Editor's Overview

THIS 18TH ISSUE OF THE *International Productivity Monitor* published by the Centre for the Study of Living Standards contains seven articles. Topics covered are the relationship between education, productivity and economic growth, new estimates of multifactor productivity for the Canadian provinces, the World Productivity Database developed by the United National Industrial Development Organization (UNIDO), and a symposium on the recently released Council of Canadian Academies Expert Panel report on business innovation in Canada.

It has long been known that education is important for productivity growth. But the exact mechanisms and channels by which education affects productivity have not always been well specified. In the lead article **Serge Coulombe** and **Jean-Francois Tremblay** from the University of Ottawa review the evidence of the linkages between education and productivity. They find that the Canadian data fit the neoclassical prediction that in an open economy growth model, the evolution of capital and output are largely driven by the accumulation of human capital. The authors point out that investment in education will only generate macroeconomic benefits if it has real effects on aggregate productivity, thus emphasizing that what really matters for productivity growth is the skills that are produced by education. A key conclusion of the review is that returns to additional investments in post-secondary education in Canada would likely be substantial.

Multifactor productivity growth, a key concept in the economists' toolbox, captures the increased in output that cannot be explained by increases in inputs. Historically, labour input has been defined as hour worked, unadjusted for changes in quality, and capital input as the capital stock, also unadjusted for changes in composition. More recently statistical agencies have developed input estimates that adjust for quality and compositional changes. In the second article, **Andrew Sharpe** and **Jean-Francois Arsenault** from the Centre for the Study of Living Standards present new estimates of multifactor productivity for the Canadian provinces for the 1997-2007 period that are adjusted for these quality and composition changes. The estimates were prepared by Statistics Canada for the CSLS with the financial support of Alberta Finance and Enterprise. Not surprisingly, these multifactor productivity estimates exhibit much slower growth than earlier estimates that did not take account of the increased labour quality and the composition shift of the capital stock toward assets with shorter lives, such as information and communications technologies. The article finds that multifactor productivity growth for the market economy varied greatly across provinces between 1997 and 2007, from a high of 4.1 per cent per year in Newfoundland to a low of -1.6 per cent in Alberta.

The monitoring and analysis of international productivity developments requires the construction of international productivity databases, which are major undertakings. The third article by **Anders Isaksson** from the United Nations Industrial Development Organization (UNIDO) reports on a new database, the UNIDO World Productivity Database. This database contains estimates for levels and growth rates of aggregate total factor productivity for up to 112 countries for the 1960-2000 period. A key feature of the database is that it allows researchers to specify the measure of the labour and capital input they would like used for the productivity calculation, as well as the functional form of the production function.

It is widely recognized that Canada's record on innovation trails that of many other developed countries. To assess the reasons behind this situation the Minister of Industry asked the Council of Canadian Academies to establish an expert panel on business innovation in Canada. In April 2009 the panel released its report *Innovation and Business Strategy: Why Canada Falls Short*. The last four articles in this issue comprise a symposium on the report.

The first article in the symposium by **Peter Nicholson** from the Council of Canadian Academies summarizes the report. The report presents statistical evidence to show how lagging productivity growth has been due to subpar innovation, defined not just as the outcome of research and development but also as the day-to-day activities of all kinds of businesses looking for new or more efficient ways to serve the needs of customers. The panel finds that too many businesses in Canada are technology followers, not leaders. It concludes that a fresh discussion on innovation in Canada is needed, one that focuses on the factors that influence adoption of innovation-based business strategies.

The second article in the symposium is by **Richard Hawkins** from the University of Calgary. To critically assess some of the major successes and mistakes of Canadian industrial policy, he focuses on the innovation experiences of the automotive and telecommunications sectors, two currently troubled industries. He concludes that the innovation problem in Canada has less to do with capabilities or opportunities than with recent tendencies not to follow through when ambitious innovation initiatives in specific industries could be transformed into new national "engines of growth".

In the third article in the symposium **Jorge Niosi** from the Université du Québec à Montréal makes the case that a missing component of Canada's innovation strategy is direct incentives targeted at small technology firms to assist them cross the "valley of death" and become eligible for venture capital. He points to the Small Business Innovation Research Program (SBIR) in the United States as a model for Canada to adopt to fill this public policy gap .

In the fourth article in the symposium **Ian A. Stewart**, former Deputy Minister of Finance, finds the report comprehensive in its gathering and assessment of available research, and innovative, in its own right, in its analysis of innovation as an outcome of business strategy formation. He suggests that given both the economic and environmental crises facing humanity, future actions, including public policies toward innovation, may now require more explicit collective resolve than reliance on private markets. Shareholder value may cease to be the sole criterion by which enterprises are judged.

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

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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

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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 α 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 neo-classical 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,

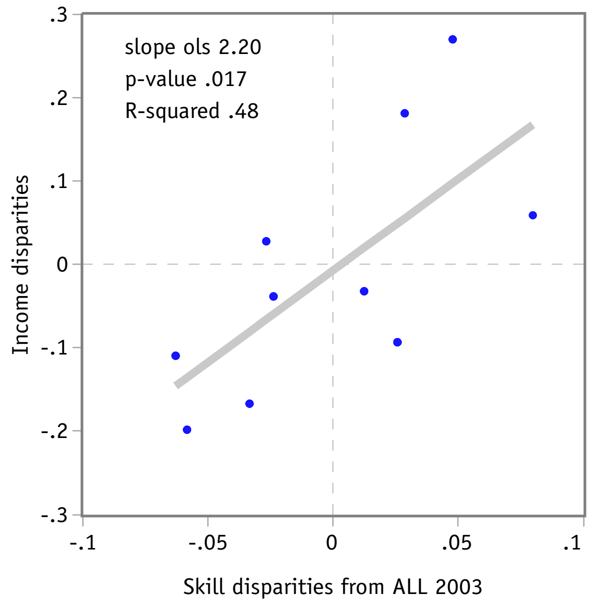
11 Market income is measured using national accounts data on per capita personal income net of government transfers to individuals.

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.

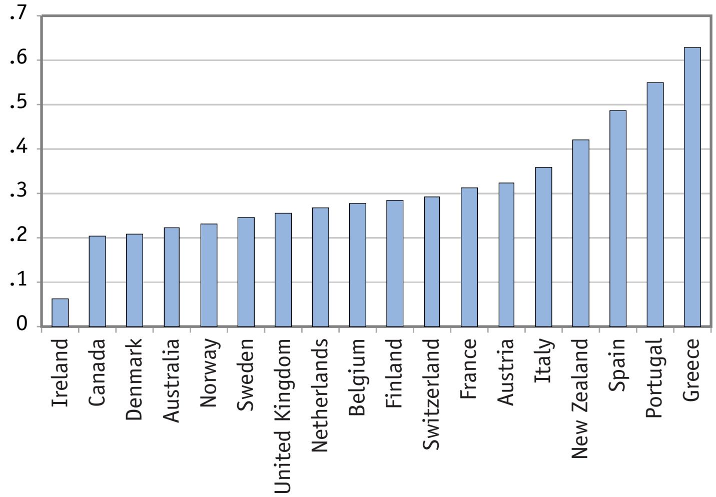
Overall, the estimates of the macroeconomic returns to advanced education discussed earlier, and the relationship between the return on education investments and the distance from the technology frontier, seem to indicate that the demand for skills in the economy adjusts to increases in supply, in the 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

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).

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.

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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New Estimates of Multifactor Productivity Growth for the Canadian Provinces

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Abstract

This article presents new estimates of multifactor productivity for the Canadian provinces for the 1997-2007 period. In contrast to earlier estimates, these estimates incorporate both changes in labour and capital composition or quality. Reflecting differences in labour productivity and capital productivity, multifactor productivity growth varies greatly by province. Newfoundland enjoyed the strongest multifactor productivity growth and Alberta the weakest.

The objective of this article is to present new estimates of multifactor productivity (MFP) or total factor productivity[2] for the Canadian provinces. In contrast to previous estimates of MFP (e.g. CSLS, 2008), these estimates for the first time take account of changes in labour composition or quality and changes in capital composition or quality. The estimates have been prepared by Statistics Canada for the Centre for the Study of Living Standards (CSLS), which received financial support from Alberta Finance and Enterprise in producing this report. The estimates are posted on the CSLS website (www.csls.ca/data/mfp.asp) for free public access.

This report is divided into three main sections. The first section provides a brief overview of the methodologies and data sources used by Statistics Canada to construct the provincial multifactor productivity database. The third section presents the new estimates of labour productivity, capital productivity, multifactor productivity, labour composition or quality, and sources of growth by province. The third and final section concludes.

Methodologies and Data Sources for the Provincial Multifactor Productivity Database

Statistics Canada has detailed the methodologies and data sources used in the preparation of its estimates of multifactor productivity at the national level in the publication *User Guide for Statistics Canada's Annual Multifactor Productivity Program* (Baldwin, Gu, and Yan, 2007). The methodologies and data sources used to generate the provincial multifactor productivity estimates

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2 The terms multifactor productivity and total factor productivity are used as synonyms in this article.

largely follow those used for the national estimates. There are, however, notable differences.

In this section, we first review the growth accounting framework on which MFP measurement is built in Canada. We then provide an overview of the data available from the national MFP program and the Provincial Multifactor Productivity database. We then outline the exact methodologies and data sources used in producing the provincial estimates, with particular emphasis on how they differ from those used to produce MFP estimates at the national level.

Growth Accounting Framework

Multifactor productivity growth measures have been developed as summary statistics to measure improvements in the efficiency of the production process. They do so by comparing actual growth rates in output with the increase in output that would have been expected solely from an increase in inputs.

The growth accounting system provides the framework for measurement of MFP. It allows the decomposition of output growth into the portion that comes from increases in labour input and capital input and a residual (MFP) that captures changes in output that are not directly related to the increasing use of inputs.

The growth accounting framework is based on the extensive literature identifying human capital, physical capital and technological progress as the three fundamental determinants of economic growth. In Canada, the framework used in the MFP program decomposes output growth into five distinct components.

Two components refer to human capital, or labour inputs:

1 Output growth related to changes in hours worked (H)

2 Output growth related to changes in the average skill composition (or quality) of hours worked (QL)

Two components refer to physical capital, or capital inputs:

3 Output growth related to changes in the amount of capital per hour worked, or capital intensity (KI)

4 Output growth related to changes in the average composition (or quality) of capital (QK)

The final component is a residual component, and is often interpreted as a proxy of technological progress:

5 Residual output growth, also called multifactor productivity growth (MFP)

With the exception of hours worked, which is assumed to have a one-to-one relationship with output growth (but a negative relationship with capital intensity), each of the other three factors (excluding MFP) must be weighted by its importance in the economy. In practice, the cost share of labour (L_s) and capital (K_s) are used to weigh the components.[3] In simple mathematical terms, output growth can thus be decomposed as such:

1) $$\Delta \text{GDP} = \Delta H + (\Delta QL \times L_S) + (\Delta KI \times K_S) + (\Delta QK \times K_S) + \Delta MFP$$

Significant challenges arise in the measurement of each of these components, both from a theoretical and practical standpoint. Because MFP is measured as a residual component of output growth, it embodies the measurement issues facing each component. These challenges and their significance for the interpretation of growth accounting results will be discussed later in the

3 The labour share is measured as the share of GDP taking the form of labour compensation, while the capital share is measured as a residual of the labour share. The labour share in Canada hovers around 0.6, with the capital share around 0.4. For more information on the composition of and trends in the labour share in Canada, see Sharpe, Arsenault and Harrison (2008). It should also be noted that there are different 'types' of labour (in terms of education or experience) and capital (in terms of depreciation and asset life, and hence the speed at which they provide services). The weights that are generally used to aggregate changes in a type of factor (labour or capital) are the relative shares of each type of factor in the total compensation received by that factor.

section detailing the methodology and data sources used in MFP measurement in Canada.

Labour productivity growth, or change in output per hour worked, is a partial measure of productivity growth. It represents the portion of output growth not accounted for by changes in hours worked ($\Delta GDP - \Delta H$). Using formula (1), we can see that changes in output per hour worked can be expressed as the sum of the remaining four weighted components: labour quality, capital intensity, capital quality and MFP. Evidently, growth accounting is not only a way to obtain estimates of MFP, but also a diagnosis tool to assess the importance of different factors to growth across time and space. As such, it is useful not only in the context of MFP analysis, but also as a way to shed new light on estimates of labour productivity.

This dual role is important to note because economists differ in their interpretation of multifactor productivity and the importance to give this concept relative to labour productivity. Some see multifactor productivity as more important than labour and capital productivity as it represents gains in efficiency in the use of both of these factors of production. To this group multifactor productivity is the fundamental productivity concept. Others see multifactor productivity as less fundamental and view it more as one of the sources of labour productivity growth. Since it is labour productivity growth that drives real wage and income growth, this group sees labour productivity as the fundamental productivity concept. This group also points out that multifactor productivity estimates are much more affected than labour productivity estimates by data limitations and by the underlying assumptions used to generate the estimates. In both cases, however, growth accounting is considered to hold some analytical value.

An Overview of the Provincial Multifactor Productivity Database

Three levels of industry aggregation exist within the System of National Accounts. The Small (S) level of aggregation represents two-digits NAICS (North American Industry Classification System) industries (up to 25 industry aggregation), the Medium (M) level three-digits NAICS industries (up to 63 industry aggregation) and the Link (L) level four-digits NAICS industries (up to 121 industry aggregation). At the national level, the Multifactor Productivity program develops estimates of MFP and its component at the S-level for the 1961-2007 period and at the M- and L-levels for the 1961-2005 period.[4]

The provincial multifactor productivity database constructed by Statistics Canada for this project covers the ten provinces over the period 1997 to 2007. The database includes indexes of multifactor productivity (MFP), gross domestic product (GDP), capital input (*K*), and labour input (*L*) for the market sector and for 15 industries (the S-level of industry aggregation).[5] Excluded from the database, from the industry dimension, are the non-market sector industries, which include health care, education, and public administration, and from the geographic

4 The national and provincial MFP programs exclude some industry aggregation due to data limitations. MFP estimates for Canada are updated annually at the S-level with a seven-month lag, and at the M- and L-level with a 36-month lag. An annual index of MFP in the business sector is available publically for the 1997-2007 period at http://www40.statcan.gc.ca/l01/cst01/econ86a-eng.htm?sdi=multifactor. Estimates of MFP by industry, and for a longer time series, are available through CANSIM for a fee (Table 383-0021 for the S-level and Table 383-0022 for the M- and L- level).

5 The 15 industries are agriculture, forestry, fishing and hunting (AFFH); mining and oil and gas extraction; utilities, construction, manufacturing, wholesale trade, retail trade, transportation and warehousing, information and cultural industries; finance, insurance, real estate and rental and leasing (FIRE); administrative and support, waste management and remediation services (ASWMR); arts, entertainment and recreation; and other services (except public administration).

dimension, the three territories.[6] The database also includes indexes of total hours and labour composition, which are used to calculate the labour input index, and indexes of capital stock and capital composition, which are used to calculate the capital services index.

From these basic data, the Centre for the Study of Living Standards developed a series of additional tables, including growth accounting summaries for each province and indexes of MFP levels across provinces with the ten-province aggregate as a base. These summary tables are included in the database posted on the CSLS website.

Detailed Methodology

The data requirements for the national and provincial MFP databases are onerous. In general, the methodologies and data sources used to generate the provincial MFP estimates largely follow those used for the national estimates. Statistics Canada has detailed the methodologies and data sources used in the preparation of its estimates of multifactor productivity at the national level in the publication *User Guide for Statistics Canada's Annual Multifactor Productivity Program* (Baldwin, Gu, and Yan, 2007). This section will review these methodologies, and highlight differences between the provincial and national estimates.[7]

MFP estimates can be developed based on either a value added measure of output (in which case inputs are capital and labour) or a gross output measure (in which case inputs are labour, capital, and intermediate inputs, that is energy, materials and services). Because provincial estimates are available only on a value added basis, we focus primarily on the measurement of these estimates.

This section follows a structure similar to the one presented earlier in the section on growth accounting. First, we discuss the measurement of output. Second, we discuss the measurement of labour inputs, that is hours worked and their skills composition. Third, we review the methodology used to measure capital inputs, that is the capital stock and its composition.

Output

At the national level, Statistics Canada's MFP program provides data on chained-Fisher quantity indices for the period 1961-2007 at the S-level and 1961-2005 at the M- and L-levels. Annual estimates are derived from annual Input-Output (IO) tables up to 2005. For the following years, estimates of real GDP are projections obtained from the Industry Accounts Division of Statistics Canada. All estimates are calculated at basic prices.[8]

National GDP estimates obtained from the IO tables are based on make-and-use tables in current prices and in Laspeyres prices (using prices in period t-1). The IO tables in Paasche prices (using prices in period t+1) are not used in the MFP program to ensure that estimates are comparable with those produced in the United States.[9] A make matrix provides data on the

6 The business sector components of the health sector (e.g. doctors' offices) and the education sector (e.g. private schools) are therefore excluded from the market sector.

7 In this section, we compare national estimates with a ten-province aggregate obtained using methodologies consistent with those used for the new provincial MFP database. The reader should be aware that some of the differences between these estimates stem not from methodological differences, but from differences in coverage. Indeed, the ten-province aggregate excludes the three Territories and is for the market sector, not the business sector. This section draws heavily on Baldwin, Gu and Yan (2007), Baldwin and Gu (2007) and Gu et al (2002).

8 The difference between value added at market prices and basic prices is taxes on products less subsidies on products.

9 This methodology for estimating GDP at the national level was adopted by the Canadian Productivity Accounts to ensure that the method for deflating output of the wholesale and retail trade industries is comparable to the one used in the United States by the Bureau of Economic Analysis.

value of a given commodity made by a given industry in the reference year. A use matrix provides data on the value of a given commodity used as an input in a given industry in the reference year. Value added for a given industry can be obtained by subtracting the sum of the value of all its inputs (from the use matrix) from the value of its output (from the make matrix). Estimates of nominal value added are derived directly from the make-and-use table in current prices, while real GDP in the form of a chained-Fisher index is derived from the current-price and Laspeyre-prices indices.

These output estimates are for the business sector, not total economy. This construction involves splitting the chained-Fisher GDP index for all economic activities between the business and non-business sectors. The share of the business sector in total economic activities is estimated as the portion of GDP in chained-Laspeyres dollars going to the business sector for the period covered by IO tables (1997-2005). For subsequent years, the share is extrapolated using the growth of hours worked in the non-business sector, with the assumption of no productivity growth in the non-business sector.

Two methodological differences exist between the national and provincial estimates of output in the respective MFP programs. The most important difference is that for the provincial estimates, the chained-Fisher index of GDP is derived from the IO tables in both Laspeyres and Paasche prices, rather than from the IO tables in Laspeyres prices only. This methodological difference translates into some differences in output growth at the industry level. The second difference is the treatment of the health and education industries which are completely excluded from the business sector aggregate at the provincial level, while the business sector portion of these industries is included at the national level. However, these two methodological differences have little effect on the aggregate output growth rate in Canada over the period 1997-2007.

Capital input

Capital input measures the flow of services provided by the capital stock, hence the term 'capital services'. It can be divided into two components: the level of the capital stock and the composition of the capital stock. In practice, capital services are measured directly as the weighted sum of capital stock across assets using the user costs of each asset as weights (Baldwin and Gu, 2007).

The difference between capital stock and capital services stems from the fact that not all forms of capital assets (or stock) provide the same services, just as not all hours worked provide the same labour services. Short-lived assets, such as a car or a computer, must provide all of their services in just a few years, that is before they become obsolete and completely depreciate. On the other hand, office buildings provide services over decades. So, in a year, a dollar's worth of computers provides relatively more services than a dollar's worth of buildings. Because of differences in capital services between assets, capital input can increase not only because investment increases the amount of the capital stock, but also if investment shifts toward assets—such as equipment—that provide relatively more services per dollar of capital stock. In practice, the effect of capital composition has been a shift towards short-lived assets, measured as the difference between capital stock and capital services.

The measurement of capital services is theoretically straightforward. As noted earlier, capital services can be estimated as the weighted sum of capital stock across assets using their user costs as weights. In practice, however, the methodology used to estimate the user cost of different types of assets is a thorny issue. While the price of the capital good is available (the acquisition price of capital goods is observable), the price of the services that the capital good should command is not usually observed and needs to be inferred.

The user cost of capital can be thought of as the price that a well functioning market would produce for an asset that is being rented by an owner to a user of that asset. That price would comprise a term reflecting the opportunity cost of capital, a term reflecting the depreciation of the asset, and a term reflecting capital gains or losses from holding the asset. This formulation requires data on the rate of return, depreciation, capital gains from holding assets, tax rates on capital, and the price of the asset.[10]

Analysts who calculate rental prices of capital services face several choices: with regard to the expected rate of return; depreciation rates; expected capital gains; expectations; and finally whether to include tax parameters in the formula or not. Needless to say, each of these choices requires justification, either from a practical or theoretical perspective. Baldwin and Gu (2007) review each of these in detail.

Some aspects of the estimation procedure for capital services in Canada merit mention. First, unlike outside researchers, Statistics Canada benefits from detailed capital stock data by asset type. As such, its estimation of capital services is based on a bottom-up approach. This approach involves the estimation of capital stock by asset type, the aggregation of capital stock of various asset types within each industry to estimate industry capital services, and the aggregation of capital services across industries to derive capital services in the business sector and in the aggregate industry sectors. This approach for estimating aggregate capital input takes into account the difference in the rate of return across industries (as well as tax differences in tax parameters) and does not require the assumption of perfect mobility of capital inputs across industries.

Second, the rate of return used in the user cost formulae is measured endogenously rather than exogenously from observed market rates. The main advantage of using an endogenous rate of return, based on estimates from the System of National Accounts, is the provision of a fully integrated set of accounts.[11]

Finally, the user costs of assets with negative user costs — which are generally due to short-term fluctuations in returns and are not in keeping with the spirit of measuring long-term capital costs — are set to equal the average user costs of the assets across all industries for those assets, and are then adjusted for inter-industry differences in the user cost of capital.

