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DETERMINANTS OF CANADIAN PRODUCTIVITY GROWTH: ISSUES AND PROSPECTS

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1. OVERVIEW

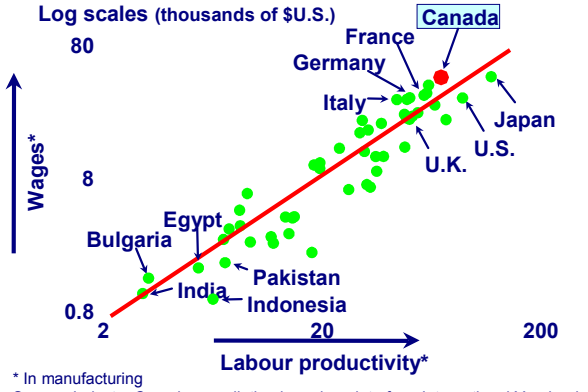
The theme of this conference is the future of the Canadian economy. This paper is about one particular aspect of that vision — the future for productivity growth in Canada. Given the high profile of the productivity debate in the last year, what was once a relatively arcane subject to most people is now daily grist for the editorial and business pages of our newspapers. Talk of a productivity crisis and various counterpoints to this argument have become commonplace. In this paper, I will try to step back somewhat from the current debate and take a broader look at what economists know, or think they know, about productivity growth, and how this knowledge might shape our views about the future for economic growth in Canada. Obviously one cannot know with any great certainty what the future will bring. Nevertheless we can say with somewhat more precision what are likely to be important potential developments, either positive or negative for productivity growth and thus living standards in Canada. The paper will first review the theory and empirical evidence and then go on to a forward looking perspective on productivity growth in Canada in the coming decades. Finally, I will offer some opinion as to how productivity considerations should enter in the formulation of economic policy.

The organization of the paper is as follows. Chapter 2 discusses some of the basic theory and measurement issues, with references to the recent Canadian and international debates on productivity. Two themes are covered. First, the link between productivity and living standards. Here we draw out the links between other determinants of living standards such as labour force participation and terms of trade changes, with an emphasis on productivity growth as the most important long term permanent determinant of living standards. Second, a discussion of the relationship between theory and measurement in light of the widespread use of the concept of multifactor productivity, and lastly a review of the on-going measurement debate as to whether and how well economists can actually measure outputs and inputs. Chapter 3 turns to a discussion of the empirical literature on the 'determinants' (correlates) or drivers of productivity growth including investment, education and training, innovation, diffusion, and the broader context in which productivity growth is set. Chapter 4 of the paper deals with the prospects for future productivity growth in Canada over the next couple of decades. This chapter is largely speculative in nature drawing on what we know from economic history and the recent contributions of the endogenous or 'new' growth literature. It includes a discussion of a number of important external and domestic developments in the Canadian and global economies. Chapter 5 concludes with a discussion of how traditional economic policies should account for potential productivity effects.

2. PRODUCTIVITY GROWTH: WHY DO WE CARE?

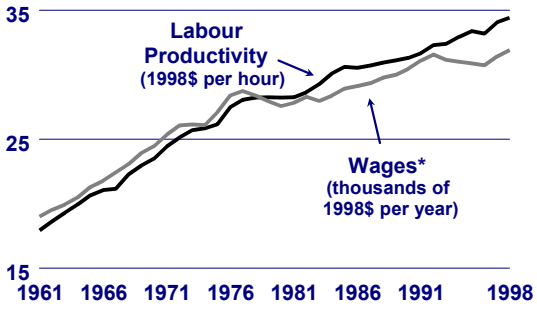
Productivity is roughly speaking a measure of how effectively the resources of an economy are translated into the *production* of goods and services. Over long periods of time, productivity is the single most important determinant of a nation's living standard or its level of real income. This relationship for a cross section of countries is illustrated in Chart 1 which plots real wages, a fairly conventional measure of real income, against labour productivity. We make a distinction between the level of productivity in the economy at a point in time, and the changes in the level of productivity or productivity growth rate. It is common to discuss both of these without making clear which concept is being used. Productivity *levels* are related to the standard of living in a country, and productivity *growth rates* are the major determinant of the rate of increase in living standards over time. In Chart 2, Canadian real wages and labour productivity are shown from 1961 to 1998. It is evident the two are strongly related over time.

Chart 1
Wages and Productivity Across Countries, 1993



* In manufacturing
Source: Industry Canada compilation based on data from International Yearbook of Industrial Statistics, 1998; Rodrik, 1998.

Chart 2
Wages and Productivity in Canada, 1961-98



* Real producer labour compensation (wages/salaries plus benefits) per worker
Source: Industry Canada compilation based on data from Statistics Canada.

Productivity, living standards and income are however slightly different concepts and it is useful to consider more closely how they are related to each other. To make the connection with living standards we need to make the links between the production side of the economy and the way in which production determines income. In most western economies, income is generated in factor markets; it is the value of the services of labour and earnings of assets that occur as a consequence of supplying these factor services to producers of goods and services (either the private or the public sector). The wages and profits that result reflect a combination of (a) the value of the particular goods and services produced, and (b) the productivity of the factor inputs in producing those goods and services. Income from a *given* supply of labour and capital can rise because either (a) the value of the goods produced rises or (b) the productivity of those factors has risen. Higher productivity means that more goods and services can be derived from the same factor inputs.

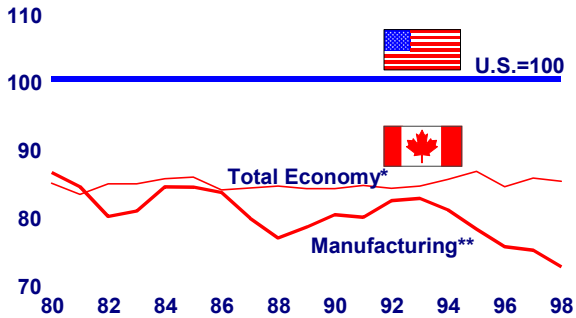
The distinction between the effect of prices on factor income and the productivity effect is often confused. Productivity growth in the sense that more is produced with less can have important price

effects in the market as the supply of the goods produced increases; these supply effects can in turn affect incomes and real purchasing power. Productivity improvements often result in lower prices, which benefit consumers, but which may or may not raise the incomes of those producing the goods in question. In an economy such as Canada's, which participates heavily in international trade, this means that what we produce is generally not the same as what we consume. Hence if what we produce goes down in price and what we consume goes up in price then living standards will fall, holding productivity, as conventionally measured, constant.

Living standards refer to the real value of consumption that a given real income will purchase. The differences between consumption and production activities however can create some problems in making the connection between living standards and incomes. An economy in which income is high but much of that income goes into investment will be generating a lower level of consumption that would otherwise be the case. I will not take up these issues here except to note that when looking at long term economic growth it is possible that productivity will vary as a direct consequence of the decision to consume versus invest. Often the decision to be 'more productive' involves a choice to defer consumption to the future. To that extent, becoming more productive can be coincident with a reduction in real living standards as measured by what we consume. Clearly, the best kind of productivity growth is the kind that does not require a sacrifice of current consumption.

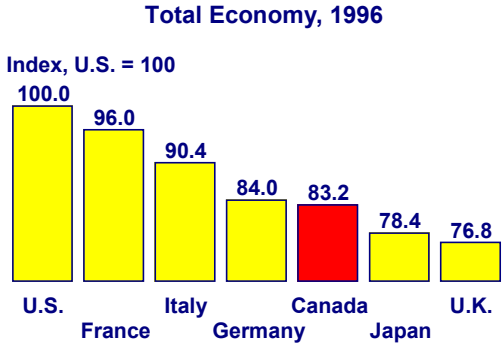
National productivity statistics are commonly used to make international comparisons, both in terms of levels and in terms of growth rates. In Canada, the comparison with the United States our closest neighbour and largest trading partner is the one most familiar to people. Generally, productivity growth rates in Canada seem similar to those in the United States. Nevertheless there still appears to be a productivity gap between Canada and the United States in terms of *levels,* as illustrated in Chart 3. This chart also illustrates that the 'productivity gap' seems to be getting worse in the manufacturing sector. Looking at productivity levels, across countries in Chart 4, we see that Canada in 1996 appears in the middle of the OECD pack, with the United States still the lead country. As will be discussed in this paper there are a number of debates both on the interpretation of these statistics, and on the theories explaining these 'gaps' and what policies might lead to their reduction.

Chart 3
Productivity Levels



* Labour productivity measured using $1998 GDP per hour.
** Labour productivity for the manufacturing sector is measured by GDP per hour, based on the methodology of the Centre for the Study of Living Standards.
Source: Industry Canada compilation based on data from Statistics Canada and U.S. Bureau of Labour Statistics.

Chart 4
Productivity Levels*



* Output per worker.
Source: OECD, Science, Technology and Industry Outlook, 1998.

The study of productivity growth tends to be compartmentalized into three different sub-disciplines each with their own perspective. One most familiar to non-economists is associated with the writings of economic historians such as Nathan Rosenberg. It takes a broad system or economy-wide approach to productivity in which markets and institutions play a key role and is depicted in the following schematic.

Figure 1

Explanations ranging from the role of institutions such as the rule of law, public health, communications and transport innovations, industrial innovations and of interest-group politics and rent-seeking, cultural differences and numerous others are offered. These wide-ranging accounts are undoubtedly both valid and important and find some counterparts in the empirical evidence discussed below. A second group of scholars uses what might be called the macroeconomic growth perspective, and is reflected in the writings of people such as Robert Solow and Raul Romer. There is a reliance in this approach on more formal modeling, quantitative analysis, and often medium-run perspective — that is, they tend to think in terms of decades rather than centuries. Also, much of this literature is not concerned with the question of what causes the transition from pre-industrial to industrial economies. This approach tends to employ traditional supply and demand explanations for economic growth relevant to a modern mixed economy with substantial public and private sectors. Factors that enter the analysis include:

A. Supply Side Growth Factors
1. Primary inputs (labour, resources)
2. Re-producible capital goods (physical and human capital)
3. Technology/management/knowledge base
4. Allocative efficiency of markets/external spillovers
5. International comparative advantage
6. Terms of trade
7. Public policy

B. Demand Side Factors
1. External market access
2. Global business cycle
3. Domestic macroeconomic policy.

'Productivity' emerges from the supply and demand side integration in a number of different ways, but generally speaking we can think of productivity — i.e. the efficiency with which inputs are transformed into useful outputs — as a summary statistic of the performance of the entire system. Public policy implications almost always follow from an analysis undertaken in this perspective.

