

Chart 2 presents the estimates of investment in human capital, depreciation, revaluation and change in human capital stock in current dollars for the period from 1971 to 2007. Table 6 presents the estimates in current dollars and Table 7 presents the estimates in constant dollars. The change in human capital stock in current dollars is equal to gross investment in human capital stock net of depreciation plus revaluation. The change in human capital stock in constant dollars is estimated as a Tornqvist aggregation of gross investment net of depreciation and revaluation using their shares (mean values of gross investment, depreciation and revaluation) in the change in nominal human capital stock as weights.

Both the revaluation component and the overall change in human capital exhibit large fluctuations over time, caused by the variations in the rate of change in the average lifetime labour income. Most of the short–run change in the value of human capital reflects the revaluation of human capital stock. Net investment in human capital (defined as gross investment in human capital net of depreciation) made a smaller contribution to the change in human capital than the revaluation of human capital. The revaluation term and change in human capital stock was relatively small in the early 1990s, as a result of a decline in participation rates and slow growth in worker earnings in the period.[15]

Over the long run, the changes due to gross investment, and depreciation trend upward with little cyclicality. On the other hand, movements due to revaluation that correspond to fluctuations in the economy and the state of the labour market fluctuate markedly around the long-run trend that is due to the fundamentals of population growth and ageing. Nevertheless, over the entire period from 1970 to 2007, the growth in all three components was about the same.[16]

15. The revaluation and change in human capital stock was also minimal in the 1970s. This was probably because of the entry of younger workers and women into the labour force.
16. The annual growth rates of gross investment, depreciation and revaluation in current dollars were 4.7%, 5.8%, and 4.3% respectively over the period (Table 8).

Chart 2
Gross investment, depreciation and revaluation of human capital in Canada

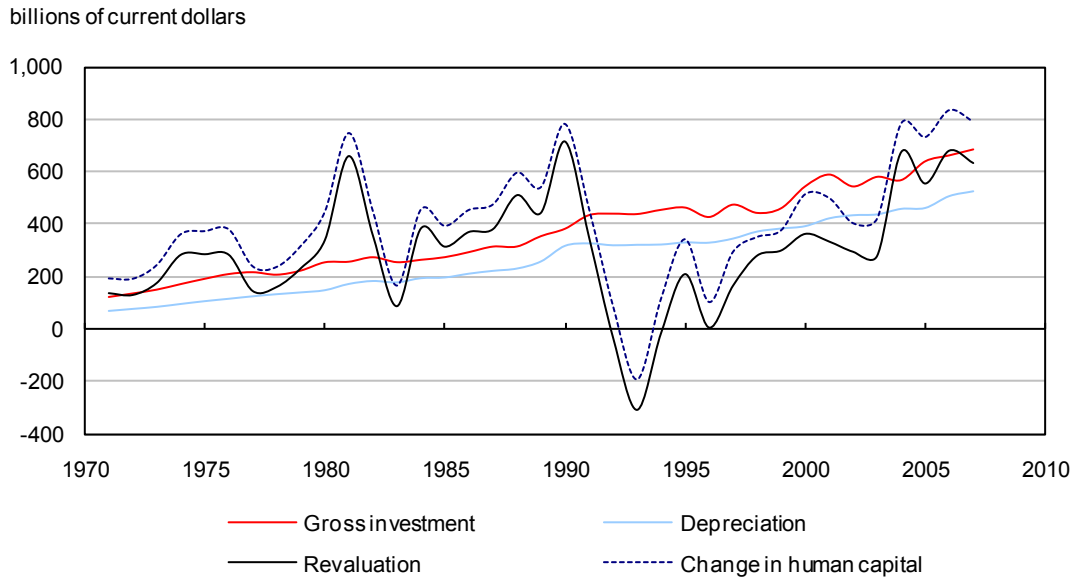


Table 8 presents the growth of the price and quantity index of investment, depreciation and revaluation of human capital. Gross investment in human capital in constant prices rose by 0.4% per year over the period from 1971 to 2007. Net investment (gross minus depreciation), while positive, declined over time as the growth of depreciation on human capital exceeded the growth of gross investment in human capital. From 1971 to 2007, net investment in human capital in 2002 prices declined by 3.1% per year from about 200 billion dollars in 1971 to about 60 billion dollars in 2007. Almost all of the overall increase occurs because of the revaluation component. This is not surprising as most of the growth in human capital stock is due to the increase in the number of individuals in the working-age population. The growth in the volume index of the revaluation term measures the increases in the number of individuals in the working-age population, holding their characteristics constant.