The concept of capital input used in the provincial MFP database is similar to that adopted for the national MFP estimates. Similar to the national estimates, capital input in the provincial MFP database measures the flow of services provided by the capital stock. Yet, the methodologies for estimating capital input differ slightly between the two databases. For the provincial MFP estimates, land and inventories are excluded from capital input estimates due to data limitations, and the effect of tax parameters is not taken into account in the estimation of user costs of capital. The differences in methodologies have little effect on the capital input estimates at the aggregate business sector, but have

10 In Canada, the following variable are included in the user cost formula for asset *k* at time *t* (C_{kt}): the corporate income tax rate at time t, the present value of depreciation deductions for tax purposes on a dollar's investment in asset type k over the lifetime of the investment at time t; the rate of the investment tax credit for asset type k at time t; the market price for asset type k at time t; the real rate of return at time t; the depreciation rate of asset type k at time t; the expected capital gains; and the effective rate of property taxes at time t;.

11 See Baldwin and Gu (2007) for a full discussion of the benefits and problems related to endogenous and exogenous rates of return. The effect of using either rate of returns affects primarily the contribution of capital composition to output growth. In general, the effect on annual MFP growth rates is relatively small.

some effect at the industry level, most notably in the business services industry.

Both nationally and provincially, the database source for estimating capital input is the investment data by asset type maintained by the Investment and Capital Stock Division of Statistics Canada. To ensure the consistency of industry coverage between the investment data and GDP estimates, an estimate for investment in rental buildings is added to the finance, insurance and real estate industry (FIRE).

Labour input

As was noted earlier, labour input includes both the number of hours worked and the quality (or composition) of those hours. In the context of its Productivity Accounts, Statistics Canada already produces labour statistics covering the 1997-2007 period (including hours, jobs and labour compensation) for Canada and the provinces, for both the business and non-business sectors at the L-level of industry aggregation. The national and provincial data are consistent and are built from estimates obtained through the Labour Force Survey and the Survey of Employment, Payrolls and Hours (particularly for industry estimates). The Public Institutions Division's (PID) estimates of public sector employment are also used to estimate hours worked in the non-business sector.

Labour composition captures changes in the 'quality' of workers. In practice, hours worked are weighted by the share of labour compensation of a given group relative to other groups, with the relative weights assumed to reflect productivity differences. The variables used to differentiate labour quality in Canada are education (four education level), experience (proxied with seven age groups) and the class of workers (paid employees versus self-employed workers). In other words, 56 different types of workers are identified. The hours worked of each group is then weighted by its share of labour compensation to obtain an aggregate measure of labour services. Labour services will increase if there is a compositional shift in hours worked favouring high productivity workers (as proxied by relative labour compensation) and/or if there is an increase in the number of hours worked. Labour composition can then be computed as the difference between growth in hours worked and growth in labour services.

The measure of labour composition in Canada does not differentiate workers based on gender. Differences in hourly labour compensation between genders are assumed to be related to factors other than productivity differences (which are captured through education, experience and the class of worker), for example workplace discrimination. Moreover, unlike for capital input, changes in the industry composition of labour are not accounted for, mainly because little or no additional information seems to be embedded in the industry breakdown once education and experience are accounted for.

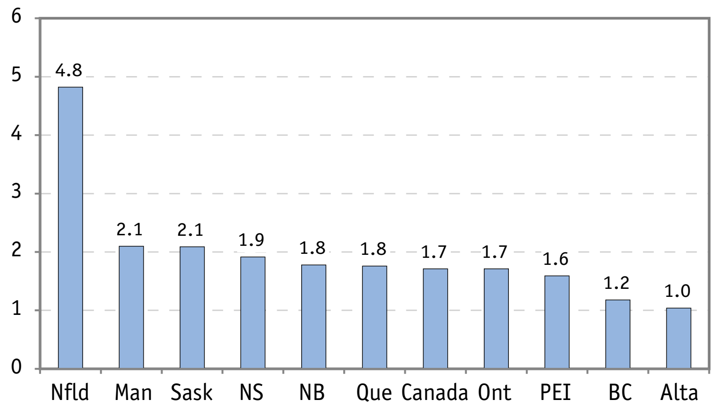
The concept of labour input in the provincial MFP database is the same as the one adopted for the national MFP estimates.[12] The methodologies and data sources for constructing labour inputs are identical in the two databases. For both national and provincial estimates, labour input is estimated as the weighted sum of hours worked across different types of workers using labour compensation as weights. There is little difference at the aggregate market/business sector, and the differences at the industry level due to differences in geographical coverage are minor.

A Summary of Methodological Differences

The different methodologies in the measurement of output, labour and capital between the national and provincial MFP estimates are

12 For a detailed discussion of the methodologies and data sources used to estimates labour input, see Gu *et al.* (2002).

Chart 1
Labour Productivity Growth by Province, 1997-2007
Average annual rate of growth, per cent



Source: CSLS calculations based on unpublished Statistics Canada data.

numerous. The key differences that were noted are:

- The health and education industries are completely excluded from the market sector aggregate at the provincial level while the business sector portion of these industries is included in the national level estimate of business sector.
- The estimate for Canada based on the provincial program is an aggregation of the ten provinces, and thus excludes the three territories.
- Output in the provincial program is derived from the IO tables in both Laspeyres and Paasche prices, rather than from the IO tables in Laspeyres prices only.
- Land and inventories are excluded from capital input estimates at the provincial level.
- The effect of tax parameters is not taken into account in the estimation of user costs of capital at the provincial level.

For some industries, the sum of these methodological differences translates into significant differences in growth rates.[13] In general, however, the estimates remain fairly consistent between the provincial and national program. At the market / business sector level, the difference is only 0.1 percentage points per year.

Results from the New Provincial Multifactor Productivity Database

This section of the report provides an overview of the main results from the new provincial productivity estimates produced by Statistics Canada. It first provides a discussion of labour and capital productivity, followed by an introduction to the new provincial measures of labour composition, capital composition and multifactor productivity. The section closes with a provincial perspective on the sources of growth.

Labour productivity

Table 1 and Chart 1 provide estimates of labour productivity for the market sector for the provinces. At the Canada level output per hour in the market sector advanced at a 1.71 average annual rate between 1997 and 2007.[14]

There was significant variation in market sector labour productivity growth by province. Newfoundland[15] was the province with by far the most rapid labour productivity growth. At 4.82 per cent per year from 1997 to 2007, Newfoundland's rate of advance was nearly three times the national average and more that double that of the province with the second fastest labour productivity growth, Manitoba (2.10 per cent). At the other end of the spectrum, Alberta had the weakest productivity growth at 1.04 per cent per year, fol-

13 See Sharpe and Arsenault (2009) for a detailed discussion of these differences.

14 The first three years of the period (1997-2000) saw much more rapid productivity growth than the period since 2000: 3.21 per cent per year versus 1.08 per cent. This article will focus on the whole period, not the two sub-periods.

15 The term Newfoundland is used to refer the province of Newfoundland and Labrador throughout this report.

Table 1
Productivity Measures by Province, 1997-2007
Average annual rate of growth, per cent

	Labour Productivity	Capital Productivity	Labour Composition	Capital Composition	Multifactor Productivity
Canada – Based on Provincial Estimates*	1.68	-0.68	0.58	1.58	0.32
Canada – Based on National Estimates**	1.71	-0.57	0.52	1.20	0.44
Newfoundland	4.82	4.25	0.60	0.89	4.14
Prince Edward Island	1.59	-1.87	0.59	2.34	-0.18
Nova Scotia	1.92	0.26	0.24	0.51	1.12
New Brunswick	1.78	-1.00	0.44	0.73	0.37
Quebec	1.76	0.44	0.46	1.18	0.94
Ontario	1.71	0.24	0.52	1.07	0.82
Manitoba	2.10	-0.54	0.61	1.38	0.62
Saskatchewan	2.09	-0.62	0.90	1.98	0.11
Alberta	1.04	-3.40	0.49	1.29	-1.58
British Columbia	1.18	-0.46	0.12	0.97	0.48

* Aggregation of the ten provinces, market sector.
** National estimates, business sector.

lowed closely by British Columbia at 1.18 per cent.[16]

Capital Productivity

At the Canada level, capital productivity in the market sector fell at a 0.57 per cent average annual rate between 1997 and 2007 (Table 1). The first three years of the period (1997-2000) saw positive capital productivity growth (1.15 per cent per year), while capital productivity has fallen in the period since 2000 (-1.30 per cent per year). Again, this report will focus on the whole period, not the two sub-periods.

There was even more variation in market sector capital productivity growth by province than labour productivity (Chart 2). Newfoundland again was the province with by far the most rapid capital productivity growth (4.25 per cent per year). No other province was close. Quebec was second with capital productivity growth at a meagre 0.44 per cent. At the other end of the spectrum, Alberta had the worst capital productivity performance, with real GDP per unit of capital services falling at a 3.40 per cent average annual rate.[17]

Labour Composition or Quality

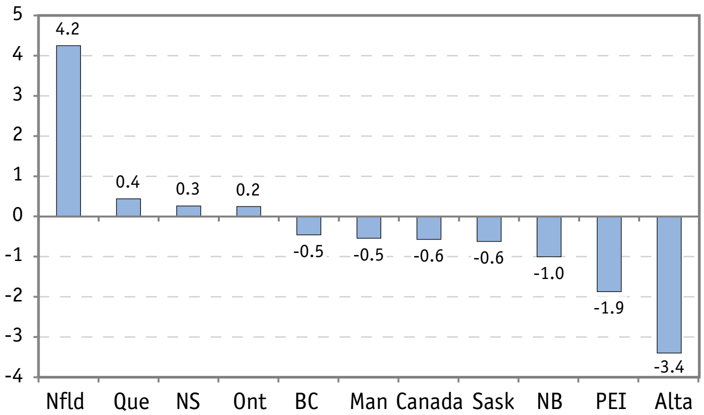
At the Canada level, labour quality in the market sector advanced at a 0.52 per cent average annual rate between 1997 and 2007 (Table 1). The first three years of the period (1997-2000) saw very similar growth to the post-2000 period: 0.56 per cent per year versus 0.50 per cent.

There is much less variation in market sector labour quality growth across provinces than manifested by the three productivity measures (Chart 3). Saskatchewan was the province with the most rapid labour quality growth (0.90 per year), followed by Manitoba (0.61 per cent), and Newfoundland (0.60 per cent). British Columbia experienced the slowest increase in labour quality, a very weak 0.12 per cent per year, followed by Nova Scotia (0.24 per cent).[18]

16 The unabridged version of this article (Sharpe and Arsenault, 2009) provides a comparison of labour productivity growth at the sector level for Canada and the provinces.

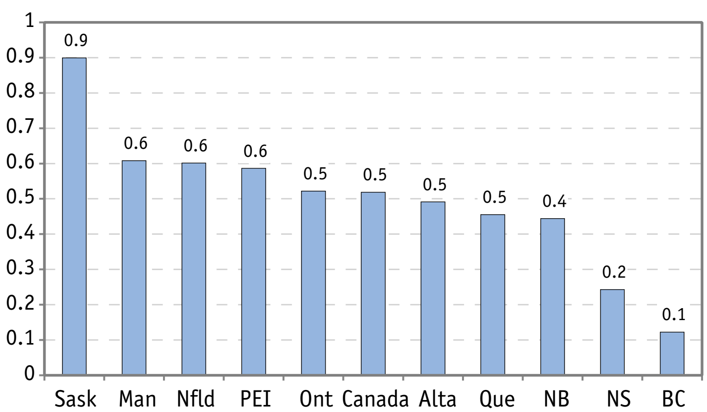
17 The unabridged version of this article (Sharpe and Arsenault, 2009) provides a comparison of capital productivity growth at the sector level for Canada and the provinces.

Chart 2
Capital Productivity Growth by Province, 1997-2007
Average annual rate of growth, per cent



Source: CSLS calculations based on unpublished Statistics Canada data.

Chart 3
Labour Quality Growth by Province, 1997-2007
Average annual rate of growth, per cent



Source: CSLS calculations based on unpublished Statistics Canada data.

Capital Quality or Composition

At the Canada level, capital quality in the market sector advanced at a 1.2 per cent average annual rate between 1997 and 2007 (Table 1). Capital composition growth as twice as fast in the first three years of the period (1997-2000) than in the post-2000 period: 1.86 per cent per year versus 0.93 per cent.

There is significant variation in market sector capital quality growth across provinces (Chart 4). Prince Edward Island and Saskatchewan were the provinces with the most rapid capital quality growth (2.34 and 1.98 per cent per year respectively), followed by Manitoba (1.38 per cent), and Alberta (1.29 per cent). Nova Scotia experienced the slowest increase in capital quality, a relatively weak 0.51 per cent per year, followed by New Brunswick (0.73 per cent).[19]

Multifactor Productivity

At the Canada level, multifactor productivity in the market sector rose at a 0.44 average annual rate between 1997 and 2007 (Table 1).[20] The first three years of the period (1997-2000) saw much stronger multifactor productivity growth (2.02 per cent per year), while the period since 2000 saw falling multifactor productivity (-0.24 per cent per year).

There was more variation in market sector multifactor productivity growth across provinces than labour productivity, but less than capital productivity growth. Newfoundland again was the province with by far the most rapid multifactor productivity growth, an impressive 4.14 per cent per year (Chart 5). No other province was close. Nova Scotia was

18 The unabridged version of this article (Sharpe and Arsenault, 2009) provides a comparison of labour quality growth at the sector level for Canada and the provinces.

19 The unabridged version of this article (Sharpe and Arsenault, 2009) provides a comparison of capital quality growth at the sector level for Canada and the provinces.

20 The CSLS productivity database has until now provided estimates of multifactor productivity growth for Canada and the provinces based on hours worked and capital stock estimates that were not adjusted for quality or composition. Not surprisingly, these estimates show considerably stronger total factor productivity growth than the estimates in this article. For example, total economy total factor productivity growth grew 1.3 per cent per year between 1997 and 2006, in contrast to the 0.6 per cent per year over the same period for the market sector measure found in this article.

second with multifactor productivity growth at 1.12 per cent, and Quebec third at 0.94 per cent. Alberta had by far the worst multifactor productivity performance, with real GDP per unit of combined labour and capital falling at a 1.58 per cent average annual rate. The only other province to experience negative multifactor productivity growth was Prince Edward Island (-0.18 per cent).[21]

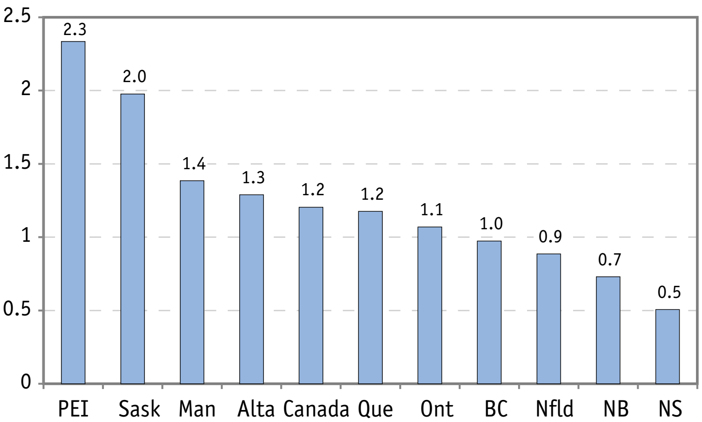
Sources of Labour Productivity Growth by Province

Table 2 provides estimates in both percentage point contributions and percentages of the sources of labour productivity growth for the market sector for Canada and the provinces for the 1997-2007 period. As noted earlier, labour productivity growth can be decomposed into a labour composition or quality effect, a capital services intensity effect (in turn broken down into capital stock and capital composition effect), and multifactor productivity growth, the residual.

As was noted by way of illustration earlier in the report, at the Canada level the 1.7 per cent average annual rate of labour productivity growth for the market sector for the 1997-2007 period can be decomposed into a 0.3 percentage point (17.5 per cent) contribution from labour quality, a 1.0 percentage point contribution from capital services intensity (57.6 per cent) and a 0.4 percentage point contribution from multifactor productivity growth (25.5 per cent).

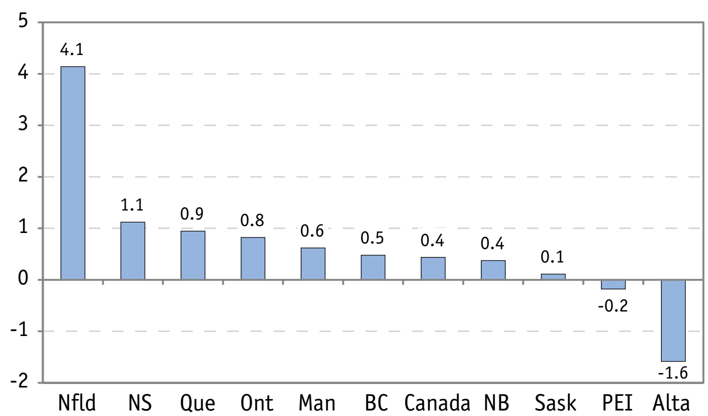
The relative importance of the sources of labour productivity growth at the provincial level deviated significantly in many instances from that observed at the national level. As the provincial labour productivity growth rate is used for the calculation of per cent contribution to labour productivity growth, differences in this rate can affect the relative importance of the sources of growth. Equally, differences in the absolute or percentage point contributions from the three sources of productivity growth affect the relative importance of these sources. For example, the percentage point contribution of labour quality to labour productivity growth ranged from a low of zero in British Columbia to a high of 0.4 points in Saskatchewan, while the

Chart 4
Capital Quality Growth by Province, 1997-2007
Average annual rate of growth, per cent



Source: CSLS calculations based on unpublished Statistics Canada data.

Chart 5
Multifactor Productivity Growth by Province, 1997-2007
Average annual rate of growth, per cent



Source: CSLS calculations based on unpublished Statistics Canada data.

21 The unabridged version of this article (Sharpe and Arsenault, 2009) provides a comparison of multifactor productivity growth at the sector level for Canada and the provinces.

Table 2
Sources of Growth in the Market Sector by Province, 1997-2007

	Canada	Nfld.	P.E.I.	N.S.	N.B.	Que.	Ont.	Man.	Sask.	Alta.	B.C.
	Average annual rate of growth										
Output	3.61	6.68	2.95	3.22	3.08	3.33	3.71	2.86	1.98	4.06	3.29
Total Hours	1.87	1.78	1.34	1.28	1.28	1.54	1.97	0.75	-0.10	2.99	2.08
Labour Composition	0.52	0.60	0.59	0.24	0.44	0.46	0.52	0.61	0.90	0.49	0.12
Capital Services	4.21	2.34	4.92	2.95	4.12	2.88	3.46	3.42	2.62	7.72	3.76
Capital Stock	2.97	1.44	2.52	2.43	3.37	1.68	2.36	2.01	0.63	6.35	2.76
Capital Composition	1.20	0.89	2.34	0.51	0.73	1.18	1.07	1.38	1.98	1.29	0.97
Capital Services Intensity	2.30	0.55	3.53	1.65	2.81	1.32	1.46	2.65	2.73	4.59	1.64
	Percentage point contributions to labour productivity growth										
Labour Productivity (Output per hour)	1.71	4.82	1.59	1.92	1.78	1.76	1.71	2.10	2.09	1.04	1.18
Labour Composition	0.30	0.27	0.35	0.15	0.26	0.27	0.32	0.35	0.37	0.23	0.08
Capital Services Intensity	0.97	0.39	1.42	0.64	1.13	0.54	0.56	1.12	1.60	2.43	0.62
Capital Stock	0.68	0.24	0.73	0.53	0.93	0.32	0.38	0.66	0.39	2.00	0.45
Capital Composition	0.28	0.15	0.67	0.11	0.20	0.22	0.17	0.45	1.21	0.41	0.16
Total Factor Productivity	0.44	4.14	-0.18	1.12	0.37	0.94	0.82	0.62	0.11	-1.58	0.48
	Percent contributions to labour productivity growth										
Labour Productivity (Output per hour)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Labour Composition	17.5	5.5	22.0	7.6	14.8	15.1	18.8	16.6	17.8	22.1	6.5
Capital Services Intensity	56.6	8.0	89.2	33.5	63.7	30.7	32.5	53.4	76.5	233.9	52.6
Capital Stock	39.9	4.9	45.8	27.6	52.1	18.0	22.2	31.3	18.5	192.4	38.6
Capital Composition	16.2	3.0	42.4	5.7	11.3	12.6	10.1	21.6	57.7	39.1	13.6
Total Factor Productivity	25.5	85.9	-11.3	58.4	20.9	53.6	48.1	29.4	5.3	-152.5	40.6

Source: Unpublished Statistics Canada Estimates. Growth rates calculated by the CSLS.

per cent contribution ranged from a high of 22.1 per cent in Alberta to a low of 5.5 per cent in Newfoundland. The weak labour productivity growth in Alberta (1.0 per cent) and the very strong growth in Newfoundland (4.8 per cent), combined with the narrow range of labour quality contributions, accounts for this situation.

The contribution of capital services intensity to labour productivity growth varied greatly across provinces. This situation of course reflected differences in capital services intensity growth, and possibly differences in the capital share of income. The largest contribution of capital services intensity was in Alberta (2.4 percentage points) and the smallest in Newfoundland (0.4 points). Given the weak labour productivity growth in Alberta, capital services intensity growth was responsible for 234 per cent of labour productivity growth in this province. In contrast, given the strong labour productivity growth in Newfoundland, capital services intensity growth accounted for only 8.0 per cent of labour productivity growth.

Labour productivity growth not accounted for by labour quality and capital services intensity growth is said to be accounted for by multifactor productivity growth. Given the very large contribution of increased capital services intensity to labour productivity growth in Alberta, it is not surprising to find that multifactor productivity was responsible for -152.5 per cent of labour productivity in this province. In contrast, with the limited importance of capital services intensity growth for labour productivity growth in Newfoundland, multifactor productivity accounted for 85.9 per cent of labour productivity growth.

