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Productivity and Economic Performance

An Overview of the Issues

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Contents

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Executive summary

One of the most hotly debated policy issues in Ottawa these days is whether or not Canada has a productivity problem. The official line of the federal government is that Canada does not have a productivity problem. Politicians at the highest level of the country have stated publicly that they think that Canada's productivity performance has been satisfactory. But, studies released by several organizations—including the Organisation for Economic Co-operation and Development (OECD), the Centre for the Study of Living Standards, and even one of the federal government's own ministries, Industry Canada—have made the opposite claim, that Canada does indeed suffer from very poor productivity and, without major improvements here, Canada's living standards are in jeopardy.

This study provides a non-technical overview of the issues surrounding the debate about productivity and discusses why productivity growth is essential if Canadians want a high and rising standard of living. Productivity refers to the efficiency with which an economy transforms inputs (capital and labour) into outputs (goods and services). A more productive economy requires fewer inputs to produce a given amount of output. Most economists would agree that growth in productivity—being able to produce more with less—is necessary for increases in per-capita income over the long term. Developed countries are wealthier than Third-World countries precisely because they are more productive. Estimates suggest that productivity growth accounts for one-quarter to one-third of the increase in real living standards in the period since World War II. It is for this reason that productivity growth is the cornerstone of economic growth and wealth creation.

After surveying the relevant literature and examining the empirical evidence, I find that Canada's productivity performance has indeed been poor. In particular, the data reveals that Canada's productivity growth has been among the worst in the OECD since the 1970s. Moreover, Canada is the only G-7 country to experience negative productivity growth during the period from 1979 to 1996. As a result, real income per capita has stagnated: during the 1990s, Canada's per-capita income dropped from third to ninth place among OECD countries. This is why Industry Canada and other observers believe that Canada has very poor productivity.

While there is much disagreement about the productivity statistics themselves, it cannot be that Canada's poor productivity performance is simply "measurement error." In this study, I discuss the problems associated with productivity measurement and find that Canada's poor productivity is not merely a statistical artifact. While the rapidly growing services sector may have resulted in Canada's productivity growth being underestimated, this cannot explain Canada's poor productivity performance relative to other OECD countries—in particular, the United States—that have also experienced growth in the service sector. In addition, Canada's manufacturing productivity growth has been the weakest among G-7 countries. The annual growth rate of output per hour in Canada's manufacturing sector from 1979 to 1996 was 1.8 percent a year while the growth rate in the G-7 was 3.2 percent a year. This is cause for serious concern, for the theoretical and empirical literature supports the view that manufacturing productivity growth has important spill-over effects for the economy as a whole.

To date, little attention has been given by researchers to examining the policy issues surrounding the productivity debate. Nonetheless, it is clear that if advancing the standard of living of Canadians is indeed the objective of government policy, then the role of the state is to provide an institutional environment that is conducive to the creation and diffusion of new knowledge and new technologies—the very sources of productivity growth. This, in turn, requires an institutional framework that rewards individual effort and entrepreneurial activity. While Canada is a nation with fine institutions, it is becoming increasingly clear that without certain reforms—in particular, tax reform and more deregulation—Canada will fall behind other industrialized countries. For one thing, Canada's current tax structure is not conducive to the accumulation of inputs of higher quality—more productive machines and equipment and more highly educated personnel. There is growing evidence that high marginal tax rates on personal and capital income have imposed large dynamic efficiency losses on the economy. Additionally, many studies suggest that, in the absence of significant reductions in personal income-tax rates, Canada will lose many of its best and brightest innovators to the United States. Hence, a necessary ingredient in an economic policy that will encourage the growth of productivity is a reduction in marginal tax rates on personal and capital income.

Introduction

Recently the economics of productivity has become a hot topic among Canadian politicians and policy-makers. Evidence of a growing gap between Canadian and American per-capita income has sparked concern about the economic prospects of Canada over the long term. In particular, many observers feel that Canada's lagging productivity growth is responsible for the stagnant performance of the Canadian economy. Many of these commentators believe that, in the absence of sustained growth in productivity, Canadians will not be able to enjoy a high and growing standard of living in the future (see OECD 1998; Sharpe 1998; Policy Research Initiative 1999; HCSCF 1999; *Globe and Mail* 1999).

Interest in the economics of productivity and growth has also increased among academic economists. In the past 20 years, important academic economists have increasingly focused their attentions on growth theory (see *Journal of Economic Perspectives*, Winter 1994). Measurement of productivity change, and the role of technical progress in the growth process is of paramount interest (see Canadian Journal of Economics, April 1999). There is now a plethora of theoretical and empirical papers on the subjects of economic growth and endogenous technological progress in the academic economics journals. Much of the current public debate on productivity growth in Canada has been framed in terms of this literature.

At present, there is much disagreement among academic economists about the relevance of many of the new theoretical models of growth. In addition, the empirical literature does not tend to offer robust conclusions in support of one theory or another. The only conclusion that does appear to be accepted across studies is the problem of measurement: the reliability of our current measures of productivity are suspect given the poor quality of our data. Hence, increasingly, economists have tried to improve the existing stock of data (Griliches 1994).

In spite of these disagreements, however, most economists would argue that the focus on productivity growth is warranted, for it is almost universally agreed among economists that growth in productivity is essential for a sustained increase in the material standard of living of Canadians. Ultimately, productivity growth is what produces the wealth of nations. Industrialized nations like Canada and the United States owe much of their wealth to productivity growth. A slowing in the rate of the growth of productivity will necessarily imply a decline in the rate at which living standards improve. Hence, politicians and policy-makers who care about the long-term prospects for Canadian living standards are justified in being concerned about productivity growth.

The purpose of this study is to provide a non-technical overview of the issues surrounding the debate about productivity and to discuss why productivity growth is important if Canadians want a high and rising standard of living. To do this, I will first describe how economists determine the sources of growth and what this growth accounting implies about the importance of technological change for long-term growth. This will be followed by a brief outline of various theoretical growth models and their implications and by an examination of the data with a particular focus on the Canadian experience. I will then outline what the recent empirical literature has to say about the Canadian experience. A short policy discussion will follow.

Growth accounting: determining sources of economic growth

To motivate an understanding of why productivity growth is so important for a sustained increase in real per-capita incomes, I will briefly discuss how economists determine the sources of economic growth. This is an essential exercise, for a thorough understanding of the concept of productivity growth requires us to define rigorously what productivity is and how it contributes to economic growth. Although this approach—called growth accounting—is not without flaws, it is instructive to start here to illustrate some basic concepts that are essential to the economics of growth.

Central to our analysis is the reality that in an economy, firms take factor inputs such as labour, capital, and raw materials and convert these inputs into desirable outputs—goods and services. The relationship between factor inputs and outputs can be summarized mathematically by what economists call a production function. A production function is a purely technological relation that tells us the maximum output that an economy could produce using a given amount of inputs. Formally, a production function could be written as follows:

$$Y(t) = A(t)F\,[K(t), L(t)] \qquad (1)$$

where $Y(t)$ is output at time t, $K(t)$ is the stock of capital (i.e. machines and equipment) at time t, and $L(t)$ is labour (i.e. the total number of people working or the total time worked) at time t. Hence, output in period t is produced by combining capital and labour in the function F with some object $A(t)$ (which we will define shortly). It is useful to think of F as the technology for putting capital and labour together. Economists generally assume that the function F is increasing in both K and L. That is, the more capital or labour employed, the more output produced. If workers work harder or the economy accumulates more capital (i.e. firms accumulate more machines and equipment), total output rises.

The variable $A(t)$ is defined as total factor productivity. The higher the value of $A(t)$, the more output a given amount of capital and labour can produce. Therefore, as $A(t)$ increases, the economy is able to produce more and more output from a given stock of labour and capital inputs. When economists speak of productivity growth, this is essentially what they mean—the growth rate is the economy's ability to produce output from a given stock of input. In ordinary parlance, one can think of productivity growth as "working smarter" rather than "working harder." While it is true (from the discussion above) that working harder (i.e. increasing the stock of labour or capital) will increase total output, the total factor productivity of an economy only increases if people "work smarter" and learn to obtain more output from a given supply of inputs. "Working smarter" therefore corresponds to an increase in $A(t)$.

It is important to note that in popular discussions, different definitions of the term "productivity" are employed. For instance, journalists for the business press often speak of productivity in terms of average labour productivity (i.e. output per worker, or Y/L). While average labour productivity is an important indicator for measuring the economic well-being of the average worker, it provides an incomplete measure of the productivity of the economy as a whole, since, according to our framework, increases in both capital and labour input will increase total output. A rising ratio of output per worker may not necessarily

indicate growing productivity throughout the economy, since growth in output per worker could be entirely due to an increase in the available stock of machinery and equipment (i.e. an increase in the capital stock) rather than an increase in $A(t)$. In other words, average labour productivity is a poor indicator of economy-wide productivity since increases in the ratio of output per worker could be entirely due to agents in the economy "working harder" (i.e. accumulating more capital) rather than "working smarter."