Table 6
Decomposition of changes in human capital stock

Year	Gross investment	Depreciation	Reevaluation	Change in human capital
		billions of current dollars		
1971	124.0	64.4	133.8	193.4
1972	137.3	72.1	126.9	192.1
1973	151.7	79.9	172.7	244.5
1974	172.7	91.0	279.9	361.6
1975	192.7	101.7	282.0	373.1
1976	210.7	110.9	279.8	379.6
1977	217.6	120.3	141.6	238.9
1978	208.2	128.4	157.6	237.4
1979	223.8	135.2	228.7	317.3
1980	255.0	143.6	335.7	447.2
1981	257.2	167.5	655.8	745.5
1982	274.1	178.7	353.4	448.9
1983	255.4	173.4	84.2	166.2
1984	264.5	189.4	380.3	455.4
1985	274.5	192.2	310.8	393.0
1986	293.5	206.7	366.9	453.7
1987	314.4	217.4	377.6	474.6
1988	314.7	226.3	506.9	595.2
1989	353.9	253.5	440.0	540.5
1990	381.9	313.0	711.2	780.0
1991	433.2	322.3	346.9	457.8
1992	438.8	315.0	-35.1	88.6
1993	437.2	317.0	-310.6	-190.4
1994	453.2	318.0	-18.3	116.9
1995	461.8	325.9	206.3	342.2
1996	426.1	325.0	2.7	103.8
1997	473.0	340.8	162.9	295.1
1998	441.6	367.4	276.8	350.9
1999	459.2	379.1	296.3	376.4
2000	542.0	388.2	359.5	513.3
2001	586.5	418.0	330.2	498.8
2002	541.5	429.8	291.3	403.0
2003	578.0	433.1	276.3	421.2
2004	565.6	454.3	671.0	782.4
2005	636.7	457.6	551.2	730.3
2006	659.0	502.9	676.5	832.6
2007	681.6	521.3	629.1	789.4

Source: Change in human capital is equal to the sum of gross investment net of depreciation and revaluation.

Table 7
Decomposition of changes in human capital stock

Year	Gross investment	Depreciation	Reevaluation	Change in human capital
		billions of dollars in 2002		
1971	458.7	255.4	116.8	349.2
1972	462.6	260.9	122.4	359.9
1973	469.0	266.3	127.6	370.9
1974	476.0	271.5	132.4	382.1
1975	483.7	276.6	137.0	393.5
1976	490.6	279.5	141.4	404.9
1977	474.5	283.9	145.9	400.9
1978	438.3	290.5	149.7	375.0
1979	438.1	297.4	152.8	375.9
1980	471.4	305.3	155.9	395.7
1981	455.0	308.0	159.9	396.7
1982	441.7	315.0	163.1	394.8
1983	445.2	319.7	166.3	399.0
1984	435.8	322.5	167.3	389.1
1985	428.7	323.5	168.5	386.8
1986	445.8	324.7	170.0	399.2
1987	459.8	328.8	172.2	409.3
1988	459.9	335.6	174.2	409.7
1989	486.3	342.3	175.9	423.3
1990	511.6	345.6	176.6	435.5
1991	436.2	349.5	173.5	380.2
1992	460.8	356.4	175.3	429.5
1993	453.5	360.9	194.3	442.7
1994	521.2	366.9	188.5	479.1
1995	536.3	371.2	205.3	514.9
1996	492.9	371.8	369.9	490.5
1997	462.6	378.5	289.5	367.2
1998	498.8	390.3	280.5	387.1
1999	487.3	397.2	282.5	371.4
2000	490.3	405.8	284.2	368.6
2001	501.5	419.3	287.0	370.8
2002	541.5	429.8	291.3	403.0
2003	513.0	436.9	295.1	371.4
2004	467.8	444.3	299.4	336.3
2005	472.9	452.1	302.4	338.4
2006	513.6	462.1	306.3	361.2
2007	534.4	469.7	309.5	372.6

Source: Change in human capital in 2002 dollars is estimated as Tornqivst aggregation of gross investment net of depreciation and revaluation using their share in the change in nominal human capital stock as weights.

