# Education, Productivity and Economic Growth: A Selective Review of the Evidence

Serge Coulombe and Jean-François Tremblay[1]
*University of Ottawa*

ABSTRACT

We review a selection of the theoretical and empirical literature on human capital and growth that appear to provide the most relevant insights for policy development in the Canadian context. We first focus on the extension of the neo-classical growth model with the inclusion of human capital in an open economy framework, and discuss its empirical applications to the Canadian economy. We also examine other issues such as the returns to education and the distance from the technological frontier, the microeconomic versus macroeconomic return to education, and the quantity versus quality of education. Although the levels of investment in education and the overall quality of the educational system in Canada are fairly high, we argue that the returns of additional investments in post-secondary education could still be substantial since Canada is relatively close to the technology frontier.

FROM THE 1960S TO THE 1980S, economic growth was a relatively neglected topic in macroeconomics.[2] Macro textbooks and courses devoted little attention to the study of long-run growth, and focused mostly on business cycles, unemployment and inflation. It changed dramatically, however, since the end of the 1980s when economic growth came back to the front stage of the mainstream economics research agenda. In fact, economic growth now covers roughly one-half of typical macroeconomics courses.[3]

With the seminal contributions of Lucas (1988) and Mankiw, Romer, and Weil (1992), human capital has been, right from the start, one of the key actors in modern economic growth. Human capital has been seen, with R&D, as one of the candidate vehicles for knowledge accumulation and endogenous growth. As convincingly shown by Mankiw *et al.* (1992), the introduction of human capital in growth theory was necessary to reconcile neo-classical growth predictions with the quantitative aspects of economic development.

In this article, we review parts of the theoretical and empirical literature on human capital and growth with the objective of deriving insights about the likely effects of investment in

1 Serge Coulombe is Professor and Jean-Francois Tremblay Associate Professor in the Department of Economics at the University of Ottawa. This is an abridged version of a paper prepared for the Strategic Policy and Research Branch of Human Resources and Skills Development Canada (Coulombe and Tremblay, 2009). Email: Serge.Coulombe@uottawa.ca; Jean-Francois.Tremblay@uottawa.ca.

2 The last focus on economic growth in the 1960s was the so-called "Cambridge capital controversy" that involved Paul Samuelson and Robert Solow from Cambridge, Mass. and Piero Sraffa and Joan Robinson from Cambridge, UK. The controversy, which was basically methodological, lacks practical interest and might account for the disappearance of economic growth from the front scene of the economic research agenda.

3 It should be noted though, that the recent financial crisis and the renewed interest in Keynesian economics might well swing the pendulum back to the business cycle horizon.

post-secondary education on per capita income growth in Canada. Our review will be quite selective, focusing only on the issues that are most relevant for evaluating the macroeconomic gains of post-secondary education and for human capital policy in Canada.

After a discussion of the concept of human capital, our review starts with a brief overview of some theoretical considerations about the different approaches that have been used to analyze the role of human capital in growth. As will be argued below, the neo-classical growth model, extended to take into account the accumulation of human capital, is quite consistent with the cross-country empirical evidence, and its open-economy version is well suited for the analysis of economic and productivity growth in the Canadian context. As a result, this model has provided the theoretical background for much of the Canadian empirical literature on education and growth. The key prediction of this open-economy growth model, for our purposes, is that the evolution of capital and output will be largely driven by the accumulation of human capital. As will be discussed, this prediction appears to fit the evidence from Canadian data.

In principle, despite the solid evidence at the microeconomic level that education increases wages, investment in education will only generate macroeconomic benefits if it has real effects on aggregate productivity. It has been alleged in the theoretical literature that education could potentially increase individual wages without having any effect on productivity if it acts as a signalling device by conveying information to the labour market about the characteristics of workers (Spence, 1973). Macro-level evidence is necessary to assess the full aggregate productivity gains from education, including the gains that arise because of human capital externalities not reflected in wages. Moreover, the aggregate productivity gains of advanced education will depend on how rapidly the marginal benefits of education decrease with the level of education, and on how close an economy is from the technology frontier. Our survey will discuss the evidence about these issues.

The recent literature has devoted considerable attention to the measurement of human capital. Although the empirical literature has traditionally used years of education as indicator of human capital, what really matters for growth is the skills that are produced by education. We will review the recent evidence which highlights the critical importance of using, as human capital indicators, the measures that best proxy the output of the education system, when assessing the growth effects of education. The contrasting results of recent empirical studies that use measures of human capital based on educational inputs versus educational output suggest that improving the quality of education may be as important for growth, if not more important, as increasing enrolment rates (Hanushek and Woessmann, 2008).

In evaluating the potential growth effects of investing in post-secondary education, it is important to distinguish between the impact of public education spending and that of overall education, given that post-secondary education is largely financed publicly in Canada. The distinction is not irrelevant because private investment in education could respond to public investment, and raising public funds to finance education spending will have indirect effects on growth. Our review will discuss the evidence on the relationship between public education expenditures and growth.

## Human Capital and Growth

In this section, we analyse the growth revival from a human capital perspective. After an initial discussion of the concept of human capital we highlight the key difference between endogenous growth and neo-classical growth. We then synthesize the theoretical contributions of new growth theories, underline the central role of

human capital, and show how the new growth approach has been the underlying theoretical framework for a series of Canadian empirical studies that have focused on human capital accumulation. Finally, we briefly come back to the issue of distinguishing between alternative determinants of economic growth.

## What is human capital?

'Fourthly, of the acquired and useful abilities of all the inhabitants or members of the society. The acquisition of such talents, by the maintenance of the acquirer during his education, study, or apprenticeship, always costs a real expense, which is a capital fixed and realized, as it were, in his person. Those talents, as they make a part of his fortune, so do they likewise of that of the society to which he belongs. The improved dexterity of a workman may be considered in the same light as a machine or instrument of trade which facilitates and abridges labour, and which, though it costs a certain expense, repays that expense with a profit.' (Smith, 1776 Book II, chapter 1)

As clearly demonstrated by the above quote, the idea that part of economic activities might not be devoted to immediate production or consumption, but might rather be diverted to education, study, or apprenticeships, is well entrenched in the history of economic thought. Adam Smith's idea came back under the closed scrutiny of economists at the end of the 1950s and in the early 1960s when it was discovered, following the growth accounting framework proposed by Solow (1957), that a substantial proportion of U. S. economic growth was not accounted for by the increases in the stock of physical capital (machinery and equipment, and structures) and labour (number of people employed).[4] Human capital was proposed as a competitor to technological progress to account for the Solow residual.

The human capital concept developed separately from the economic growth literature with the influential works of Mincer (1958) and Becker (1962, 1964). Mincer explained the differences in the personal income (wage) distribution by the investment in human capital. He analyzed how rational agents freely determine the time they allocate to studying (or training) or working. The cost of studying is the direct cost of education (tuition fees) plus forgone labour earnings, while the return to studying comes from higher future earnings. Initially, because the return to extra years of education is decreasing, the value of future earnings exceeds the cost of studying and the individual continues to invest in education. In equilibrium, the benefit of an extra year of schooling equals its costs. This analysis is generally regarded as the theoretical foundation of empirical labour economics.

To fix ideas, consider a simple production process where output is produced using physical capital and labour:

*Output* = *f* (*physical capital*, *labour*).

Using the best available techniques to describe the production process *f*, economists discovered at the end of the 1950s that something was missing (the Solow residual). The growth of labour and capital could not account for most of output growth. Along with technological growth (changes in *f*), human capital was a serious candidate for a possible missing input. People and governments spent substantial efforts and resources in education instead of producing *output*. The efforts invested have to increase future *output*. The concept of *human capital* measures the skills, abilities, and knowledge acquired by the studying efforts. The extended production function is:

*Output* = *f* (*physical capital*, *labour*, *human capital*).