Conclusion

This article has presented new estimates of labour, capital and multifactor productivity growth by province. These estimates were produced by Statistics Canada for the Centre for the Study of Living Standards, with financial support from Alberta Finance and Enterprise. Estimates of the levels of labour, capital, and multifactor productivity will also be produced and will appear in the unabridged version of this article (Sharpe and Arsenault, 2009). The full database upon which these estimates are based is posted at http://www.csls.ca/data/mfp.asp and can be accessed without charge.

The first major finding of the article is the poor productivity performance of Alberta over the 1997-2007. This province experienced the slowest labour productivity growth (1.0 per cent per year), the worst capital productivity growth (-3.4 per cent) and the worst multifactor productivity growth (-1.6 per cent) of all ten provinces.

The second key finding of the article is the strong productivity performance of Newfoundland over the 1997-2007. This province experienced by far the fastest labour productivity growth (4.8 per cent per year), by far the best capital productivity growth (4.2 per cent) and by far the best multifactor productivity growth (4.1 per cent) of all ten provinces.

A third major finding of the report is the key role played by the mining and oil and gas extraction sector in shaping productivity performance at the provincial level. This role, perhaps surprisingly, can be both positive and negative. Newfoundland experienced by far the most rapid market sector labour productivity growth among the provinces. The very rapid labour productivity growth (15.3 per cent per year) in the mining and oil and gas extraction (primarily the latter) as well as the increased importance of this high productivity level industry in the province's employment, were the drivers of this productivity success. In contrast, Alberta's poor productivity performance is in large part explained by the 4.3 per cent average annual decline in labour productivity in mining and oil and gas extraction, in large part due to the shift in resources from conventional oil and gas production to non-conventional production (i.e. the oil sands). A much greater amount of capital and labour is needed to extract a barrel of oil in the latter sub-industry.

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The UNIDO World Productivity Database: An Overview

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ABSTRACT

This article introduces a new unique database, the World Productivity Database (WPD), which contains information on levels and growth of aggregate total factor productivity (TFP) for up to 112 countries, covering the period 1960 to 2000. At its core are numerous measurement methods, variations in functional forms and specifications — including schooling and health — of the production function, constant and variable returns to scale, as well as measures of technical progress and change in technical efficiency. In addition, five labour and four capital stock measures are used to derive a variety of TFP measures. Another significant feature is TFP forecasts for the period of 2001-2010.

THE PURPOSE OF THIS ARTICLE is to describe a new, unique database—the World Productivity Database (WPD) — which contains information on aggregate productivity performance, level and growth for up to 112 countries from 1960 to 2000. In addition, forecasts of TFP levels and growth are provided from 2001 to 2010. Although the WPD mainly focuses on measures of total factor productivity (TFP), it also includes partial measures, such as labour productivity (output per worker), and basic statistics, such as capital per worker and its change over time.

To a great extent, the work of the United Nations Industrial Development Organization (UNIDO) is concerned with long-term sustainable industrial development and its role in overall economic development. Sustained growth relies on productivity growth. To understand better what policies for industry and productivity growth to recommend to countries at different stages of development, UNIDO launched a project on productivity performance in 15 developing countries. Based on case studies, it examined country-specific conditions regarding productivity measurement and attendant policies along with conventional cross-country analysis.[2] The project revealed that, while many international and national organizations in industrialized countries regularly publish pro-

1 Researcher in the Research and Statistics Branch, United Nations Industrial Development Organization (UNIDO). The author thanks Tim Coelli for his advice on Data Envelopment Analysis (DEA) as well as for his generosity, without which the WPD would not have contained any Long-Memory DEA (LMDEA) results, and Chuck Hulten for excellent discussions and insights on productivity measurement. Important contributors to the database include Margarita Grushanina, Harvir Kalirai and Katarina Zigova. The World Productivity Database website (www.unido.org/data1/wpd/Index.cfm) was constructed and is maintained by Ömer Aksoycan and his contribution is gratefully acknowledged. Comments and suggestions by two anonymous referees and the editor of this journal have improved the article. The author alone assumes responsibility for any errors in the WPD and its documentation. The views expressed herein are those of the author and do not necessarily reflect the views of UNIDO. This paper is based on Isaksson (2007c) posted at http://www.unido.org. Email: a.isaksson@unido.org.

2 The countries covered were Argentina, Brazil, Chile, Mexico, China, India, Indonesia, Republic of Korea, Egypt, Morocco, Kenya, Nigeria, South Africa, Uganda and United Republic of Tanzania. Cross-country analysis of productivity and its determinants used for comparative purposes were produced by Isaksson (2007a and 2007b).

ductivity figures, this is generally not the case in developing countries. Hence, the idea of the WPD was born.[3]

By making internationally comparable productivity data available to policymakers in developing countries, the WPD enables them to track productivity performance and prospects for increased living standards, as well as track their progress relative to others. Moreover, with productivity growth at the heart of industrial and overall economic development, the WPD is also potentially useful to multilateral institutions, such as the World Bank and many United Nations organizations, as well as bilateral aid donors and non-governmental organizations (NGOs).

The WPD also provides data to academe for analysis. In particular, the WPD caters to the many existing preferences and views among researchers regarding productivity measurement. For example, TFP measures are provided based on more than ten different measurement methods, several approaches to measuring capital and labour input, measures of technical change, change in technical efficiency and scale efficiency, and various specifications of the aggregate production function, including those accounting for schooling and health. For the many researchers who link information on productivity to other issues such as poverty reduction, effects of environmental regulation, and wage determination, the WPD can considerably shorten the time needed for data collection and measurement.

Data Sources and Coverage[4]

The principal data source is Penn World Tables (PWT) version 6.1 (Heston, Summers and Aten, 2006), which provide estimates of gross domestic product (GDP) and investment, both expressed in 1996 US dollars at power purchasing parity exchange rates. Labour force data are also provided. Real investment is used to compute capital stock in international prices. The combination of output, investment and labour force data from PWT defines the maximum number of countries and years covered.

Refined labour measures and more intricate specifications require additional data. From the Groningen Growth and Development Centre (GGDC, 2005), the Organisation for Economic Co-operation and Development (OECD, 2004) and the Asian Development Bank (ADB, various issues), data on employment and hours worked have been obtained, while unemployment rates have been collected from the International Labour Organization *Yearbook 2003* (ILO, 2003a), the ILO's Key Indicators of the Labour Market (KILM) (ILO, 2003b) and the ADB (various issues). Barro and Lee (2000) is the source for schooling data, while the health indicators of life expectancy and adult mortality rates come from the World Development Indicators (World Bank, 2005).

In cases where dubious data were encountered, they have been verified against national sources and, occasionally, adjusted. The countries included in the WPD are listed in Appendix Table 1 and are sorted on the basis of stage of development.

Output and Inputs

Output

Output is measured as chain-weighted real GDP in constant 1996 prices adjusted for purchasing power parity. For countries that did not have full coverage of output data — with typically one or a few of the end years missing — the general solution is to use information on the growth of real GDP, as obtained from the World Development Indicators (World Bank, 2005).

3 Although the project has now been completed, UNIDO's work on productivity in developing countries continues.

4 Isaksson (2007c) describes data coverage and adjustments in detail.

When GDP estimates are missing for the middle of the series (for example, Haiti in 1966), they are interpolated by taking the average of two years.

Capital input

Capital is the most difficult production factor to measure, partly because of data requirements but also due to controversies related to the computation of the initial capital stock and depreciation rates.[5] For that reason, the WPD includes TFP estimates based on four definitions of the capital stock. These differ in how the initial capital stock is computed, the rate at which capital is assumed to depreciate,[6] whether that rate is constant or varies over time, and whether the lifetime and attendant efficiency of an asset is explicitly accounted for.[7]

The perpetual inventory method provides a standard way of formulating how capital evolves. In this computation, the rate of depreciation and initial capital stock are unknowns and have to be estimated or assumed. Since the appropriate values of these two unknowns can be debated, the WPD offers capital measures based on alternative estimates or assumptions, leading to three different measures of the capital stocks called K06, K13 and Ks. Common to all three is that capital is assumed to depreciate at a constant rate over time.

For two of these, K06 and K13, it is assumed that ten years of investment serve as an adequate proxy for initial capital stock. For example, for investment data starting in 1950, investments from 1950 to 1959 are used to construct initial capital stock for 1960.

These two capital stock estimates only differ in terms of their assumed depreciation rates, which are 6 and 13.3 per cent, respectively (hence, K06 and K13). The latter measure is based on Leamer (1988) and assumes an unusually rapid depreciation rate, implying an emphasis on relatively recent investments and less impact of initial capital. It implicitly assumes an asset lifetime of 15 years. By contrast, K06 places relatively less emphasis on recent investments, with the effect of the initial year capital stock lingering longer.[8] The implied lifetime for K06 goes beyond the end of the sample period.

Another common way of computing the initial capital stock is to assume that the country is at its steady state capital-output ratio, leading to what is termed steady-state capital stock (Ks). The major advantage of this capital stock measure compared to K06 and K13 is that ten years of data are not lost in the calculation of the initial capital stock.

The steady state capital-output ratio requires estimates of steady state values of the investment rate, rate of GDP growth, and depreciation rate. The depreciation rate is set at 6 per cent. Following Easterly and Levine (2002), the GDP growth rate is a weighted average of all countries' average growth rate and world growth rate of GDP for the first ten years (1960-1969). The weights are set to 0.75 and 0.25 for the world and country growth rates, respectively, leading to country-specific estimates of the steady state

5 The flow of capital services is the preferred measure of capital input. As this measure cannot be easily obtained for many of the countries in the WPD sample, the convention that capital services are proportional to the stock of capital is assumed.

6 Depreciation should be understood in terms of the decay of productive capacity of a fixed asset and not as a reduction in the value of the asset. The former refers to the production process, while the latter is a wealth accounting concept.

7 The effect of different ways of calculating capital is most apparent when comparing TFP levels. For comparisons of TFP growth the effect is much less discernible.

8 Specific countries can have different depreciation rates due to different compositions of capital. For example, developed countries tend to have a larger share of IT-related assets, which have relatively high depreciation rates, while capital stocks in developing countries contain a relatively large share of buildings and machines, which have a slower rate of depreciation

growth rate. The average investment rate for the first ten years serves as a proxy for the steady state investment rate. Finally, the initial capital stock is computed as the initial year GDP (i.e. the 1960 value) multiplied by the steady state capital-output ratio.

A different way of measuring capital — the physical efficiency method (Keff) — is to assume a time-varying depreciation rate. This method starts from the notion that an asset's productive efficiency declines with age. The age-efficiency function is assumed to be hyperbolic in shape, which means that, at year one, the efficiency of the asset is 100 per cent and, as the asset ages, its efficiency declines at an increasing rate. After some time, the asset's lifetime is considered over or, at least, the asset's efficiency is so low that the asset is scrapped. Using this age-efficiency function, efficiency coefficients are derived and used to adjust the investment series, which leads to investment data expressed in standardized efficiency units. The perpetual inventory method is then applied to this new investment series to obtain a capital stock series (Keff).

According to Crego *et al*. (1998), when the different capital assets — which have different lifetimes — are translated into aggregate investment, the aggregate service life turns out to be 20 years.[9] The WPD adopts 20 years of service life for each year's aggregate investment. As a consequence, it also uses 20 years for the calculation of the initial capital stock for this particular capital stock. The implication is that the capital stock and TFP series based on this method only begin in 1969, compared to the standard of 1960 used elsewhere in the WPD.

Labour input[10]

The WPD offers productivity estimates based on five labour input measures: labour force, employment, derived employment, hours worked based on employment and hours worked based on derived employment. It is standard in the cross-country empirical literature to use the labour force as a proxy measure of labour input. The advantage of this labour measure is its superior availability and, possibly, quality compared to alternative labour measures. The main disadvantage is that it leads to underestimation of measured productivity levels because not everyone in the labour force is actually working (either due to unemployment or underutilization), thus overestimating labour input. The effect on productivity growth is uncertain, since labour force growth could be smaller or larger than that of other measures of labour such as employment or hours worked.

In several cases, periods of unusually rapid labour force growth were observed, possibly due to changing measurement methods or population coverage. In Argentina, for example, the average annual labour force growth rate over the sample period is 1 per cent. In 1991, it suddenly jumped to 5 per cent, a rate that lasted until 1995. Thereafter, it returned to 1 per cent. The fluctuation may reflect an administrative change in coverage, such as the inclusion of rural areas or women, which may have been previously excluded. Large increases in the growth rate of the labour force are considered unrealistic and are, therefore, smoothed out. While these adjustments do not affect TFP growth, they have implications for the TFP level. Continuing with this example, because pre-1996 labour force levels are adjusted upwards in Argentina, TFP levels are correspondingly adjusted downward.

There are two kinds of labour utilization rates for which labour force should be adjusted: variations in the number of workers employed and in the average number of hours worked by these

9 In this case, the so-called decay, or curvature, parameter is 0.70.

10 Here, labour is understood as raw or unadjusted labour. This distinguishes it from cases when adjustments are made for its quality (see the discussions on schooling and health).

workers. Employment is obtained either as a direct measure or is derived by applying unemployment rates to labour force data (derived employment). There are two reasons for using two measures of employment. First, employment figures derived from unemployment rates differ from "measured" employment. Second, compared with direct employment measures, the country coverage for derived employment differs because countries that have information on unemployment may not have data on employment, and vice versa.[11] As can be expected, employment data are more difficult to obtain than are labour force data. Consequently, the country coverage is reduced by 50 per cent compared to that for labour force. In cases where unemployment series are shorter than the employment series described above, the unemployment series are extrapolated based on growth of derived unemployment resulting from subtracting employment from labour force.

Hours worked are computed based on employment and derived employment. In addition to correcting labour input for variations in the number employed, hours worked also adjust labour for the intensity with which employees work (for example, part-time and overtime). Intensity, here, refers to the number of total hours worked per worker, rather than the level of effort within a specific number of hours. Hour worked thus account for two adjustment mechanisms available to employers in case of shifts in demand: changing the number of workers or changing the number of hours worked by each worker. Again, the number of countries reporting hours worked for a sufficient time period is relatively smaller, with coverage largely confined to OECD countries.

Schooling and Health

In addition to the primary inputs used in production functions, the WPD includes schooling as one of two additional secondary inputs. Schooling is measured using educational attainments levels for the population 15 years and older, as obtained from Barro and Lee (2000). Economists differ in how they include schooling in the production function. The WPD offers two approaches: as a separate regressor or as an increase to labour input (Hall and Jones, 1999). In the latter case, it is assumed that returns to schooling differ according to the stage of development, such that, in less advanced countries, returns to education are higher.

Another characteristic of labour quality is health, which is only included together with schooling. Following the work of Weil (2001), it is hypothesized that differing levels of nutrition and health have a significant impact on the capacity to work across countries. The WPD employs two measures of health, both from the World Development Indicators (World Bank, 2005). Life expectancy is used when health enters the production function as a separate input, because it has very good country coverage. However, adult mortality rate (AMR) — the fraction of current 15 year-olds expected to die before the age of 60 — is the preferred measure when labour is adjusted for health (Weil, 2001). In any case, the correlation between life expectancy and AMR is very high.

Mankiw, Romer and Weil (1992) estimate the output elasticity to human capital, as measured by schooling, to be one-third. This value becomes useful when attempting to account for health in growth accounting calculations for which, otherwise, no obvious income share is available. In the WPD, an income share of a third is assumed for the composite of schooling and health.[12] The, admittedly, ad hoc solution used in the WPD to make health operational in growth accounting — while maintaining that it can only enter the production function with

11 This concerns Costa Rica, Ghana, Kenya and Malawi.

12 The income share of raw labour is reduced by the same amount.

schooling — is, first, to estimate statistically a relationship (non-linear, as it turns out) between schooling and health and, then, use it as a broad measure of human capital.[13] The reason for undertaking this operation is that schooling, in terms of scale, is only 10 per cent of life expectancy in terms of years in our sample. For example, if life expectancy in a country is 70 years, the years of schooling turn out to be approximately seven on average. To add simply schooling and health would not do justice to schooling, since variation in the composite would almost entirely be due to variations in health.

Measuring Total Factor Productivity

TFP levels

TFP measurement at the total economy level — implicitly or explicitly — starts from the notion of an aggregate production function. Such an assumption is almost unavoidable when measuring TFP.[14] However, it is only a parable, since it is unlikely that the true shape and properties of such a function can be accurately established. Yet, it is justified as a means to organize data in a way that makes economic sense, as well as a framework for interpreting empirical results. The WPD, therefore, makes use of the notion of the aggregate production function.

For TFP level measurement, a standard constant returns to scale Cobb-Douglas production function with Hick-neutral technical change is assumed, and then computed relative to the TFP level of the United States. The respective weights of capital and labour are the capital's and labour's income shares in output, which, when perfect competition in factor markets prevails, equal the respective marginal products. Table 1 shows the top and bottom ten countries in terms of TFP levels.

This way of ranking countries by relative TFP levels is only possible because income shares are assumed to be country- and time-invariant. If income shares vary across countries or over time, TFP ranking should be based on the formula provided by Caves, Christensen and Diewert (1982).

In the literature, income shares are often assumed to approximate, respectively, one-third and two-thirds. This practice is adopted here because the true income shares for most of the countries in the WPD are unknown. Table 2 shows how sensitive productivity measurement is to the choice of income shares. In the table, 'conventional' refers to the one-third/two-thirds rule, 'United Nations' to calculations based on United Nations National Accounts data, while 'Rodriguez-Ortega' is a third source of income shares.[15]

As the concept of TFP is not universally accepted, the WPD also offers simple output per worker, relative to the United States, and capital per worker measures. Although they serve as reasonable starting points for productivity analysis, they should not be seen as equivalent alternatives to TFP.

TFP growth

The many measurement methods for TFP growth included in the WPD are, generally, variants of each other. In attempting to measure TFP growth, they relax restrictions or estimate what another method might simply assume.

The first choice is *how* the user wishes to measure TFP growth. In other words, a measurement method needs to be selected. In principle,

13 Hence, a broader concept of human capital than that often found in the literature is applied here. The definition of human capital is generally reduced to education. The user should be aware of the slightly different view applied in the WPD.

14 Isaksson (2009) provides a survey of methods for measuring TFP.

15 For a more thorough discussion on income shares, see Hulten and Isaksson (2007), who explore the implications of this not-so-innocuous assumption and discuss different possibilities as to how more accurate income shares can be acquired.

Table 1
TFP Levels, Relative to the United States, 2000

Ranking	Country	Level (United States = 100)
1	Luxembourg	139
2	Ireland	112
3	United States	100
4	Belgium	86
5	Hong Kong, SAR of China	83
6	Netherlands	83
7	Italy	83
8	Canada	83
9	Taiwan, Province of China	83
10	Australia	82
103	Togo	13
104	Chad	12
105	Burkina Faso	12
106	Malawi	12
107	Zambia	11
108	Nigeria	9
109	Burundi	8
110	Guinea-Bissau	8
111	United Republic of Tanzania	6
112	Congo, Democratic Republic of the	3

Note: Functional form is Cobb-Douglas, while inputs are labour force and capital stock (K06).
Source: Isaksson (2007a).

Table 2
Income Shares and Sources of Growth Analysis, 1970-2000
(average annual growth rate, %)

		Conventional		United Nations		Rodriguez-Ortega	
Meta Country	**Y/L**	**K/L**	**TFP**	**K/L**	**TFP**	**K/L**	**TFP**
Low Income	0.17	0.25	-0.07	0.52	-0.35	0.38	-0.20
Lower-Mid Income	1.01	0.61	0.40	1.17	-0.16	0.79	0.22
Upper-Mid Income	0.99	0.59	0.40	1.05	-0.06	0.68	0.31
New Tigers	3.79	1.70	2.09	3.53	0.26	2.49	1.31
Old Tigers	4.89	2.37	2.52	3.92	0.97	2.67	2.23
High Income	1.95	1.00	0.95	1.36	0.58	1.00	0.95

Note: Y/L = Output per Worker, K/L = Capital per Worker and TFP = Total Factor Productivity. Meta Country = groups of countries belonging to a certain income bracket. Old Tigers refer to the first-generation Asian fast-growers, while New Tigers consists of second-generation Asian fast-growers.
Source: Hulten and Isaksson, 2007.

the different measurement methods can be divided into three main groups: growth accounting, regression analysis, and frontier analysis. Within these groups there are several methods from which to select.

If a parametric measurement method (i.e. one based on regression analysis) is selected, two functional forms are available, namely Cobb-Douglas and Translog, where the former is a restricted version of the latter.[16] Within para-

16 Statistical tests undertaken invariably show a preference for the Translog functional form. However, because there are many observations, statistical tests may have a tendency to over-reject the null hypothesis of Cobb-Douglas.

metric measurement methods, TFP growth can be measured based on production functions with and without time trend (or time dummy variables).[17] The main reason for offering this option is that some users might be particularly interested in isolating technical change from overall TFP growth.

For all methods but growth accounting, TFP growth estimates are available based on both constant (restricted) and variable (unrestricted) returns to scale, the default assumption being that of constant returns to scale. However, the user may have good reason to believe in non-constant returns to scale.[18] Under variable returns to scale, TFP growth is calculated as the residual plus the scale effect. However, one can also see this as a distinction between scale effects and technology. Since the scale component is provided, the user can subtract it from TFP growth.

The default production function specification contains one output and two inputs, capital and labour. As alluded to above, however, the WPD allows for the inclusion of schooling and health, in addition to capital and labour. It also allows the user to compare the impact on TFP of how capital and labour are measured.

Growth accounting

Four growth accounting measurement methods are available:

- Growth Accounting with Hicks-Neutral Technical Change;
- Growth Accounting with Harrod-Neutral Technical Change;
- Dynamic Growth Accounting with Hicks-Neutral Technical Change; and
- Dynamic Growth Accounting with Harrod-Neutral Technical Change

In all cases, income shares are the conventional 2/3 and 1/3 for labour and capital input, respectively, irrespective of country and time period. As is customary, TFP growth is calculated as the residual, in other words, as the difference between output and weighted input growth. The four growth accounting methods differ in their assumptions regarding the type of technical change and whether endogeneity of capital accumulation with respect to TFP growth is taken into consideration. Although it is, in principle, possible to include a term to represent increasing returns to scale, this is seldom done in growth accounting.[19] In the WPD, only growth accounting under the assumption of constant returns to scale is provided.