A third group of scholars focuses primarily the measurement side of the debate and is represented by people such as Erwin Diewert of University of British Columbia and Zvi Griliches of Harvard University. They are concerned with the way in which inputs and outputs are measured, how they might be mis-measured, and various ways in which productivity statistics can be constructed and compared both over time and between countries, industries, and firms. Generally speaking the measurement school of productivity is primarily if not exclusively empirical and uses a framework based on the concept of the neoclassical production function. They tend not to focus on theorizing about the determinants of productivity growth, nor is their research concerned with either system-wide, general equilibrium or large-scale institutional explanations of productivity change. Measurement is however extremely important and we turn now to a discussion of the way in which productivity statistics are constructed and used in the debate.

Measuring Productivity

Productivity statistics are index numbers of the resources used in the economy's production activities relative to the output of those activities. We usually define this as a simple ratio:

$$\textbf{Productivity} = \frac{\textbf{Quantity of Output}}{\textbf{Quantity of Input}}$$

This definition is made operational by statisticians in a number of ways. At the level of both the individual firm and the economy, the most common productivity measure is average labour productivity. Thus, if X is a measure of output and LAB is a measure of labour input, *average labour productivity* is given by:

Average labour productivity (ALP) = X/LAB.

At the level of the individual country, by far the most common statistic used in doing economic growth calculations or international comparisons is *real GDP per capita*, which is the economy analogue to the ALP concept. Let Y denote real GDP (we get to the issue of measuring this variable later) and Pop the population. Then real GDP per capita is defined as:

$$r = \frac{Y}{Pop}$$

As a productivity measure this variable does not a make lot of sense because (a) what fraction of the population the economy allocates to production can be quite different than simply counting the population, and (b) there are a lot of factor inputs other than 'people' that go into production. In many cases, it is used as a measure of living standards. It is useful to note how productivity and other factors affect this widely used statistic.

Productivity and Real GDP per Capita Indexes

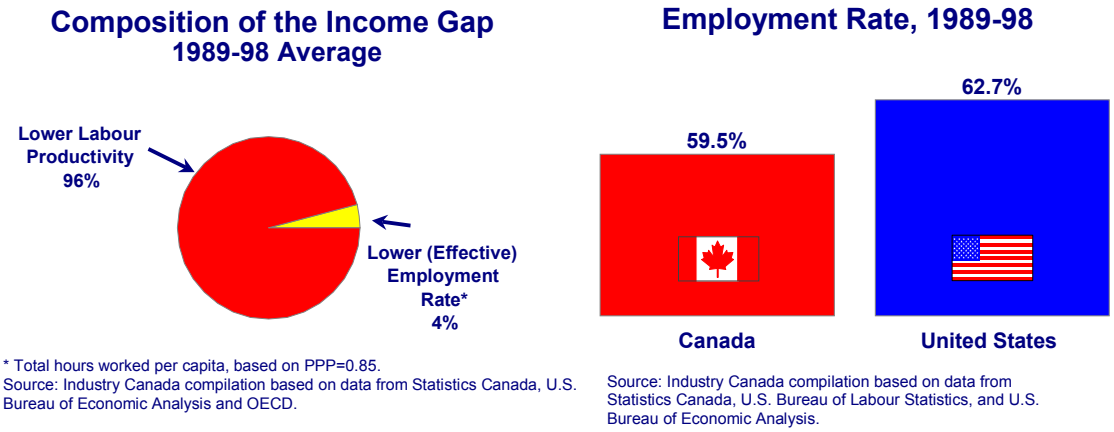
1. Labour force participation. A common correction is to adjust the population by the number of people who are employed. Let *e* be the employment population ratio *L/Pop*, where *L* is the labour force, then GDP per worker is often reported as:

$$r_W = \frac{Y}{L} = \frac{Y}{ePop}.$$

Note that holding *r* constant, GDP per worker will change with changes in the number of employed persons, or for a given labour force, with the labour force participation rate. Higher labour force participation may or may not be a good thing from the point of view of ultimate social well-being.

In Canada-U.S. comparisons of economic performance, it is often claimed that the per capita real income gap is due to higher unemployment or a lower employment rate in Canada. Chart 5 indicates however that most of the real income gap is due to differences in productivity rather than to differences in the employment rate.

Chart 5
Sources of the Income Gap Between Canada and the United States



* Total hours worked per capita, based on PPP=0.85.
Source: Industry Canada compilation based on data from Statistics Canada, U.S. Bureau of Economic Analysis and OECD.

Source: Industry Canada compilation based on data from Statistics Canada, U.S. Bureau of Labour Statistics, and U.S. Bureau of Economic Analysis.

2. A further refinement is to correct for the number of hours worked. This has become more common with large shifts to part-time work and substantial international differences in average hours of work. Let *H* be the total hours worked and *h* the average hours worked per person employed. Then, we define GDP/hour as:

$$r_H = \frac{Y}{H} = \frac{Y}{hL}$$

This index is very close to a measure of average labour productivity at the economy-wide level, and thus receives a lot of attention. Note that GDP per capita can go up if people work longer hours, but strictly speaking this does not correspond to an increase in 'productivity' as measured by r_H. Both the hours correction and the labour force participation correction bedevil productivity comparisons across countries and over long periods of time. The absence of good comparable data often forces one to rely on the more

commonly used *r* variable than a true productivity index. The history of economic growth is one in which hours of work have been reduced and this is generally regarded as a good thing. Many international comparisons fail to make this correction. Hours of work for example are much longer in the United States than in Germany, and thus comparisons of GDP per capita between Germany and the United States make the United States appear to have higher 'real incomes,' while a productivity comparison shows Germany to be very close and by some measures better off than the United States. On the other hand, the economic performance of a nation is often judged in terms of its ability to generate employment either in terms of job numbers or hours of work. As we shall see the connection between productivity and employment is quite complex, and both productivity and employment are endogenous to the economic system. A crucial issue is whether there is a long-term trade-off between employment and productivity, or alternatively whether higher productivity is necessary for greater employment.

Getting Sophisticated: Multifactor Productivity

It has long been recognized that the notion of inputs must go beyond the simple labour input, although how this is done remains one of the most contentious areas in economics and relates to the problem of how to treat investment and technology. Suppose that there are two factor inputs — hours of work, *H*, and a single index of capital goods used in production, *K*. The purpose is to define an index that can measure how much output growth is *not accounted for* by changes in *H* and *K*. This index is called the multifactor productivity (MFP) growth. Let *F (H,K)* be an index of resources used in production — it is critical that this index be time invariant (or geographic invariant if we are doing comparisons across space). The level of multifactor productivity is defined as the index *A* given by the ratio:

$$A \equiv \frac{Y}{F(H,K)}.$$

Many economists think of changes in *A* as being the 'true' or correct measure of productivity change. This view derives from the traditional neoclassical theory of production which takes technology as exogenous at a point in time, and all markets are assumed to be competitive. In this case, *F* is identified as the time invariant portion of a firm's production function. This leads to the famous Solow growth accounting equation (actually developed by Tinbergen in the 1930's) which gives an equation for the *growth rate of MFP, (GMFP)*.

$$GMFP \equiv \frac{\Delta A}{A} = \frac{\Delta Y}{Y} - \alpha \frac{\Delta H}{H} - (1-\alpha)\frac{\Delta K}{K}$$

where α is the cost share of labour in total costs, or at the national level the share of wages in total national income. This equation is one of the most famous in economics and is often referred to as the 'Solow residual calculation': In words,

> *The growth rate of MFP equals the growth rate of output less a weighted sum of the growth rates of capital and labour inputs, where the weights on each factor input correspond to their shares in the cost of producing the output Y.*

MFP statistics are now routinely reported by statistical agencies including Statistics Canada. Long-run average MFP annual growth rates vary from 0 to 2 percent historically. The interpretation of these numbers however remain controversial. It is essential to remember that as a simple matter of measurement, *GMFP* is defined as a residual — i.e. it is that portion of output growth that cannot be accounted for by input growth.[1]

What's Good About the MFP Growth Rate?

One important motivation for looking at MFP rather than the simple growth rate of labour productivity is the essential role of capital accumulation in the economy. Let *G (x)* denote the annual growth rate of any variable *x*. The average growth rate of labour productivity under the 'normal assumptions' is given by:

$$G(r_H) = G(A) + \alpha\, G(K/H).$$

Thus real output per hour can increase either because MFP growth has occurred or because capital per hour worked has increased. It is important to note that these normal assumptions include an absence of spillovers, or equivalently the perfect correspondence between market prices and social costs.

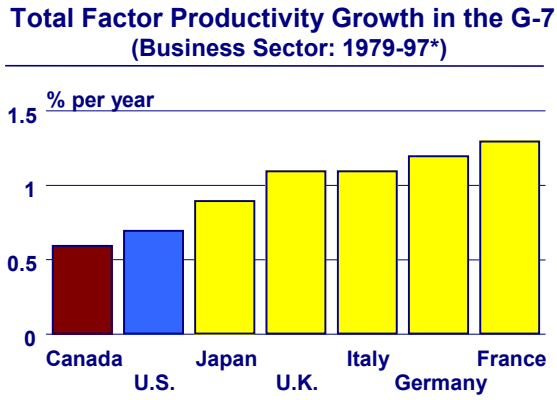
In practical measurement terms, accumulation will tend to be more important in explaining average labour productivity growth the greater the share of 'capital,' given by the parameter α. For years this share was identified with the share of profits in national income at the aggregate level — approximately one third for most advanced economies. Recently this conventional wisdom has been called into question by those who argue that inclusion of human capital, which is also subject to long-term accumulation, brings this number closer to two thirds.[2] The debate is more than academic. With very high shares of 'capital' in national income, changes in investment rates can have sustained and long-term effects on growth rates of productivity even in the absence of technological change. This is in sharp contrast to economies with low capital shares; in these economies, the law of diminishing marginal productivity quickly limits the growth effects of additional investment. Higher investment can lead to higher income levels but not to permanently higher growth rates.