Consequently, human capital affects output and growth directly by the production process.

4 In his preface to the first edition, Becker (1964) assimilates the revival of interest in human capital after 1957 to the fundamental growth accounting result.

Two intrinsic characteristics of human capital are that it is a stock, and that it is entirely embedded into a person. Being a stock, like a machine, a house, or a car, human capital has the possibility of keeping its usefulness, or value, through time. Like other capital goods, human capital is the result of past investments. Investments in human capital might come from education, studying, apprenticeship, and learning-by-doing (experience). Like any capital good, human capital is also subject to depreciation. The depreciation of human capital might simply be the result of aging and the loss of intellectual and physical capacities. Depreciation can also result from technological change that makes acquired skills obsolete.

The second characteristic of human capital is that, unlike technology, it is a private good (or rivalrous good) that belongs only to the person in which it is embedded. Many components of technology or knowledge, like differential calculus, are non-rivalrous or pure public goods. As we will discuss in a later section, human capital and technology interact in the production process since it is the human capital level of an individual that allows him or her to make the best use of technology.

### Level versus growth effects

In its first phase of development, new growth theories place the emphasis on the level versus the growth effect of education on output.[5] According to the level approach (Lucas, 1988, and Mankiw *et al.*, 1992), human capital is modelled as an input in the production function and has a level effect on output. In this approach, only continuous improvements in education will exert a sustained effect on the growth rate of output in the long run. In the growth approach, often refered to as the Nelson and Phelps (1966) approach, education is an essential input in the innovation process. Consequently, an increase in education level increases innovation and the long-run growth rate of the economy.

The difference between level and growth effects loses some of its interest if the economy adjusts only slowly and gradually to a level shock. The voluminous empirical literature on convergence clearly indicates that this is indeed the case.[6] The annual convergence speed to the long-run equilibrium measured for developed economies ranges from 2 to 5 per cent. Suppose that an increase in human capital only has a level effect in the long run as in the neo-classical growth model; the slow convergence speed implies that the adjustment, to a once-and-for-all increase in the education level will affect the growth rate of the economy for decades. With a convergence speed of 2 per cent, one half of the adjustment to the education shock will be completed after 35 years and three quarters after 70 years. With a convergence speed of 5 per cent, one half of the adjustment to the education shock will be completed after 14 years and three quarters after 28 years. Consequently, the growth rate of the economy will be affected by the level shock for a time span that is well beyond the usual economic policy agenda.

The difference between level and growth rate effects has also lost of its interest because comforting evidence was found on growth rate convergence across countries and regions within countries.[7] This implies that the endogenous growth approach which emphasizes pure long-run growth effects lacks empirical support. Growth rates across countries cannot at the same time converge and be determined by a set of cross-country specific institutional and policy fundamentals.

5 See for example Aghion and Howitt (1998, section 10.4)

6 On the convergence literature, refer to Barro and Sala-i-Martin (2004).

7 In the terminology of Barro and Sala-i-Martin (2004), the cross-country evidence is for conditional convergence in which countries converge to different long-run equilibria that are determined, among other factors, by the level of human capital.

What matters for the purpose of our analysis is that the channel by which human capital exerts an effect on economic growth is fundamentally different in the two approaches. In the level approach, human capital in an input in the production function and what matters for living standards is to increase the mean level of human capital. Since it is widely recognized that individual returns to education are decreasing (Psacharopoulos, 1994), the highest returns to investment in education could possibly be found in investment in basic education. In the growth approach, specialized education (e.g. engineering, technical) is probably more related to innovation. Consequently, investment in some advanced skills might well be the best growth enhancing education policy. We will come back to this essential issue in the third section.

## The role of human capital in new growth theories

The key feature of the Solow growth model is that capital accumulation faces decreasing returns. Therefore, capital accumulation is not a source of long-run growth. Long-run growth is determined by technological progress and, along a given equilibrium growth path, the relative (to other countries) living standard of a country is determined by fundamentals such as its population growth rate and investment ratio.

In a seminal contribution to economic growth theory, Mankiw *et al.* (1992) argue that, from a qualitative perspective, the Solow model predictions pass relatively well the test of empirical analysis. Long-run living standards across countries appear to be correlated correctly with investment ratios (positively) and population growth rates (negatively) and growth rates of countries appear to converge. However, from a quantitative point of view, the Solow growth model does not get things right. Suppose that the five richest countries in the world are 25 times richer than the five poorest. In the poor countries, the population growth rate is larger and the investment ratio is smaller than in rich countries, as predicted by the Solow model. However, given the predicted magnitude of the population growth and the investment ratio effect on output, the observed differences in the two fundamentals can only account for a three to one standards of living ratio between rich and poor countries.

Mankiw *et al.* (1992) show that the reason for this problem is that, in the neo-classical growth model, long-run differences in living standards can only be explained by capital accumulation and, relatively speaking, capital accumulation is not important enough as an economic activity or driver of growth. In national income, the returns to capital (profits) account for only one third of total income. The rest, two thirds, is the share of labour income. If the returns to capital accounted for around 0.8 of national income, Mankiw *et al.* (1992) show that the neo-classical growth model would be able to capture the size of the cross-country income gap given the magnitude of the observed differences in fundamentals. This spectacular increase (8 times) of the effect of the fundamental determinants comes from the fact that the long-run effect of a change in the determinants is proportional to $\alpha/(1-\alpha)$ where $\alpha$ is the share of the return to capital in national income.

The solution to the quantitative puzzle is to recognize that the return to some sort of capital is hidden in the share of labour income. Human capital, which is the only candidate for this role, makes the extended neo-classical growth model consistent with national income facts and per capita income disparities across countries. The extended neo-classical model has a broaden capital concept. According to Mankiw *et al.*, based on the comparison between the mean wage rate and minimum wage in the United States, the share of the returns to human capital should account for roughly 50 per cent of national

income. From an accounting point of view, human capital is more important than physical capital. Human capital entered modern macroeconomics by the big door: it has become a must for a fresh *Inquiry into the Nature and Causes of the Wealth of Nations*.

The next important research that has contributed to increase the profile of human capital accumulation in modern macroeconomics is the theoretical work of Barro, Mankiw, and Sala-i-Martin (1995). They extend the neo-classical growth model with human capital to the open economy and they show that under the assumption of perfect capital mobility, the convergence speed should be infinite since capital will instantaneously move where its return is the highest. Because of decreasing returns, the return to capital is higher in the poorest countries where the capital/labour ratio is the smallest. Of course, this prediction is rejected by the facts since convergence is rather slow.

The solution adopted by Barro *et al.* (1995) is to assume that human capital can only be financed in the domestic economy. Physical capital remains perfectly mobile (with no set-up costs) since it can be financed abroad. The main argument raised by Barro *et al.* to justify their conjecture is the impossibility of using human capital as collateral for financing investment in education. This assumption follows from the intrinsic nature of human capital. In the modern rule of law, where slavery is no longer tolerated, future labour income cannot generally be seized by dissatisfied creditors.[8] Therefore, human capital cannot be financed easily in a free market economy. The financing of education becomes even more challenging given that most investments in education are done in childhood when the returns to investments are the highest. Consequently, the financing of investment in education has to rely on altruist behaviour from parents, or on the intervention of the state. The failure of credit markets to finance education is possibly the most important efficiency rationale for public education.

The consequence of the open economy and the binding constraint for the financing of human capital is that the evolution of capital and output along a growth path is determined by the evolution of human capital. Physical (and financial) capital does not float instantaneously in poor economies because the lack of human capital is a barrier to development. The return to capital is not higher in poor economies than in rich ones despite the fact that the physical capital/labour ratio is smaller in poor economies. Given the complementarity between physical and human capital, the lack of human capital in poor economies decreases the return to physical capital.