Table 8
Average annual growth of investment, depreciation and reevaluation of human capital

	1970 to 2007	1970 to 1980	1980 to 2000	2000 to 2007
		percent		
Nominal value				
Gross investment	4.7	8.0	3.8	3.3
Depreciation	5.8	8.9	5.0	4.2
Reevaluation	4.3	10.2	0.3	8.0
Net investment	2.7	7.0	1.6	0.6
Price index				
Gross investment	4.3	7.7	3.6	2.0
Depreciation	4.1	6.9	3.6	2.1
Reevaluation	1.6	7.0	-2.7	6.8
Net investment	5.9	8.9	5.5	3.0
Volume index				
Gross investment	0.4	0.3	0.2	1.2
Depreciation	1.7	2.0	1.4	2.1
Reevaluation	2.7	3.2	3.0	1.2
Net investment	-3.1	-1.9	-3.9	-2.5

The growth in the volume of investment in human capital was slower than investment in non-human capital. Over the period from 1971 to 2007, the growth of gross investment in produced capital was 3.9% per year.

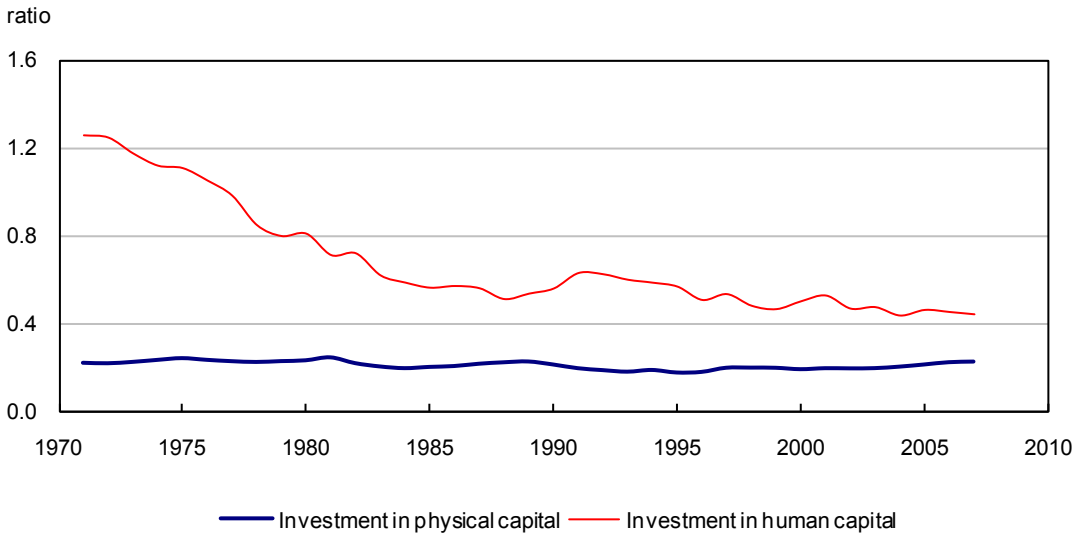
Chart 3 plots the ratio of investment in human capital to gross domestic product (GDP) in nominal value in Canada. To compare investment in human capital with investment in non-human capital, we have also plotted the investment to GDP ratio for physical capital.[17] We find that the ratio of investment in human capital to GDP declined from 1971 to the mid-1990s, and changed little after the mid-1990s. The decline in the investment-to-GDP ratio was fastest during the 1970s because of a relatively rapid increase in GDP. The ratio of human capital investment to GDP was 1.26 in 1971 and 0.44 in 2007.[18]

While the ratio of investment in human capital to GDP declined over time, the ratio of investment in physical capital to GDP remained virtually unchanged. Investment in physical capital as a share of GDP was about 20% over the period.

Investments in human capital exceed investments in physical capital. In 2007, nominal investment in human capital was about twice as large as nominal investments in physical capital in the Canadian economy. The magnitude of human capital investment relative to non-human capital investment was even larger in 1971, when human capital investment was about 5.7 times that of physical capital investment.