If the capital share is quite high low productivity growth may be due to either low rates of MFP growth, or to the fact that investment (in a comprehensive sense) is too low. There has been a vigorous debate for example in this tradition on the role of public capital infrastructure in productivity growth, and the possibility that low productivity growth is due to low rates of investment in public infrastructure, such as roads, bridges, sewers, etc.

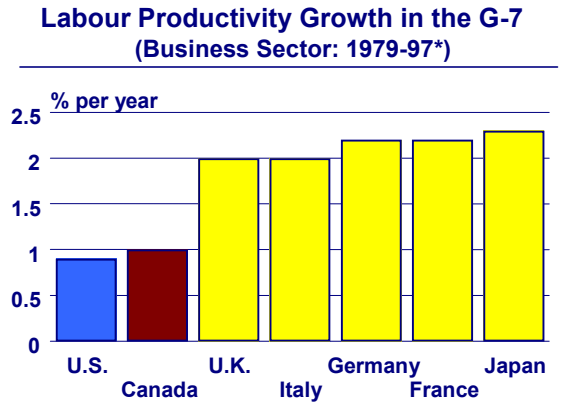
In many countries and in certain periods of industrial development the 'capital deepening effect' has been thought to be very important. A good example is the recent controversy on East Asia. Alywn Young's[3] work challenged the view that Asian growth rates represented substantial technological upgrading; he did this by showing that much of the high growth rates were obtained by increases in capital per worker associated with high investment rates. Going back to our discussion of investment versus consumption, if high labour productivity comes about through capital deepening effects this is not necessarily welfare-improving since investment can only occur at the expense of consumption.[4]

It turns out that for industrial countries, most of the change in measured labour productivity appears to be strongly related to total factor productivity (TFP) growth rates. In Chart 6, the 1979–97 growth of both average labour productivity and TFP for the G-7 countries are shown as calculated by the OECD. It also illustrates the low ranking of both Canada and the United States in terms of productivity growth relative to Japan and the European Countries. The sources of this divergence in productivity statistics remains a hotly debated subject and part of this debate pertains both to the interpretation of TFP statistics and to more complex measurement issues.

Chart 6
Productivity Growth in the G-7 Countries



*Or the latest year available: 1996 for Japan, France, Italy and the U.K.
Source: OECD, December 1998; OECD Economic Surveys, Canada 1999.



*Or the latest year available: 1996 for Japan, France, Italy and the U.K.
Source: OECD, December 1998; OECD Economic Surveys, Canada 1999.

MFP and Technological Change: Are They the Same Thing?

There are many who take the view that MFP is not a useful measure of technological change because new technology is inherently embedded in new goods and thus one cannot identify technological change independent of the measurement of these goods either as inputs — say in the case of a computer — or as outputs, as in the case of a new drug. There is an older literature which tries to correct within an exogenous technological change framework for the 'vintage effect'; if new technology is embodied in new capital goods then higher rates of investment will tend to be associated with higher rates of observed productivity change. Correcting MFP calculations for vintages effects is a complicated business. A recent effort on Canadian data is an Industry Canada study by Gera, Gu and Lee (1998). Recent work using quality change in computers and other electrical/electronic capital goods lends some credence to the view that these corrections are very important at the aggregate level. Greenwood, Hercovitz and Krusell (1997) for example argue that much of the infamous productivity slowdown is in fact a 'measurement problem' on the input side and that much of the post-1974 technological slowdown as measured by slow MFP growth can be explained by inappropriate measures of the change in capital, K.

A lot of work has been done to extend the same type of arguments to human-resource inputs in the form of what economists call 'human capital'. Economic growth in virtually all countries has been characterized by substantial increases in the level of educational attainment and in resources devoted to education and training of workers. It is thus argued that H should be replaced by an index of labour services $S = \theta H$, where θ is some index of the average quality of the skills applied to hours worked. The important point is that education and training policies involve investments in human capital which are durable and thus lasting. That is θ increases slowly and as a consequence of conscious policy and investment decisions. When these corrections are made what happens to MFP growth? Not surprisingly growth attributable to 'pure' MFP declines due to the skill upgrading that has occurred in the labour force. But can one seriously take the view that skill upgrading is not real productivity change? This leads us to the next topic.

The Measurement Debate

In this subject measurement is everything. Much of the disagreement on the 'facts' follows simply from the fact that measuring both output and factor inputs is becoming increasingly difficult, both conceptually and in practice.[5] In the face of this disagreement, the debate tends to be less constrained by indisputable 'facts'. The measurement problems on the output side pertain both to comparisons across time and across space. In services there are well known problems in areas such as retailing where margins have been the conventional output measure. Yet we know that increased competition has led precisely to a reduction in these margins, but in any reasonable sense 'output' in retailing has not declined. Increased quality and variety of goods has been a major source of economic growth, yet we know these are generally not accounted for in output statistics. International comparisons are fraught with difficulty even in traded goods industries. Baily and Gersbach (1996) report how product mix differences between plants across countries can severely distort price deflators used in fairly narrow industrial classifications. Just how important is all this? To put it in context we have the Nordhaus (1996) argument that with appropriate quality adjustments to the CPI for new goods, real wages over the last century would have increased 40 to 190 times rather than the reported 13–18 fold increase. Others argue that with respect to the productivity slowdown, only a small fraction can be explained by measurement — around 0.2 percentage points.

The general issue of economic growth based on quality change rather than quantity change poses some serious problems for growth economists and policy-makers. Not the least of these is simply that the traditional concept of the price level as a nominal measuring stick becomes increasingly difficult to defend. The 1986 Bureau of Labour Statistics adjustments to computer prices is a good example. Suddenly, the official statistical view was that computer prices had been declining at 15 percent per year, rather than the previously reported flat numbers. This led to serious revisions in a wide range of other statistics and changed the magnitude of the estimated productivity slowdown. As we shift to a knowledge-based economy, it is reasonable to expect that a much larger fraction of economic growth will be quality growth rather than quantity growth. After all just how many cars or computers or heart bypasses do you really need? As economic growth is increasingly quality based, concepts such as potential output will be increasingly difficult to define and quantify. Policy-makers will be faced with a much wider range of estimates of 'real output growth' both in the past and in the future.

Ignoring for the moment how new goods come into being, we know that much of the process of economic growth is associated with the introduction of new goods, and statistical procedures to correct for these changes are very imperfect, and in many cases not carried out at all. The debate on CPI revisions in the United States has focused on these issues extensively.[6] If GDP is mis-measured and there are good reasons to believe it is then MFP will be low. This problem is thought to be particularly severe in service industries, but my own view is that manufacturing has many of the same problems as the boundaries between manufacturing and services blur. Griliches (1992) notes that the unmeasured sector (services) now accounts for most of what appears in the national accounts and is the same sector which has the lowest MFP growth. He does not think this is a coincidence.

On the input side there are similar problems, particularly with respect to human and physical capital. The difficulties here relate directly to the debate as to whether MFP is a useful measure of technological change. There is a host of critics of MFP, including Richard Lipsey (1996), who take the view that since so much of what we think of as technological change involves the transformation of both the nature of the outputs and the inputs, then measuring it by a residual calculation as done in MFP accounting is meaningless.[7] Common reasoning certainly would seem to support this view, but the counter argument is that economics by definition is full of index number problems and technological change is just one more of these. Measured MFP growth must occur if real living standards are to rise,

and furthermore most of the available evidence points to a strong correlation between MFP and real income measures. This alone suggests that the concept should be taken seriously.

Policy: Does it Matter How We Measure Productivity?

The productivity measurement literature reflects a substantial tension between those who view productivity growth as the outcome of rational maximizing investment decisions by firms and individuals, and those who view productivity change as resulting primarily from endogenous changes in technology, which in turn are a consequence of the growth of knowledge. The former group is identified closely with the Jorgenson school of TFP measurement. Generally their approach is to adjust factor input for quality change which has the effect of reducing the residual. For example if the labour input is disaggregated into skilled and unskilled, then as skill upgrading occurs this shows up as an increase in the skilled input and a decrease in the unskilled. Since the skilled workers earn higher wages, weighting factor input growth rates by cost shares has the effect of increasing the measured rate of aggregate input growth and thus reducing the residual MFP number.

The 'non-endogenous' growth school can (somewhat crudely) be associated with the view that non-intervention is the appropriate policy stance since by definition all margins have been optimized and there are no 'externalities' or spillovers which have not been internalized. The endogenous technological change school takes the view that observed changes in MFP reflect a host of factors including technological change. Quality change itself is an aspect of technological change. Moreover, markets for new technology are viewed as unreliable and characterized by both imperfect information and appropriability problems, all leading to a number of market failures which can potentially be corrected via appropriate policy. In this sense then the endogenous growth approach is *potentially* supportive of interventionist policies which can affect productivity growth, subject to the usual caveats about the limits of government intervention. MFP statistics are viewed as useful by the endogenous growth school but it remains cautious about correcting for quality changes, since much of what its proponents would think of as technological change is no longer counted as such.