## An overview of the canadian empirical evidence

As shown by the literature following Feldstein and Horioka (1980), physical and financial capital between countries are not perfectly mobile. Differences in rules of law, set-up costs, and institutional and cultural heterogeneity across countries appear to impede the mobility of capital flows.

However, as pointed out in Coulombe and Tremblay (2001), the theoretical framework of Barro *et al.* (1995) appears to be particularly well suited to analyze regional economic development in a country like Canada. With its financial system largely made up of large pan-national multibranch banks that can redistribute savings across regions, the assumption of perfect capital (physical and financial) mobility appears to fit well the Canadian regional economies. Savings can be redistributed across regions by the financial system and the provinces are relatively homogeneous from a cultural, political and institutional points of view, with Quebec being a notable exception.

8 In many legal jurisdictions, divorce laws are the obvious exception to this principle.

Coulombe and Tremblay (2001) used Canadian provincial data to test the key predictions of the model of Barro *et al.* (1995). They used census data which provide indicators of human capital across the Canadian provinces since 1951. The use of the time dimension is particularly useful in the Canadian provincial analysis given the limited number of cross-section units (provinces) at hand.[9] They used a variety of human capital indicators based on the percentage of the population (15-years and over, 15 to 24-years, and 25-years and over, for males, females and both sexes) that have achieved at least two benchmark education levels: grade nine, and a university degree.[10] The census data were then available on a ten year span from 1951 to 1991 and for 1996.

The key findings of Coulombe and Tremblay (2001) are the following. First, they estimate the share of human capital return in national income to be around 50 per cent. As mentioned earlier, this is precisely the share that should be attributed to human capital in order to make the neoclassical growth model quantitative predictions consistent with economic development facts.

Second, Coulombe and Tremblay (2001) found that the human capital indicators based on the total population did indeed converge at the same speed, around 3 per cent, as per capita income (net of government transfers to individuals). Third, around 50 per cent of the relative per capita income growth across provinces between 1951 and 1996 appear to be explained by the convergence process of the main human capital indicators. Finally, based on the comparisons of regressions using human capital indicators for the total population and for the young cohort, Coulombe and Tremblay (2001) show that the speed of convergence at the regional level might have been two to three times faster if everybody had invested in education at the same pace as the young cohort. The relative slowness of the convergence process, even within a federation intensively using interprovincial redistributive transfers such as Canada, can be explained by the conjuncture of two factors: 1) the catching-up process of poor regions is driven by the catching-up process of human capital, and 2) only a sub-set of the population, the youth, have a clear incentive to invest in education.

Coulombe and Tremblay (2001) also use the absolute convergence model to test the Barro *et al.* (1995) model. In this framework, the provinces converge to the same long-run equilibrium and differences in living standards are only accounted for by pure short-run shocks to regional trade patterns. In this set-up, all provinces will in turn be members of the poor and the rich clubs. Obviously this framework does not capture the relative stability of the membership in the two clubs. Coulombe (2003) extends the framework of Coulombe and Tremblay (2001) by allowing the provinces to converge to different long-run growth paths which are mainly determined by relative rates of urbanization. Even though urbanization rates have tremendously increased in all provinces since World War II, relative rates of urbanization are quite stable and richer provinces appear to be systematically more urbanized than the poorest.

9 The pooling of time-series and cross-section data (TSCS) allows the use of a particularly sophisticated error term in the econometric analysis that can account for cross-section heterogeneity and time-specific shocks that are common to all provinces. Practically speaking, Coulombe and Tremblay (2001) used time dummies, which imply that all variables are transformed as deviations from the cross-section mean (over the entire period). Consequently, the human capital measures used are relative data, relative to the province mean. This procedure overcomes most of the problems encountered by the measurement of human capital across relatively homogenous economic units.

10 The human capital indicator based on the percentage of the population with at least a university degree appears to generate empirical results that are consistent with the neo-classical open economy growth model of Barro et al. (1995). The data based on grade nine do not perform as well since by the end of the sample period, almost 100 per cent of the population had at least achieved grade nine.

The paper investigates if both human capital indicators (percentage of the population with at least a university degree) and nominal per capita income (net of transfers to individuals) have followed the same growth patterns toward their long-run equilibrium.

Overall, the results support the extended open-economy framework. Both human capital and per capita income appear to converge at around the same speed to their long-run growth path determined by the urbanization rate. One-time structural breaks to Quebec's and Alberta's relative growth paths are also detected. For Quebec, a negative structural break is detected around 1970 and is associated with the Anglophone exodus from Montreal. Both human capital and per capita income have been negatively affected. In Alberta, per capita income has been stimulated by the 1973 oil shock but the same shock has exerted a significant effect on the human capital stock of females only. Finally, human capital appears to remain at a high level in the relatively poor province of Nova Scotia without generating the same income effect than in other provinces. This result suggests that, at the regional level, human capital accumulation is a necessary but not a sufficient condition for being richer.

Following the methodology proposed by Coulombe, Tremblay and Marchand (2004) for cross-country studies, Coulombe and Tremblay (2007) develop synthetic time series of the skills of labour market entrants for the 10 Canadian provinces over the 1951-2001 period from the Canadian database of the Adult Literacy and Lifeskills Survey (ALL). These skills data can be considered direct measures of human capital. Their effect on market income is then compared to the effect of the input measure of human capital derived from the percentage of the population with a university degree.[11] Coulombe and Tremblay (2007) use specific econometric techniques to account for cross-section heterogeneity and interprovincial migration.

They found a significant and substantial effect of the skills variable on regional income. Following the Mincerian approach in labour economics, Coulombe and Tremblay (2007) found that the skills acquired by one extra year of schooling generate an increase of around 5 per cent in per capita income. The literacy indicator of human capital does not perform better in econometric analysis than their traditional one derived from university achievement. We will revisit this in the next section.

The main result from Coulombe and Tremblay (2007) is synthesized geometrically in Chart 1. The fit between the mean skill level and per capita income disparity across the Canadian provinces is striking. Despite the very small number of observations (10), the slope coefficient of the relationship between the two variables is significant at the 5 per cent level and skill disparities by themselves account for around one half of per capita income disparities in 2003.

The human capital data in Chart 1 is based on the mean skill level of the non-migrant population. Non-migrants are defined as individuals who were residing, at the time of the survey, in the same province as the one where they did their last year of high school education. We focused on the non-migrant population in this exercise to control for the fact that the inter-provincial migration process in Canada tends to redistribute human capital from the poor to the rich provinces.

## Alternative determinants of economic growth

Human capital accumulation is one of the two modern candidates for explaining economic growth and development, the other one being good institutions in the form of democracy and,

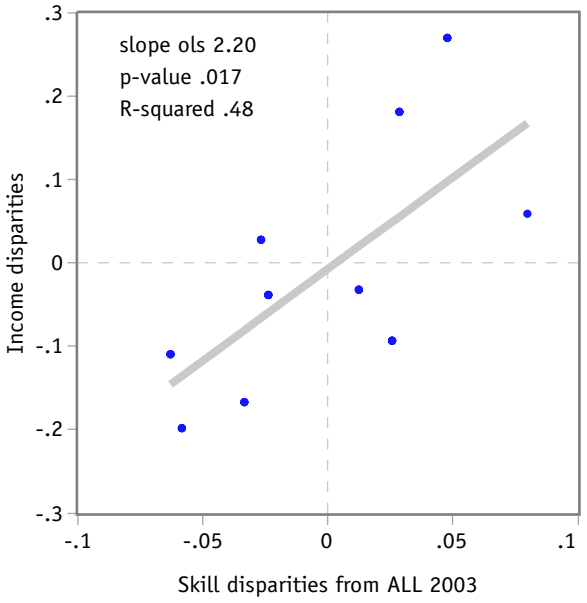
11 Market income is measured using national accounts data on per capita personal income net of government transfers to individuals.

what Hall and Jones (1999) called, social infrastructures. Social infrastructures might be viewed as the set of social arrangements and institutions that, in the framework of Olson (2000), promote production over predation. The debate regarding the merits of the following two propositions: A) education causes good institutions and growth; or, conversely, B) good institutions cause education and growth; is an old one going back at least to Aristotle, according to Glaeser *et al.* (2004). Although a complete survey of the issue is well beyond the scope of this article, we will focus, for the remaining of this section, on the link between human capital, institutions, technological progress, and growth. It should be pointed out, however, that according to the evaluation of Glaeser *et al.*, empirical evidence nowadays tends to favour proposition A over B.