What causes total factor productivity $A(t)$ to rise over time? Improvements in technology—the invention of the internal combustion engine, the introduction of electricity, of semiconductors—clearly increase total factor productivity. With better machines, tools, and equipment, it is possible to use labour and capital more efficiently. Improvements in the education and skill of the labour force also cause $A(t)$ to rise since more skilled workers may work more efficiently with capital inputs than less skilled workers. Organizational change may also induce growth in total factor productivity. More efficient ways of motivating workers to perform productive tasks, improvements in teamwork and so on will result in increases in total factor productivity. Additionally, the institutional environment plays a critical role in determining the overall productivity of the economy. Countries where corruption is rampant or where basic infrastructure is inadequate are likely to have much slower (possibly negative) growth rates in total factor productivity. Conversely, countries with a stable legal and political framework that rewards investment and innovation are likely to have faster rates of total factor productivity. This list of factors that influence the growth rate of total factor productivity $A(t)$ is certainly not exhaustive but it does point out a few of the channels through which public policy may affect productivity performance.

Productivity is the cornerstone of economic growth. We are wealthier than our ancestors and our Third-World neighbours largely because we are more productive than they are. Productivity also affects our position relative to other developed countries in the world: the more productive we are in Canada, the higher our per-capita GDP is in the world rankings. In other words, productivity is the reason why the developed world enjoys a standard of living higher than that of the Third World today or that of the developed world one hundred years ago (Mokyr 1990; Lipsey 1996).

To illustrate why this is so, it is first necessary to develop a theoretical framework to determine the sources of economic growth. The relationship between the economy's inputs and outputs can be represented by a production function, which tells us that we can get more output for three reasons: (i) because people are working harder or more people are working (higher L); (ii) because workers have more tools and equipment to work with (higher K); or (iii) because labour and capital are combined more efficiently (higher A). My objective is to determine how much each of these factors contributes to total output growth. That is, I want to decompose the growth rate of total output into components due to each of these three elements. This is what economists call growth accounting.[1]

To do this requires that one assume a particular functional form for the production function. As is standard in this literature, I will assume that the production function takes the following algebraic form:

$$Y(t) = A(t)K(t)^{x}L(t)^{1-x} \qquad (2)$$

where $0 < x < 1$. A production function of this form is called a *Cobb-Douglas production function*.

1 See Barro and Sala-i-Martin 1995: ch. 10 for a more detailed discussion of growth accounting.

Cobb-Douglas production functions have a number of convenient economic properties. For our purposes, it is sufficient to note that a Cobb-Douglas production function embodies the assumption of constant returns to scale (i.e. if we double our inputs of labour and capital, we double total output). Furthermore, it can be shown that for a Cobb-Douglas production function, the exponent x corresponds to capital's share of total output. For most industrialized countries like Canada or the United States, x is approximately 30 percent, or 0.3. Conversely, labour's share of total output is 70 percent, or 0.7 (Hall, Taylor, and Rudin 1995).

To perform growth accounting, it is necessary to do a bit of tedious algebra. Since my goal is to provide a non-technical overview of the issues, I will not formally derive the results here. Interested readers can see Appendix 1 for the algebraic details. After doing the algebra, however, it is possible to obtain the following expression:

$$\Delta Y(t)/Y(t) = \Delta A(t)/A(t) + x[\Delta K(t)/K(t)] + (1-x)[\Delta L(t)/L(t)] \quad (3)$$

For any variable $Z(t)$, $\Delta Z(t)/Z(t)$ is the growth rate (i.e. the percentage increase) of Z between periods t and t–1. Thus, $\Delta Y(t)/Y(t)$ denotes the growth rate of real output, $\Delta A(t)/A(t)$ denotes growth rate of total factor productivity, $\Delta K(t)/K(t)$ is the growth rate of the capital stock, and $\Delta L(t)/L(t)$ is the growth rate of the stock of labour. Hence, equation (3) says that the growth rate of output is equal to the growth rate of total factor productivity plus a weighted sum of the growth rate of the capital stock and the growth rate of the stock of labour. This is the fundamental growth accounting equation for it tells how the growth rate of real output can be partitioned into the growth rates of its component parts.

In principle, the growth rates of output ($\Delta Y/Y$), the capital stock ($\Delta K/K$), and the stock of labour ($\Delta L/L$) are measurable over any interval of time. Moreover, as noted earlier, the variable x is capital's share of total output. For Canada, the value of x is roughly 0.3. Hence, the only variable that is not directly measurable is $\Delta A/A$, the growth rate of total factor productivity. Note, however, that knowledge of all the other variables enables us to estimate total factor productivity's growth rate ($\Delta A/A$). In particular, by solving equation (3) for $\Delta A/A$ it is possible to find the growth rate in total factor productivity as a residual of the other growth rates. That is, I can compute the growth rate of total factor productivity by using the following expression:

$$\Delta A(t)/A(t) = \Delta Y(t)/Y(t) - x[\Delta K(t)/K(t)] - (1-x)[\Delta L(t)/L(t)] \quad (4)$$

All empirical estimates of total factor productivity growth are obtained by using these means. Total factor productivity growth is not a variable that can be measured directly. However, through growth accounting, it is possible to measure the total factor productivity growth indirectly as a residual of our measurable growth rates. Solow (1957) was one of the first economists to use this procedure; hence, estimates of total factor productivity growth are sometimes called estimates of the Solow Residual.

Qualifications

A few qualifications regarding this estimation process should be noted. The first is that, since total factor productivity growth is a residual, measurement error in any of the observable growth rates will affect estimates of total factor productivity growth. For instance, if the growth rate of the labour force or the capital stock is underestimated, then measured total factor productivity growth will be biased upwards (i.e. overestimated). If output growth is underestimated, then total factor productivity growth will be biased

downward (i.e. underestimated). Hence, empirical estimates of productivity growth are only as good as the underlying data.

Another important fact that should be noted is that, since total factor productivity growth is not directly measurable, it is an inherently vague magnitude. In a sense, total factor productivity growth is a catch-all expression for everything that affects growth but cannot be observed. Many economists believe that estimates that find a large value for total factor productivity growth reveal our ignorance about the sources of economic growth (Griliches 1994; Solow 1994). Knowing that total factor productivity growth is important may not tell us very much, since it is not quite clear exactly what "total factor productivity" is. As noted earlier, there are many factors that could influence total factor productivity growth. Simply measuring the magnitude of this variable does not tell us what underlies it.

One should also bear in mind that the enigmatic nature of total factor productivity growth is the source of some confusion in discussions about the sources of economic growth. For instance, an improvement in the quality of labour (due, say, to an increase in the average skill level of workers) is not directly measurable. In addition, improvements in the quality of the existing stock of capital are not easily measured. It is not obvious whether such improvements in input quality should be attributed to productivity growth or simply input growth (should we count more skilled workers as simply more workers, i.e. larger L, or productivity improvement, i.e. larger A?). In practice, most researchers attempt to incorporate quality change into our measures of inputs but nevertheless this ambiguity should be emphasized.

A final, technical, digression should be made before we move on. Often one is interested in accounting for the growth rate in per-capita output rather than the growth rate of total output. This is motivated by the fact that improvements in material living standards are much better approximated by using output per capita than total output. With little change to the underlying growth-accounting framework, it is possible to account for growth rate in per-capita output. Dividing the Cobb-Douglas production function by $L(t)$, the stock of labour, yields an expression for output in per-capita terms:

$$Y(t)/L(t) = A(t)[K(t)/L(t)]^x \qquad (5)$$

Define $y(t) = Y(t)/L(t)$ and $k(t) = K(t)/L(t)$. Following a procedure similar to that outlined in Appendix 1, I can decompose the growth rate of output per worker ($\Delta y(t)/y(t)$) as follows:

$$\Delta y(t)/y(t) = \Delta A(t)/A(t) + x[\Delta k(t)/k(t)] \qquad (6)$$

Equation (6) states that output per worker can rise for two reasons: (i) total factor productivity $A(t)$ is rising, and (ii) the amount of capital per worker ($k(t)$) is increasing. Notice, however, that the impact of the growth rate of capital per worker on the growth rate of output per worker is scaled down by x, capital's share of total output. Hence, a one-percentage increase in total factor productivity has a larger impact on the growth rate of output per worker than a one-percentage increase in the ratio of capital per worker.

Empirical growth accounting: what do the data tell us?

Productivity is the cornerstone of real economic growth: productivity growth distinguishes wealthy economies from poor economies. Economist Robert Solow first noted this fact in the late 1950s. Applying the tools of growth accounting, Solow (1957) found that the growth rate of total factor productivity accounted for a large portion of American economic growth since the Second World War. More recent estimates by Edward Denison (1985) and Dale Jorgenson (1990) confirm this fact, although the importance of total factor productivity in more recent studies is somewhat smaller as the more recent studies use better measures of "effective" labour and capital inputs (i.e. they incorporate quality improvement in their measures of input supplies). Some of the key findings from Denison (1985) and Jorgenson (1990) are displayed in table 1.