3. PRODUCTIVITY DRIVERS AND LEVERS

In the last section we considered how productivity has been measured and how the measurement debate sets part of the context in which productivity 'policies' are discussed. There is a long empirical and theoretical tradition which seeks to explain what determines productivity in a causal sense. Empirically this has involved both cross-section and time-series analysis of industries and countries. Having measured productivity in some manner, other factors are brought in which are thought to explain, or *cause* productivity growth. The basic statistical model of such a study has the form of a regression analysis where productivity is on the left-hand side and various 'determinants' X are on the right-hand side. Thus,

$$(1) \qquad \Delta A = \beta \bullet X + \gamma Z,$$

X is a set of factors such as investment or innovation and Z is a set of policy variables, such as taxation. In equation (1) the parameters β are thought of as productivity multipliers or 'spillover parameters'. Policy variables may have a direct effect on productivity or an indirect effect through their influence on X. Note that the change in productivity on the left-hand side is itself a constructed variable and therefore how one measures productivity will influence the outcome of the study in important ways. One of the most influential group of studies in this vein derive from what is known as the cross-sectional growth regression literature and are reviewed by Temple (1999). What is studied here is not productivity directly, but rates of growth of real GDP per capita for a large number of countries in the post-war period. Subject to the caveats discussed earlier about the connection between these two variables, most researchers feel that at least over long time periods the two are highly correlated. The cross-country growth evidence therefore is viewed as highly pertinent of what we know about the determinants of productivity growth.[8] The availability of this evidence has profoundly changed the way economists think about economic growth and the results have been widely supportive of the endogenous growth perspective. While growth in GDP per capita is not the same as MFP for example, a number of studies show that they are very closely related. The outcome of these studies, and of a host of other country-specific studies, has led to what I would call a consensus view on the three main correlates of national productivity growth — let's call then the Big 3. They are, respectively, investment in machinery and equipment, human capital development, and openness to trade and investment. In the literally hundreds of studies that have been done these three variables show up as robustly and highly correlated with productivity growth or growth in per capita GDP. Let us consider each of these in turn.

Productivity Drivers: the Big 3

Investment in Machinery and Equipment

Productivity growth is strong and highly correlated with investment in machinery and equipment (M&E) measured as a share of GDP. Countries with high rates of investment in M&E as a share of GDP have high growth rates on average, after controlling for obvious factors such as the level of income at the beginning of the period. This latter effect corrects for what is known as conditional convergence or 'catch-up' — other things being equal a poor country can be expected to grow faster than a rich country.[9] This strong correlation holds up over long historical periods and, based on more recent evidence, in both developed and developing countries. The correlation is subject to multiple interpretations. The conventional view is that M&E investment carries with it new technology and new ideas which diffuse slowly through the economy, ultimately contributing to further growth. De Long and Summers (1991) calculate that that social returns to M&E investment exceed private returns by a substantial margin.

Estimates put social returns in the range of 16 to 18 percent while private returns are usually in the 6 percent range suggesting substantial spillovers (see Masden, 1998, for a review). Causality however remains a contentious issue. Some scholars point to the difficulty of showing that investment causes growth and some claim to find the opposite. A related literature on vintage effects has lent further weight to the importance of investment in economic growth. Greenwood, Hercovitz and Krusell (1997) note that the fact that the relative price of equipment has fallen steadily at the rate of approximately 4 percent a year over the last two decades is strongly suggestive that recent technological change is embodied in new machinery, or what they term *investment-specific technological change*. Using a more appropriate accounting framework than is used in conventional growth accounting, they calculate that 63 percent of U.S. output growth per worker has been due to investment-specific technological advance. Taken together this evidence is strongly supportive of the role of investment as a proximate cause of productivity growth. If one could establish reverse causality this would significantly weaken the case for economic policies targeted at investment.[10] The case for investment led economic growth has been an enduring theme of the endogenous growth literature.

Education, Training and Human Capital

The endogenous growth literature has placed a lot of importance on the role of human capital formation in the growth process, and these variables find considerable support in various growth and productivity studies. Human capital appears as an engine of growth in two ways. One, it serves to facilitate knowledge spillovers, which raises the productivity of all factors. Or in more conventional language, being more skilled makes it more likely you will transmit what you know to others, who then will do the same and so on. Two, higher skills enter directly into the production of new technology (product and process innovation), and are necessary to facilitate the adoption of new technology. In other words, a computer without software is not very useful, nor is it of much use if the workers don't know how to run it. At the aggregate level, empirical work by Barro and Lee (1994) on various proxies of human capital and growth comes to the conclusion that it figures prominently in explaining the growth performance in a broad cross section of national economies from 1970 to 1990. Unfortunately, much of this work may not have a great deal of bearing on Canadian TFP performance as the proxies used for human capital are sufficiently crude as to leave Canada indistinguishable from a number of other advanced countries. Furthermore, much of the evidence from the cross-country growth regressions is no doubt driven by the developing country experience. Slightly more interesting is the work on MFP growth by Benahib and Spiegel (1994). They interestingly reject the conventional assumption that the level of output depends on the stock of human capital as one would expect in a conventional production function framework, but find support for the endogenous growth hypothesis that the rate of change of MFP depends on the stock of human capital. Human capital therefore increases the rate at which knowledge grows and is utilized. Furthermore, they find strong support for the view that this form of growth interacts positively with the openness variable. These results are clearly very favorable to countries such as Canada — those with a high degree of openness and a high level of human capital.

Once we go beyond the macro results things get rather murky. As is well known, the literature on training suggests that these programs don't seem to accomplish much. Learning-by-doing (LBD) has received increased support in a number of recent studies,[11] and suggests that firm-specific experience of individuals matters a lot. LBD interacts with demography because of the job experience of youth. In terms of the Canada-U.S. comparisons, human capital both helps and hinders in resolving the puzzle. As noted by Murphy, Riddell and Romer (1998) in looking at Canada versus the United States, Canada has had substantially faster growth in human capital in the 1980's as measured by educational outcomes in the two countries. The faster relative growth rate of Canadian human capital under the Benahib-Spiegel endogenous growth framework should have led to faster growth in conventionally measured Canadian MFP than in the United States.[12]

Openness to Trade and Investment

A wide range of data points to the importance for productivity growth of openness to trade and investment. This shows up in careful case study evidence as the Ben-David (1993) study of European income convergence and in cross-country data; there is a long list of studies on this point, but Sachs and Warner (1995) has been one of the more influential. The evidence now seems overwhelming although for many years there was considerable doubt as to the potential causal links between trade and growth. While the correlation is strong between openness and productivity growth there are a wide range of potential reasons for this link. Among the more important arguments suggesting why the link is so strong are the following:

- Low trade barriers facilitate better use of resources based on traditional comparative advantage arguments.
- For small countries, openness allows the realization of scale economies which are necessary in modern manufacturing and not feasible if reliance is placed on the domestic market alone.[13]
- International trade facilitates diffusion, learning and the transmission of ideas and technology from abroad. There is substantial recent evidence on the importance of international spillovers in facilitating productivity growth. This is true both internationally (Coe and Helpman, 1995) and in the Canadian case (Bernstein, 1994).
- Similar effects are fostered through foreign direct investment (FDI). Inward FDI in addition to providing capital, provides technology, skill upgrading, and market access (perhaps indirectly) and sometimes in those industries where global concentration is high (e.g. commercial aircraft, where we sell parts). Outward FDI helps in generating market access (e.g. in the United States), and securing durable links for Canadian firms with international networks, which provide high-wage jobs for Canadians, and in securing technology links in foreign countries.
- Openness implies a greater share of economic activity in exporting and there is some evidence that exporting firms tend to have higher productivity growth than do domestic or import competing firms. (Bernard and Jensen, 1999; Rao and Ahmad, 1997).

The Broader Context of Productivity Growth

While there is overwhelming empirical support for the Big 3 as proximate productivity drivers, there is no lack of alternative hypotheses on what determines productivity growth, especially as we move from the proximate determinants to the indirect linkages. The economic literature and the business press are virtually awash in explanations as to what drives productivity growth. This should not be a surprise since the basic question — the source of the wealth of nations — remains one of the most contentious and frequently debated issues of the day. In order to draw some boundaries around the debate let me mention some of the explanations that have had some relevance in the recent Canadian context.

- Innovation (both product and process)
- Diffusion of technology (national and international)
- Spatial agglomeration (Silicon Valley)
- External economies of scale at industry level
- Government consumption (negative)
- Management practices
- Public infrastructure (positive)

- Income inequality (negative)
- High taxes (negative)
- Small firms (negative)
- Labour market flexibility (positive)
- Exchange rate stability (positive)
- Low inflation (positive).

One can find studies which suggest the link of one of more of these variables to productivity or growth in GDP per capita, and in many cases there is some supportive evidence of correlation. There are of course a number of problems: (1) Causality is not the same as correlation and most of these variables are in fact endogenous; (2) in many instances, the time period examined is limited or the sample size is small; (3) economic theory is usually ambiguous as to the predicted effect on productivity. On almost all of these the evidence remains controversial. Moreover, the lags between the initial application of any lever and ultimate productivity effects are very long and highly uncertain due to inherent uncertainty in the transmission process. Finally, the feedback effects running between and from these various factors are potentially enormous, complicating the ability of any study to identify the causal pathways. Nevertheless, some of these are likely to be more important than others in the productivity debates of the next century. In the interest of adding to this debate, I want to focus my remarks on four factors which are likely to figure prominently in future productivity debates in Canada.

Innovation and Technology Diffusion

Most of the endogenous growth literature identifies knowledge spillovers as the ultimate engine of growth. As Paul Romer has emphasized, ideas are not subject to the law of diminishing returns. As knowledge accumulates this knowledge is potentially available for all to use at very low cost, and can lead to a self-reinforcing endogenous growth process. However, ideas in the form of useful technology are created by individuals, firms and governments in a highly imperfect process. There is a long tradition in Canadian industrial policy to focus on concerns about the weakness of the innovative process in Canada. These concerns are shared in virtually every smaller open industrialized economy that I am aware of, and come naturally when (a) most of your markets for new products are external, (b) a large share of the world's knowledge is generated outside your own borders, and (c) foreign-owned multinationals have a large presence in the domestic economy. I will not review the large Canadian policy literature on this issue except to note that recent productivity numbers suggest Canada does quite well at process innovation but tends to lag in product innovation.[14] International diffusion of technology either via spillover, or via explicit technology adoption figures prominently in any likely explanation of productivity change in Canada. On the technology adoption front, the evidence for Canada is mixed. Baldwin and Sabourin (1998) find that the major disadvantage Canadian plants face in technological adoption relative to the United States is the smaller market size, with some additional worries about labour market inflexibility. Beyond that, barriers to technological adoption in the two countries appear to be similar.