More generally proposition A argues that most of economic growth could be accounted for, and is caused by, the accumulation of factors. As already noted, it was precisely the discovery by Solow (1957) that a substantial portion of economic growth was not accounted for by factor accumulation that led to the introduction of the Solow residual, which became known as technological progress, yet which remains for many economists 'the measure of our ignorance'. In modern economic growth, factors that are hard to quantify such as the quality of institutions became the determinants of economic growth through the technological progress channel.

Another important stance of the modern literature follows Romer (1986) by emphasizing R&D as the main driver of technological progress and knowledge. Two points are worth mentioning here. R&D activities are only a small component of economic activities in developed countries and cannot be the main driver of economic growth. Second, as illustrated by the distance to the technological frontier of Aghion and Howitt (2009), advanced education appears to be a complementary input to R&D in the growth process.

**Chart 1**
**Skill and Income Disparities in 2003**




Note: Skills of non migrants and personal income (minus transfers to individuals) 10 provinces, 2003. Logarithm deviations from the cross-sectional sample mean. Figure taken from Coulombe and Tremblay (2007).

## Basic versus Advanced Education

In this section, we first review what can be learned from the general literature on human capital regarding the relative contribution of advanced and basic education to growth. Second, we discuss recent results where the distance to the technological frontier appears to affect the relative returns of investing in basic versus more advanced education. Finally, in order to determine where Canada stands in terms of investment in education relative to OECD countries, and how investment is allocated between basic and advanced education, we present data on education attainment and education expenditures.

### Macroeconomic returns of primary/secondary and post-secondary education

Most of the empirical literature on the effects of education on economic growth, or standards of living, does not estimate separately the effect of elementary/secondary education versus the effect of post-secondary education. This essentially results from the fact that most of this literature uses average years of education as measures of human capital. Given that the individual return to education may be non-linear, the estimated macroeconomic effect of average years of schooling will not necessarily provide a good estimate of the aggregate benefits of investing in advanced education. If the marginal return to human capital accumulation is decreasing, one would expect that the growth effects of basic education tend to be higher than that of advanced education.

Psacharopoulos (1994) provides cross-country evidence on Mincerian rates of return consistent with decreasing marginal returns to education. Micro-Mincerian returns measure the percentage increase in wages resulting from an additional year of education. Psacharopoulos reports that the average Mincerian rate of return is 13.4 per cent in Sub-Saharan Africa, 10.1 per cent for the world as a whole and 6.8 per cent for OECD countries. If the average number of years of schooling is around four in Sub-Saharan Africa and around eight in the world as a whole, one might view the average Mincerian rates of return to be approximately 13 per cent for the first four years of education, 10 per cent on the next four years, and 7 per cent on years of education above eight, as was assumed by Hall and Jones (1999) in their cross-country growth accounting study that focus on level differences.

In evaluating the aggregate benefits of investment in post-secondary education, it is therefore useful to estimate the growth effects of advanced education, rather than only those of average years of schooling. There are a few macroeconomic studies that estimate the impact of various indicators of post-secondary attainment on growth. The results of these macro-level studies are quite insightful, and in fact, do not generally provide strong evidence that the aggregate return to advanced education are lower than the return to basic education.

For example, Barro and Sala-i-Martin (2004) looked at the effect of schooling attainment on GDP growth rates in a sample of 87 countries over the 1960-2000 period, and distinguished between primary level, high-school and college education. They found that the average years of secondary and higher schooling for men had a significantly positive effect on subsequent growth while the effect of schooling of both sexes at the primary level was insignificant. Gemmell (1996) also found that educational attainment at the tertiary level had a positive effect on growth in a sample of OECD countries.

Using Census data for Canadian provinces, Coulombe and Tremblay (2007)[12] found that the proportion of the population that holds a university degree has a positive effect on provincial per capita income (net of government transfers to individuals).[13] Quantitatively, the estimated effect of university attainment is similar to the effect of the average skills of the population, measured from the Adult Literacy and Lifeskills Survey. When the university attainment and skills variables used in their study are standardized, so that the estimates are independent of the different scale on which each variable is measured, the results indicate that an increase of one standard deviation in a province's human capital, relative to the ten-province average, leads to an increase

12 See also Coulombe and Tremblay (2001) and Coulombe (2003) for related results.

13 Provincial per capita income is measured using national accounts data on personal income.

of approximately 0.3 standard deviation in personal income, whether human capital is measured by university attainment or skills. Given that the skills variable reflects the average level of education of the population, this finding suggests that the macroeconomic return to advanced education in Canada may not be much lower than the return to basic education.

Coulombe and Tremblay (2007) also estimated the impact of university attainment on provincial per capita income, while controlling for the average level of skills in the population. They found that the partial effect of university attainment remains positive and significant. A potential interpretation for the fact that university attainment has a positive effect over and above the effect of skills may be that university education provides individuals with a set of complementary skills, which taken as a whole, have a greater impact on productivity than the general cognitive skills measured by the Adult Literacy and Lifeskills Survey. This effect could be part of the explanation for the fact that the estimated return to advanced education appears to be comparable to the return on lower-level education.

Note that, even if the marginal individual returns to education are decreasing, the macroeconomic return to post-secondary education could be as high, or higher, than the return to basic education if post-secondary education generates larger externalities than basic education. This would certainly be consistent with the idea that much of the human capital externalities are associated with the impact of skills on innovation and technological progress (e.g. Romer, 1990), or that firms have more incentives to invest in R&D in economies well endowed in highly skilled individuals (e.g. Redding, 1996 and Acemoglu, 1997).

### Returns on education and the distance from the technology frontier

Other interesting findings on the relative macroeconomic returns of higher versus more basic education come out of the distance to frontier model of Vandenbussche, Aghion, and Meghir (2006).[14] According to their theoretical model, a marginal increase in the population with higher education has a larger effect on a country's total factor productivity growth the closer the economy is to the world technology frontier. This result follows from the idea that workers with higher education will contribute more to productivity if they are employed in the innovation, rather than the imitation, sector. The innovation sector is concentrated in countries that are close to the technology frontier.

Vandenbussche *et al.* (2006) and Aghion, Boustan, Hoxby, and Vandenbussche (2005) test the prediction of the distance to frontier model using OECD data and data for U.S. states. In Vandenbussche *et al.* (2006), the distance to the frontier in country *i* is measured by the relative gap between this country's total factor productivity and the total factor productivity of the United States.

The key result from Vandenbussche *et al.* (2006) rests on the interaction terms between the fraction of the labour force with higher education and the distance to the frontier. It appears that the closer the economy is to the frontier, the higher is the return to advanced education. Similarly, the results from Aghion *et al.* (2005) suggest that the return from expenditures on universities that are research- oriented is large in states that are closer to the frontier. By the same token, the return on spending on two years of college education is larger in states that are far from the frontier.