Table 1: Sources of American economic growth (average annual growth rates, in percent)

	1929–1948	1948–1973	1973–1982	1929–1982
Labour Growth	1.42	1.40	1.13	1.34
Capital Growth	0.11	0.77	0.69	0.56
Total Input Growth	1.53	2.17	1.82	1.90
Productivity Growth	1.01	1.53	–0.27	1.02
Total Output Growth	2.54	3.70	1.55	2.92
Source: Denison 1985: table 8.1.				
	1973–1979	**1979–1985**	**1947–1985**	
Labour Growth	1.39	0.89	1.12	
Capital Growth	1.40	0.98	1.45	
Total Input Growth	2.79	1.87	2.57	
Productivity Growth	-0.67	0.34	0.71	
Total Output Growth	2.12	2.22	3.28	
Source: Jorgenson 1990: table 1.				

Growth in the United States

The data in table 1 reveal a few important "stylized facts" regarding American economic growth. One is that productivity growth accounts for a fairly significant portion of total output growth over the sample period. According to Denison, the average annual growth rate of real GDP for the United States from 1929 to 1982 was 2.92 percent. Denison estimates that 1.02 percent—approximately one-third—of this growth was due to improvements in total factor productivity. Output growth during the post-war period from 1947 to 1985 occurred at an average annual rate of 3.28 percent. According to Jorgenson, 0.71 percent—slightly less than one-quarter—of this growth rate can be attributed to total factor productivity growth. The differences between Jorgenson's and Denison's estimates are due to two main factors—different sample periods and different ways of measuring the quality of the capital stock and the labour force. The basic message is clear: total factor productivity growth is an essential ingredient for sustained growth in real incomes. Total factor pro-

ductivity growth accounts for approximately one-quarter to one-third of the increase in American output since World War II. America would be a much poorer country if there were no total factor productivity growth. Hence, "working smarter" definitely pays.

Another stylized fact highlighted by the table 1 is that total factor productivity growth does not appear to be constant over the post-war period. Table 1 shows that total factor productivity declined from an annual average growth rate of 1.53 percent from 1947 to 1973 to –0.27 percent from 1973 to 1982. Jorgenson estimates that from 1973 to 1979, total factor productivity grew at an annual rate of –0.67 percent. This sharp reduction in productivity growth is dubbed the "productivity slow-down." Economists worry about developments like this because a slow-down in productivity growth implies lower material living standards in the long run. Hence, the "productivity slow-down" has been the subject of significant economic research. I will return to this topic later.

Growth in Canada

The Canadian experience mirrors the American in a number of respects. According to Nason's back-of-the-envelope calculations, Canadian real output grew at an average annual rate of 3.1 percent from 1960 to 1985 (Nason 1994). He attributes 0.81 percent of this annual growth rate to total factor productivity growth, 0.96 percent to growth of the capital stock, and 1.33 percent to increases in the stock of labour (which reflects increasing participation in the labour force by women). According to these numbers, total factor productivity growth is responsible for about one-quarter of total output growth in Canada since 1960. Canada would be much poorer today in the absence of total factor productivity growth—it is only by "working harder" and "working smarter" that Canada has been able to attain its current living standard. Like the United States, Canada also experienced a "productivity slow-down" during the 1970s though, unlike most other industrialized countries, Canada's total factor productivity growth rate did not recover during the 1980s and 1990s (see below, page 18). Nason (1994) estimates that total factor productivity growth was positive for only three years from 1975 to 1985 period. Imagine how much higher Canadian output would be today if productivity had not slowed during the 1970s and 1980s.

International evidence

The international evidence reveals similar trends in total factor productivity growth. Among most industrialized nations, total factor productivity growth accounts for a significant portion of total output growth. This suggests that productivity is important for improvements in material living standards over the long term. Moreover, during the 1970s, productivity growth rates declined significantly in most of these countries. Table 2 displays total factor productivity growth rates since 1960 in the countries of the Group of Seven (G-7). The productivity slow-down appears to be an international phenomenon. There has been some recovery in total factor productivity growth rates during the 1980s and 1990s but, by and large, total factor productivity growth rates have not been restored to their immediate post-war levels.

Table 2: Total factor productivity growth in the G-7 countries (average annual growth rates, in percent)

	1960–1996	1973–1979	1979–1996
United States	2.5	0.1	0.5
Japan	5.7	1.1	1.1
Germany	2.6	1.8	0.6
France	3.7	1.6	1.3
Italy	4.5	2.0	1.1
United Kingdom	2.6	0.6	1.5
Canada	2.0	0.6	–0.2

Source: OECD 1997: annex table 58.

Growth theory: the causes of economic growth

Understanding the sources of economic growth is important. Our central concern, however, is with the causes of economic growth and it is difficult to say much about that without a theory of growth. Hence, in this section I will briefly discuss developments in the theory of economic growth over the past few decades. In the subsequent section, I will discuss this theoretical work in the Canadian context, and review some of the more recent empirical studies. I will attempt to keep the discussion as non-technical as possible. More technically minded readers are advised to read Barro and Sala-i-Martin 1995.

Neoclassical growth models

Although most analysts would date the birth of the modern theory of economic growth to the 1950s, the classical economists—Adam Smith, David Ricardo, and Thomas Malthus—were the first to discuss many of the basic ingredients of modern growth theory.[2] In particular, their emphasis on competitive behaviour, equilibrium dynamics, and the impact of diminishing returns on the accumulation of labour and capital are integral elements of what is called the neoclassical approach to growth theory. During the 1950s, this approach to understanding growth was formalized by Solow (1956) and Swan (1956), and was later extended by Cass (1965) and Koopmans (1965). The basic assumptions underlying the neoclassical growth model are as follows.

- The productive capacity of the economy can be adequately characterized by a constant-returns-to-scale production function with diminishing returns to capital and labour.[3]

- Firms are price-takers in a competitive market place. In other words, no individual firm has any influence over market prices and individual firms are assumed to possess no market power.

- Technological change (i.e. productivity growth) is entirely exogenous (i.e. independent of the actions of the consumers and producers) and is available to all countries at no cost.

The implications of the neoclassical model of growth are straightforward. The first major implication is that sustained increases in per-capita income can be supported only by sustained increases in total factor productivity. In this model, output per worker can rise only if (a) the ratio of capital per worker increases or (b) total factor productivity increases. Since this model assumes diminishing returns to capital, there is a limit to how much capital accumulation can add to output per capita. Hence, the only way to increase output per worker in the long run is to have sustained productivity growth. This is a major weakness of the neoclassical growth model, since long-run growth is exogenous, i.e. determined by an element that is entirely outside of the model.

2 Many economists date the birth of modern growth theory in the 1920s with Frank Ramsey's (1928) seminal article on optimal savings over time.

3 As we noted earlier, constant returns to scale implies that a doubling of inputs doubles output (i.e. if the firm uses twice as many machines and twice as many workers, it produces twice as much output). Diminishing returns to, say, capital implies that as we add more capital (holding fixed the number of workers), we get more output but each additional unit of capital adds less to output than the previous unit.

The second major implication of this model is the "conditional convergence thesis," which states that economies with lower initial levels of real output per worker relative to the long-run level should experience faster economic growth. This property follows from the assumption of diminishing returns to capital: the lower the ratio of capital per worker, the higher the return to investing in capital. Hence, the lower the ratio of capital per worker, the faster the rate of capital accumulation and the faster the growth rate of output per worker. This implies long-run convergence in output per capita. Convergence is said to be conditional here since the long-run level of capital per worker and output per worker depend on the saving rate, the growth rate of the population, and the existing technology—factors that are unlikely to be identical across countries. The convergence thesis is strengthened by the assumption that all countries can acquire technological progress at no cost.

Endogenous growth models

For several decades, the neoclassical growth model remained the benchmark model of economic growth. Starting in the 1980s, however, a number of newer, more sophisticated growth models have been developed. A key feature of these new models is that, unlike the neoclassical model, technological change is not assumed to be exogenous. Hence, the new growth models are sometimes dubbed "endogenous growth models" since a key task in these models is to explain where technologically driven productivity growth comes from. In particular, the accumulation of knowledge plays a key role in driving productivity growth in these models.

There are essentially two strands in the endogenous growth literature. The first strand takes its cue from articles by Romer (1986) and Lucas (1988).[4] In this variety of endogenous growth theory, the assumption of constant returns to scale is dropped. In particular, knowledge is assumed to be an input of production with increasing returns to scale.[5] In this class of models, it is possible for per-capita output to grow without bound. In addition, convergence of per-capita incomes need not occur in the long run. A survey of some of the developments in this area can be found in Romer 1994.