The standard Hicksian growth accounting approach allows for a proportional shift of the production function, with TFP growth occurring along a constant capital-labour ratio. Output growth is decomposed into growth of the capital-labour ratio and TFP growth. This standard approach can be extended to allow for labour-augmenting, or labour-saving, technical change, implying a disproportionate shift of the production function. In this case, technical change is said to be Harrod-neutral, with the production function shifting along a constant capital-output ratio, instead of a constant capital-labour ratio. This means that output growth is decomposed into TFP growth and change in the capital-output ratio.

Another issue with growth accounting is that it neglects induced capital accumulation due to TFP growth. In other words, there may be

17 The advantage of using time dummy variables is that technical change can be allowed to evolve over time, whereas, when using a time trend only, the annual average technical change over the entire period is obtained. However, both ways of estimating technical change are period-average when estimated across countries. This was relaxed in the case of random-effects stochastic frontier estimation, where country- and year-specific technical change were obtained by including interaction terms between country and time dummy variables.

18 Statistical tests carried out tend to favour non-constant returns to scale.

19 See, for example, Hall (1988) for a case where this is done.

important dynamic effects for which to account. Failing to do so could lead to understatement (overstatement) of the role of TFP growth (capital accumulation). Hulten (1979) has explored this matter and developed a method that accounts for such effects, in the WPD called dynamic growth accounting. The method derives a dynamic residual, which is a weighted sum of the standard growth accounting residual over a period of T consecutive years and an expansion of the intertemporal production possibilities frontier. TFP growth measured this way can be expressed in terms of both Hick and Harrod-neutral technical change. To underscore the difference between standard and dynamic growth accounting, the standard residual is understood as the average rate at which the production function shifts, while the dynamic residual measures the importance of TFP change for output growth.

Regression analysis

Actual income shares may in reality differ from the aforementioned standard assumption. Regression analysis offers a partial resolution as it allows the estimation of income shares based on the country's stage of development. In addition, the assumption of constant returns to scale can be relaxed. On the negative side, parametric estimation introduces thorny issues such as the choice of functional form and uncertainties about statistical properties.

Regression analysis broadly includes:

- Pooled regression analysis
- Fixed-effects regression analysis

where the regression's residual represents the measure of TFP growth.

In pooled regression analysis, cross-sectional heterogeneity is omitted, which means that the estimated parameter may be biased, with TFP growth, likewise, biased. The WPD, therefore, also supplies TFP growth measures based on the fixed-effects estimator. Panel-data fixed-effects estimators allow the analyst to account directly for country-specific effects, while maintaining the statistical advantages of a large sample. Country-specific effects imply that each country has its own intercept, but assumes that the slope parameters are the same for all countries.

There are two ways to account for country-specific effects. One is to include country dummy variables, while the other is to transform the data (so-called 'within transformation'). Although the former reduces the statistical advantage of having a large sample and, thus, may produce larger standard errors, thanks to the large dataset it is the solution chosen. The main reason for choosing country dummies is that they can be used to obtain country-specific technical change by way of interaction terms between such dummies and a trend variable.

Although income shares are estimated, only one value for the entire sample can be obtained in this manner. Ideally, income shares should be country-specific. While this has not yet been accomplished — individual country regressions produced results with little confidence — steps have been taken to let those shares vary, according to the development stage of the country and its geographical location.

To this end, TFP growth has been computed based on the residual obtained from pooled and fixed-effects estimations on industrialized, developing and least developed countries, on the one hand, and industrialized,[20] Latin America, Asia and the Pacific, North Africa and Middle East and sub-Saharan Africa, on the other. For example, income shares in OECD countries are likely to differ from those in least developed countries, with return to capital being higher in relatively poor countries. While the geographic distinction is possible for all measures of the capital stock, among the labour measures the country coverage is sufficient only in the case of

20 It did not seem plausible to group, for example, Australia with Fiji and Bangladesh.

the labour force. For other labour measures, the samples are too small to obtain reasonable estimation results. In the case of the development stage distinction, TFP growth based on employment and derived employment is possible for industrialized countries and developing countries. Few least developed countries have employment or unemployment data.

Frontier analysis

So far, it has been assumed that countries are technically efficient and that TFP growth primarily is driven by technical change. Perhaps, a more realistic picture is that of allowing for technical inefficiency, defined as falling short of best practice. This benchmark of best practice can be seen as a technology frontier, and even as a world technology frontier if all industrialized countries are part of the sample. Both parametric and non-parametric methods can be used to estimate the technology frontier and the distance to it. As in the case of regression analysis, frontier methods estimate, rather than assume, the income shares.

Frontier analysis does not directly deliver measures of TFP growth but primarily exists to measure technical efficiency. However, with panel data, frontier analysis produces the necessary components for computing TFP growth. Under constant returns to scale, change in technical efficiency and technical change can be derived and combined into an index that measures TFP growth. The Malmquist TFP index (Malmquist, 1953) is such an index and is used in the WPD. Under variable returns to scale, change in technical efficiency can be further decomposed into change in scale efficiency and change in pure technical efficiency.

Popular methods for frontier analysis include both parametric and non-parametric tools. On the parametric side, the WPD offers the random-effects Stochastic Frontier Analysis (SFA) estimator due to Battese and Coelli (1992), while in the case of non-parametric estimation Data Envelopment Analysis (DEA) and Long-Memory DEA (LMDEA) estimators are provided (Forstner and Isaksson, 2002).[21] The difference between DEA and LMDEA is that the latter is constrained not to accept technical regress.[22] All other methods previously discussed allow for technical regress.

Although it is useful to be able to account for technical inefficiency, frontier analysis has its own problems. In the case of SFA, previous issues discussed under regression analysis apply. In addition, distributional assumptions of the error term are crucial, as they can have profound effects on the outcome. Non-parametric methods are free of these problems, but, because they are deterministic in nature, they are sensitive to outliers and measurement problems of output and inputs. Because SFA is stochastic, it does not share these problems. Coupled with the fact that standard errors can be obtained and hypotheses tested, these are SFA's main advantages over non-parametric frontiers. The advantage of DEA and LMDEA is that no distributional assumptions or functional form have to be assumed regarding the "production function". Generally, compared to other parametric methods, they are very flexible.

Forecasting TFP

The WPD has endeavoured to tackle the complicated challenge of forecasting TFP levels and growth. Such forecasting can be approached in two broad ways. Either the individual compo-

21 DEA and LMDEA present TFP growth in index form, which means that a score of 1.00 implies no TFP growth, 1.01 a one per cent TFP growth and 0.99 a negative growth of one per cent. To convert these into percentage form, subtract 1 and multiply by 100, e.g., (1.01-1)*100.

22 The first to question technical regress in a DEA framework were Tulkens and Vanden Eeckaut (1995). Other empirical applications using macro data include Timmer and Los (2005).

nents of TFP — outputs and inputs — are forecast separately and TFP is calculated based on those, or forecasts are derived directly from the TFP series. As it is simpler to forecast one series than three or more — for example, output, capital and labour — WPD forecasts are based directly on TFP growth series.

The WPD offers ten-year forecasts (2001-2010) for TFP growth based on: the capital input variable K06; the labour input variable based on the labour force; LMDEA; and constant returns to scale. Forecasts are available for the following specifications: labour and capital; labour, capital and schooling; labour, capital, schooling and health; capital and labour adjusted for schooling; and capital and labour adjusted for schooling and health. These forecasts are, in turn, extended to measures of TFP growth based on the other capital stock measures (Keff, K13 and Ks). Forecasts of TFP growth are, then, used to forecast TFP levels, based on labour force and the four capital stocks. For a technical description of how the forecasts were carried out, see Isaksson (2007c).

Next Steps

Several extensions to the WPD are planned. First, to date, only productivity measures at the aggregate economy level have been calculated. The next step is to estimate manufacturing TFP for a large number of countries. Thus far, a database for aggregate manufacturing TFP has been estimated and will shortly be uploaded to the WPD website for general access. Once that has been accomplished, estimation of TFP at sub-sectoral manufacturing levels, e.g. food, textile and electronics, will be undertaken.

Second, to date, only countries with data spanning long time periods have been included . In addition, the most recent version of PWT includes more countries than version 6.1. The plan is to include those additional countries, as well as countries for which data are limited over time. The next version of the WPD will, thus, feature, for example, Germany and all of Eastern Europe, as well as other transition economies.

Third, whereas land as an input has become relatively unimportant for most industrialized countries — with agriculture no longer a major contributing sector to aggregate GDP — the contrary holds true for many developing countries. Because many countries in the sample are developing countries, the next version of the WPD will expand specifications to include land.

Fourth, in the current version, labour input has been adjusted for two quality measures, schooling and health. For a subset of countries, it has also been corrected for utilization, in terms of both unemployment and hours worked. However, no such correction has been made to capital. Ideally, in the future, the WPD will account for changes in capital utilization.

Fifth, in addition to the Cobb-Douglas and Translog functional forms, the CES function is popular and will be added to the database. With respect to estimators, the plan is to make use of dynamic panel methods in order to improve the statistical properties of WPD estimations.

Sixth, only one SFA version is currently provided. The aim is to implement more alternatives in the next version of the WPD.

Finally, the issue of country- and time-specific income shares will be addressed by applying income shares supplied by Rodriguez and Ortega (2006) and the United Nations National Accounts Database, in addition to the conventional one-third/two-thirds assumption. Table 2 already gave a first hint of what such an application will bring.

The next version of the WPD will contain TFP measures to at least 2006, with forecasts to at least 2015. These updates are planned for the summer of 2009. The WPD data are a public good. As such they can be freely downloaded from www.unido.org.

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Appendix Table 1
List of Countries by Country Group

Industrialized (24 countries)	Developing (45 countries)	Least Developed (43 countries)
Australia	Algeria	Angola
Austria	Argentina	Bangladesh
Belgium	Barbados	Benin
Canada	Botswana	Bolivia
Cyprus	Brazil	Burkina Faso
Denmark	Cape Verde	Burundi
Finland	Chile	Cameroon
France	China	Central African Republic
Greece	Colombia	Chad
Iceland	Costa Rica	Comoros
Ireland	Dominican Republic	Congo
Israel	Ecuador	Cote d'Ivoire
Italy	Egypt	DR Congo
Japan	El Salvador	Ethiopia
Luxembourg	Equatorial Guinea	Fiji
Netherlands	Gabon	Gambia
New Zealand	Guatemala	Ghana
Norway	Honduras	Guinea
Portugal	Hong Kong, SAR of China	Guinea-Bissau
Spain	India	Guyana
Sweden	Indonesia	Haiti
Switzerland	Iran	Kenya
United Kingdom	Jamaica	Lesotho
United States	Jordan	Madagascar
	Korea, Republic of	Malawi
	Malaysia	Mali
	Mauritius	Mauritania
	Mexico	Mozambique
	Morocco	Nepal
	Namibia	Nicaragua
	Nigeria	Niger
	Pakistan	Papua New Guinea
	Panama	Peru
	Paraguay	Rwanda
	Philippines	Senegal
	Singapore	Seychelles
	South Africa	Sierra Leone
	Syria	Sri Lanka
	Taiwan, Province of China	Tanzania, United Republic of
	Thailand	Togo
	Trinidad and Tobago	Uganda
	Tunisia	Zambia
	Turkey	Zimbabwe
	Uruguay	
	Venezuela	

Innovation and Business Strategy: Why Canada Falls Short

Peter Nicholson[1]
Council of Canadian Academies

ABSTRACT

This article summarizes the report of the Expert Panel on Business Innovation appointed by the Council of Canadian Academies. The report presents a fresh look at innovation as an economic process rather than primarily as a science and engineering activity. Noting that Canada's productivity has been falling further behind that of the United States and many other advanced countries for the past 25 years, the report argues that lagging productivity growth has been due to subpar innovation. Innovation is interpreted broadly to encompass the day-to-day activites of all kinds of businesses looking for new or more efficient ways to serve the needs of customers. The panel concludes that too many businesses in Canada are technology followers, not leaders, and that a fresh discussion on innovation in Canada is needed, one that focuses on the factors that influence adoption of innovation-based business strategies.

INNOVATION — NEW OR BETTER ways of doing valued things — is the creative capacity to transform the imagined into the real. Innovation matters for *businesses* because novel products and more efficient processes are the principal means of making businesses more competitive. It is through innovation that businesses find ways to generate more value from existing resources. Innovation is, directly or indirectly, the main driver of productivity growth and is thus the principal source of national prosperity. Canadians should therefore be concerned in the face of evidence suggesting that Canada's business sector on the whole, though with notable exceptions, is lagging in innovation relative to many of our peer group of economically advanced countries.

The question is "why." If innovation is good for business, why is Canadian business apparently less committed to innovation than analysts and policy-makers believe it should be? The question has been asked for decades, yet the situation has not changed much in relative terms. The causes of Canada's innovation deficiency must therefore run deep in the nature of the economy, and perhaps in Canadian society as well. To bring to bear a comprehensive contemporary analysis of the issue, the federal Minister of Industry asked the Council of Canadian Academies to appoint a panel of business, labour and academic experts (Box 1) to answer the following questions:

1 The author is President of the Council of Canadian Academies. This article is a highly condensed summary of the report of the Expert Panel on Business Innovation entitled *Innovation and Business Strategy: Why Canada Falls Short*. The panel was appointed and supported by the Council of Canadian Academies following a request by the federal Minister of Industry. The report can be accessed from the Council's website www.scienceadvice.ca. Email: peter.nicholson@scienceadvice.ca.

Box 1
Expert Panel on Business Innovation in Canada

Robert Brown (Chair), President and Chief Executive Officer, CAE Inc. (Montréal, QC)
Savvas Chamberlain, Chairman and Founder, DALSA Corporation (Waterloo, ON)
Marcel Côté, Founding Partner, SECOR Inc (Montréal, QC)
Natalie Dakers, Chief Executive Officer, Centre for Drug Research and Development, University of British Columbia (Vancouver, BC)
Meric Gertler, Dean, Faculty of Arts and Science; Co-Director, Program on Globalization and Regional Innovation Systems, University of Toronto (Toronto, ON)
Bronwyn Hall, Professor of Economics of Technology and Innovation, University of Maastricht (Maastricht, The Netherlands); Professor of the Graduate School, University of California at Berkeley (Berkeley, CA)
André Marcheterre, Company Director, Former President and Chief Executive Officer, Merck-Frosst Canada (Lorraine, QC)
Arthur May, President Emeritus, Memorial University; Chairman of the Advisory Board, Atlantic Innovation Fund (St. John's, NL)
Brian McFadden, President and Chief Operating Officer, Prestige Telecom Inc. (Baie d'Urfé, QC)
Walter Mlynaryk, Executive Vice-President, Kruger Inc. (Montréal, QC)
David Pecaut, Senior Partner and Managing Director, Boston Consulting Group (Toronto, ON)
Jim Roche, Company Director, and Former President and Chief Executive Officer, CMC Microsystems (Ottawa, ON)
Charles Ruigrok, Former Chief Executive Officer, Syncrude Canada Ltd. (Calgary, AB)
Andrew Sharpe, Executive Director, Centre for the Study of Living Standards (Ottawa, ON)
Jim Stanford, Economist, Canadian Auto Workers (Toronto, ON)
Guthrie Stewart, Former Partner, Equity Fund, Edgestone Capital Partners (Montréal, QC)
Alexandre Taillefer, Co-Founder, Stingray Digital Group Inc (Montreal, QC)
John Thompson, Chairman, TD Bank Financial Group (Toronto, ON)

- How should the innovation performance of Canadian firms be assessed?
- How innovative are Canadian firms, and what do we know about their innovation performance at a national, regional and sector level?
- Why is business demand for innovation inputs (for example, research and development, machinery and equipment, and skilled workers) weaker in Canada than in many other OECD countries?
- What are the contributing factors, and what is the relative importance of these contributing factors?

The Context

The panel first met in November 2007, a time when the Toronto Stock Exchange index was nudging 14,000, oil was close to $100 a barrel, the Canadian dollar was above par with the U.S. dollar, economic growth was solid and the unemployment rate was at a multi-decade low. But beneath the bullish daily headline data were worrisome longer-term trends, particularly the persistently weak productivity growth in Canada. Investment in leading-edge technology — especially related to computers and communications — was lagging significantly behind not only that of the United States, but also many of the advanced countries with which Canada compares itself. Business spending on research and development as a share of the economy was down 20 per cent from its 2001 peak at the end of the technology boom.

While the panel was completing its work in late 2008 and early 2009, the world changed dramatically. Because the extent of the global economic crisis, and its ultimate impact on Canada's economy and society, remains unknown, the panel did not attempt to factor the crisis prominently into its diagnosis of business innovation in Canada. A longer-term perspective is needed in any event since the symptoms of lagging innovation are of very long standing. The panel therefore focused its analysis primarily on long-run phenomena, stretching across several ups and downs of the economic cycle. Thus its findings remain relevant notwithstanding the severe contemporary shock to the global economy.

It is emphasized that the panel's report is primarily a diagnosis based on existing sources and not a policy prescription, though it provides a body of fact and informed opinion that is of policy relevance.

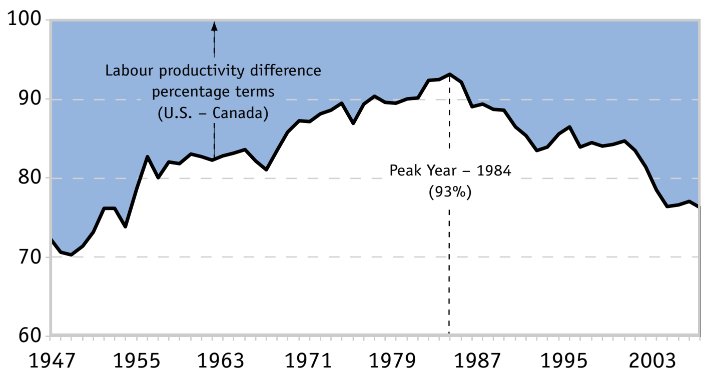
Innovation as an Economic Process

The panel approached innovation as an *economic* process rather than as a primarily science and engineering activity. The theme of its analysis is the link between business strategy and innovation activity, interpreted broadly. An "invention" is not an innovation until it has been implemented to a meaningful extent. Moreover, innovation is not limited to products but includes improved processes like the assembly line, and new business models like web-based commerce. Radical innovations like the steam engine and the transistor create entirely *new markets*. Much more prevalent is incremental innovation in *established markets* in which goods and services are continuously improved — a process that is responsible for the majority of labour productivity growth. These observations imply a much broader conception of innovation than the traditional R&D-centric views.

Canada has a serious productivity growth problem. Since 1984, relative labour productivity in the business sector has fallen from more than 90 per cent of the U.S. level to about 76 per cent in 2007, a trend (Chart 1) that continued in 2008. Over the 1985-2006 period, Canada's average labour productivity growth ranked 15th out of 18 of the larger and most advanced comparator countries in the OECD (OECD, 2008b).

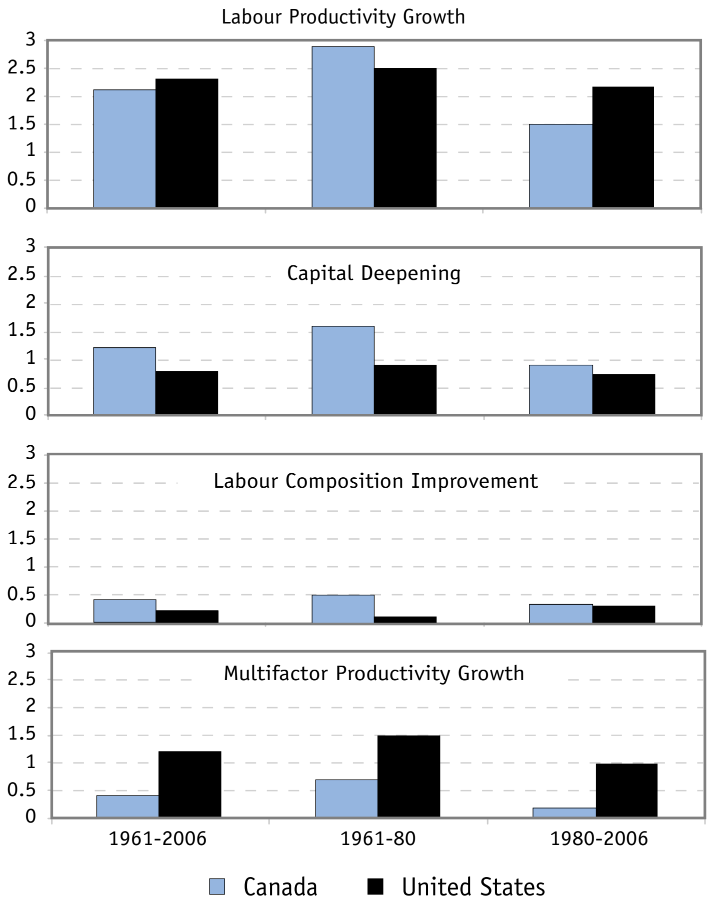
Canada was rapidly closing the productivity gap with the United States until the early 1980s. The strength of U.S. productivity growth, since the mid-90s, is primarily associated with the production and use of information and communications technologies (ICT).

Chart 1
Relative Labour Productivity Levels in the Business Sector, 1947-2007
(real GDP per hour Canada as per cent of U.S.)



Source: Centre for the Study of Living Standards (2008a).

Chart 2
Accounting for Labour Productivity Growth in Canada, 1961-2006
(average annual growth rates, per cent)



Note: Labour productivity growth can be accounted for by increasing capital intensity, improvement in workforce skills, and a residual called multifactor productivity (MFP) — which broadly reflects the effectiveness with which labour and capital are used. Growth rates in the top panel are the sum of contributions of the factors in the bottom three panels. The time periods cover the total 45 year interval (leftmost bars) and two sub-periods when Canada was closing the productivity gap (roughly 1961 to 1980) and falling behind (roughly 1980-2006).