Innovations result in the most part from deliberate and costly attempts to develop new technologies or products. There are two important debates here: (a) What are the private and social returns to innovation? and (b) To what extent is the innovation process subject to market failures or 'spillovers'? Productivity and innovation are uniquely related in a number of ways. Some measures of MFP attempt to internalize the inputs to innovation by measuring resources devoted to R&D as inputs and isolating the MFP changes after costing out R&D inputs. Within this framework, some of the returns to innovation are ultimately captured by the innovator, just as in the case of any other form of investment. Critics argue that the static production function framework fails to capture the inherently risky and non-appropriable nature of knowledge creation.

Going beyond this approach in a lot of recent empirical work, the effect of R&D expenditures on productivity is measured as the changes in private sector MFP attributable to the 'spillovers' from collective R&D, both domestic and foreign, but not captured by the R&D inputs directly. Coe and Helpman (1995) set off a new line of research when they linked the strength of international R&D spillovers on national MFP growth to trade patterns. The international non-appropriable transfer of knowledge in economies more open to international trade and investment has been one hypothesis suggested by numerous scholars. The Coe-Helpman research distinguished between domestic R&D, global R&D and the facilitating role of trade. For Canada, their results indicate that global R&D is more important than domestic R&D and that this variable interacts with trade, measured by the import share, in facilitating knowledge transfers. To give an example, Bayoumi, Coe and Helpman (1995) estimate the cumulative effect of permanently increasing the share of GDP devoted to R&D by 0.5 percent in selected countries and looking at the macroeconomic effects over a 75-year period. In the case of the United States, for example, this would amount to about a 25 percent increase in R&D spending. Their simulations show this would produce a 9 percent increase in U.S. potential output and a 6.8 percent increase in Canadian output. Jeff Bernstein looking at Canada-U.S. spillovers comes to similar conclusions. The results suggest that Canada is a major beneficiary of U.S. and global innovation spillovers, although the dynamics of this process are uncertain.

In contrast to the spillovers approach, many economists view R&D and the innovations it leads to as fully 'bought and paid for'. Thus, the market is assumed to correctly price innovation inputs and outputs with no identifiable market failure. The policy implications of the two alternative approaches to innovation are very important and have played a long-standing role within the Canadian debate about R&D policy. Economists still argue at great length about how innovation shows up in the economy.[15] There are a number of potential channels — lower prices, higher factor returns, greater output growth, or higher profits. In a closed economy, where production must equal consumption, with some caveats the exact channel will not matter at the aggregate level. But where innovation impacts on consumers versus producers versus workers matters a great deal in an open economy for the ultimate impact on living standards.

Many people, myself included, put substantial weight on the Schumpeterian view that innovation occurs in imperfectly competitive industries, and that over medium term horizons the rents from innovation are an important driving force for entrepreneurial activity. Furthermore, this process is characterized by substantial risk to the individual innovator. Schumpeter argued that a successful innovation causes 'creative destruction' which not only results in new goods with high economic value, but at the same time destroy value in old goods or industries through obsolescence. If this is an accurate description of how technological change occurs then some interesting implications follow. First, policies which affect private sector innovation, and in particular policies toward new firms and entrepreneurs, become potentially important 'productivity levers'. Second, measured ex post productivity growth in Schumpeterian industries can be biased downward due to the inappropriate measurement of inputs by counting obsolesced resources. Third, one has to be careful drawing a close link between high rates of innovation and socially optimal policies. It is quite possible that private markets can actually overinvest in innovation relative to the socially correct level due to the 'destruction effect' of innovation. The cost-benefit calculation is further complicated by the fact that innovation rents which result from holding price above marginal cost do not constitute a national efficiency loss if the majority of consumers are foreigners. The consumer loss in other countries constitutes a gain to producers and workers in the country which has a temporary monopoly by reason of a Schumpeterian innovation success. Microsoft's monopoly may not benefit American consumers but it has certainly benefited Microsoft employees and shareholders.

Scale, Urbanization and Agglomeration

There are a number of economic theories which emphasize the (Marshallian) observation that the greater the scale of an activity through the agglomeration of like activities in a particular region (Silicon Valley) or city the higher are productivity levels in that activity or sector. Most of these theories emphasize the mobility of firms across space, but others focus on mobility of people as well. The exact source of these productivity gains remains a subject of considerable controversy: dynamic knowledge spillovers, ease of communication, facilitation of learning, and so forth. Much of the literature is focused on the apparent correlation between economic growth and the growth of cities. Localization economies and informational externalities are thought to be important reasons for the agglomeration of economic activity within cities. The recent literature contains a number of interesting facts that bear directly on the growth process in Canada. Here are some of the more interesting ones.[16]

1. There is growing consensus on the existence of strong economies due to agglomeration, at least in manufacturing. Agglomeration can be either at the city level or at the regional level. (Ellison and Glaeser, 1997).

2. From 1900 to 1950, the average metropolitan area population tripled and the number of metro areas doubled in the United States. Despite growth in individual city size in every decade the *number* of cities also increased — urbanized population rose from 40 to 60 percent. Note at the same time the large increase in average human capital as evidenced by school completion rates. (Black and Henderson, 1997).

3. Cities are either economically specialized into financial services, business services or manufacturing — with significant differences in education levels associated with these city types — or they are diversified. Diversified cities tend to be larger than specialized cities.

4. There is evidence that city growth rates are strongly related to growth rates in human capital within cities. (Black and Henderson, 1999).

5. Diversity within cities and local competition tend to foster urban employment growth while specialization appears to reduce growth (thus diversity may be important for attracting new and growing sectors).

6. Diversity also tends to promote innovation. Feldman and Audretsch (1999) find in a data set involving U.S. product innovations in 1982 that 96 percent were created in metropolitan areas that account for only 30 percent of the U.S. population.

7. Specialized cities have some advantages — stronger localization economies within the sector of specialization and thus the ability to attract new plants and firms entering that type of activity, but they also have disadvantages — less innovation and greater exposure to risk as the specific sectors and technologies rise and fall.

Most of these facts derive from U.S. and European studies but they carry implications for Canada. Canada is also highly urbanized with only four major cities that might be thought of as diversified. Given the importance of city growth to the overall growth process, it seems odd that most accounts of Canadian productivity performance make little mention of the role of cities. Some of this analysis has been extended to regions and, of course, there is a long Canadian concern with regional inequalities and its effect on growth (Coulombe, 1997). The manner in which city growth contributes to overall growth in Canada needs further research.

General Purpose Technologies

A new paradigm of historical technological change is that much of what we observe is associated with large scale shifts in the entire technological system. The introduction of steam and railways in the last century, electrification early in this century and later Fordism or mass production methods. The concept of a *general purpose technology* refers to a major innovation which has widespread uses within the economy and whose introduction in turn leads to wholesale transformation of production and distribution systems with attendant innovation. This topic has been explored intensively at the Canadian Institute for Advanced Research, and the recent volume edited by Elhanan Helpman (1998) covers the topic in detail. The introduction of GPTs is characterized by long lags between the date of introduction and ultimate productivity gains. There is also considerable initial uncertainty as to the ultimate effect of a new GPT. Growth based on a new GPT is to be contrasted with technological innovation which is thought to be continuous and incremental in nature. The information technology revolution based on computerization and low-cost electronic networks surely constitute a classic GPT. From a measurement perspective, a GPT is a nightmare. The basic difficulty stems from the long lags which occur between the original emergence of the innovation and it's ultimate usefulness in the economy due to a host of problems. People need to learn about the technology, there are extensive networks and facilitating infrastructures that need to be created, and many uses of the technology only become apparent long after it has first appeared. Furthermore, the economy goes through a substantial adjustment period in which the old technology is slowly discarded. Measured MFP will almost certainly tend to fall during this period both because output growth slows initially, and because inputs are actually made obsolescent by the shift, but are still measured. Economic growth is thus characterized by waves of slow to negative measured growth, perhaps lasting as long as two decades, followed by increasingly rapid growth in productivity. The productivity slowdown of the 70's and 80's might be attributed to the emergence of this new GPT and the recent pickup in productivity is likewise explainable by the payoff of this technology finally becoming evident in the data.

The GPT concept parallels closely the 'new economy' debate which will be addressed up in the next section. If a lot of productivity change is due to a maturing GPT a number of issues follow. First, in order to justify policy interventions one needs to know the precise manner in which a GPT is likely to affect future economic development, and in particular the best form of the facilitating innovation and infrastructure. As governments do not have perfect foresight, this is not easy to do. Nevertheless governments can help to coordinate market expectations as to the likely course of a GPT, and secondly provide the appropriate public infrastructure that is often necessary for a GPT to reach its full potential.

Productivity Dynamics and Microeconomic Heterogeneity

Measured productivity growth of almost any economic aggregate, be it an industry a region or a country, reflects two things going on at the microeconomic level of the many individual sectors/activities/firms which make up the aggregate. The aggregate rate of productivity growth can reflect either a pattern or relatively uniform productivity change within the respective micro units, or alternatively it can reflect a reallocation of resources across micro units with substantial heterogeneity in both levels and rates of productivity growth. There is a growing body of evidence that the growth process is fundamentally driven by the *reallocation of resources from low-productivity growth activities to high-productivity growth activities, rather than by limits on the availability of new technology***.**

The principal data behind this observation is the incredible heterogeneity which microeconomic productivity statistics has revealed in a large number of studies in recent years. Looking across firms within an industry, or across industries within a country, or at industries across countries, we observe

remarkable heterogeneity in measured productivity levels and growth rates. It is quite common to find plant productivity levels which differ by a factor of two to three in a narrowly defined industry and time period. Furthermore, there is a remarkable persistence in the lack of convergence of productivity levels within industries. Important studies which have contributed to this view include Baily et al (1992), Baldwin (1996), and Dwyer (1995), and new ones have been appearing with increasing frequency. At the national level, this appears to have shown up in a reversal of convergence trends in productivity levels in manufacturing across countries beginning about the mid-80's (Bernard and Jones, 1996). In this case, heterogeneity has extended to the international level.