The second strand of endogenous growth models also takes its departure from an article by Romer (1990) but has been extended by other economists such as Grossman and Helpman (1991), Aghion and Howitt (1992), and others. In these models, an effort is made to model the microeconomic environment in which firms accumulate knowledge. In particular, the assumption of perfect competition is dropped. This is because the acquisition of knowledge through research and development activity is costly and can only be rewarded if firms have some *ex post* market power.[6] Hence, in these models, firms are assumed to compete in a monopolistically competitive environment. As in the first class of endogenous growth models, per-capita output growth can occur without bound since there need be no tendency for the economy to run out of ideas. Furthermore, convergence across countries need not occur in the long run.

4 In fact, these papers have antecedents in an earlier literature pioneered by Arrow (1962) and Sheshinski (1967).

5 In these models, knowledge enters the production function as an input, just as capital and labour do. Hence, the production function can now be written as $Y = F[L, K, I]$ where Y is real output, L is the stock of labour, K is the capital stock, and I is the stock of knowledge. The assumption of increasing returns to scale in knowledge implies that an increase in I will result in a more than proportionate increase in Y.

6 This idea—that firms compete in the production of knowledge and that market power is necessary for technological advance—was first articulated by Schumpeter (1934) and is called the process of "creative destruction."

Much of the new research also includes models of the diffusion of technology (see Grossman and Helpman 1994 for a survey of this literature). As we noted earlier, in the neoclassical model it was simply assumed that technological change could be adopted at no cost by all countries. In many of the newer growth models, this assumption is dropped and an effort is made to analyze directly how technological progress is transferred across countries. One important implication of this research is that the location of research and development (R&D) activity may matter. If there are significant agglomeration effects associated with R&D activity, then the benefits of R&D are largely captured by the country in which R&D activity takes place.[7]

Another key feature of the endogenous growth models is that the long-run growth rate can depend on government actions. In the basic neoclassical growth model, government does not have an impact on the long-run growth rate. In an endogenous growth framework, however, government policy can affect the long run rate of growth, since government policy actions—taxation, provision of infrastructure, protection of intellectual property, regulations, maintenance of law and order, and so on—can affect the underlying rate of inventive activity. Government, therefore, has great potential for harm or good in these models.

Empirical tests of the models

In recent years, significant empirical work has been conducted to test a number of the predictions of both the neoclassical and endogenous models of growth. Tests of the neoclassical model have focused on the conditional convergence thesis and the results have generally been mixed. While most studies reject the hypothesis of convergence across all countries, many find support for convergence across more homogenous subsets of countries or regions. For instance, Baumol (1986) finds support for the convergence thesis among OECD countries, while Barro and Sala-i-Martin (1991, 1992a, 1992b) find support for the convergence thesis across American states, regions of several European countries, and prefectures of Japan.

Much empirical work has also been done to test a weaker version of the convergence thesis. This weaker convergence thesis posits that convergence should occur among countries, holding constant such factors as initial levels of human capital, measures of government policy, political stability, and so on. The broadest cross-country sample supports this weaker form of the convergence thesis (see Barro 1991; Mankiw, Romer and Weil 1992). These studies find that the rate of convergence is about two percent per year. This implies that it takes about 35 years for an economy to eliminate half of the gap between its initial level and its long-run level of per-capita income.

Most other tests of modern growth theory take the form of regression analysis using data from a broad sample of countries. In these studies, variations in the growth rates of the per-capita GDP of these countries are analyzed for statistically significant association with a number of variables including the initial level of per-capita income,

7 Loosely speaking, agglomeration effects arise when there are positive locational spill-overs associated with a particular industry. Agglomeration effects are often used to explain the clustering of firms in the same industry in particular locations—for instance, the clustering of high technology firms in Silicon Valley. Firms in the same (or similar) industry may benefit from locating near each other since, by being in close proximity, they can gain from (i) increased interaction that facilitates the transfer and development of ideas; (ii) economies of scale in the production of industry-specific infrastructure; (iii) the presence of a large pool of skilled personnel. See Krugman 1991 for an overview of some of this work; see also Grossman and Helpman 1991.

the initial quantity of human capital approximated by the average years of schooling, the ratio of government consumption expenditures to total output, measures of political stability, measures of market distortion by government, measures of openness to international trade, and the ratio of gross investment to output. Across many studies we find that growth seems to be positively related to human-capital attainment, negatively related to government consumption, positively related to the investment-to-output ratio, positively related to measures of openness to international trade, negatively related to measures of market distortion (i.e. economies with more extensive market distortions grow more slowly) and positively related to political stability (i.e. more politically stable countries experience faster growth). Measures of economic freedom also appear to be positively related to economic growth (see Gwartney, Lawson, and Block 1996). Using Mankiw, Romer and Weil's (1992) model, Easton and Walker (1997) estimate that increases in measured economic freedom raise the steady-state level of per-capita income.[8] Other studies find that investment in research and development is also positively related to growth (see Coe and Helpman 1993), lending support to some of the basic ideas behind the endogenous growth literature.

There are several weaknesses to this approach to testing growth theory. One major flaw, which has been identified by Pack (1994) among others, is that these studies do not test the growth model under consideration directly. The problem with an regression analysis of growth that uses data from a sample of several countries is that such analysis can only identify correlations among the relevant variables. It does not tell us the direction of change nor does it test directly the growth process under investigation. Hence, definitive conclusions in support of one model or another cannot be drawn from these studies.

Another major weakness to this approach is that many of the variables that appear to be significant in regression analysis of growth using data from a sample of several countries do not survive sensitivity testing. Levine and Renelt (1992) conduct a sensitivity analysis of regression analysis of growth in a sample of several countries and find that very few variables appear to be consistently related to growth across different regression-equation specifications. In particular, they find that the only variable that appears to be robust across regressions is the investment-to-output ratio; none of the broad array of fiscal-policy variables and very few of the variables from trade policy and political stability that we have considered are robustly correlated with growth in per-capita income. Thus, the meaningfulness of much of the empirical work on growth theory remains in question. As is common in economics, the theoretical work in the economics of growth is far ahead of the empirical work.

Conclusions about economic growth

A few broad conclusions can be drawn from this brief overview of the economic growth literature.

While endogenous and neoclassical growth models offer different explanations for the growth process, in both models, growth in total factor productivity (i.e. technological change) is an essential component of economic growth. In the neoclassical model, technological progress is

8 In particular, Easton and Walker (1997) estimate that an increase of one standard deviation in economic freedom (as measured by The Fraser Institute's Economic Freedom Index) raises the steady-state level of income by US$1,556. See Gwartney, Lawson and Block 1996 for more details about the construction of The Fraser Institute's Economic Freedom Index.

essential for long-run growth in per-capita output. In endogenous growth models, productivity growth results from spill-overs from human capital accumulation or inventive activity and this is what generates long-run growth in per-capita income. Hence, productivity growth—"working smarter" as opposed to "working harder"—is an essential component of overall economic growth.

Straightforward capital accumulation and population growth is not sufficient for sustained growth in per-capita income. In the neoclassical model, the law of diminishing returns limits the extent to which raw factor accumulation can raise per-capita income. The emphasis, therefore, should be on accumulation of inputs of superior quality. The accumulation of capital and labour will increase the long-run rate of economic growth if this capital embodies more sophisticated technology and if workers are more skilled.

The development of new technologies and their diffusion across firms and nations are critical components of the growth process (Mokyr 1990; Lipsey 1996). Productivity-enhancing technological change does not fall from the sky. It is the result of purposive inventive activity on the part of economic actors. Hence, the incentives for individuals and firms to innovate and create new products, machines, tools, and production techniques is critical. In addition, it is costly for other economic agents to adopt new technologies. Clearly, a country that is able to adopt new technologies faster is able to grow faster. Moreover, if agglomeration effects are present, the location of R&D activity will matter, with countries that are host to R&D activity reaping the largest gains. Hence, the location and diffusion of technological progress across firms and nations are almost important as technological change itself.

Institutional factors—government regulations, taxes, provision of basic infrastructure, political stability, etc.—clearly matter for long run economic performance (see North 1990). This is because the accumulation of factors of production and the development of new technologies do not occur in a vacuum. Rather, economic exchange and production occurs in the real world where the incentives matter. How public policy is set over the long run will therefore influence productivity growth and economic growth since public policy is a critical determinant of the institutional environment.

Productivity growth and economic performance in Canada

In recent years, Canadian economists in universities, government agencies, and private think-tanks have devoted considerable attention to productivity growth and measurement, the diffusion of technology across countries and firms, the role of the international sector in transmitting technological progress, the impact of different fiscal-policy regimes on long-term growth, and a variety of other related topics. Most of the research is empirical in nature and focuses on the Canadian economy.[9]

Before proceeding, however, I think it important to show why Canada has a productivity problem. To do this, it is essential to compare productivity performance in Canada with the rest of the world. The structure of this section will therefore be as follows. I will begin by discussing how Canada's productivity growth and economic performance fare relative to the rest of the developed world. I will then examine recent research that highlights some of the difficulties in measuring productivity performance. I conclude here that, while our estimates of Canadian productivity growth are imperfect, the Canadian productivity slow-down is not entirely a statistical artifact. This will be followed by an overview of some of the work being conducted by scholars in government, the academy, and elsewhere on various aspects of the slow-down in Canadian productivity.