17. The data on investment and GDP were obtained from the income and expenditure accounts of Canada from Statistics Canada (CANSIM table 380-0017).
18. In the systems of national accounts proposed by Jorgenson and Fraumeni that include the accumulation of human capital, GDP needed to be adjusted to include investment in human capital. When this was done, the ratio of human capital investment to the adjusted GDP was 0.55 in 1971 and 0.31 in 2007.

Chart 3
Ratio of nominal investment to gross domestic product in Canada



4.4 Human capital stock by gender, education and age group

Table 9 presents average lifetime labour income or human capital per capita by types of individuals in the working-age population. The average lifetime labour income per capita is used to weigh the number of individuals in the population to derive a measure of aggregate human capital.

Table 9
Average lifetime labour income per capita

	1970	1980	1990	2000	2007
	thousand of dollars				
All individuals	100.4	249.1	469.4	526.3	661.0
Gender					
Male	155.0	356.5	612.9	661.8	803.2
Female	47.4	142.8	327.7	391.7	519.6
Educational attainment					
Primary education	51.6	86.6	142.1	153.7	220.1
Secondary education	108.5	241.3	405.5	468.5	585.2
Post-secondary education	141.1	335.6	592.0	584.2	691.0
Bachelor's degree	194.7	405.4	722.4	713.0	848.7
Master's degree or above	256.2	472.2	832.4	743.5	874.7
Age group					
Young, 15 to 34 years	152.7	365.6	712.4	846.3	1,074.7
Prime age, 35 to 54 years	70.3	198.7	416.1	484.3	634.3
Older, 55 to 74 years	14.2	28.5	46.1	61.0	105.2

First, the average lifetime labour income per capita or human capital per capita rose from $100,400 in 1970 to $661,000 in 2007, a 6.6-fold increase during the period. Average human capital embodied in women was lower than that in men for the period 1970 to 2007 because of differences in expected lifetime earnings. But the difference decreased over time, as the growth

in average human capital per capita was much faster for women than for men. In 1970, the average lifetime labour income for women was 30.6% of that for men. In 2007, the average lifetime labour income for women reached 64.7% of that for men.

Second, human capital was higher for those with relatively more than those with less years of schooling because of differences in lifetime earnings. The percentage difference in human capital between those with more years of education and those with less years of education (people with 0 to 8 years of schooling) increased before 1990, and declined after 1990. The difference in lifetime incomes per capita assocated with more education here accords with the estimated 8%-to-10% increase in annual earnings of an additional year of schooling (Emery, 2004). For example, the difference in lifetime incomes between an individual with bachelor's degree and an individual with some post-secondary education is 23% in 2007. This represents an increase of 11.5% per year as an individual is assumed to spend two years to obtain a bachelor's degree.

Third, the average lifetime labour income of young people (aged 15 to 34) was higher than that of older people because of the longer working life for young people. The difference in human capital between prime-age individuals (aged 35 to 54) and young people declined over time, while the difference in human capital between older people (aged 55 to 74) and young people was virtually unchanged over time.

Table 10
Average annual growth of the volume of human capital stock by types of individuals

	1970 to 2007	1970 to 1980	1980 to 2000	2000 to 2007
		percent		
All individuals	1.7	3.1	1.2	1.0
Gender				
Male	1.6	3.1	1.2	0.9
Female	1.8	3.0	1.4	1.2
Educational attainment				
Primary education	-4.2	-4.8	-4.4	-2.8
Secondary education	0.5	2.9	-0.3	-0.4
Post-secondary education	2.6	4.4	2.3	0.9
Bachelor's degree	4.1	5.8	3.4	4.0
Master's degree or above	5.1	9.7	3.7	2.5
Age group				
Young, 15 to 34 years	1.0	3.0	0.0	1.0
Prime age, 35 to 54 years	3.0	3.2	3.7	0.8
Older, 55 to 74 years	3.5	3.5	2.8	5.3

Table 10 contains estimates of the average annual growth of human capital for individuals in each gender group, the five education levels and the three age groups. Over the period from 1970 to 1980, the growth of human capital was similar for women and men. After 1980, the growth of human capital embodied in women was slightly higher than that embodied in men.

The growth of human capital in individuals with more years of schooling was higher than that in individuals with fewer years of schooling. The human capital in individuals with less than a high school education actually declined at a rate of 4.2% per year over the period from 1970 to 2007.