An important research question is why this heterogeneity persists. One explanation is simply that the data reflect vintage effects — older firms tend to use older technology and thus are less productive or further from best practice. Other explanations hinge on the observation that productivity can be dependent upon firm-specific assets, such as location or the skills of management, which are not replicable. It turns out that the latter story seems to be more important at least in some studies.[17] Productivity growth appears to be an aggregation phenomena. New plants tend to have significant and relatively permanent higher productivity levels. Output growth within an industry occurs due to entry, exit and output growth or contraction at the level of the individual plant. Output growth and contraction appears to play a dominant role in explaining productivity growth. Productivity growth is observed as more productive plants expand and less productive plants contract.

There are a number of implications that can be drawn from the widespread evidence on extensive heterogeneity in productivity levels. One, the resource allocation process is far from perfect in that similar resources have differential returns (rewards) in different activities. Observed economic growth is due in substantial part to the re-allocation of resources from low-value uses to high-value uses. The productivity effect of any policy will thus depend in part on the way in which it either retards or promotes the re-allocation of resources from low to high value uses. Second, the potential economic gains from these re-allocations are likely to be larger during periods of rapid technological progress. This occurs since rapid technological progress has also been associated with greater dispersion in observed micro productivity levels. The greater the dispersion the larger the benefit in moving resources from low-productivity plants to high-productivity plants.

Macro Factors: Unemployment, Aggregate Demand and the Exchange Rate

Most of the debate on changes in productivity is motivated by either secular changes in measured growth rates, or by persistent differences in living standards which go beyond the time period associated with a business cycle. Nevertheless, there is a long tradition in economics of identifying weak aggregate demand as a potential cause of productivity change. As is well known and argued forcefully by Pierre Fortin (1994, 1996), output growth in Canada in the 1990's has been unusually weak. Fortin attributes this weakness to macroeconomic factors on the aggregate demand side. If there is a causation running from aggregate demand to long-term productivity growth this has the potential to be an important factor in both explaining and resolving some of the productivity problems in Canada. Virtually all economists would accept the proposition that there are medium-term links between productivity and output growth; however, there is substantial disagreement as to whether long-term productivity trends can be affected by economic stabilization policy — either fiscal or monetary.

In the literature, there are three separate potential linkages running from aggregate demand to productivity growth:

1. Some theories suggest that weak aggregate demand reduces output growth for a given labour force. Low output growth tends to reduce productivity growth directly via negative dynamic learning-by-doing effects or the existence of dynamic scale economies. Firms which are not expanding are not learning and this reduces productivity. This is sometimes referred to as the 'Verdooun effect.'

2. Other theories suggest that the temporary reduction in aggregate demand has lasting long-term negative effects on unemployment. Over a period of a few years, a high rate of unemployment can induce hysteretic negative productivity effects on the labour force through de-skilling — i.e. being out of work for a long period causes a loss of skill which in turn leads to lower future productivity.

3. Finally, there is what might be termed the 'heterodox view' associated with the Austrian school that recessions are a good thing. The 'cleansing recession' hypothesis is that cyclical downturns facilitate the obsolescence of old technology and the re-allocation of resources to new, more highly productive uses. In essence, recessions are manifestations of 'creative destruction'.

If one takes the Keynesian view that economies will tend not to revert naturally to a long-run full-employment equilibrium, then the first two theories would both suggest that sustained periods of weak output growth can reduce productivity over the longer run. Furthermore, supply-side oriented policies which may otherwise enhance productivity are doomed to failure unless aggregate demand is sufficiently buoyant. It is interesting to note that the Europe-U.S. comparisons have not been brought up more often in the Canadian productivity debate. Europe has high unemployment and high productivity growth relative to the United States, although Europe also had a productivity slowdown. The standard explanation for this difference is that rigid labour markets in Europe have induced firms to substitute capital for labour leading to both job losses, but increased productivity. This is sometimes characterized as the 'OECD hypothesis' and has received a lot of attention by Canadian labour economists, most recently Craig Riddell (1999). However, the same evidence casts doubt on whether weak output growth or high unemployment necessarily has long-term effects on productivity given the strong European productivity record. However, the recent pick-up in both output growth and productivity growth in the United States is likely to re-new this debate.

A related macroeconomic productivity link is the exchange rate. Recently there has been considerable debate on whether the trend depreciation in the Canadian dollar could have contributed to the low levels of productivity observed in Canadian manufacturing relative to the United States. This hypothesis is discussed at length by Tom Courchene and myself (Courchene and Harris, 1999) and is an important part of the debate on the costs and benefits of a North American Monetary Union. A number of commentators have pointed out that short-term measures of cost competitiveness between Canada and the United States have been favorable to Canada largely due to the lower Canadian dollar. Canadian productivity levels in manufacturing are still below those of the United States. Of the various arguments that would suggest a causation running from the exchange rate to productivity the simplest is that domestic firms faced with a depreciating currency simply could avoid making necessary productivity improvements in order to remain internationally competitive. A more complicated argument involves the simultaneous interaction between a depreciating currency during a period of rapid product innovation in the United States. A cheap dollar has the effect of encouraging Canadian firms to expand in areas where

cost competitiveness was most valuable, and to avoid making investments in product-based R&D, the cost of which had risen due to the use of new technology and skilled labour inputs priced in U.S. dollars. Both these explanations await further research. The more conventional macroeconomic theory is that lower trend productivity growth in tradable manufacturing sectors relative to one's trading partners *causes* a depreciating real exchange rate, rather than having the exchange rate depreciation cause lower productivity growth. But it is also true that the evidence on the traditional linkage is quite weak.[18]

4. PRODUCTIVITY GROWTH IN THE 21ST CENTURY

Assessing the historical record on productivity is an area subject to considerable dispute. It is obvious but no less important to note that productivity trends in Canada are likely to mirror closely those of the global economy. The recent pickup in productivity numbers, particularly in the United States, has raised considerably expectations that these trends will start to emerge elsewhere. One should be cautious however to extrapolate recent trends either through time or across countries. Over the economic cycle, there is enormous volatility in measured labour productivity growth. Business cycles vary in length from 5 to 36 quarters in the post-war period — the current one is of course particularly long. In recoveries, productivity growth varies between 0 and plus 6 percent with weak persistence. Looking across countries, there are two striking features in the data. First, a large variation across countries in growth rates, and secondly over longer periods remarkably little long term persistence in growth rates between periods. In the 125-country Summer-Hestons data set, growth rates in the last 25 years have ranged from over 5 percent to negative. In terms of persistence, the correlation between 1962–72 growth rates and 1975–83 growth rates is only 0.16.[19] The implication of this is that individual country experience probably cannot be extrapolated either to other countries or into the future with any great degree of certainty. The good news however is that a poor growth performance in the past is not a sentence for life. Good policy and good luck are always possible.

Despite the problems inherent in 'productivity speculation', vision requires a forward looking view. What might turn out to be the important trends that matter for Canadian productivity growth in the next few decades? My remarks will focus on three key developments:

- demography,
- globalization and North American economic integration, and
- the 'new economy' debate.

The Demographic Challenge

It is clear that one of the most important future developments with strong productivity implications is demographic trends in Canada, and indeed in most western industrial countries. Most demographic experts agree on the following:[20]

- over the next four decades, the median age of the labour force will increase from about 35 to 45, whereas only 30 years ago the median age was 25;
- the share of the population over 65 will be more than double by 2030;
- after 2011, there will be substantial slowing in labour force growth; holding immigration trends constant, the rate of growth in the labour force will be well below that of the population with a leveling off in the increase in female participation rates and the entry of smaller youth cohorts.

If recent productivity trends persist, these developments are problematic to say the least — for both public policy and economic growth. Most forecasters note that since the government tends to spend about three dollars on the elderly for every dollar spent on youth there will be a dramatic rise in the expenditure dependency ratio — i.e. spending on dependents as a share of GDP. The only hope for an offset to this in the absence of policy changes would be a dramatic increase in labour productivity growth.

Most estimate that if labour productivity growth were to move into the 2 percent range current expenditure programs could be maintained without a substantial increase in budget deficits.[21] What is the likelihood of such a trend increase in productivity growth? Perhaps not impossible as we shall see. However, the aging population carries with it another implication. As workers age, particularly after the mid 40's, existing studies by labour economists show that their productivity tends to decline. The major evidence for this is found in cohort-wage studies. The substantial increase in the median age of the labour force should therefore also be associated with a decrease in the average productivity level of the labour force. Simply put, a labour force full of 55–60 year-olds will produce a lot less than a labour force full of 40–45 year-olds. Therefore, we are in a double bind; not only are expenditures linked to increased dependency likely to rise, but the average productivity of those who will be working is likely to decline.

Are there any outs to this otherwise rather pessimistic scenario? Well, there are at least four possible developments that might at least reduce the tension:

1. Machine-muscle substitution: The history of technological change has been a series of innovations which have substituted machine movements for muscles. Robots on the floor of manufacturing plants are only one example. Since loss of muscle strength and agility is a major feature of the aging process, additional innovation which results in the substitution of machines for muscles is likely to continue to be an important feature of future technological change. Examples abound and are found increasingly in service industries as well as in manufacturing. Automatic food serving vendors, better baggage handling technology, and so forth.

2. Machine-neuron complementarity: The modern Luddite worries that smart machines will eliminate the need for human intelligence — the substitution of chips for neurons. While in some cases there is of course one-to-one replacement of a person by a machine (the ATM for example), much of modern technology built around the computer is to aid human intelligence — that is, it is complementary to human intelligence. Additional innovation with respect to this type of technology is likely to help an aging labour force retain it's productivity. Two areas which come to mind are of particular importance with respect to aging. Technology to facilitate memory intensive tasks, and technology to facilitate learning new technology. In much the same way that rising wages induced machine-muscle innovations in the industrial era, we can reasonably expect that as the labour force ages there will be strong economic incentives to develop neuron-machine complementary innovations.