14 For a synthesis of this approach, refer to Aghion and Howitt (2009, section 13.4).

### Where does Canada stand in terms of education attainment and expenditures?

Levels of education investment in Canada are generally quite high relative to OECD countries. Table 1 presents data on attainment rates for upper secondary education and tertiary education in OECD countries in 2005. In Canada, the percentage of the population that has attained at least upper secondary education is 86 per cent among individuals who are between 25 and 64 years old, and 91 per cent in the 25-34 age-group. This is considerably higher than the OECD averages, which are 68 per cent for the 25-64 age-group and 78 per cent for the 25-34 age-group. Relative to Canada, the upper secondary attainment rate is slightly higher in the United States in the 25-64 age-group (88 per cent), but slightly lower in the 25-34 age-group (87 per cent). Canada seems to do even better at the tertiary level. While 47 per cent of the 25 to 64 years old have attained tertiary education, the proportion reaches 55 per cent among the 25-34 years old. The corresponding OECD averages are 27 per cent and 33 per cent. In the United States, 39 per cent of both the 25-64 and the 25-34 age-groups have attained tertiary education.[15]

Interestingly, as we move across age-groups from the oldest to the youngest, there is a growing gap in tertiary attainment rates between Canada and the United States. Among the 55-64 years old, a slightly larger proportion of Americans have attained tertiary education (38 per cent versus 37 per cent for Canadians). However, this proportion is higher in Canada in all other age-groups and the gaps between Canada and the United States are equal to 3 percentage points, 10 percentage points and 16 percentage points in the age-groups 45-54, 35-44 and 25-34, respectively. This is an important trend that may be viewed as a source of competitive advantage for Canada.

Table 2 presents some data on education expenditures as a percentage of GDP and on expenditures per student in 2005. Relative to the OECD average, total expenditures as a percentage of GDP are slightly lower in Canada for primary, secondary and post-secondary non-tertiary education (3.6 per cent versus an OECD average of 3.8 per cent), but are significantly higher at the tertiary level (2.6 per cent versus 1.5 per cent among OECD countries). The United States spends a greater proportion of its GDP than Canada in primary, secondary and post-secondary non-tertiary education (3.8 per cent), as well as in tertiary education (2.9 per cent). As one would expect, the share of public expenditures in tertiary education expenditures is larger in Canada than in the United States.

In terms of expenditures per student at the tertiary level, Canada ranks second. It spends considerably more than the average among OECD countries ($13,463 versus $7,976), but it spends considerably less than the United States ($18,656).[16]

Although the levels of investment in education in Canada are fairly high, at least relative to the OECD average, the results of Vandenbussche *et al.* (2006) and Aghion *et al.* (2005) suggest that the returns of additional investments in post-secondary education could still be

15 Data from the OECD on tertiary education includes bachelor's degree and above, but also some vocational and college diplomas. In Canada, the Labour Force Survey (LFS) does not allow for a clear delineation of attainment between post-secondary non-tertiary (for example, CEGEP programmes designed to prepare students for studies at the tertiary level) and some tertiary education (e.g. college diplomas focusing on occupationally specific skills geared for entry into the labour market such as nursing). As a result, the proportion of the population with tertiary education is somewhat inflated.

16 It should also be noted that the OECD average tends to be pulled downwards by a number of countries that are at much lower levels of development than Canada, such as the Czech Republic, Greece, Hungary, Korea, Mexico, Poland, and the Slovak Republic. The same caveat applies to the OECD averages for the education attainment rates discussed above.

**Table 1**
**Percentage of the Population Attaining at least Upper Secondary Education and Tertiary Education, 2005**

| | Upper Secondary Education | | | | | Tertiary Education | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Age group | | | | | Age Group | | | | |
| | 25-64 | 25-34 | 35-44 | 45-54 | 55-64 | 25-64 | 25-34 | 35-44 | 45-54 | 55-64 |
| Australia | 67 | 80 | 68 | 63 | 52 | 33 | 39 | 33 | 32 | 26 |
| Austria | 80 | 87 | 84 | 77 | 71 | 18 | 19 | 19 | 18 | 14 |
| Belgium | 67 | 82 | 74 | 60 | 50 | 32 | 42 | 35 | 27 | 22 |
| Canada | 86 | 91 | 89 | 85 | 76 | 47 | 55 | 51 | 43 | 37 |
| Czech Republic | 90 | 94 | 94 | 89 | 84 | 14 | 15 | 15 | 13 | 11 |
| Denmark | 82 | 88 | 84 | 78 | 76 | 35 | 41 | 36 | 33 | 28 |
| Finland | 80 | 90 | 87 | 80 | 63 | 35 | 38 | 41 | 34 | 27 |
| France | 67 | 82 | 72 | 61 | 52 | 26 | 41 | 27 | 19 | 16 |
| Germany | 83 | 84 | 85 | 83 | 79 | 24 | 22 | 25 | 25 | 23 |
| Greece | 59 | 75 | 67 | 53 | 34 | 22 | 27 | 26 | 20 | 13 |
| Hungary | 78 | 86 | 82 | 77 | 66 | 18 | 21 | 17 | 17 | 15 |
| Iceland | 63 | 67 | 67 | 64 | 51 | 30 | 32 | 34 | 29 | 21 |
| Ireland | 66 | 82 | 71 | 58 | 41 | 31 | 42 | 33 | 24 | 17 |
| Italy | 51 | 67 | 55 | 47 | 32 | 13 | 17 | 14 | 11 | 9 |
| Korea | 77 | 97 | 90 | 62 | 37 | 33 | 53 | 37 | 19 | 11 |
| Luxembourg | 66 | 78 | 67 | 60 | 55 | 24 | 33 | 24 | 19 | 18 |
| Mexico | 32 | 39 | 36 | 28 | 17 | 15 | 19 | 16 | 15 | 8 |
| Netherlands | 72 | 81 | 76 | 70 | 60 | 30 | 36 | 30 | 30 | 25 |
| New Zealand | 69 | 78 | 72 | 69 | 55 | 38 | 44 | 39 | 38 | 30 |
| Norway | 79 | 83 | 79 | 77 | 75 | 33 | 42 | 35 | 30 | 25 |
| Poland | 53 | 64 | 51 | 49 | 44 | 18 | 28 | 17 | 13 | 13 |
| Portugal | 28 | 44 | 28 | 20 | 12 | 13 | 20 | 14 | 11 | 7 |
| Slovak Republic | 87 | 94 | 91 | 86 | 70 | 14 | 17 | 13 | 14 | 12 |
| Spain | 50 | 64 | 55 | 43 | 27 | 28 | 39 | 31 | 22 | 15 |
| Sweden | 84 | 91 | 90 | 82 | 73 | 31 | 39 | 29 | 29 | 25 |
| Switzerland | 85 | 88 | 87 | 84 | 80 | 30 | 32 | 33 | 29 | 24 |
| Turkey | 28 | 37 | 25 | 22 | 15 | 10 | 13 | 9 | 9 | 8 |
| United Kingdom | 69 | 76 | 70 | 67 | 61 | 30 | 37 | 31 | 29 | 24 |
| United States | 88 | 87 | 88 | 89 | 87 | 39 | 39 | 41 | 40 | 38 |
| OECD average | 68 | 78 | 72 | 65 | 55 | 27 | 33 | 28 | 24 | 19 |

Source: *Education at a Glance 2008,* OECD.

substantial if Canada is relatively close to the technology frontier. Chart 2 depicts the distance from the technology frontier for a group of OECD countries, including Canada. The distance from the frontier is measured as the absolute value of the logarithm of the ratio of total factor productivity of each country to total factor productivity in the United States, constructed from the data of Vandenbussche *et al.* (2006). They measured total factor productivity as the level of output per adult minus the level of the capital stock per adult multiplied by the share of capital in output. Canada does very well, ranking second among this group of eighteen developed countries.