Canada and the developed world

The data in table 3 below shows business-sector productivity growth rates in the OECD countries over a variety of sample periods. Two productivity indexes are displayed. The first three columns show average annual growth in total factor productivity and the last three columns show the average annual growth rates of average labour productivity (i.e. growth rate of output per worker). While the former measures economy-wide productivity, the latter is a better measure of how much living standards have increased for the average worker.

The data in table 3 reveal a few very disturbing trends. In terms of the total factor productivity growth rate, Canada does not fare very well among the OECD countries. While most countries experienced slower total factor productivity growth during the 1970s (the so-called "productivity slow-down"), Canada was one of the few for which total factor productivity growth did not recover during the 1980s and 1990s. Indeed, from 1979 to 1996, Canada was one of only three countries to experience negative growth in total factor productivity. Among the G-7 countries (Canada, Japan, France, Germany, Italy, the United States, and the United Kingdom), Canada's total factor productivity growth was the most sluggish over the entire sample period. Hence, to the extent that one believes these estimates (more on this later), this data suggests that Canadian productivity growth has been languishing over the past two decades.

In terms of average labour productivity growth, Canada also fares relatively poorly. The annual growth rate of average labour productivity declined in Canada from 1.5 percent in the 1970s

9 For a readable survey of some of the work undertaken for Industry Canada on these topics, see Policy Research Initiative 1999: ch. 2. Sharpe 1998 also provides an excellent summary of this work.

Table 3: Average annual productivity growth rates in the OECD countries, in percent

	Total factor productivity			Average labour productivity		
	1960–1996	1973–1979	1979–1996	1960–1996	1973–1979	1979–1996
Australia	2.2	1.1	0.8	3.3	2.4	1.3
Austria	3.1	1.1	0.8	3.3	2.4	1.3
Belgium	3.8	1.3	1.2	5.3	2.7	2.1
Canada	**2.0**	**0.6**	**–0.2**	**2.9**	**1.5**	**1.0**
Denmark	2.3	0.9	1.2	3.9	2.4	2.1
Finland	4.0	1.9	2.6	5.0	3.2	3.5
France	3.7	1.6	1.3	5.3	2.9	2.2
Germany	2.6	1.8	0.6	4.5	3.1	1.1
Greece	2.5	0.7	–0.3	9.0	3.3	0.6
Ireland	4.5	3.4	2.8	5.0	4.0	3.4
Italy	4.5	2.0	1.1	6.4	2.8	2.0
Japan	5.7	1.1	1.1	8.4	2.8	2.2
Korea	n/a	3.0	2.6	n/a	6.6	5.6
Netherlands	3.5	1.7	1.1	4.9	2.6	1.6
New Zealand	1.5	–1.4	1.1	2.1	–1.1	1.3
Norway	2.3	1.4	0.2	3.8	2.7	1.6
Portugal	4.1	–0.7	1.0	7.5	0.5	2.4
Spain	3.2	0.9	1.6	6.0	3.3	2.8
Sweden	1.9	0.0	1.1	3.7	1.4	2.0
Switzerland	2.2	–0.2	–0.1	3.3	0.9	0.4
United Kingdom	2.6	0.6	1.5	3.9	1.5	1.9
United States	2.5	0.1	0.5	2.6	0.3	0.8

Source: OECD (1997): annex table 58.

to 1.0 percent in the 1980s and 1990s. Among the G-7 countries, Canada also had one of the lowest average labour productivity growth rates. Hence, the productivity improvements of the average Canadian worker appear to be low relative to other countries.

As noted earlier, most studies suggest that slow productivity growth should result in slow increases in the material standard of living. This is borne out by the data. Table 4 below shows the percentage growth in real GDP per employed person in 13 OECD countries. Real GDP per employed person increased by only 4.3 percent in Canada from 1989 to 1996, compared to an increase of 6.5 percent in the United States, 9.8 percent in Japan, and 23 percent in Norway. Canada ties the Netherlands for the slowest growth in real GDP per employed person among these countries.

Another way to illustrate how the slow-down in productivity growth in Canada has taken its toll on material well-being is to examine per-capita GDP in Canada relative to other countries. Table 5 shows GDP per capita as a percentage of American GDP per capita in 1989 and in 1996 for the same 13 OECD countries. While almost every other country improved its per-capita GDP relative to the United States between 1989 and 1996, Canada's per-capita GDP relative to the United States actually declined, from 81.7 percent to 76.7 percent. The only other country to register a de-

Table 4: Percentage increase in real GDP per employed person in 13 OECD Countries

	1989–1996
Austria	13.4
Belgium	12.2
Canada	**4.3**
Denmark	18.2
France	9.9
Germany	14.3
Italy	13.4
Japan	9.8
Netherlands	4.3
Norway	23.0
Sweden	15.2
United Kingdom	11.2
United States	6.5
Source: Sharpe 1998: chart 2.	

Table 5: Real GDP per capita as percentage of the American level in 1989 and 1996.

	1989	1996
Austria	73.3	76.3
Belgium	75.3	77.6
Canada	**81.7**	**76.7**
Denmark	74.8	77.6
France	74.6	74.8
Germany	79.4	81.7
Italy	69.8	71.6
Japan	76.5	81.9
Netherlands	69.7	72.4
Norway	78.4	90.8
Sweden	72.3	68.0
United Kingdom	69.7	69.4
United States	100.0	100.0
Source: Sharpe 1998: table 3.		

cline in this statistic is Sweden. Hence, it appears that the material well-being of the average Canadian is slipping relative to that of the United States and other countries: Canada's position has fallen from first place (behind the United States) in 1989 to sixth place in 1996.[10]

It should be noted, however, that not all analysts unequivocally accept this evidence of a productivity slow-down in Canada.[11] Indeed, as I discussed earlier in the section on growth accounting, conventional measures of total factor productivity are only as good as the quality of the underlying data. If measurements of input and output growth are biased in some way, then estimates of productivity growth will also be biased.

Measuring productivity growth

The measurement of productivity growth has been studied widely. (For a very detailed discussion of the measurement issue, see Diewert and Fox 1999.) To show briefly how the measurement problem can arise, it is instructive to examine productivity growth in Canada on a sectoral basis (i.e. industry by industry). So far, my discussion of productivity has been at an aggregate level. Aggregate productivity growth is, of course, a weighted sum of industry-level productivity growth. The data in table 6 below, which was compiled by the Centre for the Study of Living Standards, shows productivity growth rates in Canada by industry from 1984 to 1996. The

10 Indeed, according to the Policy Research Initiative 1999, Canada's relative living standards among OECD countries, measured by GDP per capita, have fallen from third place in 1979 to ninth place in 1996.

11 In particular, the official repsonse of Jean Chretien's government is that Canada does not have a productivity problem. Citing as evidence some of the findings from a recent KPMG study (1999), the Prime Minister has argued that this is so because Canada has the lowest overall business costs among the G-7 nations. This view is problematic for the KPMG study is a cost-comparison study not a productivity study. For a critique of the official government view, see Appendix 2.

Table 6: Average annual productivity growth rates in Canada by industry, from 1984–1996, in percent

	Total Factor Productivity	Average Labour Productivity
Agriculture	5.64	3.06
Fishing and trapping	6.36	2.40
Forestry and logging	3.44	3.25
Mining	0.93	3.25
Manufacturing	–0.57	0.8
Construction	–1.12	–2.31
Transportation and storage	1.48	0.66
Communication and other utilities	1.30	0.14
Trade	1.49	2.28
Financial, insurance, and real estate sector	–3.21	0.56
Community, business, and personal services sector	–0.82	–0.49
Government services	–0.80	–0.92
Total business sector	0.65	0.48

Source: Sharpe 1998: table 5.

first column reports the average annual growth rate of total factor productivity while the second column reports average annual labour productivity growth rates.

According to these estimates, both average labour productivity growth rates and total factor productivity growth rates vary significantly by industry. In particular, we observe very rapid productivity growth in some of the traditional sectors of the economy (e.g. agriculture, fishing and trapping, forestry and logging), moderate productivity growth in transportation and storage and communications and other utilities, and sluggish to negative productivity growth rates in manufacturing, financial services, and community, business, and personal services. Why does productivity growth differ so widely from sector to sector?