Table 11 breaks down the growth of aggregate human capital into contributions from people of each gender, from people grouped into five education levels and from people in three age groups. Before 1980, 0.8 percentage point or about one quarter of the growth in aggregate human capital was due to the growth in human capital in women. After 1980, the importance of women in the growth of aggregate human capital increased. For the recent period from 2000 to 2007, about half of the growth of aggregate human capital can be attributed to the growth of human capital in women.

Table 11
Contribution to growth of the volume of human capital stock by types of individuals

	1970 to 2007	1970 to 1980	1980 to 2000	2000 to 2007
		percent		
All individuals	**1.7**	**3.1**	**1.2**	**1.0**
Gender				
Male	1.1	2.2	0.8	0.6
Female	0.6	0.8	0.5	0.5
Educational attainment				
Primary education	-0.3	-0.5	-0.2	-0.1
Secondary education	0.2	1.2	-0.1	-0.1
Some or completed post-secondary education	0.9	1.4	0.9	0.4
Bachelor's degree	0.5	0.5	0.4	0.7
Master's degree or above	0.3	0.4	0.2	0.2
Age group				
Young, 15 to 34 years	0.7	2.3	0.0	0.6
Prime age, 35 to 54 years	0.9	0.7	1.1	0.3
Older, 55 to 74 years	0.1	0.1	0.1	0.2

The growth of aggregate human capital in Canada was predominantly accounted for by the growth of human capital in individuals with at least post-secondary education over the period from 1970 to 2007. The contribution of individuals with secondary school education to the growth in aggregate human capital was small in the 1970s and negative after 1980. The contribution of individuals with primary school education was negative in the period.

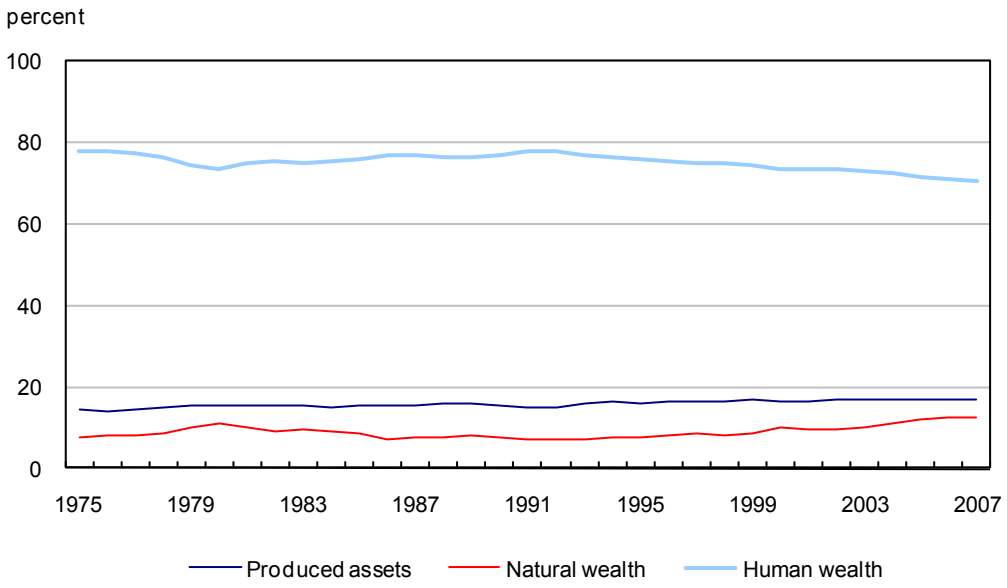
Human capital increased for all age groups, but the relative importance of each age group to overall human capital growth changed over time. In the 1970s, most of the growth in aggregate human capital was due to the growth in human capital in younger people, as a result of the entry of post-war baby boomers to the working-age population. In the period from 1980 to 2000, most of the growth in aggregate human capital was due to the growth of human capital in prime-age individuals, as the baby boomers reached the prime age. In the period after 2000, the growth of human capital in younger people was again the most important contributor to the growth of aggregate human capital, as the children of baby boomers, or “Generation Y,” reached working age.