Given Canada's proximity to the frontier, the analysis of Vandenbussche *et al.* (2006) and Aghion *et al.* (2005) implies that investments

**Table 2**

**Expenditure on Educational Institutions as a percentage of GDP, and Expenditures per Student on Educational Core Services, 2005**

| | Expenditures as a percentage of GDP | | | | | | | | | Expenditures per student | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Primary, secondary and post-secondary non-tertiary education | | | Tertiary education | | | All levels of education | | | Primary, sec. and non-tertiary | Tertiary |
| | Public | Private | Total | Public | Private | Total | Public | Private | Total | Total | Total |
| Australia | 3.4 | 0.7 | 4.1 | 0.8 | 0.8 | 1.6 | 4.3 | 1.5 | 5.8 | 6,856 | 9,544 |
| Austria | 3.5 | 0.2 | 3.7 | 1.2 | 0.1 | 1.3 | 5.2 | 0.4 | 5.5 | 9,046 | 9,952 |
| Belgium | 3.9 | 0.2 | 4.1 | 1.2 | 0.1 | 1.2 | 5.8 | 0.2 | 6.0 | 7,021 | 7,725 |
| Canada | 3.2 | 0.4 | 3.6 | 1.4 | 1.1 | 2.6 | 4.7 | 1.5 | 6.2 | 7,398 | 13,463 |
| Czech Republic | 2.7 | 0.3 | 3.0 | 0.8 | 0.2 | 1.0 | 4.1 | 0.6 | 4.6 | 3,801 | 5,234 |
| Denmark | 4.4 | 0.1 | 4.5 | 1.6 | 0.1 | 1.7 | 6.8 | 0.6 | 7.4 | 8,997 | - |
| Finland | 3.8 | - | 3.9 | 1.7 | 0.1 | 1.7 | 5.9 | 0.1 | 6.0 | 5,896 | 7,575 |
| France | 3.8 | 0.2 | 4.0 | 1.1 | 0.2 | 1.3 | 5.6 | 0.5 | 6.0 | 6,492 | 7,015 |
| Germany | 2.8 | 0.6 | 3.4 | 0.9 | 0.2 | 1.1 | 4.2 | 0.9 | 5.1 | 6,878 | 7,158 |
| Greece | 2.5 | 0.2 | 2.7 | 1.4 | - | 1.5 | 4.0 | 0.3 | 4.2 | 5,355 | 4,459 |
| Hungary | 3.3 | 0.2 | 3.4 | 0.9 | 0.2 | 1.1 | 5.1 | 0.5 | 5.6 | 3,668 | 4,590 |
| Iceland | 5.2 | 0.2 | 5.4 | 1.1 | 0.1 | 1.2 | 7.2 | 0.7 | 8.0 | - | - |
| Ireland | 3.3 | 0.1 | 3.4 | 1.0 | 0.1 | 1.2 | 4.3 | 0.3 | 4.6 | 6,269 | 7,386 |
| Italy | 3.2 | 0.1 | 3.3 | 0.6 | 0.3 | 0.9 | 4.3 | 0.4 | 4.7 | 7,111 | 5,011 |
| Japan | 2.6 | 0.3 | 2.9 | 0.5 | 0.9 | 1.4 | 3.4 | 1.5 | 4.9 | - | - |
| Korea | 3.4 | 0.9 | 4.3 | 0.6 | 1.8 | 2.4 | 4.3 | 2.9 | 7.2 | 5,133 | 6,574 |
| Mexico | 3.7 | 0.7 | 4.4 | 0.9 | 0.4 | 1.3 | 5.3 | 1.2 | 6.5 | 2,025 | 5,346 |
| Netherlands | 3.3 | 0.1 | 3.4 | 1.0 | 0.3 | 1.3 | 4.6 | 0.4 | 5.0 | 6,972 | 8,717 |
| New Zealand | 4.0 | 0.7 | 4.7 | 0.9 | 0.6 | 1.5 | 5.2 | 1.4 | 6.7 | - | 8,864 |
| Norway | 3.8 | - | - | 1.3 | - | - | 5.7 | - | - | - | 9,897 |
| Poland | 3.7 | 0.1 | 3.7 | 1.2 | 0.4 | 1.6 | 5.4 | 0.6 | 5.9 | 3,065 | 4,881 |
| Portugal | 3.8 | - | 3.8 | 0.9 | 0.4 | 1.4 | 5.3 | 0.4 | 5.7 | 5,606 | 6,785 |
| Slovak Republic | 2.5 | 0.4 | 2.9 | 0.7 | 0.2 | 0.9 | 3.7 | 0.7 | 4.4 | 2,336 | 4,273 |
| Spain | 2.7 | 0.2 | 2.9 | 0.9 | 0.2 | 1.1 | 4.1 | 0.5 | 4.6 | 6,152 | 7,182 |
| Sweden | 4.2 | - | 4.2 | 1.5 | 0.2 | 1.6 | 6.2 | 0.2 | 6.4 | 7,067 | 8,281 |
| Switzerland | 3.9 | 0.5 | 4.4 | 1.4 | - | - | 5.6 | - | - | - | 13,041 |
| United Kingdom | 3.8 | 0.8 | 4.6 | 0.9 | 0.4 | 1.3 | 5.0 | 1.2 | 6.2 | 5,723 | 7,793 |
| United States | 3.5 | 0.3 | 3.8 | 1.0 | 1.9 | 2.9 | 4.8 | 2.3 | 7.1 | 9,006 | 18,656 |
| OECD average | 3.5 | 0.3 | 3.8 | 1.1 | 0.4 | 1.5 | 5.0 | 0.8 | 5.8 | 5,994 | 7,976 |

Note: Expenditures per students are in US dollars and adjusted for purchasing power parities. In some countries, expenditures on all levels of education include expenditures on pre-primary education. As a result, expenditures on primary, secondary, post-secondary non-tertiary and tertiary education do not add up to expenditures on all levels of education.

Source: *Education at a Glance 2008,* OECD.

in advanced education will tend to have greater growth effects than investments in basic education, and that the growth effects of advanced education can still be substantial despite the fact that tertiary attainment rates and expenditure levels are already high relative to the OECD average.

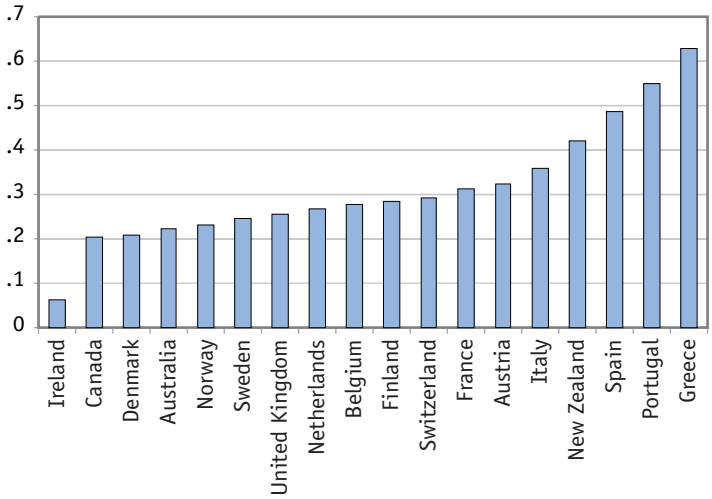
The attainment data discussed above indicates that a considerably larger fraction of the population has attained tertiary education in Canada

than in the United States. However, Bowlus and Robinson (2005) have shown that this has not necessarily resulted in more efficiency units of labour, or human capital, in Canada. They find that the difference between the number of efficiency units supplied by individuals with and without post-secondary education is much greater in the United States. Part of this gap seems to be explained by the fact that a larger fraction of individuals with post-secondary education in Canada do not have a BA degree or higher. Thus, the average size of post-secondary education investments may be smaller in Canada. However, the difference in efficiency units supplied by individuals with and without a BA degree or higher is also larger in the US. In other words, university education seems to be producing more skills in the United States than in the Canada. This appears consistent with the data on expenditures per student discussed above. We will come back to the distinction between the quantity and quality of education in the next section.