One might think that investment in new capital equipment—capital equipment that embodies new productivity-enhancing technologies—has been faster in those sectors that have experienced faster productivity growth. A quick glance at the evidence refutes this explanation. Capital accumulation—particularly the accumulation of new information technology—has been fastest in those industries that have experienced the slowest rates of productivity growth, in particular, the financial services sector (Sharpe 1998). Hence, industries showing slow productivity growth have not been growing slowly because of a lack of investment in new capital and equipment; they appear to be growing slowly in spite of the rapid accumulation of new capital. This, of course, is a re-statement of the "computer paradox" of productivity measurement.[12]

Another explanation for sluggish productivity growth in these sectors is that our measurements of output in the service sector—financial and insurance services, community, personal, and business services—are inherently problematic.

12 Sharpe 1998 provides an excellent discussion of this issue. For lack of space, we shall not discuss it further in this paper.

For instance, output in the banking industry is measured by the spread between lending rates and borrowing rates. Is this the basis of an adequate measure of productivity? The services provided by these industries are inherently difficult to measure. From an economic standpoint, it might be desirable to measure the output of, say, the insurance industry, as the increase in utility insurance provides the consumer by reducing his exposure to risk. However, this is not a measurable quantity. Most scholars agree that service sector output is seriously underestimated by traditional national income accounting measures. Hence, estimates of service sector productivity are also significantly underestimated. Since the service sector now accounts for a very large (and growing) fraction of total output, this underestimate of service sector productivity will result in an underestimate of economy-wide productivity.

While measurement error may explain much of the slow-down in productivity due to the service sector, however, it does not entirely account for sluggish productivity growth in the manufacturing sector, which has more readily measurable output. Total factor productivity growth in the manufacturing sector was negative from 1984 to 1996 while average labour productivity grew at a slow rate of 0.8 percent per year. According to Sharpe (1998), productivity growth in the manufacturing sector in Canada has been the weakest among the G-7 countries. Growth of output per hour from 1973 to 1996 averaged 1.8 percent a year in Canada compared with a G-7 average growth rate of 3.2 percent a year. Hence, measurement error alone cannot explain Canada's poor performance.

Indeed, the fact that all countries use roughly the same methods to estimate output growth in the service sector implies that service sector growth in all countries is biased downward. Since the growing importance of the service sector is not unique to Canada but is rather a trend reflected among nearly all industrialized countries, the measurement problem should have a more or less symmetrical impact on all countries. Hence, if the measurement problem accounts for a portion of the slow-down in productivity growth in Canada, it also accounts for a portion of the slow-down of productivity growth in other industrialized countries. What it does not account for, however, is the slow-down in Canadian productivity relative to these other countries. The fact that productivity growth, however measured, has fallen in Canada relative to other OECD countries is, therefore, evidence of a specifically Canadian productivity problem.

Sources of Canada's productivity problem

According to the Policy Research Initiative (1999), the major source of Canada's poor productivity performance relative to the United States is the manufacturing sector. As we noted earlier, total factor productivity growth and labour productivity growth in the Canadian manufacturing sector has been among the worst in the OECD. New growth theory suggests that investments in knowledge-related goods are a major source of productivity advance because of the spill-overs associated with such investments (see Sargent and James 1997). Since the manufacturing sector is a major source of such investments, most empirical research on Canada's productivity performance has focused on this sector.

Positive spill-overs from knowledge-related investments in the manufacturing sector have been found in most Canadian studies. Gera, Gu, and Lee (1998a) find that investments in information and communications technology have a larger impact on productivity growth in the manufacturing sector than other types of physical capital. They estimate that the rate of return on such investments is generally higher than the

rate of return on investment in physical capital. Investment in human capital is also an important source of productivity advance. Baldwin and Sabourin (1996), for instance, find that those firms that train their workers enjoy higher productivity growth than those firms that do not. New innovations that raise productivity are often found in new capital investment. According to Gera, Gu, and Lee (1998b), capital accumulation is major channel through which new technology is adopted. In particular, they note that capital accumulation is an important channel through which Canadian firms catch up with their American counterparts.

The new growth theory also suggests that domestic R&D activities should also contribute to productivity growth. Gera, Gu, and Lee (1998b), and Lee and Tang (1998) have found empirical evidence of this direct linkage. Gera, Gu, and Lee (1998a) and Bernstein (1998) have also uncovered evidence of an indirect linkage between R&D expenditures abroad and Canadian productivity growth. These authors find that R&D expenditures in other countries spill over into Canada through international trade and foreign direct investment.

Most of the recent research suggests that much of the slow-down in Canadian manufacturing productivity performance can be attributed to a weakening of some of these channels through which knowledge-related investment finds its way into productivity advance. Slower rates of capital accumulation in Canada relative to the United States have contributed to a widening of the productivity gap between these two countries since new technology is usually embodied in new capital investment. R&D investment is much lower in Canada in spite of very generous R&D tax incentives. Additionally, foreign direct investment in Canada has fallen in recent years, resulting in a slow-down in international R&D spill-overs. Furthermore, there is evidence that the small size of Canadian firms precludes extensive investment in new technology and extensive human capital investment. Some of the major results from this research are highlighted below.

Results

Lee and Tang (1998) estimate that the productivity gap (in favour of the United States) in the manufacturing sector has widened from 22 percent in the period between 1985 and 1988 to 30 percent in the period between 1993 and 1995. They attribute the growth of this productivity gap to the slow-down in capital accumulation in the Canadian manufacturing sector. The net manufacturing capital stock declined by 1.3 percent per year in Canada between 1990 and 1997, compared to a growth rate of 1.7 percent per year in the United States. Since productivity gains are often embodied in new capital investment, the result has been a slow-down in Canadian manufacturing productivity.

According to the Policy Research Initiative (1999), Canada's share of inward foreign direct investment in North America has declined significantly since the mid-1980s. Hirschhorn (1997) argues that Canada derives significant benefits from foreign direct investment since: (a) technology transfer is much faster within multinational firms rather than through licensing or other external agreements; (b) the higher average productivity of foreign affiliates has a positive impact on Canadian total factor productivity; and (c) the highly productive nature of direct foreign investment has a positive impact on economic growth and job creation. The reduction in Canada's share of inward foreign direct investment may therefore be cause for concern.

Industry Canada (1997) has found that American businesses invest almost twice as much in R&D as Canadian businesses relative to the size of the

economy. In 1995, R&D investment as a percentage of GDP was 1.7 percent in the United States but 0.9 percent in Canada. A larger share of the American work force is devoted to R&D activities. Patent applications in Canada by Canadians (per person) are much fewer than the corresponding American statistic.[13] Gera, Gu, and Lee (1998a) report that R&D performance in Canada is lower in nearly all industries, particularly in those industries that make up a large portion of the Canadian economy.[14]

Canadian firms appear to lag American firms when it comes to adopting new technologies. Sabourin and Baldwin (1997) find that in several industrial sectors, Canadian plants were less likely to use advanced technology than American plants. They attribute this to the smaller average size of Canadian firms. This, in turn, may be linked to Canada's smaller market.

13 According to Industry Canada (1997), foreigners seeking patent protection within Canada make most of the patent applications in Canada. Patent grants to foreigners out-number grants to Canadians by a factor of 12.

14 It is not unambiguously clear whether the location of R&D activity matters for an open economy like Canada's. If technological progress is cheaply available to all countries and there are no agglomeration effects, then whether R&D activity occurs in Canada or elsewhere is irrelevant. However, as I discussed earlier, in a world where technological transfer is costly and where there may be significant agglomeration effects associated with R&D activity, then the location of R&D activity matters. The empirical evidence suggests that the latter may be a better description of the real world. See Krugman (1991) for a summary of some of this work.

What next? Prospects for policy and research

There appear to be several factors contributing to Canada's poor productivity performance. How much each factor matters quantitatively is still debatable: the evidence accumulated so far suggests that no single factor dominates the others and this, of course, is largely due to the fact that empirical work on these issues is still in its infancy. It is encouraging that Canada's productivity slowdown is a major topic among academic and non-academic researchers at present although very few of the studies completed to date discuss the role that public policy plays in determining the rate of productivity growth. A few studies have been released that attempt to grapple with some of the policy implications of the productivity problem in a very general manner. An overview of some of the more frequently cited of these studies is provided in Appendix 2. However, as most of these studies are fairly non-technical, a professional consensus on the optimal policy response has yet to emerge. In the absence of greater professional consensus, definitive policy analysis is difficult.

Nonetheless, it is possible to draw a few conclusions from which some policy stance can be derived. While experts may disagree about which growth model best describes the growth process, few would disagree with the fact that technological progress is what ultimately drives growth. The accumulation of factors—bringing more people into the workforce, investing in more of the same machines and equipment—can only go so far in promoting economic growth. Canada's House of Commons Standing Committee on Finance (HCSCF 1999) makes this point quite forcefully in its recent report on productivity.