4.5 The contribution of human wealth to the wealth accounts

In this section, we present a more complete set of wealth accounts for Canada. The value of wealth is defined as the sum of produced capital and natural wealth as calculated by the National Balance Sheets Accounts (CANSIM table 378-0005), and includes our estimates of human wealth. The produced capital in the National Balance Sheets Accounts includes residential structures, non-residential structures, machinery and equipment, consumer durables and inventories. The natural wealth includes land and natural resources (timber, energy resources and minerals).

We present the estimates of human wealth, produced capital and natural capital for the period from 1970 to 2007 in current prices in Table 12 and in constant dollars in Table 13. We have also plotted the share of human wealth, produced capital and natural wealth in Chart 4. The largest component of the full wealth accounts in Canada is human wealth, followed by produced capital and natural capital. Human wealth accounted for 70% of full wealth in 2007, while produced capital and natural capital accounted for 17% and 13%, respectively, in that year.

Chart 4
Distribution of total wealth in nominal dollars in Canada



Source: Statistics Canada, CANSIM table 378-0005 and authors' calculations.

Over the last 40 years, the share of human capital in full wealth declined slightly, and the share of produced capital and natural capital increased. From 1975 to 2007, the share of human capital declined from 78% to 70%, the share of produced capital increased from 15% to 17%, and the share of natural capital increased from 8% to 13%.

Table 12
National wealth in Canada

Year	Total wealth	Produced assets	Natural wealth	Human wealth
		billions of current dollars		
1970	…	253	…	1,446
1971	…	280	…	1,640
1972	…	315	…	1,832
1973	…	371	…	2,076
1974	…	456	…	2,438
1975	3,608	523	274	2,811
1976	4,099	581	327	3,191
1977	4,435	644	361	3,430
1978	4,806	721	418	3,667
1979	5,349	823	541	3,984
1980	6,043	933	679	4,431
1981	6,919	1,055	687	5,177
1982	7,449	1,134	689	5,626
1983	7,726	1,185	749	5,792
1984	8,266	1,252	766	6,248
1985	8,725	1,335	749	6,641
1986	9,195	1,435	666	7,094
1987	9,855	1,544	741	7,569
1988	10,647	1,673	810	8,164
1989	11,404	1,800	899	8,705
1990	12,299	1,887	927	9,485
1991	12,749	1,922	885	9,942
1992	12,873	1,954	888	10,031
1993	12,774	2,027	907	9,841
1994	13,053	2,116	979	9,958
1995	13,517	2,179	1,038	10,300
1996	13,784	2,242	1,139	10,404
1997	14,251	2,340	1,212	10,699
1998	14,720	2,448	1,223	11,050
1999	15,344	2,566	1,352	11,426
2000	16,261	2,701	1,621	11,939
2001	16,873	2,811	1,623	12,438
2002	17,485	2,952	1,692	12,841
2003	18,192	3,072	1,858	13,262
2004	19,407	3,257	2,106	14,045
2005	20,687	3,455	2,457	14,775
2006	22,026	3,698	2,721	15,608
2007	23,301	3,956	2,947	16,397

Note: Estimates of natural wealth are not available before 1975.
Source: Statistics Canada, CANSIM table 378-0005.

The value of human capital exceeded the value of produced capital. However, the ratio of human capital to produced capital declined over time. In 2007, the value of human capital was about four times that of produced capital. In 1970, the ratio of human capital to produced capital was 5.7 to 1.