Source: Baldwin and Gu (2007).

Chart 2 is a growth accounting decomposition by Statistics Canada comparing labour productivity growth in the United States and Canada over a 45-year period, 1961-2006. Productivity growth is analyzed as a weighted sum of (i) improvement in the "quality" of the labour force (based primarily on higher educational attainment and more employment experience); (ii) growth of capital services per hour worked ("capital deepening") and (iii) the residual, multifactor productivity (MFP) growth, which broadly reflects the effectiveness with which labour and capital are combined in the economy. Chart 2 shows that Canada's relative productivity growth weakness is not due to comparative shortcomings in its workforce. Neither, for the most part, does it reflect inadequate capital investment though, as will be described subsequently, business investment in information and communications technology has been especially weak. The decomposition demonstrates clearly that Canada's poor productivity growth is due mainly to the weak growth of MFP. In fact, MFP growth in Canada has lagged behind that of the United States for as long as comparable measurements have been made. Studies by the OECD also show that Canada's MFP growth, at least since the mid-1980s, has been among the weakest in its peer group of economically advanced countries.

The significance of multifactor productivity

Intuitively, changes in MFP measure that portion of labour productivity growth that can *not* be accounted for by measured growth of both capital intensity and the quality of the workforce. Most significant for this discussion is that *MFP growth contains the macroeconomic signature of aggregate business innovation* — the extraction of increasing value from inputs of capital and labour through inventive activity. Two examples will illustrate:

- Consider the addition of a drive-through window in a fast food outlet. A small amount of construction and one or two extra servers could substantially increase sales volume by expanding the effective "seating capacity" of the restaurant, and, more importantly, by increasing service convenience and thereby attracting more customers. After accounting for the modest capital cost of installing the drive-through window and some extra labour, the remainder of the increased output is chalked up to MFP growth.

- Consider a sales force in the field before the advent of the cellphone or, better yet, the BlackBerry. Today's relatively inexpensive wireless capital equipment has amplified greatly the value of each field employee, not only through more efficient allocation of time but also through more timely and co-ordinated service for customers. While some of the added value comes from new investment in equipment, most is measured as an increase in MFP.

Micro-examples like these can be multiplied endlessly. In each case, we see an innovation that may be based on science and technology (e.g. the BlackBerry) or on some very simple engineering combined with entrepreneurial insight (e.g., the drive-through window). The economic impact of thousands upon thousands of such innovations, large and small, is huge.

There is an important interaction between new capital investment (which "embodies" innovation) and MFP since successive generations of capital induce complementary, and often highly innovative, changes in the organization of work and the training of employees — e.g. as the adoption of computer and communications technologies has done, or as the electric motor did in an earlier era. Thus the distinction between the component of productivity growth ascribed to more and better capital, and the component ascribed to MFP, can be somewhat artificial. The impact of innovation on productivity growth enters jointly through both channels (Rao, Tang and Wang, 2008).

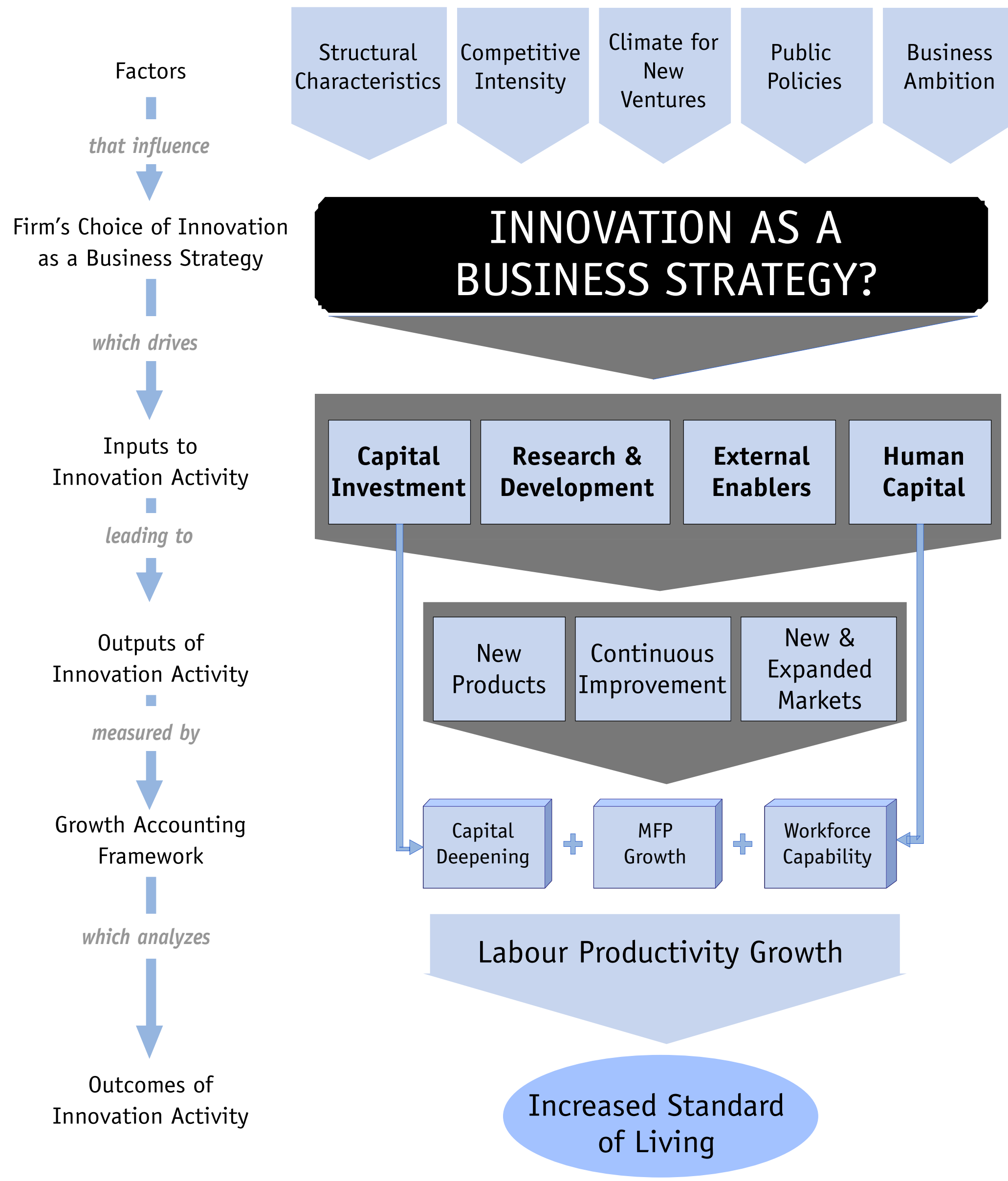
Since MFP is the residual after improvements in labour quality and capital intensity have been accounted for, it reflects all other factors that affect labour productivity. So the innovation signal in MFP growth comes mixed with a lot of "noise". These other confounding factors include, prominently, changes in capacity utilization caused by booms and recessions, and changes in economies of scale that might be due to opening up of big new markets. The business cycle effect averages out over sufficiently long time periods, as in Chart 2. MFP derived purely from scale effects might arise from growing markets, as would typically occur after trade liberalization (e.g. NAFTA). Canadian MFP should have benefited from this increased scale to a greater extent than the United States has since the 1980s. Thus changes in scale economies can not explain the *slower* MFP growth in Canada — in fact, the effect of scale economies since the 1980s would be expected to be the opposite. The analysis summarized in Chart 2 applies the same procedures to both Canadian and U.S. data, minimizing the effect (on estimates of differences in growth rates) of methodological differences or errors in model specification.

The panel concluded that the rate of MFP growth over suitably long periods is primarily due to business innovation — interpreted broadly to include better organization of work, improved business models, the efficient incorporation of new technology, the payoff from R&D and the insights of entrepreneurs. Since the long-term analyses by Statistics Canada (and also by the OECD) show that Canada's relatively poor productivity growth is due almost entirely to weak MFP growth, the panel concluded that *Canada's weak productivity growth is largely due to weak business innovation performance*.

The Central Role of Business Strategy

Business strategy drives innovative behaviour. Explaining business innovation performance in Canada therefore comes down to explaining the business strategy choices of Canadian firms. This requires a shift of perspective away from innovation

Chart 3
Logic Map of the Business Innovation Process



activities themselves — e.g. inputs like R&D and investment in M&E — to a focus instead on the factors that influence the choice of business strategy. This reframing of the innovation puzzle is the most important contribution of the panel's analysis.

What are the factors that principally influence firms in Canada to choose, or not to choose, business strategies based around innovation? The five factors that are, in the panel's view, of greatest importance are those at the top of Chart 3 which serves as the conceptual framework for the panel's analysis.

- *Structural characteristics* — For example, is the firm in a sector of the economy that typically does little in-house innovation, relying instead on technology embodied in capital equipment and/or on production of relatively standard goods or services? Or is the firm foreign controlled with most innovation originating in the home country?

- *Competitive intensity* — Is the pressure from competitors so intense that innovation is needed to maintain profitability and/or market share? This would be the case in many export markets, and particularly in those where technology or customer requirements or tastes are changing.
- *Climate for new ventures* — Is sophisticated early-stage venture financing available? Are there research universities nearby to provide potential innovation partners and highly trained graduates? Is there a local "ecosystem" of supplier firms to help carry an innovation from concept to success in the market?
- *Public policies* — Are government policies in respect of tax, regulations, targeted assistance programs or public procurement favourable to innovation, or not?
- *Business ambition* — Is the business dedicated to market expansion and prepared to take the required risks? Business ambition, in this context, reflects the extent of entrepreneurship and drive.

Once a firm has decided on an innovation strategy, it assembles the enabling inputs. These include the appropriate mix of highly qualified employees; investment in the necessary capital equipment and training; an R&D program if needed; and retention of consultants and various external suppliers, including licensing arrangements and partnerships with other firms. While these inputs, and R&D spending in particular, can be regarded as indicators of innovation, they are actually the *consequences* of the degree of commitment to innovation as a business strategy.

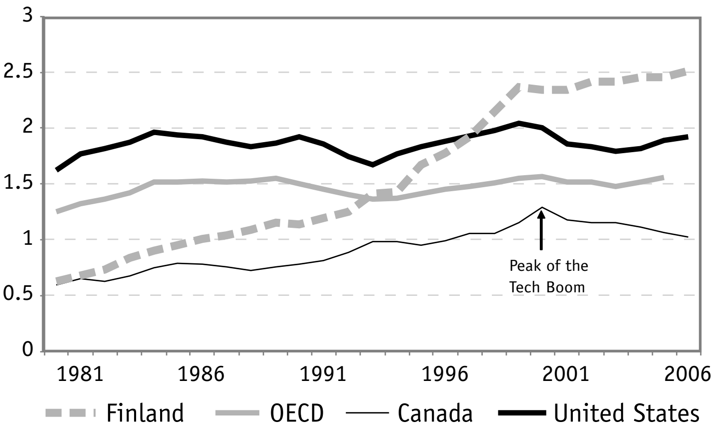
To the extent that Canadian businesses lag in respect of innovation, the reasons lie primarily in some combination of the primary influencing factors outlined above. Business ambition will be a key factor in almost every case. For would-be radical innovators in new markets, the other significant influencing factors will be the climate for new ventures and perhaps some supportive public policies. For firms in established markets, the innovation strategy choice is likely to be most influenced by the state of competition, by specific features of public policy or by some industry characteristic such as the firm's sector or its domicile of control.

For policy-makers, the concern is the extent to which the factors that influence the innovation strategies of businesses can be affected by public policy. Clearly some can be — taxes, regulations, procurement, assistance programs, foreign investment rules and certain aspects of competition. Policy has much less impact on factors such as industry structure and the ambition of business leaders, though business attitude can certainly be affected by competitive intensity, which is amenable to policy influence.

The five key influencing factors in Chart 3 are themselves influenced by certain long-standing features of Canada's economy, of which the two most significant appear to be the following:

- **Canada is "upstream" in many North American industries.** This positioning is the result of the nation's resource endowment and development history as a commodity supplier and technology adopter. Canada's upstream position in many continentally integrated value chains limits contact with ultimate end-customers — who are a strong source of motivation and direction for innovation — and shapes the nature of business ambition in many sectors.
- **Canada's domestic market is relatively small and geographically fragmented.** Small markets offer lower potential reward for undertaking the risk of innovation and tend to attract fewer competitors, thus pro-

Chart 4
Business Expenditure on Research and Development Intensity, 1981-2006
(BERD as per cent of GDP)



Note: BERD intensity in Canada declined by 20 per cent between 2001 and 2007 reflecting the pull back in Canada's large telecom equipment sector. The commitment of Finland to innovation-led growth accelerated sharply in the wake of a severe banking crisis in 1991, exacerbated by weakness in Finland's traditional exports following the collapse of the USSR.

Source: OECD (2008a).

viding less incentive for a business to innovate in order to survive. Of course, the innovation success of countries like Finland and Sweden shows that the disadvantage of a small domestic market can be offset by a strong orientation toward innovation-intensive exports.

The following sections present a highly abridged account of the panel's analysis and commentary on the five factors considered to have the greatest influence on business innovation strategy.

Industry Structure Characteristics

The effect of structural factors (particularly sector mix and foreign ownership) on business strategy choice is most readily seen through analysis of the gaps between Canada and the United States in respect of R&D spending and ICT investment. Since the collapse of the technology boom in 2001, Canada's business expenditure on R&D (BERD), expressed as a percentage of GDP, has been declining (Chart 4). Although the gap between Canada and the United States narrowed significantly between the mid-1980s and the peak of the technology boom, it has since begun to open up again. Structural factors are part of the explanation of the gap, but only part.

Sector mix

A sector by sector analysis of the overall U.S.-Canada R&D gap (Table 1) shows that generally lower Canadian R&D spending within the *same* sectors in both the United States and Canada accounts for a greater portion of the gap (the precise share of which varies from year to year) than does Canada's adverse sector mix — i.e., the greater weight in Canada's economy of resource-related and other activities that have inherently low R&D spending. (Resource-based industries do invest heavily in innovation, though via the indirect route of its embodiment in advanced capital equipment.)

Chart 5 traces the evolution, by sector, of the U.S.-Canada BERD intensity gap over 16 years from 1987 through 2002 (the latest year for which a reasonably complete sector breakdown was available in the OECD data). The total gap diminished from about 1.7 percentage points in the 1988-91 period to about one percentage point in 2001-02, though it has increased somewhat since then. The most significant drivers of the long-run trend have been (i) a sharp reduction in the contribution of the manufacturing sector to the Canada-U.S. gap; versus (ii) an increasing gap in business services R&D (particularly wholesale and retail trade). The broad shift of output and employment toward services, and the application of ICT in service sectors, has been occurring more rapidly in the United States than in Canada.

Table 1

U.S.-Canada Business Expenditure on Research and Development Intensity Gap by Sector, 2002

	Sector Share of Nominal Business Sector GDP (%)		BERD Intensity (BI)		Contribution to BI Gap (U.S.-Can)
	Canada	U.S.	Canada	U.S.	GAP (2)
BUSINESS SECTOR (1)	100.0	100.0	1.87	2.90	1.034
Manufacturing	27.0	21.9	4.16	8.03	0.634
Motor vehicles and parts	3.4	1.7	1.88	13.41	0.166
Pharmaceuticals	0.5	1.0	27.17	21.16	0.066
Chemicals (excl. pharmaceuticals)	1.5	1.5	2.01	6.45	0.066
Office accounting and computing machinery	0.1	0.4	65.01	32.80	0.053
Machinery and equipment n.e.c.(3)	1.8	1.5	2.70	6.59	0.048
Food, beverages and tobacco	3.3	2.6	0.45	1.28	0.018
Aircraft and spacecraft	0.8	0.8	15.41	18.49	0.018
Rubber and plastics products	1.4	1.0	0.73	2.32	0.013
Other non-metallic mineral products	0.7	0.6	0.29	0.98	0.004
Electrical machinery & apparatus n.e.c.	0.4	0.6	7.20	5.46	(0.001)
Pulp & paper, paper products printing and publishing	4.1	3.2	1.29	1.52	(0.004)
Textiles, leather and footwear	0.9	0.7	1.44	0.53	(0.010)
Fabricated metal products	2.0	1.6	1.61	1.24	(0.011)
Basic metals	1.6	0.6	2.04	1.14	(0.025)
Radio, TV & communication equipment	0.7	1.1	53.67	29.52	(0.054)
Other manufacturing (4)	3.8	3.0	1.88	11.80	0.288
Business services	53.4	66.2	1.26	1.71	0.457
Wholesale and retail trade	17.1	20.5	0.53	1.83	0.285
Other business services	19.0	28.9	2.85	2.49	0.181
Transport and storage	6.2	4.6	0.10	0.11	(0.001)
Financial intermediation	11.0	12.3	0.33	0.23	(0.007)
Mining and quarrying	7.5	1.6	0.64	0.68	(0.037)
Utilities	4.0	3.2	0.46	0.06	(0.016)
Construction	8.1	7.2	0.08	0.03	(0.004)

1) Excludes agriculture, primary forestry and fishing and real estate services (largely the imputed value of owner-occupied housing). The definition of Business GDP ($715 billion in 2002) differs from the Statistics Canada breakout for that sector ($873 billion in 2002) which the panel believes to be largely due to real estate services.

2) The contribution to the gap is calculated as: "Sector share of BERD intensity times sector share of GDP" for the United States, minus the analogous product for Canada. For example, for manufacturing the contribution is: (8.03 x .219)-(4.16 x .27)=0.634. Negative contributions to the BI gap — i.e., those numbers in parentheses in the final column of the table — are associated with sectors where the ratio of Canada's BERD to total GDP exceeds that of the United States — i.e., sectors that reduce the gap.

3) n.e.c. = not elsewhere classified.

4) An omnibus group of subsectors (including precision instruments among others) that is not further broken down in the OECD database.

Data Source: Panel calculations based on the OECD STAN Database.

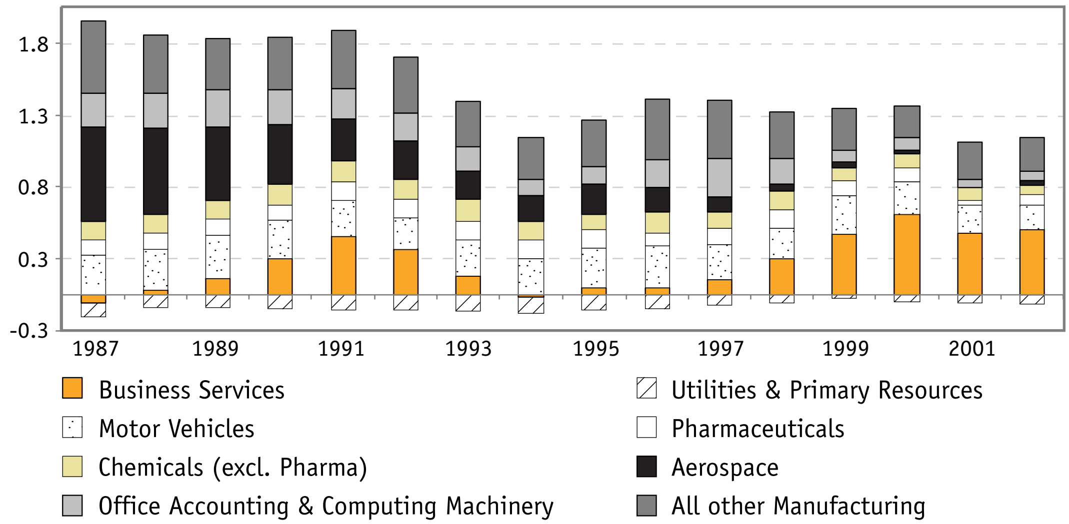
Foreign control

The extent of foreign control of several major Canadian sectors is well known to be part of the explanation for low R&D intensity — e.g. accounting for very low Canadian R&D in the automotive and chemicals industries. This reflects the traditional tendency of global corporations to conduct most innovation activity near

Chart 5

Evolution of the U.S.-Canada BERD Intensity Gap, 1987-2002

(percentage point)



* BERD Intensity = Business Expenditure on R&D as a per cent of GDP.

Note: This chart traces the evolution of the most important sectoral components of the R&D intensity gap. The narrowing of the manufacturing gap (at least through 2002) has been due entirely to the aerospace sector as the U.S. industry down-sized after the Cold War and due to commercial competition from Airbus. The business services gap has meanwhile widened since the mid-90s. Much more work is needed to improve data on sub-sectors of business services.

Source: Panel calculations based on the OECD STAN database.

their headquarters. But foreign control does not automatically imply low R&D activity. In fact, foreign subsidiaries in several sectors — e.g. pharmaceuticals and computers — have been major contributors to Canadian R&D and have had R&D intensities that actually exceed the U.S. average for these sectors. Moreover, if the foreign-controlled facilities were not here, there is no guarantee that Canada would have developed a "replacement set" of domestically owned R&D performers. Analyses of individual firms, based on R&D spending data and innovation surveys, reveal a common pattern and produce a three-tiered structure (relative to ownership) of R&D and innovation behaviour in Canada (Baldwin and Gu, 2005):

- Canadian-owned multinationals are the most likely to engage in product innovation and R&D spending.
- Canadian subsidiaries of foreign multinationals are second, with generally lower R&D intensity than Canadian-owned multinationals, but higher than purely domestic Canadian firms.
- Canadian firms with only domestic operations have both the lowest incidence of R&D spending and the lowest BERD intensity.

This underlines the fact that Canada's failure to develop a greater number of innovative Canadian-based multinationals has been a key contributor to the country's overall R&D weakness.