Overall, the estimates of the macroeconomic returns to advanced education discussed earlier, and the relationship between the return on education investments and the distance from the technology frontier, seem to indicate that the demand for skills in the economy adjusts to increases in supply, in the sense that firms may be willing to hire more skilled labour at any given wage rate in an economy that is well endowed in skilled labour. In other words, an increase in the supply of skilled workers might induce a shift of the skilled labour demand curve. Such an adjustment on the demand side could result from the fact that firms will have greater incentives to invest in technologies and in modern capital in economies where skilled labour is abundant (e.g. Acemoglu, 1997). In turn, these investments will increase their demand for skilled labour.

In any case, if the economy did not have the capacity to absorb the increasing number of skilled individuals that enter labour markets, at current levels of educational attainment, we would not find relatively large macroeconomic returns to advanced education, or that returns on advanced education are higher in economies that are closer to the technology frontier. Although it is difficult to estimate the empirical relationship between the supply of skilled workers and the demand for skilled workers, the empirical evidence discussed in this section is consistent with the view that the Canadian economy would absorb the skills produced by additional investments in post-secondary education.

**Chart 2**
**Distance from the Productivity Frontier**
Ratio of total factor productivity to US total factor productivity in 2000 (absolute value of logarithm)




Source: Author's calculations using data from Vandenbussche, Aghion and Meghir (2006).

## Macroeconomic Returns versus Individual Returns from Education Investments

For several reasons, individual returns to human capital accumulation may not translate into equivalent macroeconomic returns for an economy as a whole. On one hand, if education acts as a signalling device, investing in education may have a greater effect on an

individual's wage than on its actual productivity. As advocated in the pioneering work of Spence (1973), holding an degree may provide a signal to the labour market about some unobservable characteristics of the worker leading to a higher wage even if education does not have any real effect on productivity. If the job-market signalling hypothesis is valid, the wage returns from education, estimated at the individual level, may be high even if the macroeconomic returns are low.[17] This would imply that the private return to education is higher than the social return.

On the other hand, there may be external effects associated with human capital, implying that part of the social return of an individual's education may be captured by other workers or by the owners of other factors of production. It is well understood that such external benefits may arise, for example, if the human capital of workers has a positive effect on the productivity of co-workers, or if highly educated individuals have a positive effect on innovation and technological progress. If human capital externalities are substantial, the estimated macroeconomic return of education on an economy's aggregate labour productivity may be greater than individual wage returns.

From an efficiency perspective, large public investments in education may be more difficult to defend if the macroeconomic returns of education are not at least in the same range as the individual returns. Leaving aside credit constraints, individuals will not tend to under-invest in education if the private returns are as high as the social returns. Given that it is very difficult to measure the size of human capital externalities directly, the efficiency rationale for public investment in education relies critically on the comparison of aggregate and individual returns from education.

It should be noted, however, that part of the estimated private return to skills in the Mincerian literature is actually shared with the public sector through taxation. Mincerian rates of return estimates typically used pre-tax wages as the dependent variable. Therefore, these estimates do not distinguish between the parts of the return on education that are effectively captured privately versus publicly. Given that the effective taxation of the return on human capital is fairly high in Canada, as in most developed countries, there will remain a substantial gap between the return that is captured privately and the full social return, even if we find that the micro-Mincerian and macro-Mincerian returns are in the same range. This consideration alone strengthens considerably the efficiency case for public investment in post-secondary education.

In any case, the empirical evidence on this issue is quite limited, although Coulombe and Tremblay (2007) provide evidence, based on Canadian data, supporting the view that the macroeconomic returns of education, in terms of higher per capita income, are comparable to individual wage returns. As discussed earlier, we found that the increase in provincial per capita income resulting from higher average skills in the working-age population corresponding to one additional year of education is around 5 per cent. This is very close to the increase in individual wages associated with an extra year of schooling, estimated by Psacharopoulos (1994) to be 5.2 per cent in Canada. Using a similar methodology and data from fourteen OECD countries, Coulombe and Tremblay (2006a) estimated the macro-Mincerian rate of return to be around 7 per cent. Again, this is remarkably close to Psacharopoulos's average micro-Mincerian estimate of 6.8 per cent for OECD countries.

17 Note, however, that even if the wage return from education arises because of the signal it provides to the labour market, there may still be a positive effect at the macroeconomic level if the signals provided by education generate better matching between firms and workers (Arrow, 1973; Stiglitz, 1975).

Using a new set of years of schooling data, corrected for various sources of measurement error, Cohen and Soto (2007) also find macro-Mincerian estimates in the same range as the micro estimates of Psacharopoulos (1994) in a broad set of about 80 countries for the period 1970-1990. They find that the aggregate return to an additional year of schooling in the population is approximately 9 per cent. This study, and those of Coulombe and Tremblay (2006a; 2007), appear inconsistent with the presence of large human capital externalities, which is in line with the evidence provided by Acemoglu and Angrist (2001) and Ciccone and Peri (2006).

Although there is little conclusive evidence on the size of human capital externalities, the estimates of macro-Mincerian rates of return tend to reject the pure signaling hypothesis and support the view that higher educational attainment in the working-age population does lead to substantial productivity gains at the macroeconomic level for both OECD countries and Canadian provinces.

## Human Capital: Quantity versus Quality

Another important condition required to ensure that investment in education leads to higher growth is that education be of high quality. In other words, it is important that schooling generates high levels of skills. There has recently been considerable interest in the literature on the distinction between the quantity and the quality of education.

Microeconomic studies are generally performed using individual data within a country, provinces/states, or cities. Consequently, within those jurisdictions, the other determinants in the human capital production process (such as the quality of education) are relatively homogeneous across individuals. In this case, years of schooling are a good proxy for human capital.

Following the Mincerian tradition, the traditional stance in cross-country studies (Mankiw *et al.*, 1992; Islam, 1995) was to use schooling data as a proxy of human capital. Barro and Lee (1993 and 2001) have developed a multi-country schooling data bank à la Mincer. But the assumption that the other determinants are relatively homogeneous falls when the purpose of the study is to measure the returns to human capital using cross-country data.[18] Coulombe *et al.* (2004) and Coulombe and Tremblay (2006a) argue that it is for this reason that in many, if not most, cross-country empirical analysis, the estimated macroeconomic effect of human capital is either inconsistent (across sexes for example) or not significant (Benhabib and Spiegel, 1994; Islam, 1995; Caselli et al. 1996; Barro, 2001; and Pritchett 2001, among others). The effect of human capital on economic growth is at best nil when the sample is reduced to OECD countries (Islam, 1995; Barro, 2001).

A more recent approach in the literature, following Hanushek and Kimko (2000), has opted to directly measure human capital by making the best use of cognitive skills tests.[19] Using data from the International Adult Literacy Survey (IALS), conducted in a group of OECD countries between 1994 and 1998, Coulombe *et al.* (2004) and Coulombe and Tremblay (2006a) compare the effect of direct measures of human capital with years of schooling data on the growth of 14 OECD countries. From the demographic profile of the 16 to 65 years old, they derived synthetic time series of the literacy level of labour market entrants over the 1960-1995 period.[20] The results

18 De la Fuente and Domenech (2006) and Cohen and Soto (2007) show that improving the quality of the schooling data in cross-country studies allow to estimate a more robust effect for human capital.

19 See Hanushek and Woessmann (2008) for a survey of the literature on cognitive skills and cross-country studies

of their analysis suggest that direct measures of human capital contain more information regarding future growth of countries than traditional measures based on years of schooling, as briefly mentioned in the previous section. They compute the macro-Mincerian returns from the growth effect (on labour productivity) of the skills associated with one extra year of schooling to be around 7 per cent.

The result that direct measures of cognitive skills outperformed schooling data in cross-country macroeconomic studies does not hold when the study is performed using provinces within the same country. Using IALS data from the 2003 survey for the 10 Canadian provinces, Coulombe and Tremblay (2007) found that cognitive skills data did not outperform their earlier (Coulombe and Tremblay 2001, Coulombe 2003) schooling data based on the percentage of the population with at least a university degree. This result could be explained by the fact that the other determinants of the human capital production function, including the quality of the education system, may be quite similar across Canadian provinces. Moreover, cross-country education data may be subject to substantial measurement error.