> History shows us that economic growth is not simply about achieving efficiency in a static sense. Nor is it purely a matter of using more labour or more capital. Economic growth is much more about changes in technology, allowing us to produce new goods and services and produce them in new and innovative ways. It is about invention and innovation, scientific experimentation and new management techniques. (HCSCF 1999: 29)

Thus, the key to economic progress is technological change. If advancing the living standards of Canadians is indeed the objective of government policy, then the role of government is to create an institutional environment that is conducive to the creation and diffusion of new knowledge and technologies. This, in turn, requires an institutional framework that rewards individual effort and entrepreneurial activity. Hence, analysis of how public policy affects productivity advance should focus on how policy influences the environment in which productive economic activity takes place. Future research on how policy affects productivity performance should, therefore, concentrate on the linkages between the institutional setting, the incentives in place, and the pace of productivity advance.

Most economists would likely agree that international trade and competition are important indirect determinants of productivity growth. I noted earlier that several studies find the international sector to be an important source of productivity growth. In addition, it should be noted that the increased competition brought about by free trade is also an important determinant of productivity growth. According to Trefler (1999), the Free Trade Agreement between Canada and the United States enhanced the productivity of those

sectors that saw their tariff protection reduced. Increased international competition forces firms to adopt more efficient production methods, to increase the scale of their operations, and to innovate in both production techniques and product lines. As Richard G. Lipsey writes: "Competition among three or four large firms often produces more innovation but a single firm, especially if it serves a secure home market protected by trade barriers, seems much less inclined to innovate" (Lipsey 1996: 4). Firms exposed to international competition must introduce new technologies in order to compete effectively in the world marketplace. In addition, access to a large international market enables firms to increase their output and thereby take advantage of economies of scale. Hence, a policy of open international trade will raise economic growth because competition helps to foster an environment in which productivity growth may emerge.

Another policy lever through which government policy affects productivity growth and economic performance is taxation. Taxation affects productivity growth indirectly by changing the incentives faced by economic actors. By changing relative prices, taxes influence the way consumers and firms save, invest, consume, and produce. In so doing, taxes affect productivity growth and long-run economic performance.

Hence, another reason for Canada's poor productivity growth is the Canadian government's heavy reliance on taxes that impose large distortions on the Canadian economy. Relative to other OECD countries, Canada imposes high personal and capital taxes, and low consumption and labour (i.e. payroll) taxes. Emes and Walker (1999) compare the composition of total tax revenues in several industrialized nations. According to table 8.1 (Emes and Walker 1999: 85), income and profit taxes (i.e. personal and capital taxes) raise 47.3 percent of total tax revenue in Canada, compared to an OECD average of 37.7 percent. In contrast, social security taxes (i.e. payroll taxes) and goods and services taxes (i.e. consumption taxes) make up only 16.3 percent and 24.9 percent of total tax revenues in Canada. The corresponding OECD averages are 25.1 percent and 32.5 percent respectively. According to Kesselman (1999) and Mintz (1999), this mix of taxes is inefficient as capital and personal income taxes impose the largest dynamic efficiency losses on the economy. High marginal tax rates for personal income and capital income create the largest disincentives to save and invest—activities that are key to productivity advancement and long-run economic growth. In contrast, the dead-weight losses introduced by consumption and payroll taxes are very small.[15] Hence, reductions in marginal tax rates on personal income and capital income are an important element of a fiscal policy that encourages productivity growth.

Most economists would also agree that the skill level of the labour force is an additional determinant of productivity advance. Highly skilled workers are generally highly paid, are more flexible, and are better able to adjust to a changing knowledge-based economy. In addition, highly skilled workers are better able to innovate and take advantage of opportunities in the growing knowledge-based sectors of our economy. How government policy affects the supply of skilled workers is, therefore, another way by which public policy affects productivity growth.

Among OECD countries, Canada's labour force ranks well in terms of years of education (OECD 1998). Most observers agree that Canadian workers are among the most skilled in the industrialized world. Canada has the highest post-secondary enrolment rate among OECD nations. Additionally, public expenditures in education in

15 For a comparison of the dead-weight losses of various taxes in Canada, see Dahlby (1994).

Canada, as a share of GDP, are one of the highest in the OECD. Hence, policy proposals that call for increased public funding for higher education and training are unlikely to be effective as measures to raise Canada's productivity performance.[16]

There is growing concern, however, that the high rate of personal income tax in Canada is inducing an exodus of Canada's most highly skilled (and also most mobile) personnel. Whether or not Canada suffers from a "brain drain" is one of the most hotly debated policy issues of the day.[17] Nevertheless, a few important points need to be made. One is that, relative to the United States, Canada is not competitive with respect to personal income taxes. Personal marginal tax rates are higher in Canada than in the United States and take effect at a substantially lower level (Emes and Walker 1999). Hence, the private pecuniary gains from moving to the United States are large for many of Canada's most skilled workers. The existence of such large after-tax earnings gaps may therefore provide indirect evidence of a brain drain.

Another important point to be made is that, while the aggregate figures are difficult to interpret, it is clear that there is an exodus to the United States of skilled workers in many key sectors. According to the Conference Board of Canada (1998), Canada loses four times as many engineers as it receives in return, nine times as many health professionals, almost six times as many management professionals, and two and one-half times as many professors and teachers. Thus, small changes in the aggregate supply of skilled workers may mask large compositional shifts.

Small changes in the aggregate supply of skilled personnel in Canada may conceal the departure of the very best and brightest young Canadians. As the HCSCF (1999) notes, New York law firms recruit about one-half of all "A" students from Osgoode Hall Law School. Since innovation, invention, and entrepreneurial activity depend very much upon particular individuals, the loss of Canada's best and brightest ought to be a major policy concern.

16 The fundamental problem is, therefore, not insufficient investment in higher education and training but, rather, a misallocation of investment, likely brought about by widespread government intervention in the market for higher education and training. See West 1988 for a critique of government policy toward higher education.

17 For an overview of the economics of the brain drain, see Grubel 1998. Devoretz and Laryea (1998) estimate the value of human capital flows into and out of Canada and find that Canada's brain drain to the United States is economically costly.

Appendix 1 The algebra of growth accounting

Recall that we start with the assumption that the production function for the economy takes the following Cobb-Douglas form:

$$Y(t) = A(t)K(t)^{x}\, L(t)^{1-x} \tag{A1}$$

We also assume that $0 < x < 1$. To perform growth accounting, we do the following. First, take the natural logarithm of both sides of the Cobb-Douglas production function to get the following expression:

$$\log(Y(t)) = \log(A(t)) + \log(K(t)^{x}) + \log(L(t)^{1-x}) \tag{A2}$$

Using the fact that $\log(Z^{b}) = b(\log(Z))$, we can re-write (A2) as follows:

$$\log(Y(t)) = \log(A(t)) + x(\log(K(t))) + (1-x)(\log(L(t))) \tag{A3}$$

If we lag this expression by one period (i.e. write it in terms of t–1 rather than t) we obtain the following:

$$\log(Y(t-1)) = \log(A(t-1)) + x(\log(K(t-1))) + (1-x)(\log(L(t-1))) \tag{A4}$$

Subtracting equation (A4) from equation (A3) gives us:

$$\begin{aligned}\log(Y(t)) - \log(Y(t-1)) = {} & \log(A(t)) - \log(A(t-1)) + x(\log(K(t))) - \mathrm{x}(\log(K(t-1))) + \\ & (1-x)(\log(L(t))) - (1-x)(\log(L(t-1)))\end{aligned} \tag{A5}$$

It can be shown that the log difference of a variable is approximately equal to its growth rate. That is, for any variable $Z(t)$, we know that $\log Z(t) - \log Z(t-1) \cong (Z(t) - Z(t-1))/(Z(t)$, which is simply the percentage increase (i.e. the growth rate) in Z between t and t–1. Denoting $\Delta Z(t)/Z(t)$ as the growth rate of $Z(t)$, we can write equation (A5) in terms of growth rates:

$$\Delta Y(t)/Y(t) = \Delta A(t)/A(t) + x(\Delta K(t)/K(t)) + (1-x)(\Delta L(t)/L(t)) \tag{A6}$$

Equation (A6) is the fundamental growth accounting equation. It tells us that the growth rate of real output ($\Delta Y(t)/Y(t)$) is equal to the growth rate of total factor productivity ($\Delta A(t)/A(t)$) plus a weighted sum of the growth rates of the capital stock ($\Delta K(t)/K(t)$) and the stock of labour ($\Delta L(t)/L(t)$).

Appendix 2 Overview of recent policy papers on productivity

In this Appendix, I briefly discuss a few of the major policy studies that have been released to date. In particular, I will give an overview and a critique those studies that have been most frequently cited in public discussions about Canada's productivity.