Investment in machinery and equipment

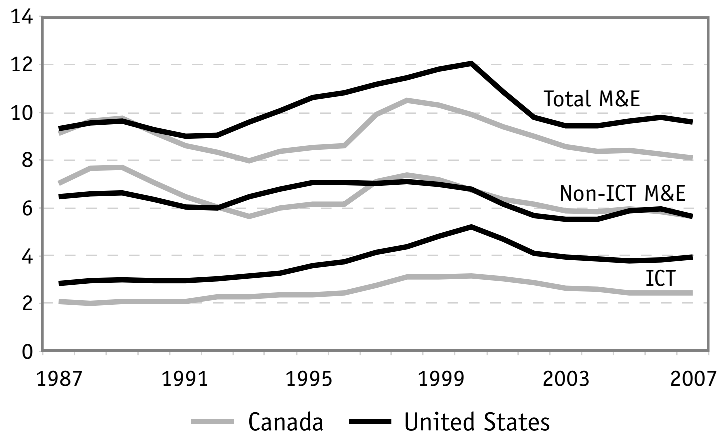
Investment in machinery and equipment (M&E) is a principal channel through which innovation drives productivity growth because such investment "embodies" the prior innovation of producers of capital goods, including software. M&E investment also stimulates innovative changes in processes and work organization to take best advantage of the new capital. (The productivity improvement resulting from such changes is captured statistically within MFP growth.) Investment in M&E (as a percentage of GDP) by Canadian business has not always lagged the United States as has been the case with R&D, though a gap has opened up since the early 1990s (Chart 6). The M&E investment gap has been mostly due to Canada's persistently weaker investment in ICT. Average ICT investment per worker in Canada was only about 60 per cent of the U.S. level in 2007. This is a serious shortcoming since the production and application of ICT have been the key drivers of innovation and resulting productivity growth in the United States and several other countries.

Empirical studies suggest that only about 20 per cent of the U.S.-Canada gap in ICT investment can be explained by structural characteristics related to sector mix and firm-size distribution. Further study is needed to determine definitively the other factors that account for this perplexing gap. For now, it can only be said that relatively low ICT adoption is consistent with a view that Canadian businesses on the whole, but always with notable exceptions, are technology followers, not leaders (Sharpe, 2005).

Competitive Intensity

In the 1940s Joseph Schumpeter argued that large firms with market power were more likely to innovate than small firms. Almost all of the recent empirical analysis contradicts Schumpeter and shows that (i) too much concentration inhibits innovation by removing the incentive created by competitive rivalry, and (ii) small firms with specialized expertise can be the most innovative.

Chart 6
Business Sector M&E Investment Intensity, 1987-2007
(per cent of nominal GDP)



Note: Since ICT prices per unit of performance have fallen substantially (especially for microelectronics and optical communications), the performance-adjusted "volume" of ICT investment would be much greater than the chart suggests. Note that Canada's non-ICT investment ratio increased from 1993 to 1998, despite Canadian dollar weakness (which increased the cost of imported capital goods), and has been flat to declining since 2002 even as the dollar strengthened.

Source: Centre for the Study of Living Standards (2008b).

Is the state of competition in Canada a significant cause of the country's weak productivity and innovation performance? The evidence does not permit a definitive answer in view of (i) the difficulty in measuring the intensity of competition; and (ii) the great variety of market situations throughout the economy, some of which are intensely competitive and others not. The following general observations are germane.

Export-oriented Sectors: For sectors where the market for the product is North American or global, the competitive intensity faced by Canadian firms is essentially identical to that faced by competitors in other countries, and most indicators suggest that Canadian firms achieve comparable levels of innovation and competitiveness. Assessments of innovation activity at the firm level demonstrate that exporting firms are more likely to invest in R&D and to manifest innovative behaviour (Baldwin and Gu, 2004).

Sectors Where Competition is Curtailed: There are some important sectors in Canada — e.g. telecommunications services, broadcasting, air transport and certain agri-foods — where regulations effectively curtail foreign entrants, thus limiting competition. Innovation tends to be dampened in those situations than might otherwise be the case because there is very little incentive for the well-established incumbents to compete for domestic market share via innovation.

Indirect Evidence of Competitive Intensity: There is a great deal of anecdotal evidence that the intensity of competition in the U.S. domestic market is far greater than in comparable sectors in Canada. For example, the generally lower level of business profit (relative to the size of the economy) in the United States as compared with Canada is indirect evidence of stiffer competition in the U.S. market.

The Effect of Canada's Market Size: The relatively small size of Canada's domestic market — made even smaller by regional fragmentation — tends to limit both competitive intensity and the returns to innovation in domestic sectors, which underlines the importance of increasing Canada's presence in global export markets for innovation-intensive goods and services. Innovation is needed to move from a domestic to a global growth strategy. Reciprocally, a heavy investment in innovation usually requires Canadian businesses to go for the scale of global markets. Canadian businesses, on the whole, have so far failed to aggressively grasp the opportunities created by globalization, a shortcoming that is demonstrated by the relative lack of innovation-oriented Canadian-based multinationals.

The Climate For New Ventures

New ventures are the "green shoots" of the innovation system, bringing new ideas to market and creating new competition. Despite some dynamic clusters — such as in Waterloo and in the largest Canadian cities — Canada needs to do better in creating the conditions to enable more of the country's impressive number of startups to become viable, growing businesses still based in Canada. The following three key conditions determine the quality of the environment in Canada for the support of such businesses.

Financing new ventures

A vibrant "angel investor" community is the key to bridging the "valley of death" that separates a promising idea from a viable startup business. (Angels are produced when innovative entrepreneurs succeed and thus generate both the financial resources and the experienced mentors to stimulate or guide a new generation of innovators.) The limited data available on "informal" investment sources in Canada suggest that they are much less extensive, in relative terms, than comparable sources in the United States. Canadian governments have sought to address the early-stage gap in financing through various initiatives. For example, the Business Development Bank of Canada has been directing a growing share of its resources to seed-stage and startup companies. While helpful, such programs do not fill other critically important aspects of the role of angel investors — experience, contacts and mentorship. To address that gap, a number of incubation centres have been created to assist small companies in their earliest stages of growth — e.g., the Regional Economic Intervention Fund established by the Quebec government, the Centre for Drug Research and Development in British Columbia and the Accelerator Centre in Waterloo.

Venture capital (VC) is the post-angel stage of funding when the basics of the business proposition have already been developed and larger sums are needed to ramp up to commercial scale. There are reasons to be concerned about the state of venture capital in

Canada. Fundraising for Canadian VC firms has been falling — 2007 marked the fifth decline in the prior six years. By contrast, there were five consecutive years of growth in the United States. The generally weak performance of Canada's VC industry (Chart 7) is due to the fact that the industry is still relatively young and thus has not yet developed sufficient depth of experience to select and mentor the best potential investment candidates. It is also the case that the VC activities of tax-advantaged Labour Sponsored Investment Funds (particularly outside Québec) have negatively affected incentives and performance in the industry.

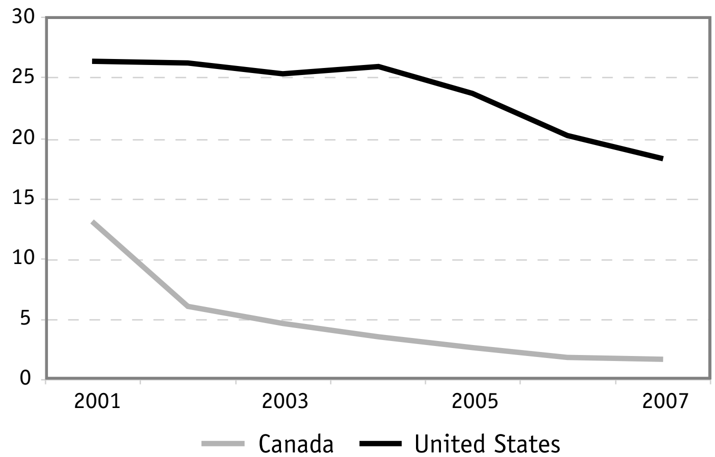
There is no quick or easy fix for the Canadian VC industry. Attracting sufficient capital to become self-sustaining will require VC firms to demonstrate they have the skills and experience to generate acceptable returns. The dilemma is that the industry requires access to sustainable pools of investment capital to develop a critical mass of investing skills. It is encouraging that recent government policy initiatives at both the provincial and federal levels have been designed to support the growth of market-based venture firms that will be judged, and will succeed or not, based solely on their performance.

Commercializing university research

Canada's record of university-based research activity is strong and ranks among the best among OECD countries, but the commercialization of university research in Canada has been, on the whole, disappointing. The principal causes relate to:

- the shortage of commercial receptor capacity in Canada, due to the fact that relatively few established firms in this country are committed to research-based innovation (and would therefore be in a position to transact with universities)

Chart 7
Venture Capital Performance
Net Return* on Previous 10 Years for 2001-07
(per cent internal rate of return)



Note: The financial underperformance of aggregate VC investment in Canada is clear. (Some individual funds may of course perform well). There has been a decline in the 10-year rate of return for VC funds in both the United States and Canada following the end of the tech boom, but the fall-off was steeper in Canada and from a much lower level to begin with.

Source: Canadian Venture Capital Association (2007) and National Venture Capital Association (2008).

- the relative weakness of new venture financing in Canada at both the angel and later VC stages; and
- the inherent differences in the incentives and professional values of the university and the business firm, an issue not unique to Canada.

The situation could be helped through better infrastructure for identifying and mobilizing potentially commercializable knowledge as it emerges from university-based research. In many cases this will involve well-designed partnerships between universities and private-sector businesses or government labs. The implication is that commercialization of research-based ideas is more likely to occur if the surrounding business environment is rich in firms that are committed to science and technology-based innovation as a major business objective — i.e., more "market pull" is needed in Canada to complement "research push".

Supporting innovation clusters

Innovation is fostered by the close personal and supplier linkages that occur in certain geographic concentrations, creating local innovation ecosystems. Public policies designed to create such clusters from scratch have yet to demonstrate much success in Canada or elsewhere, though continued learning from initiatives like MaRS in Toronto will aid the design of supportive policies. The Waterloo success story is one good example and shows that cluster development may require both considerable time to mature and the convergence of several favourable features that are typically specific to the locality.

The Public Policy Environment

Canada has provided a progressively more encouraging environment for business innovation, at least in respect of those factors over which public policy has *direct* influence — for example, prudent fiscal and monetary policies, a trend of lower tax rates and support for university research. But Canada's other benchmark competitors are not standing still and globalization and ICT are changing the way in which a great deal of business innovation is conducted. Most important, Canada's innovation performance is still far from where it needs to be so there is still much work to do.

International trade

The general liberalizing trend of trade policy, until very recently at least, has favoured innovation strategies both to counter import competition and to take advantage of new markets. The concern looking forward — particularly in view of the severe economic stress in most countries — is the risk of increased protectionism. This would reduce the size of the addressable market for many Canadian businesses and thus the potential return from an investment in innovation. As a relatively small open economy, Canada is particularly exposed to the vicissitudes of global markets and especially to conditions in the United States. While Canada's prudent macroeconomic policy over the past 15 years has provided some capacity to absorb shocks, further insulation depends on building a base of export industries at the leading edge of innovation in order to be among the last to lose market share if customers retrench.

Human capital

Education and the quality of human capital is one of Canada's most significant strengths and therefore offers little by way of explanation for the long-term relative weakness in productivity growth or business innovation. The federal government's commitment to the support of university research has been strong since the mid-to-late 1990s, which has increased the supply of leading-edge skills and, other things being equal, made Canada a more attractive location for innovative business. The competition from China and India, among others, for knowledge-intensive activity has meanwhile increased sharply as those countries have also succeeded in rapidly expanding their production of skilled people. The accumulation of human capabilities is a race without a finish line.

Of particular significance for innovation performance is the fact that Canadian business managers are, on average, not as well trained as those in the United States. This education gap may leave many Canadian managers less aware than their U.S. counterparts of developments at the leading edge of technology and business practice, and thus less likely to choose business strategies that emphasize innovation.

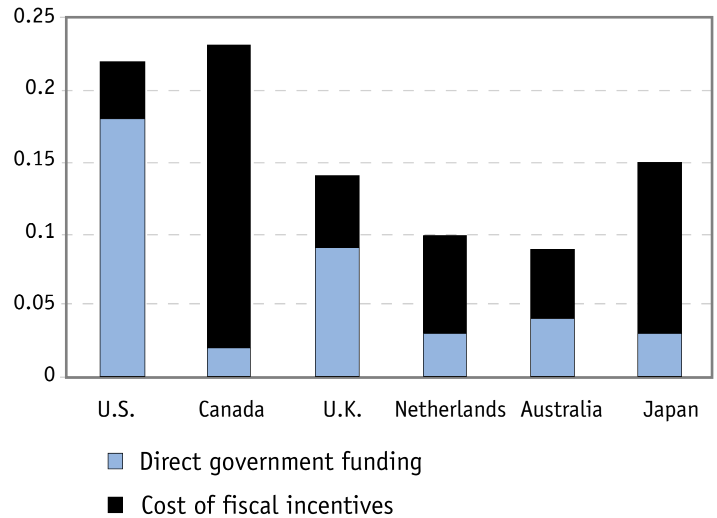
Regulation

The impact of regulatory policies is usually sector-specific, thus few generalizations can be made. Moreover, the effect of regulation on business innovation may either be stultifying or encouraging. Regulations often inspire innovation to meet the rules (e.g. auto emission limits and fuel efficiency standards) or to design around them (e.g. refrigerant substitutes for CFCs to avoid ozone depletion). The intensifying pressure on virtually all aspects of the natural environment due to population and economic growth in general, and energy use in particular, requires an unprecedented innovative response, elements of which will need to be encouraged by well-designed regulation in all countries. While Canada has some companies that have been successful innovators in various fields of environmental technology (e.g. fuel cells and wastewater treatment), it has not generally been an area of comparative global strength for Canada despite this country's outstanding research competence in many fields of environmental science (Committee on The State of Science & Technology in Canada, 2006).

Taxation

Many studies over the years have pointed to a relatively high rate of business taxation in Canada, particularly as it affects the after-tax cost of M&E investment. This reduced the incentive for firms to accumulate M&E and, because of the strong linkages among M&E, R&D and innovation generally, would explain some part of Canada's weak productivity performance. According to estimates by the C.D. Howe Institute, Canada's marginal effective tax rate (METR) for medium and large companies was the highest in the OECD in 2005 and 2006, though the comparable rate in the United States was only slightly lower (Mintz, Chen, Guillemette and Poschmann, 2005, Chen and Mintz, 2008). The federal government has meanwhile been steadily reducing corporate tax rates of various kinds, and in Budget 2009 committed to continue with measures projected to give Canada the G7's lowest overall tax rate on new investment by 2010.

Chart 8
Government Funding of Business R&D*
(per cent of GDP)



* 2005 or last available year.
Source: OECD (2008c).

R&D incentives: The Scientific Research and Experimental Development (SR&ED) tax incentive provides by far the largest direct financial support for business innovation in Canada — representing about $4 billion of federal tax foregone in 2007. Although there is good evidence that the tax credit has a positive net benefit (Parsons and Phillips, 2007), many business leaders believe that the program should be improved — e.g. by extending the "refundability" of the credit beyond small businesses to R&D performers of any size. While Canada's total government support for business R&D (tax and direct spending combined) is somewhat larger, relative to GDP, than that of the United States and the United Kingdom, it is noteworthy that Canada's reliance on the tax assistance channel to stimulate R&D is unusually heavy (Chart 8). Although most countries have been increasing the use of tax credits in their R&D

support programs, more evaluation is needed to determine the right mix.

Sector strategies

The ICT sector, among others such as aerospace, provides several examples of the government's catalytic role in enabling innovative activities to take root and build scale to the point where commercial viability emerges. This initiating influence has taken many forms — early procurement (for example, stimulating IBM's substantial presence in Canada); public-private commercial partnerships in support of a national mission (for example, creation of Telesat in 1969); and research support through targeted university funding and sector-oriented government R&D facilities and programs.

Business Ambition

The intangibles that make up Canada's business culture are believed by many to reduce the supply of entrepreneurial talent, the appetite for risk, the urge to grow and the propensity to innovate. This issue is frequently the subject of surveys and commentaries in which there are two contradictory threads. One is based on surveys of the general population and contends that Canadians are not that much different from Americans when it comes to attitudes regarding risk and entrepreneurship, and therefore any explanation of innovation shortcomings based on public attitude and "business culture" is a red herring (Institute for Competitiveness and Prosperity, 2003).

A contrary view, often voiced by members of the Canadian business community, usually based on personal experience, is that there is an inbred propensity among U.S. business people to maximize the economic heft of their enterprise — to always go for growth. In Canada and Europe, "good enough" appears more often to be reached at a lower level. Put another way, there appears to be a deficiency of business ambition in Canada. Too many successful Canadian businesses would rather behave like an "income trust" than like a "venture capitalist". On the other hand, Canadians have been bold and entrepreneurial in domains where the country has had long experience and deep knowledge flowing from the particular opportunities and challenges the country has faced — mineral exploration and project engineering being good examples. Canadian business, on the whole, has acquired much less experience at the frontiers of science and technology, and has thus been less able to gauge the risks and opportunities in many of these domains. Fewer Canadian companies have therefore been prepared to adopt strategies based on technological innovation.

Related to this is a persistent concern that too many innovative startups fail to mature in Canada with the most promising often acquired and eventually relocated to the United States. The greater supply and sophistication of venture capital investors in the United States and immediate proximity to a larger market can be irresistible attractions for young, technology-based firms. This underlines the importance of improving the climate for new ventures as discussed earlier.

The key question is whether Canadian businesses are aggressive enough and sufficiently outward-looking to compete in global markets beyond the huge and accessible U.S. market? Clearly, the many Canadians who have built successful global businesses have what it takes. But the issue is whether there are enough of them to ensure the long-term prosperity of the entire economy. The panel's view is that today, there are not. This is not due to any lack of innate capacities of Canadian business people — it is not in the "DNA", so to speak, but rather comes down to the incentives embedded in the economic environment.

Canadian business as a whole has been profitable despite its mediocre innovation record

— pre-tax business profit in Canada, as a percentage of GDP, has exceeded that of the United States in most years since 1961. So the behaviour of Canadian business is unlikely to change unless its circumstances change. Those circumstances are, in fact, changing radically due not only to the current turmoil in the world economy but, more fundamentally in the long run, to a massive reallocation of the share of global economic activity as China and others become full participants in world commerce. The demographics of the Canadian business community are also changing as immigrants and a younger generation of entrepreneurs, unencumbered by traditional attitudes, expand their presence. So whether by necessity or inclination, there is reason to expect that Canadian business will become more ambitious and innovative.

Sectoral Perspectives on Innovation

No one industry is "average" and there is no one-size-fits-all explanation for Canada's innovation shortcomings. Four sectors — automotive, life sciences, banking and ICT — were chosen by the panel for "mini-case studies" to illustrate the diversity of the innovation *problematique* in Canada and the variety of strategic responses to it. Innovation also occurs in Canada's resource-based sectors though most involves process improvements, the adaptation of foreign-sourced M&E and techniques to Canadian circumstances, mineral exploration, and the financing and engineering of resource projects at all scales. With very few exceptions, Canadian firms have not been at the forefront of innovation in capital equipment for resource industries or in the development of the most sophisticated materials and products derived from the nation's resources — further evidence of Canada's characteristic upstream, commodity-oriented position in global value chains.

Following are summaries of the panel's views as to some of the lessons for business innovation strategy in each of the four sectors.

The automotive industry — weak R&D but strong productivity

- The innovation strategies adopted by Canadian auto sector firms have been influenced heavily by structural characteristics — specifically the integration of the North American market and the role of foreign-controlled assemblers. But the global success of parts makers like Magna and Linamar proves that ambitious Canadian firms can expand from their base in a Canada-U.S. supply chain to serve the world market.
- Canada's auto industry shows that it is possible to build a competitive industry without a strong base of domestic R&D. The structure of the sector in Canada has instead led to innovation strategies that focus on process efficiency and workplace practices. This raises the question as to whether public policies could be designed to foster more such gains in productivity, including in resource industries where process innovation is also the prominent strategy.
- Innovation policies in Canada should not be focused only on the more typical measures such as R&D spending. These do not adequately take into account the Canadian context with its unusually high reliance on sectors that are components of global supply chains and that may not rely on R&D spending to achieve greater productivity.
- Canada's automotive policy will need to become more flexible and proactive. Fostering Canadian-based innovation by both vehicle assemblers and parts makers should be a goal of a new Canadian auto strategy that emerges from the industry's crisis.

Life sciences — great promise but mixed results

- The strategies of life sciences companies are strongly science-based and thus are heavily influenced by public policies that support R&D as well as research and training in universities. Public policies in respect of health procurement and regulation are also of great importance, particularly for multinational pharmaceutical firms where there is fierce competition among national affiliates for innovation and product mandates. The strategies of the smaller, biotechnology-based companies are very heavily influenced both by the availability of patient early-stage finance and mentorship, and by their ability to strike collaborative arrangements with global pharmas.
- The experience of life sciences demonstrates what can and cannot be accomplished through a targeted government policy. The federal government set out to generate increased R&D spending in the life sciences in Canada and it worked, but it has not yet produced the expected follow-on benefits, either of a growing pharmaceutical sector or a clearly sustainable biotech industry.
- Additional protection of intellectual property (IP) could strengthen Canada's position as an R&D location. But, more important is the fact that, with the exception of Quebec, governments do not view life sciences as a genuinely high *economic* priority and thus have not ensured that procurement practices are harmonized with industry development objectives.
- Canada's single-payer health care system creates an opportunity to establish a leading role in using health innovation to improve the productivity and quality of the health care system. An exceptionally promising initiative is the partnership among the federal and provincial/territorial governments through Canada Health Infoway to accelerate development of an electronic health record.

Banking services — trade-off between stability and radical innovation

- The innovation strategies of the major Canadian-owned banks strongly reflect the nature of domestic competition which has militated against a focus on product innovation leadership, being content instead with early adoption.
- The generally conservative banking and regulatory practices prevailing in Canada have kept Canadian banks off the "bleeding edge" of innovation in the design and distribution of the most sophisticated financial instruments. This has substantially insulated them from the global financial meltdown and made Canada's banks currently among the world's strongest (International Monetary Fund, 2008 and World Economic Forum, 2008).
- The success of Canadian banks over many years may have dulled their business ambition. With limited exceptions, Canadian banks were, until fairly recently, content to focus on the domestic market and to restrict their international activity primarily to commodity-type wholesale banking as parties to international lending consortia. Now Canada's banks have become more aggressively and creatively outward-looking with many examples of large investments to establish a substantive presence abroad.
- The recent turmoil in the banking industry globally has created a window of opportunity for Toronto to become one of the major North American, if not worldwide, innovation centres for the financial services industry. Canadian banks have economic and strategic decisions to make

as to where to locate their product and service development, software programming, data centres and other innovative activities going forward. With the right business climate, Toronto has the potential to emerge as a centre not only for these activities, but also to attract specialists from around the world to create financial industry products and services.