In the case of Canadian international immigrants however, Coulombe and Tremblay (2009) show that the difference between direct measures of human capital (skills) and proxies based on schooling data matters significantly. Based again on the large Canadian sample of the 2003 IALS survey, they show that, on average, international immigrants to Canada have a lower skill level but more years of schooling than the Canadian-born population. They introduce the concept of the skill-schooling gap to measure in a handy manner the typical skill deficiency of the foreign-born population in Canada. On average and evaluated at the mean of the skill distribution, they show that the skill deficiency of Canadian international immigrants corresponds to three years of formal education in Canada. One of these three years results from lower language skills in either English or French. Coulombe and Tremblay (2009) associate the remaining two years of the skill-schooling gap to a lower quality on average, compared to Canada, of the schooling received by international immigrants in their home country. This diagnostic follows from the fact that, as in the pioneering analysis of Borjas (1987), the skill-schooling gap is negatively correlated with the per capita GDP of the home country. The skill gap of Canadian immigrants is larger when they come from relatively poor countries. This result concurs with the main argument developed in Hanushek and Woessmann (2008): improving human capital in developed countries will not result only from increasing schooling enrolments. Improving the quality of the educational system is also an important channel for increasing human capital in many developed countries.

Overall, this section has highlighted the fact that the measurement of human capital is both complex and critical in assessing the growth effects of education. In addition, the discussion also suggests that investing in post-secondary education with the objective of increasing the quality of schooling, rather than only increasing enrolment rates, might be an important condition for growth.[21]

20 The synthetic time-series was constructed assuming that the level of skills of individuals remains constant during their working-age lives. The level of skills of individuals who would have been 17 to 25 years old in any given year (1960, 1965,...1995) was used as a measure of a country's relative investment in human capital during that period. An important limitation of this approach is that these human capital indicators do not take into account the accumulation and depreciation of skills over the active lifetime of an individual. However, since the pooled time-series cross-section regressions conducted in Coulombe and Tremblay (2006a) include country and period fixed effects, the results will be largely unaffected by that issue as long as the pattern of skills accumulation and depreciation over the life cycle of the workforce is similar across countries.

21 The unabridged version of this article (Coulombe and Tremblay, 2009) also discusses the impact public expenditures on education have on growth and migration and the brain drain.

## Conclusion

The literature on human capital and growth is now extremely vast. We have reviewed the parts of this literature that appear to provide the most relevant insights for policy development in the Canadian context. This selective review leads us to derive the following conclusions about the relationship between investment in post-secondary education and economic growth:

- Although some early empirical studies have expressed scepticism about whether investment in education actually has significant effects on growth, especially in samples of developed countries, there is now a fairly wide consensus in the literature about the fact that the macroeconomic gains of education are indeed substantial. A better understanding of issues associated with the measurement of human capital, as well as the introduction in growth regressions of direct measures of skills — the output of educational investments — have contributed to dissipating the doubts about the macroeconomic benefits of education.
- The Canadian empirical evidence is quite consistent with one of the key predictions of the open-economy neo-classical growth model, namely that the growth of income per capita is largely driven by the accumulation of human capital. Moreover, the Canadian evidence suggests that the share of the return to human capital in national income is around 50 per cent.
- Despite the empirical evidence of the micro-Mincerian literature showing that the individual marginal returns to education are decreasing, there is little evidence that the aggregate returns of post-secondary education for the economy as a whole are lower than the returns to basic education. This is consistent with the view that an important part of human capital externalities are associated with the impact that highly skilled individuals have on innovation and technological progress.
- Recent empirical evidence indicates that the macroeconomic returns on education depend on a country's distance from the world technology frontier. The benefits of advanced education are larger in countries that are closer to the frontier.
- Although investments in education are quite high in Canada relative to OECD countries, Canada's proximity to the technology frontier implies that the returns on additional investments in post-secondary education would likely still be substantial. Moreover, despite the fact that post-secondary attainment rates are higher in Canada than in the United States, some recent evidence suggests that the contribution of post-secondary education to the stock of human capital is larger in the United States. Perhaps consistent with this finding is the fact that expenditures per student, as well as the share of GDP investment in education, are larger in the United States than in Canada.
- There is not much conclusive evidence about the size of human capital externalities. However, there is solid evidence that the social returns to education, estimated from the empirical macro-growth literature, are at least comparable to the private returns, estimated from Mincerian-wage regressions. This tends to reject the job-market signalling hypothesis according to which education increases individual wages by providing a signal of high ability to the labour market, rather than by having real effects on productivity, and strengthens the efficiency rationale for public investment in education.
- As the literature on the quantity versus the quality of schooling suggests, the types of investments in post-secondary education will likely affect the size of the macroeco-

nomic returns. While increasing enrolment rates in post-secondary institutions will likely generate aggregate benefits, the empirical evidence suggests that improving the quality of post-secondary education should not be neglected and may provide the largest benefits.

- The results from the recent literature underlines the fact that years of schooling is a biased proxy for human capital acquired in different countries. This evidence questions the principle of selecting Canadian international immigrants using years of schooling as an important criterion. It might be preferable, from a human capital perspective, to give higher priority to the value of potential immigrants in the Canadian labour market.

Overall, our reading of the theory and of the empirical evidence leaves us with a fairly positive view of the aggregate benefits of post-secondary education, and of the notion that investing additional public funds in post-secondary education would be desirable from a macroeconomic perspective. But, despite the rapidly growing literature on human capital and growth, there remain several knowledge gaps. Moreover, some of our conclusions are largely derived from international evidence, rather than Canadian evidence. Addressing some of these knowledge gaps and generating additional Canadian empirical evidence on some of the core issues would likely produce additional insights for policy development and increase our level of confidence about some of the conclusions discussed above. In our view, some potentially important policy-oriented research issues to address, in the Canadian context, include the following:

- Explore further the relationship between the growth impact of advanced education and the distance from the technology frontier. At the cross-country level, given our knowledge about the fact that education attainment rates and average years of education are not entirely comparable across countries, it would be useful to examine the relationship between human capital and the distance from the frontier by using direct measures of skills based on test scores. The International Adult Literacy Survey allows to construct measures of the shares of the population that has acquired specific levels of skills, which would be ideal indicators of human capital for this purpose. Relative to the existing literature that uses schooling attainment, this would likely provide more reliable estimates of the macroeconomic returns from skills, and how the returns vary as a country gets closer to the frontier. Such estimates could be quite insightful for policy-makers given Canada's proximity to the technology frontier and current levels of education investments. At the Canadian provincial level, the relationship between the growth effects of advanced education and the distance from the frontier could be investigated using census data on secondary and university attainment rates, given that education systems are highly comparable across provinces.
- Investigate the relationship between the aggregate accumulation of skills and the aggregate levels of investment in capital and investment in R&D, using Canadian provincial data. This would improve our understanding of the mechanisms explaining the impact of skills on growth in Canada and could lead to insightful policy implications. A macro-level study of the relationship between skills accumulation and capital and R&D investment would be quite useful since it would capture the various spillover benefits and externalities that escape firm-level studies.
- Some recent international studies suggest that it would likely be interesting to estimate the impact of public education spending on

provincial GDP growth in Canada, while controlling for the structures of taxation. While there is now evidence on the impact of skills on provincial GDP growth in Canada, this would provide a direct estimate of whether financing skills investments publicly generates large macroeconomic gains. Such an analysis could possibly distinguish between different types of education investments.

- It would be quite important to examine empirically whether inter-provincial migration flows have an impact on the levels of investment in post-secondary education by provincial governments. A better understanding of this issue could have very important implications for the financing of post-secondary education.

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