OECD Economic Surveys 1997–1998: Canada

One of the first studies to highlight Canada's poor productivity was produced by the Organisation for Econmomic Cooperation and Development (OECD 1998). In this study, Canada's poor total factor productivity performance is documented. The study attributes Canada's poor productivity to several factors, including unused capacity, low rates of capital accumulation, low levels of research and development, and poor labour mobility across regions. The study also notes that relative to the United States and other nations of the OECD, Canada has a large number of small- and medium-sized enterprises that appear to be less internationally oriented and less innovative than their foreign counterparts. The OECD recommends that Canada improve its productivity performance by: (i) a reduction in its relatively high tax burden and a lowering of marginal income tax rates; (ii) a reduction in both interprovincial and international trade barriers; (iii) an increased focus on the acquisition of skills and training as well as innovation.

Factors such as the slow rate of capital accumulation, the large number of small- and medium-sized enterprises, poor factor mobility and low levels of research and development have probably contributed to Canada's poor productivity growth. Policy measures such as reduced tax rates and reductions in trade barriers—both international and interprovincial—will likely help boost Canada's productivity performance. However, a greater emphasis should be placed on reducing Canada's capital taxes—which are high by international standards—for capital accumulation is key to technological progress and productivity advance. Moreover, the overall tax mix should be shifted away from highly distortionary capital and income taxes and toward less distortionary consumption taxes (see Kesselman 1998). Such measures would increase the dynamic efficiency of the economy and raise the rate of productivity advance.

While an increased focus on training and skills acquisition are important in a knowledge-based economy, it is not clear that Canada can do much in this regard as educational attainment in Canada is already high by international standards. As the OECD (1998) notes, Canada already invests heavily in education and training as measured by the proportion of GDP Canada spends on formal schooling. The problem is, therefore, not insufficient investment in training and higher education but, rather, a misallocation of investment brought about by widespread government intervention in the higher education and training market (see West 1988). Less government intervention in the market for training and higher education would likely improve the allocation of resources and thereby raise productivity growth over the long term.

Productivity with a Purpose: Improving the Standard of Living of Canadians (House of Commons Standing Committee on Finance)

The House of Commons Standing Committee on Finance (1999) takes a view of Canada's faltering productivity similar to that of the OECD. In this paper, the HCSCF discusses the importance of productivity advance for increases in long-run living standards and gives an overview of the causes and consequences of Canada's low productivity. The HCSCF also offers some policy measures that could be adopted to improve Canada's productivity performance. These include: (i) reducing the ratio of debt to GDP and maintaining a low interest rate and a low inflation rate; (ii) reducing marginal income tax rates (in particular, elimination of the 5 percent surtax) and changing the corporate tax system to make it more neutral; (iii) enhancing tax support for training, higher education and research, and development activities; (iv) increasing reliance on market forces through reductions in both international and interprovincial trade barriers and through less government intervention in the marketplace.

As I discuss throughout this paper, productivity advance is what drives long run improvements in material standards. Hence, the HCSCF's focus on productivity growth is sound. The policy recommendations made by the HCSCF are also sensible. Reductions in the debt-to-GDP ratio will allow tax rates to fall over time, thereby reducing the efficiency losses induced by high marginal tax rates. Changing the tax mix—in particular, reducing marginal income tax rates and capital taxes—will also improve the dynamic efficiency of the economy as such taxes deter investment in productivity-enhancing capital accumulation. It is doubtful, however, that enhanced tax support for training, higher education, and research will improve Canada's productivity performance significantly. As Palda (1993) notes, Canada's R&D tax-support system is already among the most generous in the world. Moreover, Canada's labour force is highly educated compared with other industrialized nations (OECD 1998): there is sufficient investment in the market for higher education and training but it is misallocated as a result of government intervention. Hence, what is required here is less, rather than more, government intervention in the market for higher education and training.

Papers from Industry Canada

Industry Canada has released several papers dealing with Canada's productivity problem. In its major summary paper, *Sustaining Growth, Human Development, and Social Cohesion in a Global World* (Policy Research Initiative 1999), Industry Canada provides an excellent non-technical overview of Canada's productivity problem. Most of the results from Industry Canada's research program have been discussed at length in this paper already and I will not reiterate those findings here. While some of these results point to possible avenues for policy, no policy recommendations are made in this paper.

In a subsequent document, however, Industry Canada does discuss some of the policy options available to enhance Canada's productivity growth (Gherson 1999). In particular, the need for reduction of both personal and business taxes to improve productivity growth is discussed

at length. In this paper, Industry Canada argues that lower business taxes would help encourage firms to invest more in state-of-the-art plant and equipment. Lower business taxes would also encourage more foreign direct investment in Canada, which could bring with it more technological know-how. Lower personal income taxes would raise the return to investing in additional training and skills for Canadian workers and thereby increase the level of human capital. Since more skilled workers are better able to adjust in a dynamic, knowledge-based economy, the result will be enhanced productivity performance.

Productivity: Key to Success (Centre for the Study of Living Standards)

The Centre for the Study of Living Standards has also released papers dealing with Canada's low level of productivity and its policy implications. *Productivity: Key to Success* (Sharpe 1998) provides an excellent non-technical overview of Canada's productivity problem. In addition, Sharpe discusses the problems associated with productivity measurement and pays special attention to the so-called "computer paradox" of productivity measurement. Sharpe argues that Canada has a unique productivity problem that is apparent in Canada's poor performance in manufacturing productivity. Sharpe also offers a few policy suggestions. Like the HCSCF, Sharpe discusses the importance of a stable macroeconomic environment with low real interest rates and points to the importance of increased public support for training, higher education, and research and development. He also argues that increased reliance on market forces will likely raise productivity performance but he does not believe the impact will be large.

Unlike the OECD and the HCSCF, however, Sharpe is skeptical about the impact of tax reductions or changes in Canada's overall tax mix on productivity performance. In particular, he argues that Canada's corporate tax burden is already very low from an international perspective and that the gains to be had from reducing taxes are small.

While Sharpe does produce valuable insights into the nature and causes of Canada's productivity problems, I take issue with some of his policy conclusions. Sharpe is too dismissive of the need for fundamental tax reform and, in particular, the need for a change in the overall tax mix away from capital and personal income taxes and toward consumption taxes. High personal marginal income tax rates and high rates of capital taxation deter entrepreneurial activity and capital accumulation—activities that raise the long run productive capacity of the economy. Moreover, Sharpe is simply incorrect in his assertion that Canada's corporate tax burden is low from an international perspective. According to Jack Mintz, the average corporate tax rate among industrialized countries is 34 percent, far below Canada's general corporate tax rate of 43 percent (Mintz 1999). Mintz estimates that, by next year, Canada will have the second highest general corporate tax rate among all OECD countries. In addition, he notes that Canada's knowledge-based service sectors—sectors that are key to productivity advancement and economic growth—face the highest overall business tax rates among the G-7 nations. Hence, there is a pressing need for fundamental tax reform in Canada.

The Competitive Alternatives: A Comparison of Business Costs in North America, Europe and Japan (KPMG)

In recent public statements, both Prime Minister Jean Chetien and Finance Minister Paul Martin have argued that Canada's productivity is not lower than it should be. In support of their position, both the Prime Minister and the Minister of Finance have cited the study recently released by KPMG (1999). According to this study, which compares business costs in all G-7 countries as well as Austria, Canada takes the top position as the country with the lowest overall business costs. The study finds that, over nine major industries, overall business costs in Canada are 7.8 percent lower than costs in the United States, 14.6 percent lower than costs in Germany, and 24.4 percent lower than costs in Japan.The Chretien government claims that lower business costs imply that Canada is an attractive place to invest and infer, therefore, that Canada does not have a productivity problem.

This inference is incorrect. Productivity and cost competitiveness are related but not identical concepts. Productivity refers to the efficiency with which an economy transforms inputs—labour and capital—into useful outputs (i.e. goods and services). A more productive economy requires fewer inputs to produce a given quantity of output. Cost competitiveness, in contrast, is simply a ranking of the amount it costs in a given currency to produce a given amount of output in a particular country at a given point in time. While more productive economies are likely to have lower business costs, other factors, such as the exchange rates, tax rates, and regulations will also affect costs. Moreover, while productivity growth tells us something about how material living standards are likely to evolve over time, cost comparisons tells us nothing about the future. KPMG's cost comparison study tells us only how much it costs to do business in various countries today.

In the KPMG study, costs in each country are measured in current American dollars. Hence, fluctuations in the exchange rate will affect each country's position in the ranking. A quick glance at the KPMG study reveals that one major source of Canada's cost competitiveness is the low value of the Canadian dollar (relative to the American dollar).[18] According to the study, Canada's cost advantage over the United States vanishes if the Canadian dollar appreciates to US$0.79 or higher. Many economists estimate that the purchasing power parity value of the Canadian dollar is roughly US$0.82. Hence, an appreciation of the Canadian dollar to its estimated long-run value would eliminate Canada's cost advantage relative to the United States. To draw broad conclusions about the future performance of the Canadian economy from a cost-comparison study can therefore be seriously misleading.

18 Industry Canada (1999) has also emphasized this point. They write: "The improvement in Canada's cost competitiveness vis-à-vis the US in the 1990s has been entirely due to a depreciating Canadian dollar."

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