ICT — A Catalytic Role for Government

The ICT sector is a heterogeneous collection of industries encompassing many different innovation strategies as the following examples illustrate.

- The fact that several large players in the computer industry in Canada are foreign controlled has not stunted Canada-based product innovation activity, as has been the case, for example, in the automotive industry. The prospect of government procurement contracts for ICT firms that established a substantial presence in Canada provided — notably in the case of IBM — an initial attraction that grew into major activities with global product mandates. This shows that government's role as lead customer can, under the right conditions, provide the impetus to kick-start a new industry. The case of ICT procurement, which catalyzed substantial economic development, stands in contrast to the very different philosophy of health sector procurement that has prevailed for pharmaceutical products.
- Canada became an early leader in satellite and microwave communications technology in order to communicate across a vast geography, a mission that was initially supported by targeted government research and enterprise. For example, Telesat was founded in 1969 as a joint government-private-sector business.
- The climate for new ICT ventures (hardware, software, systems and services) in Canada has been quite favourable in view of (i) a strong base of research and training in universities and colleges, and in major players like Nortel, IBM and RIM; (ii) government supports such as the SR&ED tax credit and various laboratories and programs; and (iii) supportive clusters of ICT subsector activity in several centres across Canada. The many successes have produced numerous role models and angel investors, and bred confidence in young ICT entrepreneurs that they could succeed in Canada. Business ambition has been in ample supply although lack of a strong base of leading-edge ICT customers in Canada continues to be a significant drawback. Unfortunately, the sharp decline in the telecommunications technology sector since 2001 (now exacerbated by the global recession) has hit Canada particularly hard in view of this country's specialization in several of the most heavily affected market segments. Canada's hard-won advantages are now at risk.

A theme running strongly through the foregoing examples is the key influence of government, at least at the outset. The role of government in ICT sectors has typically been catalytic, enabling an innovative line of activity to take root and to build scale to the point where commercial viability has emerged.

Addressing Canada's Business Innovation Challenge

Canada has a serious productivity growth problem. The panel believes that Canadians should be concerned about the productivity of our export-oriented economy as competition from China and other emerging economies intensifies. The panel also believes that Canadians should be concerned about the long-run consequences of continued weak productivity performance in the domestic economy as the population ages and competition intensifies among the mature economies for the best human skills, and particularly for entrepreneurial talent.

Because *Canada's productivity problem is actually a business innovation problem*, the discussion about what has to be done to improve productivity in Canada needs to focus on the factors that encourage, or discourage, the adoption of innovation-based business strategies. This is a complex challenge because the mix of relevant factors varies from sector to sector and requires a broader conception of innovation than the conventional R&D-centred view, which, while important, is far too limiting.

Because there is no single cause of the innovation problem in Canada, nor any one-size-fits-all remedy, public policy needs to be informed by a deep understanding of the factors that influence business decision makers, sector by sector. This clearly requires extensive consultation with business people themselves as well as the further development of innovation surveys and other forms of micro-analysis of the innovation process.

Overarching the sector-specific factors that influence innovation strategies are certain issues of pervasive influence identified in the panel's analysis that suggest the need for proactive public policies to:

- encourage investment in advanced M&E in general, and in ICT in particular (such incentives should be designed only in light of a more thorough understanding of the reasons for the relatively slow adoption of ICT in Canada to date);
- sharpen the incentive for innovation-oriented business strategies by increasing exposure to competition and by promoting a stronger export orientation on the part of Canadian firms, particularly in goods and services that are downstream in the value chain and thus close to end-users;
- improve the climate for new ventures so as to better translate opportunities arising from Canada's university research excellence into viable Canadian-based growth businesses, bearing in mind that better early-stage financing and experienced mentorship hold the key; and
- support areas of particular Canadian strength and opportunity through focused, sector-oriented strategies, such as was done in the past in, for example, the automotive, aerospace and ICT industries.

Fortunately, the many successes of Canadian businesses in the hyper-competitive global marketplace show that there is nothing innate or inevitable in the national character that prevents Canada's businesses from being just as innovative and productive as those of other nations.

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Is Canada Really All That Bad At Innovation?: A Tale of Two Industries

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Abstract

This commentary raises questions about the degree to which global innovation indicators enable us to understand the historical dynamics of innovation in Canada, and about future directions for Canadian innovation policy. By focusing on the automotive and telecommunications sectors, two currently troubled Canadian industries with completely different histories, some of the major successes and mistakes of Canadian industrial policy are assessed critically. The conclusion is that the innovation problem in Canada has less to do with capabilities or opportunities, than with recent tendencies not to follow through when ambitious innovation initiatives in specific industries could be transformed into new national "engines of growth".

The Council of Canadian Academies (CCA) is rendering an invaluable service to the Canadian public. Over a very short period, the CCA has produced several of the most penetrating and useful analyses of the state of Canadian research and innovation to have appeared in a very long time. The most recent report, entitled *Innovation and Business Strategy: Why Canada Falls Short* and released on April 29, 2009 by the Expert Panel on Business Innovation in Canada, is certainly among them. Returning to Canada three years ago, after many years away, I was dismayed at how far general political and public awareness of the vital importance of research and innovation had deteriorated, and how, despite several new and long overdue initiatives, Canadians are still failing to respond positively to many of their chronic industrial challenges. The 'crisis' we now face may have been precipitated by financial adventurism elsewhere, but it has been brewing in our midst for decades.

Responsibility for these failures has been laid at many doorsteps. The university system in particular (unfairly in my view but with its own connivance to be sure) has often been singled out for its supposed underperformance in transferring new knowledge to the market. Government has been blamed for too much red tape on the one hand and too little intervention on the other. Business has been blamed for timidity and reluctance to invest. Organized labor has been blamed for preserving structural obstacles to change. The list goes on and on, and, indeed, none of the accused is entirely blameless.

But as the Panel rightly emphasizes, ultimately, the responsibility for innovation *in* business lies *with* business. And in this regard, it is a simple fact that Canadian business as a whole — particularly our largest industries — never looks

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to be more than a fair-to-middling performer in the international innovation league tables. There is no point in trying to argue with the statistics presented in this report. They say what they say and the same indicators are applied to every OECD country. We cannot wriggle free from their implications with special pleading.

Nevertheless, the crucial task is to interpret these indicators such that creative solutions can emerge that *do* take full account of Canada's own unique circumstances and history. One very important contribution of the CCA report is that it amplifies and contextualizes many of the comparative statistics such that a far more nuanced picture emerges of Canada's innovation profile.

Early on, the report suggests that our national innovation "problem" is extremely broad in scope, stating that "*The causes of Canada's innovation deficiency must run deep in the nature of the economy, and perhaps in Canadian society as well.*" I fully agree. The more I have learned since my repatriation, the more I have become convinced that the crux of our problem — and I am not sure that the Panel's report entirely pins down what that problem is — lies more in our experience and history than in our scientific, technological or business capabilities as such. One of the most positive and refreshing aspects of this report is that the Panel endeavors to get under the skin of these dry and rather abstract indicators and, with Cassius, entertains the possibility that our fault lies not in our stars but in ourselves.

The Panel's report is carefully researched, comprehensive, extensive and detailed. It is also presented critically and fairly. I am content to accept the validity of most of the evidence and analysis it contains. Instead, I will comment in two areas where I remain skeptical. The first concerns the degree to which this body of evidence really enables us to understand the dynamics of innovation in the Canadian experience. The second concerns what to do about it. Can we become more innovative through more R&D investment, tax breaks and university patenting? Somehow I don't think so. But with the reader's indulgence, I will begin with a story.

A Tale of Two Industries

In the past few months Canadians have witnessed serious declines in two of our once strongest industries — automobiles and telecommunications. These two industries have completely *opposite* profiles in Canadian industrial history, and it occurs to me that the way Canada is responding, or not, to their tribulations is highly indicative of our past and present attitudes towards industrial evolution and innovation. It is also indicative of the historical *strengths* as well as weaknesses of Canadian public policy in leveraging large technologically-intensive industries into what I will call national "engines of growth."

In the early 20th century, Canada had a strong domestic automobile industry which was highly innovative, e.g. the saloon car, which eventually became the standard platform for the entire industry globally, was a Canadian innovation. Sadly, Canadian significance as an independent force in the automobile industry dwindled steadily throughout the 20th century. Today, the structural importance of this industry to Canada's economy is based primarily on wages. The fate of thousands of Canadian auto workers and many more besides now lies entirely outside of Canada.

Our auto sector is a prime (though by no means the only) example of a Canadian industry in which control over the real means of wealth production — to *design the product* and to *make the market* — shifted out of the country and where its "engine" function was perceived by successive generations of policy makers as an employment stabilization strategy rather than an industrial strategy. Thousands of Canadians are now paying a heavy price indeed for the collective failure of virtually every institution involved with this industry since the 1950s to deal with this social and economic time-bomb. If that sounds harsh, it is meant to be.

On the other hand, and contrary to the popular mythology that Alexander Graham Bell was somehow a Canadian (he wasn't) and that the telephone was a Canadian invention (it wasn't), Canada was a marginal player in the telecommunication industry until the 1960s. But, through smart business planning, effective coordination with government agencies and labs, productive deployment of Canada's brightest young graduates, and strategic exploitation of unique and time-sensitive market conditions in the United States, by the late 1970s Canada was as important a source of innovation and productivity in this industry as any country in the world. In terms of business expenditure on research and development (BERD), Nortel is probably Canada's one and only indigenous company *ever* to be a global leader in every single category of innovation statistic. At one time it was estimated that this single company was responsible for a significant portion of all of the R&D performed in Canada. Moreover, a huge spillover of new Canadian IT-based enterprises emerged. Despite many us and downs, Canadian companies continue to lead in many of these markets, and we are still generating them (e.g. RIM and Smart Technologies).

Our IT and telecommunication sector is a prime (although by no means the only) example of a Canadian industry in which considerable control over product design and market-making both *emerged* in Canada and *stayed* in Canada. Even when, as inevitably always happens, Nortel globalized its R&D, the company continued to play a structural role in anchoring our IT and telecom industry. But just as importantly, the "engine" function of this industry was perceived by policy makers in terms first of an industrial strategy, in the expectation that it *would become* a significant generator of sustainable jobs (which by-and-large it still is). Nortel employees likewise face an uncertain future, but this is due to questionable business decisions by this particular company. An unusual occurrence? The difference is that the fate of these workers is not irrevocably sealed by systemic institutional failure. The sector will continue to create value in Canada, even if Nortel itself plays a diminishing role.

Another part of our national mythology is that because of our close structural ties to the US economy, we are condemned to be a branch-plant economy. But the story of these two industries illustrates that proximity to US markets can be exploited to our *advantage* as well as to our disadvantage. In particular, they demonstrate the dangers of relying upon foreign direct investment (FDI) to stimulate domestic innovation, which to my horror is becoming a prominent plank in most federal and provincial innovation strategies (inchoate as most of them are). FDI can work, but it works best if a country that is open to FDI is also a significant *exporter* of FDI. That makes the difference between being a branch plant and a global player.

Thus, in terms of trying to define Canada's innovation "problem", I have been struck in particular by the gross imbalance in public perception between the current crisis at General Motors compared to the crisis at Nortel. Canada's declining position in the auto sector, where we have not had a significant home-grown stake in innovation since the 1920s, is daily news. The debate is not whether to invest billions of dollars to preserve jobs, but how many billions. In stark contrast, Nortel was pretty much a one day story. To my knowledge nobody has seriously proposed financial support for this company or this industry. And, indeed, maybe this is not necessary for the best of reasons.

For me, the case of the auto industry exemplifies all of the things that Canadian businesses and governments have done to stifle innovation and the creation of high-value knowledge-based new enterprise. The auto industry has far too many analogues. On the other hand, the case of the telecommunication industry, at least until recently, represents most of the right things. And we have done basically some of these 'right' things in several other industrial areas as well — aerospace, canola and steam-assisted gravity drainage (SAGD) come immediately to mind. So we cannot let ourselves off the hook by claiming that we need to learn to innovate in order to compete more effectively in domestic and global markets. The problem is more serious and systemic than that.

What Do the Indicators Actually Say About Canada?

One of the few things that I find problematic about the Panel's report is that it takes a very conventional view of what innovation is and how it works. For example, it does not pursue some of the more intriguing new ideas about innovation as a social practice or about the dynamic properties of innovation, most of which come from outside mainstream economics. Indeed, the report casts innovation in rather linear terms as a process of finding solutions to problems.

But surely innovation also creates problems. As Schumpeter pointed out a century ago, entrepreneurs do not respond to demand — they create it! As such, the real risk lies not with the entrepreneur, but with the society that accepts the risk. Thus, the feedbacks from innovation are always diverse and unpredictable, yielding unintended outcomes, some of which turn out to be huge intractable problems — I need only mention our oil dependency. We might even claim that innovation drives growth by never quite solving anything, thus always seeding the field from which some other new idea or practice can emerge.

This observation plays into my nagging doubts about how useful it is to think about innovation too exclusively as an 'economic' phenomenon (responsive mainly to abstract economic stimuli), or to associate it as exclusively with technology as has become common practice. Thus, I find that although the report is forthright in exposing the limitations of the standard set of economically-oriented innovation indicators as deployed in the OECD countries, it is nevertheless drafted mostly in the same conceptual framework from which these indicators emerged.

Although the Panel points out that innovation is about much more than technology, their report still associates it more closely with technology than with any other factor. This is difficult not to do given that virtually all of the standard indicators in the OECD framework — R&D, patents, technology investment and highly qualified personnel (HQP) — are overwhelmingly oriented to technology.

But this is not to say that the R&D-oriented indicators do not tell us anything or that what they tell us is inconsistent with the two stories as told above. In the first place, criticism of these indicators often misses a crucial point. As spelled out clearly in the Frascatti definition, R&D as a proportion of total industrial or national output was intended originally to be an indicator of human capital. Or more specifically, to show changes in the ratio of value-creating human capital to value-utilizing wage labour. Both are necessary, but serve different functions.

As virtually by definition innovation is the product of human capital, gross expenditures on research and development (GERD), BERD etc. are extremely powerful indicators of innovation potential, if perhaps not of actual innovation performance. And potential is extraordinarily important. What you know how to do is as important as what you do. Thus, the GERD score can indicate change in the national stock of human capital. But much more importantly, changes in GERD when compared with other indicators can indicate how effectively human capital is being deployed. For example, a low

GERD score compared to the post-secondary graduation rate may indicate that the human capital stock is under-deployed; i.e. that workers capable of creating new value are employed in sectors that are not creating new value.

Thus, for me, the most important single exhibits in the report are Table 1 Chart 5 (in the accompanying article), which together tell us much about the relative R&D-intensity of key Canadian economic sectors. It is usually reckoned that 80-plus percent of global R&D expenditure is anchored in only about a dozen industries. All of these industries have a presence in Canada. Together, they sustain a high portion of Canadian jobs. And yet, as these tables indicate, only the aerospace, information technology and bio-medical industries re-invest substantial amounts of revenue in R&D that is performed in Canada.

So how does this relate to our stories? Well, globally, for example, the auto industry normally ranks towards the very top in R&D-intensity, but the Canadian contribution is insignificant. On the other hand, aerospace, IT and bio-medicine rank highly both globally and in Canada. But is it significant that we appear to be good R&D performers in only three sectors? Yes and no. It is not good that we deploy so few human resources in the auto and other manufacturing industries which pay such a large part of the wage bill. But other than that, Canada is not unique in having most of its R&D centered in just a few of the top dozen or so R&D-intensive sectors.

There is nothing intrinsically wrong with national R&D specialization and most OECD countries are even more specialized than Canada. The real issue is the extent to which innovation is endemic throughout the entire national industrial spectrum, irrespective of how much R&D we produce ourselves or in which sectors we produce it. Thus, it is important to consider if and how those industries in which we have strong domestic R&D profiles are integrated with other sectors. It is also important to understand the role of knowledge imports and exports in our industrial system (whether between companies, sectors or countries) and to assess national capabilities to absorb knowledge as well as to produce it.

But this means that we have to step beyond the standard indicators and look a lot more closely at the knowledge composition of companies that are not R&D intensive. The real problem with the R&D or technology focus is that inevitably it casts the innovation issue in terms of those relatively few industries whose business and investment models are oriented to a constant flow of new products. For most of these companies, technology in some form is their final product. But most companies are not R&D intensive and there is no reason for them to be. They are capital intensive, acquiring their technology through procurement and deploying this technology as an intermediate good — a means to some other end. But this does not mean that they do not also innovate or that the return from their innovations is any less significant.

Especially given Canada's industrial history and composition, surely the most serious omission in the report concerns the resource industries. It is easy to dismiss these industries as relics of the 'old economy'; part of the problem rather than the solution. And in some cases, forestry being a particularly egregious example, it can be demonstrated that Canada has declined significantly as a global source of innovation.

But the issue is far bigger than this. What do we actually know about the innovation system in these industries? Actually, not very much. We know that they do some conventional laboratory-based R&D, but that they ramp it up and down intermittently and that normally R&D is not a main plank in their strategies. But we also know that in most cases, even though the product remains an undifferentiated commodity, the process of financing, discovering, extracting, processing, distributing and decommissioning most resource products is radically different than it was even a few years ago. What we need to know is if, how and to what extent Canadian companies have contributed to this innovation process. We also need to know about the spillovers.

The problem is that capturing the innovation dynamics of the capital-intensive part of the economy is far less straightforward than measuring the production and application of technology. As a result, innovative activities in most of our industries — particularly services and natural resources — remain all but invisible to the indicators.

I find it particularly significant in this context that Canadians figured out how to manufacture oil from sand and turn it into a business. This was as major an innovation as any in our history. Canadians also learned to turn a toxic seed into an oil that is both edible and burnable. Another first. Unfortunately, it is also significant that Canadians evacuated the innovation playing field when it came to mitigating the environmental and social impacts of these innovations and to adding yet further value to the resources themselves. Thus, our oil sand developments are held hostage to changing environmental attitudes, and our canola is shipped offshore for transformation into bio-fuels.

These examples and many more like them underpin my final criticism of the report itself, which concerns its narrow (at least in my view) focus on productivity. Certainly innovation can drive productivity, but surely it also matters where productivity increases occur. To return to my stories, I really do not think it matters that for whatever reasons high fuel consumption cars are produced more efficiently in Canada than elsewhere. For a multitude of interconnected reasons that go well beyond greenhouse gas emissions, this product paradigm is steadily coming to an end. I dispute entirely the claim in the report that the main form of innovation in our auto sector has been in process. There is a huge difference between tweaking the normal line of efficiency management (which incidentally can also require significant investment) and incremental innovation which is a source of new value.

Where innovation is concerned, whether radical or incremental, surely productivity is a red herring unless it is positioned on the cusp of some new paradigm. Canada needs to become more productive, but in new markets in which we can carve out high value niches. We desperately need to go further down the road with industries that break out of paradigms than we do at present. But to be fair to workers in our many sunset industries, we also need to figure out how to transpose the knowledge about how to be productive that Canadian workers may have achieved in the manufacturing plants and elsewhere to industries in which we can carve out a higher value stake — where Canadians design the products and make the markets.

What Is Our "Problem" and Are We Fixing It?

It seems to me that the real nature of our innovation "problem" is that Canadians know perfectly well how to innovate, but, for a multitude of reasons, as a society we do not do choose to accept the risks of innovation as often as we could. We do not stay with our successful "engines of growth" as their learning curves steepen in response to competition and changing market conditions, and we remain more committed to preserving jobs in sunset industries than to creating jobs in sunrise industries.

This says a lot to me about our historical 'attitude' to industrial development in Canada. It says that over our history we have received much positive feedback from not exploiting opportunities to innovate. We have become very good at creating a high quality of life by leveraging inputs from elsewhere. As a seasoned reader of the innovation 'tealeaves', this is what jumps out at me from our profile in the productivity and innovation league tables. The gamble we are taking is to assume that this strategy will continue to work. And as the Panel is well aware, for the first time in our history, irrespective of the outcome of the current financial debacle, the signs are not good.

So what is missing in our 'innovation system'? Although I would not quibble with most of the Panel's conclusions, I was rather disappointed that they were so short on solutions. In the end, I found myself asking 'What measures do I see in other OECD countries that I do not see in Canada?'

Well, mostly I see the same things. Every government in the OECD hopes that by increasing investments in education and R&D, and creating positive fiscal climates, innovation will increase and sustainable prosperity will gear up. But of course, everybody can read the same league tables and most take exactly the same actions. Thus, we easily get caught in a 'Red Queen' effect where everybody runs like mad just to stand still. And indeed, with only a few exceptions now and again, most countries perform pretty much the same in all of the tables from year to year. Even the US is 'best-in-show' on only a few of them. Japan always does superbly on all of them and yet the Japanese economy has been in the tank for at least a decade. Perhaps we should not expect that a change in our position on the tables will indicate progress in meeting our challenges.

What is missing in Canada at this moment, and the Panel gives little guidance here, is precisely that crucial sense of 'system' in the interactions between the various institutions that play different roles in the innovation process — chiefly business, government and the educational sector. Whether by design or practice, most major OECD economies succeed in coordinating these resources such that they generate new industries, not just pockets of activities. In the past, Canada has succeeded with this strategy also. So what happened?

Surely part of the current problem is the evolution of our cranky constitution — the 'factor 10 dilution' as I have come to call it. Unlike the situation in some other federated countries (e.g. Germany or the United States), there are few if any mechanisms in Canada to aggregate our limited resources to support bottom-up innovation initiatives from industries that have a presence in more than one province. Instead, in virtually every key knowledge-intensive sector, there are federal initiatives and typically dozens of provincial initiatives. Nothing is connected or connectable, and the best we often achieve is that everybody gets really good at doing a part of not very much.