3. Medical innovation. One area where there appears to be virtually no slowing in innovations is medical science. Many developments relate directly to lengthening the ability of aging human bodies to continue to function effectively beyond what would be considered the normal retirement period. Hip replacement, laser eye surgery, etc.

   The other side of the demographic productivity trap is the assumption that older workers will continue to retire at the same age, thus reducing output and growth, or even worse that the trend toward earlier retirement will accelerate. There are some reasons to think that this trend may reverse.[22] Not the least are a number of policy changes that could reduce the average retirement age as discussed in the recent OECD Report *Maintaining Prosperity in an Ageing Society*. The productive effects of these could be to actually increase average productivity levels in the labour force, relative to the alternatives, if the skills and experience of workers that are now retiring could be leveraged into a few more years of useful work. This is undoubtedly one of the major challenges Canada will face early in the next century.

Globalization Arguments

Globalization is an inexorable trend that has been with us for a very long time, but it appears to have accelerated in the 1980's. Globalization has a number of important productivity implications for Canada both on the positive and on the negative side. Three aspects of globalization warrant attention with regard to Canadian productivity prospects. The potential slowdown in the growth of world trade and foreign investment, the agglomeration trends within an integrated North American market, and the emergence of a global market for the very highly skilled.

A Potential Slowdown in the Growth of the Global Economy

Chad Jones of Stanford University wrote a paper last year with the provocative title "The Coming Productivity Slowdown".[23] The thesis of the paper is actually quite simple. He argues that some of the most robust findings of the modern empirical growth literature is the close correlation between economic growth and R&D spending, the level of human capital formation, and openness to trade and investment. In the case of human capital he notes that, in 1940, less than 1 in 20 in the labour force had completed high school. By 1990, 80 percent had completed high school and more than 20 percent had some form of higher education. Over the same period, the United States had opened up substantially to trade and international investment with close to a tripling of the openness ratio. Finally, the number of scientists and engineers engaged in R&D in the United States increased from 0.25 percent of the labour force in 1950 to 0.75 percent of the labour force in 1990. He then argues that all of these trends are now slowing but the rapid increase in these variables over the last four decades has been responsible for much of the high growth observed during the same period.

The case that all these trends might slow significantly is clearly speculative. World trade has been growing steadily at about 8 percent per year — well above world GDP growth. How long can this go on? It is not difficult to take the view that the growth in international trade witnessed in the last two decades is bound to slow for a number of reasons. Not the least is the simple observation that as the share of services in the economy gets very large, trade in goods becomes less significant. Thus, growth in trade volumes expressed as a percentage of GDP will eventually level off. Jones argues that U.S. growth has been driven in large part by an increase in trade, and as that growth levels off so will productivity growth. Investment in innovation seems also to be slowing down as witnessed by the number of scientists and engineers who are engaged in R&D. Finally, the rapid increase in U.S. rates of participation in higher education is another trend that appears to have slowed. He then argues that if ones takes the empirical growth literature seriously the implications for future U.S. productivity growth are dismal to put it mildly. Using a fairly standard growth model he calculates that *the rate of growth per capita GDP in the United States will fall to one quarter of its average post-war level early in the next century.*

Is any of this to be taken seriously? While the paper was meant to be provocative, what he points out is certainly worth contemplating. First, the trends that he discusses are evident in most countries and have certainly been good for growth. Admittedly, it seems difficult to believe that these trends can persist indefinitely. Canada has benefited enormously from increased openness since the FTA/NAFTA, with international exports growing from about 25 percent of GDP to more than 40 percent. If that was positive for growth then as that export growth slows so will productivity growth, even if the level effects remain. Moreover, if growth in the United States slows, given the large extent to which Canada relies on technology spillovers from the United States any potential slowdown there will have strong negative implications for Canadian economic growth, as the Helpman-Coe/Bernstein spillover results suggest. On a more positive note, however, it may be that growth in openness of the Canadian economy is far from over. Other small open economies in Europe such as Belgium, the Netherlands and Austria have much

higher openness ratios than Canada — in some cases close to 100 percent. If their experience is indicative of where Canada is headed we may enjoy a productivity growth dividend for a number of decades as the economy evolves in that direction. This presumes of course that things 'work out' in our neighbour to the South. If Jones is correct and the United States heads into a protracted productivity slowdown, things are worse than we imagine.

North American Integration and Regional Agglomeration

In Europe, the emerging literature on trade and geography has renewed worries about regional growth poles, and center-periphery asymmetric development within the European Union as firms become increasingly mobile within a more fully integrated economic area. All of these same issues are beginning to be discussed here as an integrated North American economy emerges. Will some or all of Canada's regions become regional backwaters as the forces of agglomeration push high value-added activity into U.S. based growth poles? On theoretical grounds all of this is possible of course. One has to genuinely worry that agglomeration is such a powerful force that it may relegate Canada to a collection of locations that are highly specialized, but less involved in innovative and high value-added activities. The importance of cities, for example, suggests that Canada has to have a sufficient number of highly diversified and human capital intensive cities if it is to maintain high rates of productivity growth. As Courchene and Telmer (1998) argue, if Canada is integrating North-South it may well be that in the next century growth prospects will be region-specific with the growth of each Canadian region mirroring that of the respective region to the South. National economic policy might counteract such tendencies but given the close links between these regions it is hard to imagine how national policy could reverse a Canadian region's decline if the adjacent U.S. region were to go into a protracted growth slump.

These regional worries have international analogues — agglomeration effects which appear to be biased against small countries — small countries will be de-industrialized, will have no world-class cities, and no major Silicon valleys, etc. By this set of arguments 'smallness' in itself guarantees low productivity levels. Fortunately, I think these arguments are limited and the negative effects can be avoided by appropriate integration or exploitation of global markets.[24] Examples abound of small countries that have very high levels of productivity and income — Switzerland, Finland, Singapore, and the Netherlands, for example. Furthermore, there is virtually no evidence that growth is related to country size. On the available case-study and econometric evidence, there appears to be no a priori justification for the idea that Canada will be 'hollowed' out by a more integrated North American market.

Nevertheless, it is very important to understand how the factors which lead to agglomeration — localization economies, learning-by-doing, and knowledge spillovers — work in detail so that appropriate strategic and compensating policies can be put in place. One simple example: if low corporate tax rates are a necessary condition for a small country to attract FDI away from larger economic areas because of the presence of agglomeration effects, then being competitive on tax rates internationally for mobile economic activities will be essential to economic growth.[25]

The Global Market for Human Capital

As more economic activity is based on human capital advantages the skill mix of the labour force becomes an important long-term determinant of an economy's industrial structure, and changes in the level of investment in human capital will tend to have greater impact on economic growth than it may have had in the past. Many 'high tech' activities are inherently footloose (unlike agriculture or resource industries) — people are the only 'sticky factor'. The people that 'make or break' a firm however are the very highly skilled employees and managers; globalization has raised substantially the real wages of those who have acquired critical skills. The skills shortage in the IT sector is a good example. As noted

previously, Canada has a strong record on human capital formation, but that may not be enough. The fear of many is that the labour market for these people has become truly global, raising the prospect of a new class of worker — the global 'gold collar' worker who can work in any country and has little national allegiance as it was typically ascribed to the labour force in the past.

An emerging global market for highly skilled workers will affect Canadian productivity growth in obvious ways. First, these workers are necessary for the transfer of best-practice international technology to facilitate learning new technologies and to foster Canadian based innovation. Second, human capital is complementary to a lot of physical capital — hence in the global competition for new investment, the ability to attract and keep highly skilled human capital will be a necessary condition for growth. An opposing view is that the global market for human capital is relatively insignificant — after all, most workers never leave their home region, let alone their country, and rates of international migration are still relatively low.[26] As the media debate on the 'brain drain' indicates, both sides can point to supporting evidence, and so the arguments will go on for some time. If the global 'gold collar' labour market proponents are correct, and this trend accelerates, it will impact on all countries in a wide range of ways. The potential productivity implications are however enormous and at this point unquantifiable. Yet, a third perspective would be that of an extreme 'neoclassical optimist' who would argue that mobility of workers, skilled or unskilled, is always a good thing. Increased mobility raises world income, and with the rapid diffusion of ideas the geographic location of a particular 'brain' is of little consequence. I would like to believe this, but the evidence on agglomeration in growth patterns suggests it is too sanguine a view. There may be thresholds on skilled labour supply below which the viability of an industry in a particular region becomes tenuous.

The 'New Economy' Debate

Promises of a new 'golden age' of high but possibly unmeasured productivity growth fills the pages of newspapers daily, and has gathered considerable recent support by such notables as Alan Greenspan. The recent evidence is certainly impressive in the case of the U.S. economy. Average labour productivity grew at an annualized rate of 2.15 percent from 1995 through the first quarter of 1999, after growing at just over 1 percent from 1972 to 1995. Does this herald the return to the golden age of productivity growth witnessed in the 1950 to 1970 period, in which productivity grew at a rate in excess of 2.5 percent? If so the impact would be remarkable both on the real incomes of workers and on the ability of government to fund program spending. There are doubters, however, and their arguments are impressive. Robert Gordon (1999) of Northwestern University notes that the entire pickup is predicated on one remarkable fact — the significant drop in computer prices over the last few years.[27] Growth in computer manufacturing proceeded at an astounding rate of 42 percent over the 1995Q4–1999Q1 period. This sector alone managed to raise the aggregate growth rate even though computer manufacturing accounts for just 1.2 percent of total output in the United States. Productivity growth in non-computer manufacturing (durables and non durables) actually declined during 1995–99 relative to 1972–95. Gordon therefore argues the New Economy simply isn't a statistical reality and, furthermore, the much talked about productivity slowdown is still very much with us. As he describes it, the computer revolution thus far has only been productivity enhancing to the extent that it has resulted in more efficient production of computers. The broader based benefits of computers and related IT are still not in the data.

It is not clear where all this leads. The Gordon position is countered in two ways. First, there are the traditional Griliches concerns with unmeasured output gains in the service sectors. True enough, but these adjustments, if made appropriately, would go back a long way and provide no evidence that there has been a recent pickup in productivity growth. On the other hand, there is some recent work using stock market data to infer productivity gains which is much more optimistic.