Table 13
Produced capital and human capital

	Produced Assets		Human Wealth	
	Quantity	Price	Quantity	Price
Year	billions of 2002 dollars	index (2002=1)	billions of 2002 dollars	index (2002=1)
1970	1,127	0.22	7,245	0.20
1971	1,176	0.24	7,514	0.22
1972	1,220	0.26	7,789	0.24
1973	1,275	0.29	8,067	0.26
1974	1,351	0.34	8,346	0.29
1975	1,403	0.37	8,625	0.33
1976	1,471	0.40	8,904	0.36
1977	1,544	0.42	9,165	0.37
1978	1,612	0.45	9,369	0.39
1979	1,696	0.49	9,584	0.42
1980	1,749	0.53	9,832	0.45
1981	1,799	0.59	10,005	0.52
1982	1,818	0.62	10,178	0.55
1983	1,849	0.64	10,325	0.56
1984	1,902	0.66	10,453	0.60
1985	1,960	0.68	10,587	0.63
1986	2,016	0.71	10,719	0.66
1987	2,083	0.74	10,858	0.70
1988	2,167	0.77	10,979	0.74
1989	2,253	0.80	11,108	0.78
1990	2,304	0.82	11,205	0.85
1991	2,360	0.81	11,334	0.88
1992	2,374	0.82	11,479	0.87
1993	2,413	0.84	11,628	0.85
1994	2,455	0.86	11,789	0.84
1995	2,491	0.88	11,948	0.86
1996	2,524	0.89	12,063	0.86
1997	2,586	0.90	12,224	0.88
1998	2,649	0.92	12,307	0.90
1999	2,733	0.94	12,394	0.92
2000	2,810	0.96	12,557	0.95
2001	2,854	0.98	12,729	0.98
2002	2,921	1.01	12,841	1.00
2003	2,977	1.03	12,983	1.02
2004	3,044	1.07	13,086	1.07
2005	3,099	1.11	13,249	1.12
2006	3,157	1.17	13,382	1.17
2007	3,219	1.23	13,514	1.21
		percent		
Average annual growth				
1970 to 2007	2.8	4.6	1.7	4.9
1970 to 1980	4.4	8.6	3.1	8.1
1980 to 2000	2.4	2.9	1.2	3.7
2000 to 2007	1.9	3.5	1.0	3.5

Source: Statistics Canada, CANSIM table 378-0005.

The growth of human capital in constant prices was slower than the growth of produced assets, as shown in Table 13.[19] For the period from 1970 to 2007, human capital in constant prices increased by 1.7% per year, while produced capital in constant prices rose at 2.8% per year.

The growth rate of the price index for human capital is similar to that for non-human capital. Over the period from 1970 to 2007, the price index of human capital rose by 4.9% per year, while the price index of produced capital increased at a rate of 4.6% per year.

4.6 Sensitivity analysis

The estimates of lifetime income and aggregate human capital stock depend on the expected future real income growth and the discount rate used to discount the future income. In the estimates presented above, we have assumed that the expected future real income growth is equal to average labour productivity growth in the Canadian business sector, and the discount rate is equal to the weighted average of the rates of return to equity and debt.

In this section, we will examine the sensitivity of the human capital investment and stock estimates to alternative assumptions about the real income growth and the real discount rate. The results are presented in Tables 14 and 15.

We find that the changes in the expected future income growth and the discount rate have a slight effect on estimates of the growth rate in the quantity and price of human capital investment and stock. The changes have, however, a significant effect on the level of human capital investment and stock. As is expected from Equation (2), which we used to calculate the lifetime income, the effect of an increase in real income growth on the level of human capital is similar to the effect of a decline in the discount rate. Our results show that in 2007, a one-percentage-point increase in real income growth or a one-percentage-point decline in the discount rate increased the value of human capital stock by about 15% and increased the value of human capital investment by about 25%. The effects of a decline in the real income growth and an increase in the discount rate on estimated human capital investment and stock is slightly different from the effects of an increase in the real income growth and a decline in discount rate. Our results show that a one-percentage-point decline in the real income growth or a one-percentage-point increase in the discount rate reduced the level of human capital stock by 12% and reduced the level of human capital investment by about 20% in 2007.The effects are similar for other years.[20]

In the estimates of human capital investment and stock presented so far, we have included both full-time and part-time studies in the estimation of enrolment rates. When we excluded the part-time studies from the estimation of enrolment, we found that this had a slight effect on the level and growth of human capital investment and stock estimates.

19. The National Balance Sheets Accounts of Statistics Canada are presented in current prices only. We have used the price deflators of capital stock for residential and non-residential assets to deflate the stock of produced assets in the National Balance Sheets. The price deflator for natural wealth was not available. As such, we only compared the growth rates of human capital and produced capital.
20. Wei (2004) also found that changes in real income growth rate and discount rate had a significant effect on the level of human capital stock.