Secondly, Canadian governments seem to have a touchingly quaint faith in the sufficiency of fiscal measures to stimulate innovation. Tax incentives are one way of stimulating R&D in some cases in a few industries. But no innovation is entirely dependent upon R&D (many are not dependent upon it at all), and surely no smart business ever does R&D because they get a tax break. Moreover, fiscal policies often just reward patching holes in sinking ships. That this represents the largest share of what government actually does about innovation, our tax credit program embodies our innovation policy problem.

But thirdly and most importantly, the public sector focus in Canada has become too focused on research, and not nearly focused enough on development. Of all the terms in the innovation equation, research has the lowest risk for governments and public agencies for the simple reason that it is a step removed from anything to do with business. But as the Panel also notes (maybe more by implication), when it comes to national economic performance, and to innovation in particular, business and government are never very far apart. The orthodox economic policy catechism mandates that government has no business engaging in or with business. This is an interesting notion. Unfortunately, Canada seems to harbor the only true believers in this doctrine who also practice it.

At this point it is appropriate to close by noting that virtually all of our major past successes in creating high-value world-beating innovative industries have been engineered by visionary people in all branches of Canadian society who are not worried by doctrine. Such is the case also among our chief competitors. Our emerging 'culture of accountability' is not symmetrical with the realities of entrepreneurship or with the need for government occasionally to take some of the same kinds of risks as businesses take — with the same consequences.

Congratulations to the Panel for bringing all of these and many more issues into relief. I very much hope that their report will be received by industry, government and the academy with the seriousness it deserves. And more importantly, I hope it spurs somebody to action.

Bridging Canadian Technology SMEs Over the Valley of Death

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ABSTRACT

This comment analyses the Panel report and finds that its main diagnosis is correct: Canada's BERD is low. The Panel report is fairly silent about the necessary improvements to Canada's innovation system. This comment suggests that while Canada's tax credit for R&D and Industrial Research Assistance Program (IRAP) are useful programs, they need to be complemented by other direct incentives that may help small technology firms to cross the "valley of death", complete proof of concept and become eligible to venture capital. The US Small Business Innovation Research (SBIR) program, imitated by Japan, is the best model for such an incentive and Canada should consider its adoption.

THE STUDY *Innovation and Business Strategy: Why Canada Falls Short* produced by an expert panel under the auspices of the Council of Canadian Academies is a well-researched and well-presented report on innovation in the Canadian private sector. The authors were asked to examine the innovation performance of Canadian firms and the factors behind this performance. They conclude that Canadian business is characterized by a lacklustre innovative business-sector performance on many accounts.

The main diagnosis of the report is correct: Canadian business is lagging in terms of innovation and productivity. The gap or shortfall appears in business expenditure on R&D (BERD) which is low compared to other OECD countries and declining. It also shows itself in low levels of private investment on information and communication technologies as well as on machinery and equipment. It can also be seen in labour productivity figures, and in the limited number of large high-technology firms which are Canadian-owned and -controlled. In addition, foreign control and imported technology in important industries such as automobile and chemicals allow Canada to produce cars or basic petrochemicals with little R&D. The panel's conclusions are straightforward: Canada needs to increase its BERD in both total absolute terms and relative to sales or gross domestic product (GDP).

The report is well documented with excellent data and theoretical inputs from different currents without being excessively prone to jargon. It is easy to read for any person acquainted with the subject.

Commentary

It is impossible to analyse in a few pages the many different and relevant issues and topics covered in the report. I am thus going to concentrate on one, which appears to be one of the most important themes in the study: how to grow large Canadian-owned and controlled companies.

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The report shows that Canadian-owned multinational corporations (MNC) are those with the highest BERD intensity (BERD/GDP), followed by foreign MNC. Canadian-owned local firms are in third place. It states "Canada's failure to develop a greater number of innovative Canadian-based multinationals has been a key contributor to the country's overall R&D weakness." (p.60).[2] The question, thus, is how can Canada nurture its technology-based companies to grow MNC.

Canada's BERD intensity has declined since the peak attained in 2001 during the technology boom (Chart 4). At the same time, BERD intensity has increased in most other OECD countries including Australia, Austria, the Czech Republic, Finland, Germany, Italy, Japan, Korea, Spain, and Turkey, as well as in non-OECD countries such as China, Chinese Taipei and Singapore (OECD, 2007). And this is not all: the present economic and financial crisis, as well as the coming demise of Nortel, will accelerate the downward trend of Canadian BERD in the years to come. Meanwhile, Finland, Korea, Singapore and Sweden are pulling ahead of the pack.

Among the determinants of business innovation strategy, two deserve to be analysed: the climate for new ventures and public policy. The report finds that the Canadian climate for new ventures is good, but not outstanding; Canadian venture capital is confined mostly to seed stages, and is declining. Moreover, angel investment is reduced compared to US figures (p. 62). Canada has its share of new technology-based firms; yet these do not grow, but are instead either acquired by Canadian or foreign firms, or disappear fairly soon. Public policy is not helping either.

Using an institutional benchmark approach, a closer examination at some of our more dynamic competitors may allow us to find the appropriate solutions.

Policy Cures for Business Diseases

The Nordic (mainly Finland and Sweden) and Southeast Asian states (China, Chinese Taipei, Japan, Korea and Singapore) are very proactive in the field of science, technology and innovation (STI).[3] Since the 1990s, these governments have launched many STI initiatives that are bearing fruit in terms of new firms, new clusters, etc. Also, these governments invest more than the Canadian government on support for new firms (OECD, 2007). The more proactive orientation of some governments is briefly mentioned in the report. It is important to emphasize that the belief that business and markets know better than governments is being shaken these days, when so many large companies request public funds in order to survive; such a market-prone belief was never taken seriously in Northern Europe or Southeast Asia. Today one may say, under the light of the present crisis, that market foresight and wisdom have been much exaggerated, and the era of Keynesian governments is back. In order to catch up with Nordic and Southeast Asian leaders, and avoid being left behind in the productivity race, Canada's federal and provincial governments need to increase their direct funding for business R&D, which is too low, at present, and declining (Chart 8). In particular, direct funding of R&D has remained fairly stagnant in absolute terms.

An Accurate Diagnosis

The report is entirely accurate in asserting that our lacklustre business innovation perfor-

2 All chart, table and page numbers refer to the accompanying article by Peter Nicholson.

3 Among other studies see Ahlback (2005) for Finland, Chung (2002) for Korea, Parayil (2005) on Singapore, Casper and Whitley (2004) on Germany, Sweden and the UK, and Jan and Chen (2006) for Chinese Taipei. Also, see the Science and Technology Policy Council of Finland (2006).

mance is not primarily related to the production and attraction of human capital, or to a lack of scientific production (my figures in Niosi (2008) coincide with Chart 2). Canada is able to spin off many technology-based firms from academic institutions and public laboratories. A large part of the problem seems to be linked to the country's limited capacity to grow these new technology-based firms. These firms are either bought out in software but also in biotechnology, and their managers spend a good part of time looking for funds abroad (Veilleux, 2008), or simply collapse.[4] Market size and geographic fragmentation of the Canadian market are certainly an issue (p. 62), but this is not the extent of the problem. Canadian firms need more government support. Canadian government funding and government funding for innovation needs to increase, not only because of the small market size and fragmented domestic market in Canada, but also because governments in other countries (including the United States, Finland, Japan and Korea) are doing more and doing it better. US policy to support technology-oriented small and medium enterprises (SMEs) is discussed below as an illustration of what one major country is doing to foster business innovation.

A Useful U.S. Federal Program for Innovative SMEs

The report correctly points out that the public policy environment for innovation in Canada consists mainly of the Scientific Research and Experimental Development Tax Incentive. However, there are many other incentives in the United States that do not exist in Canada. In 1982, the Small Business Innovation Research Program (SBIR) was created in the United States through the Small Business Innovation Research Act. It is administered by eleven government agencies, but five federal departments represent 96 per cent of the program. The five agencies are the Department of Defence (DoD), the Department of Energy (DoE), the National Aeronautics and Space Agency (NASA), the National Institutes of Health (NIH), and the National Science Foundation (NSF). The smallest among the five big components of SBIR, the NSF SBIR annual budget is now US$100 million. SBIR has been evaluated several times and found extremely useful in generating knowledge, creating networks between small firms and universities, creating and disseminating intellectual capital, and moving technology from universities towards the market (Wessner, 2007). Also, a high proportion of SBIR projects resulted in new products and processes. Today, SBIR allocates US$2 billion per year to fund R&D projects by small and medium-sized enterprises (SME). By law, the eleven participating federal agencies contribute 2.5 per cent of their budgets to SBIR. SMEs can apply for a $750,000 non-reimbursable grant in two phases to examine the commercial feasibility of academic or public R&D technology. SBIR is considered a milestone program, as evidenced by Japan's copying of it in 1998 (Japan SBRI, 2008). SBIR is not the only program supporting small technology-based firms in the United States. Other similar programs include the Advanced Technology Research Program (ATP) (Wessner, 2001) and the Small Business Technology Transfer Program (STTR).

Successful State Programs for SMEs

It is not only federal programs that support technology-based SMEs in the United States. The state-based Pennsylvania's Ben Franklin

4 One third of the 100 largest Canadian software firms in the 1990s and early 2000s were acquired by foreign corporations (Chagnon, 2007). Alias Research (Toronto), Cognos (Ottawa) and Softimage of Montreal are among the most remarkable cases in software. Allelix (Toronto), Biochem Pharma (Montreal) and ID Biomedical (Vancouver) are among the biotechnology firms. One half of the 1,000 biotechnology firms that were once incorporated in Canada have disappeared since 1980.

Technology Partnerships Program, created in 1986, the Maryland Technology Transfer Fund, and others in different states are useful complements to the above-mentioned federal programs. The report accurately suggests that the poor performance of business services in Canada explains a great portion of the US-Canada BERD intensity gap (Table 1 and Chart 5). Computer software design and services, and scientific R&D services are among them and they represent the vast majority of SMEs. These firms would be among the main beneficiaries of a Canadian SBIR program, and Ben Franklin-type provincial programs.

Fund Starvation

I suggest that the major factor behind the poor growth performance of Canadian new technology-based firms is fund starvation. In order to have large Canadian-owned and -controlled multinational corporations, it would be necessary to financially support these SMEs. The solution may be the renewed engagement of Canada's federal and provincial governments in the backing of new technology-based firms. Compared to most OECD countries, and South East Asian emerging nations, the Canadian government spends too little on business innovation. In order to improve the innovative performance of our business system, the federal and provincial governments need to spend more in support of technology in Canadian smaller firms.

Conclusion

The report is a useful tool for our understanding of Canada's innovation system. It underlines the diminishing role of Canadian governments in the support of business innovation. However, it falls short in terms of public policy recommendations.

When confronted with the risk and uncertainty represented by R&D and innovation, the business sector tends to reduce its investments in such fuzzy areas. Business innovation thus needs to be given incentives from government, in the form of tax credits for R&D, direct subsidies, as well as technology transfer programs from universities and government laboratories. For several decades, Canada was at the forefront of the design and implementation of STI policy. Canada's tax credit for R&D is considered one of the world's most progressive and successful programs, as is the Industrial Research Assistance Program (IRAP), launched in 1962, and managed by the National Research Council (NRC). The last surge of such policies, mostly oriented to stimulate university R&D, took place around the year 2000, with the launching of the Canadian Foundation for Innovation, Genome Canada and the revamping of the Medical Research Council into the Canadian Institutes for Health Research. More recently, however, after the technology bubble, governments have reduced their investment in these key business areas, and the private sector has been left virtually unto itself. It has responded by curtailing BERD, and a significant number of Canadian technology-based SMEs have been acquired or went bankrupt.

In order to renew its set of STI policies for industrial R&D, Canada should examine successful incentives around the world. I suggest it examine such programs as ATP, STTR and SBIR, and contemplate launching a new program, similar to SBIR. This program might be run by Canada's most experienced public sector STI managers, namely those running NRC's IRAP. For that purpose, the federal government should increase NRC budget by 2.5 pr cent to build the first block of a SBIR program.[5] Then, after evaluation and fine-tuning, the program could be extended to other government departments, with the addition of new funds. The Canadian SBIR program should amount to

C$200 million (or one tenth of the US program). Eventually, the federal government should study the possibility of creating other national programs similar to the American ones. Provincial governments should study the Ben Franklin Technology Partnership Program and the several others inspired by Pennsylvania's initiative.

Building policy is slow and needs continuous evaluation and fine-tuning (Niosi, 2000, 2002, 2003 and 2005, Becher and Khulmann, 1994, Feldman and Link, 2001). Such an experimental program needs to be assessed and eventually enlarged in three to four years.

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5 NRC budget for 2008-09 is C$478 million for R&D and C$222 million for industrial support, for a total of C$0.7 billion. Budgets will decline in 2009-10 and 2010-11. A first phase Canadian SBIR, under rules similar to the US program, would cost in 2008-9 C$175 million, and $150 million in 2010-11, if the trend towards federal government disengagement from science, technology and innovation programs continues.

Some Reflections on the Expert Panel Report on Business Innovation in Canada

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ABSTRACT

This article reviews the Council of Canadian Academies Expert Panel report on business innovation. It finds the report comprehensive in its gathering and assessment of available research, innovative, in its own right, in its analysis of innovation as an outcome of business strategy formation, and impressively well ordered and written. Both lay readers and professional students of innovation and labour productivity will find the report to be of great value.

IN 2007, THE GOVERNMENT OF CANADA requested the Council of Canadian Academies (CCA) to canvas the innovation performance of Canadian business, and in particular to shed light on Canada's relatively weak investment among OECD countries in innovation inputs (and the consequent inferior growth in the rate of labour productivity, particularly over the last two decades). The CCA established an Expert Panel to address this request. The resulting report *Innovation and Business Strategy: Why Canada Falls Short*, presents a comprehensive survey of the research literature and a skilful and balanced interpretation of that literature that will instruct both professional and lay audiences. Further, in seeking to advance understanding of Canada's poor performance, the Panel itself innovates in analyzing the possible explanations by examining the factors that can be thought of as influencing innovation as a business strategy. All of this is presented in eleven chapters of inexorable logical flow, the interpretations of the evidence balanced and appropriately qualified, and with a felicity of presentation that is continuously striking. Though issues of measurement and interpretation in matters of innovation and productivity are inherently complex, one would not hesitate to recommend the Panel's report to any intelligent reader seeking to gain command of issues that are of considerable moment in the fortunes of Canada and Canadians.

Peter Nicholson, in the introductory article of this symposium, has summarized the report. The coherence with which the story is told and the care with which it is presented is a central strength of the report. The body of evidence which the Panel surveys and cites to measure the innovative performance of the Canadian business sector and through that performance the alarmingly disappointing growth in labour productivity serves to concentrate the mind, perhaps even those minds aware of many of the elements of the story. After making clear the

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conceptual links between innovation, productivity growth, per capita output, incomes and well-being, the empirical evidence which the Panel gathered has a considerable cumulative weight. The long-run difference in output per capita of roughly 20 per cent relative to the United States, almost entirely due to differing levels of labour productivity, appeared to be sharply narrowing into the mid-1980s as a broad-based convergence of OECD countries with the U.S. seemed to be in train. After peaking at 93 per cent of the U.S. level in 1984, annual labour productivity growth in Canada departed the train, leading to a steady descent to a level less than 80 per cent in 2007, a level not seen since the late 1960s. Further Canada's average labour productivity growth over the same period ranked 15th out of 18 OECD countries. Of this lagging performance around 90 per cent is attributed to the poor performance of multi-factor productivity in the business sector, the residual in the decomposition of labour productivity growth after increasing capital intensity and improvements in the quality of the labour force have been accounted for. Part of the explanation involves the slower investment in information and communication technologies (ICT) by Canadian businesses.

In pursuit of a more comprehensive explanation the Panel devotes a chapter to a thorough examination of the innovation performance of Canadian business. The report presents a rich and sophisticated canvas of what is known about the inputs, outputs and outcomes of business innovation activity. Among the elements examined, machinery and equipment investment, the quality of labour inputs, and an array of output and outcome measures, it is the almost astonishing under-performance of the business sector with respect to research and development expenditure that is at the heart of the story.

Most industries in Canada perform little or no R&D. Business sector R&D expenditures as a percent of GDP (BERD) hobble along at roughly half the US level and rank in the bottom half of relevant OECD countries. When it is estimated that a sustained one-tenth of one percentage point increase in BERD would lead to an increase of 1.2 per cent in GDP per capita, and when it is understood that Canadian BERD levels of approximately 1.0 per cent compare with the US level of 2.0 per cent, it is impossible to escape an explanation of Canadian BERD as a central issue. Further the fact that R&D expenditures are generally thought to carry with them consequential positive externalities underlies two central understandings of why private sector R&D may be underdone and why there is a substantial rationale for public policy involvement. To the public policy issues this review will return.

The report then seeks to broaden examination of the possible factors affecting business sector innovation performance by focussing discussion on innovation as business strategy. The Panel, with justification, sees the attempt to direct the discussion in this way as a substantially innovative contribution to the understanding of the behaviour of Canadian firms. Under five headings — structural characteristics, competitive intensity, climate for new ventures, public policies, and business ambition — the report addresses successive chapters to broadening understanding of the factors influencing firm behaviour. While the discussions under each head are again thorough and provide persuasive elements of understanding, one is left with the sense that the diagnosis is unsettlingly insufficient.

Though the Panel takes care to describe the total body of its work as 'a diagnosis' rather than a policy prescription, it recognizes that the body of facts and informed opinion that it offers are of 'policy relevance'. In fact, unless one's professional preoccupation is directed exclusively at understanding, it is difficult to read the Panel's report without continuously reflecting on its policy implications. And, indeed, it is difficult not to feel that the Panel embeds its analysis in approved Canadian policy postures of the last two decades and is itself a little baffled that the private sector's performance has been so disappointing. Controlled inflation, deregulation of product and labour markets, very sharp reductions in the program expenditures of the federal government and with that reduction a dramatic decline in the overhang of public debt, a scientific research tax credit as rich as any among OECD countries, all the fundamental prescriptions of three decades of neoliberal economics do not appear to have yielded any very measurable payoff.

To be perhaps a little unkind, though the report approves the potential complementarities between government and academic research, it generally seems to approve of low tax regimes (recognizing that all taxes are disincentives) without any very full discussion of the 'civilization' that taxes buy, affecting the context in which business ventures proceed. Further the existence of complementarities carries with it the notion of public and academic R&D supporting private sector innovation. Though well outside the Panel's mandate to explore, it may be that progressively impinging social limits to private growth may require an increasing share of Canadian R&D to be shouldered by the public sector as public rather than private goods come to dominate future enhancement of the well-being of Canadians.

However that may be, the Panel does recognize that its presumption of globalization proceeding apace where the well-being of Canadians is critically dependent on the competitive aspects of private-sector productivity growth may have to be conditioned by the dramatic collapse of growth currently in progress. There seems little doubt that this collapse, however and whenever growth is resumed, will lead to a substantial reaction to the policy structures of the past 30 years and the probable acceptance of a much expanded role for government. This probability is further enhanced by the steadily increasing evidence that climate change will compel governments to confront much more radical policy responses than so far contemplated. One does not have to believe the well known UK scientist James Lovelock (www.jameslovelock.org), that the collapse of world population to the neighbourhood of one billion by 2100 is already foregone to believe that the ascending evidence, as in the Stern Report, commends much more dramatic action. Once again the Panel makes reference to the relevance of climate change issues without embedding their imperatives in the analysis.

Both because these developments could be said to have overtaken the Panel's report and because the Panel clearly eschewed a direct concern with the report's policy implications, it is not to be critical of the report to suggest that these two issues —recession/depression and climate change — may be said to offer the opportunity to confront some of the issues which the report cites as inhibiting private sector innovation. One begins with the Finnish model, the rapid transformation of a resource-driven economy to one dedicated to R&D and innovation, which the report cites. It further suggests that the government/public sector/private sector understandings and commitment needed to implement such a rapid transformation is only possible with a much more homogeneous population and culture than Canada offers.

The notion that the lack of the possibility of a cohesive public understanding precludes public/private sector collaboration in Canada has been often asserted, particularly with respect to the possibility of industrial policy or more elaborate welfare structures. In part, of course, this may be thought of as reflecting the influence of a competing model to Canada's south. In part it reflects an industrial structure which, as the panel notes, places much Canadian private sector activity 'high up the value chain', either as subsidiaries of foreign parents, or in the extractive industries, content with up-stream profits and disinclined to invest in complementary and down-stream activities. Given sufficient urgency however, it can be argued that there is little evidence of an incapacity in Canada to mount concerted action. It can be further argued that the growing urgency of an elaborate response to global warming will demand not only the pricing of carbon (by whatever scheme) but invention and innovation across the broad waterfront of alternate energy systems, less damaging extractive industries (e.g. carbon capture) and revolutions in transportation. Indeed it may be that Canada's continued reliance on resource exports to offset its disappointing productivity record will depend on finding urgent solutions to the global warming impacts of their production. Beyond particular fixes, one might think of Canada as having some sort of comparative advantage in leading such revolutions, turning necessity to opportunity, and beginning the long trek to serious sustainability designs.

Such concerted action, both through structures of public policy and more explicit collaboration, may be made more conceivable by the need to find investment expenditures that can provide the underpinnings for the climb from the deepest economic trough since the 1930s. The 'new and better ways to do valued things' (the Panel's definition of innovation and the sources of the next 'bubble') may demand more explicit collective resolve than reliance exclusively on private markets. The world has been launched on a soul-searching, not just around the reformation and regulation of financial systems and institutions, but also to revisit the dominant faith in private markets in shaping public policy over the past 30 years. It may even be that 'share-holder value' will cease to be the sole criterion by which enterprises are judged and a rising importance of longer-term considerations and social purpose may elevate the role of 'innovation as a business strategy'.