Greenwood and Jovanovic (1999) suggests the 'new economy' is real and use as evidence the stock market values of technology intensive companies, most of whom are firms that did not even exist prior to 1972. But is the stock market valuation of technology companies to be believed? Certainly, in fully rational perfect foresight stock market we would expect stock prices to reflect future growth in earnings, which in turn reflect productivity growth. However, 'bubble theorists' are not impressed, and until productivity shows up in conventional statistics they will remain unconvinced. Of course, if computers and IT technology are a genuine GPT in the Lipsey-Helpman sense then perhaps we will simply have to wait, given the lags inherent in the evolution of a new GPT. If the 'new economy' turns out not to have arrived then the next century will bring more of what we have had in the past, although worries about Canada falling behind the United States are likely to be less compelling.

At this point, however, there is no reason to discount completely the optimists. The anecdotal evidence is certainly impressive, and the implications for Canadian productivity growth of the 'new economy' hypothesis are obviously considerable. If true, then the current period is one in which the United States can be characterized as 'forging ahead', yet again.[28] If history repeats itself, Canada should start to benefit from 'catch-up' effects and with appropriate facilitating policies can encourage a similar structural shift in the economy. Major policy issues will emerge as to what these policies might be — Internet infrastructure subsidies, more resources devoted to providing IT training, favourable tax treatment of IT intensive sectors, and so forth.

There is the broader question of whether the Internet and related technology will turn out to be the most important of these new technologies because of their impact on reducing the cost of distance in economic interactions. Canada is a country which has been shaped by geography. As the population becomes increasingly urbanized it can be described as an economy with a few major cities in which most GDP is produced with vast distances between them. The Internet could change that in the next century in ways that are hard to imagine.[29] For example, growth in medium-size cities has been hampered by the inability to overcome the benefits that agglomeration confers via localization economies on the incumbent large cities. Closely related electronic networks may substitute for physical proximity, and spillovers may arise from virtual linkages rather than geographical/physical linkages. Optimistically this might encourage growth of firms in a number of medium-size Canadian cities which are attractive living locations. In a sense this is a zero-sum activity since this activity would have to be attracted from the larger cities, but it could be productivity-improving in two ways. First, many of these spillovers might be international in scope. Firms in smaller cities could benefit from participating in virtually linked North American networks. The Internet allows firms to manage customers and suppliers in ways that hitherto were not feasible. Second, at some point large cities become inefficient as congestion rises. Transferring activity to less congested smaller cities would be efficiency-enhancing overall. Third, virtual economic integration within Canada could be expected to pickup. While Canada has a tradition of a relatively integrated common market, the fact is that interprovincial trade has fallen — interprovincial trade is now less than 20 percent of GDP whereas only a decade ago it was over 25 percent.[30] Full integration of the Canadian common market has been hindered for decades by the cost of distance. As the Internet reduces these costs, there is now the possibility of achieving the larger potential of the virtually integrated Canadian common market which comes with greater scale economies and the dynamic effects of increased competition.

5. CONCLUSION: THE POLICY FRAMEWORK

Developing economic policies that can increase the chances that Canada will improve its productivity record are at the top of both the private and public agendas these days. There remains considerable disagreement on exactly how this is to be achieved. Part of the disagreement is genuinely ideological in nature, but a lot emanates from the ambiguity in the statistical and historical productivity records. Broadly speaking, we have some agreement on how productivity should be measured, but we recognize the problems inherent in these efforts. Also, there is a broad consensus on the fact that productivity growth declined in the mid 1970's but still disagreement as to why. Looking at the broader record we recognize that trade, investment and human capital formation are the main drivers of productivity growth, within an overall framework where knowledge creation produces opportunities for growth. Within these parameters, there remains considerable debate on what levers should be pulled to produce higher productivity growth.

A good example of this is public policy toward innovation. Here we have tension between those who view innovative activity as leading mostly to knowledge spillovers that are non-appropriable, and those who view innovation as the outcome of a Schumpeterian competition with imperfect product and factor markets. The 'spillovers' school of thought is equated with market failure and it's corollary, government intervention. If you are of this persuasion you seek confirmation of your views that knowledge creation is non-appropriable and governments can effectively identify the point of social-private discrepancy with limited parameter uncertainty. Alternatively, if productivity growth is due to innovations by risk-taking firms and entrepreneurs seeking temporary monopoly rents, successful innovation results in ex post monopoly and destruction of rents on competing products and processes. Good policy in this case is focused on fostering the development of new entrepreneurs, ensuring that a temporary monopoly does not become permanent, and helping those who lose in the process of creative destruction find new jobs. However, between these perspectives, there are a wide range of alternatives corresponding to a range of theories on how the innovation process works. There is genuine unresolvable uncertainty as to which view of the world is appropriate.

The debate on 'productivity levers' is subject, at almost every turn, to this type of 'model' or what we call *Knightian uncertainty*. This is uncertainty that cannot be expressed in terms of a simple statistical probability, but refers to the unresolvable fact that the true causal economic pathways from policy to outcomes are unknown and may be unknowable within the time frame that is relevant to policymakers. Does encouraging investment in pulp mills, bridges or computer programmers lead to higher future growth? Is it done by lowering taxes or increasing subsidies? A useful question but what is the answer. Given Knightian uncertainty as to past causal linkages from policy to productivity, and also the considerable uncertainty with respect to the developments of the next century how can we think about policy choice? Here are some suggestions for the prudent Canadian policymaker:

a) Be cautious: Stick to policies that are known to be, on balance, favourable towards promoting the 'Big 3', and worry about policies that claim to address another problem but may cost the economy in terms of increased investment, trade or human capital formation.

b) Pay attention to new evidence: In the presence of severe model uncertainty you may wish to display increased sensitivity to new and unusual information — remember anecdotes are preliminary data. I think a good example of this type of issue is the current 'brain drain' debate. The traditional evidence and theory suggest that the flows of skilled workers relative

to their stocks are insignificant and suggest there is little to worry about. But recent losses of 'very highly skilled' workers have sent out alarm signals in the business community. It may be that the business community has an incompletely articulated model of the importance of highly skilled labour that the older theories do not represent, but that may be more relevant to the success of Canadian firms, and thus the Canadian economy.

c) Be a global realist: Policies directed at productivity must be considered in light of a realistic view of the international allocation of mobile and footloose resources, and Canada's relative position in the global economy. Without a competitive policy environment for new mobile investment and highly skilled people all other productivity levers may be irrelevant.

NOTES

1 A standard source on growth accounting for the OECD countries is Maddison (1995) who also discusses the history of the 'residual' calculation of productivity growth.

2 This debate is reviewed by Temple, 1999.

3 See Young, 1995.

4 Obviously one has to qualify this comment in an open economy. If investment is financed by foreigners then the debt burden of that investment represents a reduction in future consumption with similar negative consequences for welfare.

5 See Griliches (1992) and the set of papers on service sector output measurement in the special issue of the Canadian Journal of Economics (1999).

6 See Griliches (1992) and Boskin Commission (1996) on the U.S. CPI. My comments in this section draw on Harris (1998).

7 Later in the paper we discuss the concept of general purpose technologies or GPTs, a good example being computers. Work by Helpman and others in Helpman (1998) has shown that system-wide technological change initiated by the introduction of new GPT's can lead to initial declines in measured MFP.

8 There are some caveats to this when discussing developing countries. In those instances, productivity and GDP per capita growth rates can diverge because of large changes in labour force participation rates as countries climb the development ladder.

9 There is a large literature on 'convergence' as an explanation of growth rates. The basic idea is that convergence of income levels might be expected if there are common factors driving economic growth such as technology and similar economic policies. Evidence for the hypothesis is mixed at the national level which suggests that there is ample room for other, country-specific, explanations of economic growth and productivity. On the other hand, there is some evidence that within nations convergence is important in explaining different regional growth rates. In the Canadian case, Coulombe (1997) covers this issue and reviews the evidence.

10 See Bloomstron et al, 1996.

11 See Argotte and Epple (1990), and Bahk and Gort (1993).

12 The evidence on Canada-U.S. productivity growth differences remains controversial. The data we have suggests that Canada has done slightly better in terms of growth rates, particularly when we exclude computer equipment manufacturing from the U.S. data.

13 Theories supporting this view are sometimes referred to as 'extent of the market' theories. There is an alternative set of theories based on learning by doing in which smaller and less advanced countries are disadvantaged by globalization and freer trade that force them into specialization in less advanced

products where learning-by-doing is not prevalent. Recent evidence by Ades and Glaeser (1999) strongly supports extent-of-the-market theories which suggest that external demand is an important limiting factor on growth, and openness can substitute for a large domestic market.

14 Treffler (1999) has provided some evidence to this effect.

15 It is interesting that in almost two decades the arguments remain more or less the same. My MacDonald Commission study (Harris, 1985), goes over much of the same territory from the perspective of the early 1980's.

16 A useful survey of the recent work on cities, growth and agglomeration is and Duranto and Puga (1999).

17 Dwyer (1995) finds this to be particularly true in a study of U.S. textile plants.

18 This is referred to as the Balassa-Samuelson hypothesis in the literature.

19 Reported in Easterly et al, 1993.

20 Denton and Spencer (1998) provide a very useful review of demographic projections for Canada and their implications for output growth.

21 A variety of projections is provided in Session II of Courchene and Wilson, 1998.

22 As argued for example in *The Economist* , September 4, 1999, pp. 65–68.

23 See Jones, 1998.

24 A recent paper by Ades and Glaeser (1999) has evidence on growth which is strongly supportive of this view. Their results suggest that even a low income region can attain a high growth rate by sufficient access to an external market which overcomes the inherent limitations of small regional markets.

25 I take this as the central message of the Mintz Committee on business tax reform.

26 John Helliwell's recent study (1999) makes this point using Canadian-U.S. data.

27 See Gordon, 1999.

28 The historical record on leading and lagging in growth is detailed in Abramovitz, 1986.

29 Some of these issues are discussed in Globerman and Harris, 1998.

30 See Grady and Macmillan, 1998.

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