Table 14
Sensitivity analysis on aggregate human capital estimates

	Human capital stock in current prices		Growth in quantity of human capital stock		Growth in price of human capital stock	
	2007 level	Relative to baseline	Annual growth, 1970 to 2007	Difference with baseline	Annual growth, 1970 to 2007	Difference with baseline
	billions of dollars		percent			
Baseline estimate with 1.7% real income growth and 5.1% real discount rate	**16,397**	**…**	**1.7**	**…**	**4.9**	**…**
Changes in real income growth with 5.1% real discount rate						
0.7% real income growth	14,425	88.0	1.8	0.1	4.9	0.0
2.7% real income growth	18,815	114.7	1.6	-0.1	4.9	0.0
Changes in real discount rate with 1.7% real income growth						
4.1% real discount rate	18,758	114.4	1.6	-0.1	4.9	0.0
6.1% real discount rate	14,497	88.4	1.7	0.1	4.9	0.0
Full time enrollment only	**15,821**	**96.5**	**1.7**	**0.0**	**5.0**	**0.2**

Table 15
Sensitivity analysis on aggregate human capital investment

	Investment in current prices		Growth in quantity of investment		Growth in price of investment	
	2007 level	Relative to baseline	Annual growth, 1971 to 2007	Difference with baseline	Annual growth, 1971 to 2007	Difference with baseline
	billions of dollars		percent			
Baseline estimate with 1.7% real income growth and 5.1% real discount rate	681.6	…	0.4	…	4.3	…
Changes in real income growth with 5.1% real discount rate						
0.7% real income growth	554.4	81.3	0.5	0.1	4.3	0.0
2.7% real income growth	848.1	124.4	0.4	-0.1	4.3	0.0
Changes in real discount rate with 1.7% real income growth						
4.1% real discount rate	843.6	123.8	0.4	-0.1	4.3	0.0
6.1% real discount rate	559.1	82.0	0.5	0.1	4.3	0.0
Full time enrollment only	698.0	102.4	0.4	0.0	4.4	0.1

5 Conclusions

This paper has produced an estimate of human capital investment and stock for Canada over the period from 1970 to 2007 and compared it with that of non-human capital investment and stock. Our findings are summarized as follows.

First, the volume of aggregate human capital rose at an annual rate of 1.7% in Canada for the period from 1970 to 2007, and most of the growth was due to the increase in the number of individuals in the working-age population aged 15 to 74. The rising education level of the Canadian population was also a significant contributing factor to the growth in human capital. Of the 1.7% growth in the volume of human capital in the period from 1970 to 2007, 1.5 percentage points were due to the growth in the working-age population and the remaining 0.2 percentage point was due to the effect of the compositional shift of human capital (i.e., aging and rising education levels of the Canadian population) or the growth in human capital per capita.

Second, the compositional effects of aging of the Canadian population had a negative effect on the growth of human capital, and rising education levels had a positive effect on the growth of human capital. The compositional effects of aging decreased the stock of human capital because it led a greater percentage of the workforce who while they might have accumulated more experience had less of their lifetime ahead of them. Education increased expected earnings and therefore lifetime earnings. Our estimates show that the compositional effects associated with aging of the Canadian population reduced the human capital growth by 0.6% per year over the period 1980 to 2007, and the rising education levels increased it by 0.7% per year over the period.

Third, human capital stock on a per capita basis increased at 0.9% per year for the period 1970 to 1980, due to the rising education attainment during the period. After 1980, human capital stock per capita was virtually unchanged due to two offsetting factors: rising education levels which increased human capital stock and population compositional effects of aging which reduced human capital stock.

Fourth, the value of human capital investment and stock exceeded the value of non-human capital investment and stock. However, the ratio of human capital investment and stock to non-human capital investment and stock declined over time. In 2007, the value of human capital stock was about 4.1 times that of produced capital stock. In 1970, the ratio of human capital stock to produced capital stock was 5.7 to 1. Investment in human capital was about 1.9 times as large as investment in physical capital in 2007, and was about 5.7 times the magnitude of non-human capital investment in 1971.

Fifth, the growth of human capital investment and stock was slower than the growth of produced capital investment and stock. Over the period from 1970 to 2007, human capital stock increased at 1.7% per year, while produced capital stock rose at 2.8% per year. From 1971 to 2007, human capital investment grew at 0.4% per year, and investment in produced capital rose at 3.9% per year.

Sixth, the levels of human capital investment and stock estimates were sensitive to the choice of the expected future income growth and the rate used to discount the future income, but the growth of the quantity and price of human capital investment and stock was much less sensitive to these choices.

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