Measuring productivity

Diane Galarneau and Jean-Pierre Maynard

In the past few years, attention has focused closely on the productivity of Canadian industries. This interest is the result of a major slowdown in the rate of productivity growth compared with that of the prosperous 1960s. Many analysts have tried to explain the causes of this slowdown and its effects on Canada's economy and production system, most often using labour productivity. This measure was discussed in a previous issue of *Perspectives* (Galarneau and Dumas, 1993).

However, the measure itself provides little information on the underlying causes and the effects of variations in productivity. Since 1989, Statistics Canada has published a new measure: multifactor, or total factor, productivity. This indicator and its derivatives make it easier to identify the factors of production that are the major or minor sources of growth. As well, multifactor productivity helps to identify the contribution of each factor to output.

This article compares the two measures and their trends in recent years. It also examines the relationship between multifactor productivity and employment.

Definition and measurement

Productivity is the ratio of output to the factors of production. However, it is generally examined in terms of how it changes over time. If economic growth is measured by the increase in the quantity of goods and services produced by a country in a given period, growth will come from two sources:

- increases in the factors of production (labour and capital[1]), and/or
- efficiency gains.

The notion of productivity growth comes into play with the second source and measures the improvement in the efficiency with which a business, industry or country produces goods and services.

Efficiency or productivity is difficult to quantify because no direct method exists for doing so. It is therefore derived by subtracting the contribution of the additional quantities of inputs used from the change in quantity produced, both of which are quantifiable. The result, productivity growth, is the residual portion of growth that cannot be accounted for by the additional quantities of inputs (see *Technical notes*).

At the national level, productivity growth is the difference between the increase in the quantity of goods and services produced by all businesses and the additional quantities of all inputs used. In the long term, this residual portion of growth represents the improvement in the efficiency of the entire production process. In that sense, increased productivity is a key element of economic growth because, without it, output would increase only with the addition of larger quantities of the factors of production.

Two measures

Productivity can be considered in terms of the full range of inputs or only a single factor, such as labour or capital. The former is total factor productivity, and the latter, a partial measure of productivity because it takes into account only one factor of production at a time.

By far the most widely used measure is labour productivity. This partial measure expresses the quantity of goods and services produced per unit of labour (hours worked). It was long the only measure of productivity because of problems associated with collecting and interpreting[2] the data on capital, which are essential in calculating total factor productivity. Statistics Canada's multifactor productivity measure, however, expresses output per unit of all inputs combined.

Labour productivity increases more quickly than multifactor productivity

Labour productivity generally has a higher growth rate than multifactor productivity (Chart A). Labour productivity is the difference between the growth in output and the contribution of additional quantities of labour. Because it takes only labour into account, labour productivity represents the growth in output attributable to a relative change in the quantity of capital plus efficiency gains in the production process.[3] On the other hand, total factor productivity takes into account the contribution of all factors of production, so the residual portion of output growth represents only efficiency gains[4] (Figure).

Since the early 1960s, Canadian businesses have become far more automated, which has meant a steady increase in the relative quantity of capital. This largely explains why the labour productivity index[5] has grown more rap-

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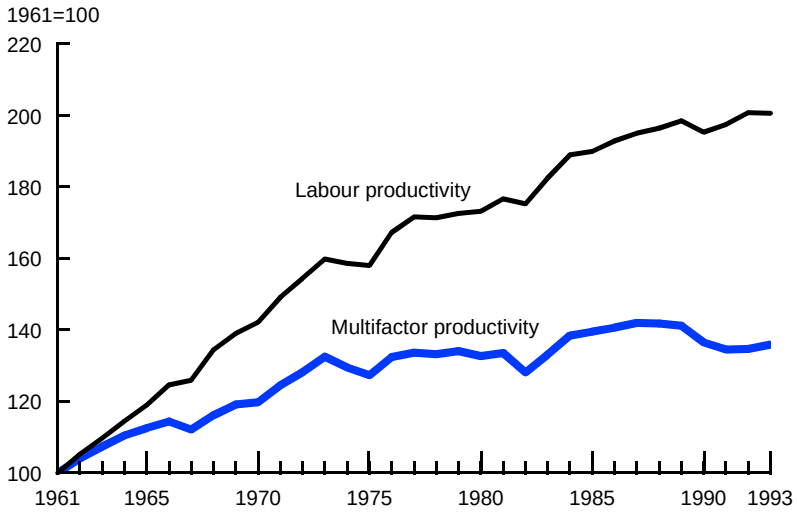
Chart A
Depending on the measure, productivity growth rates vary substantially.



Source: Input-Output Division

Figure
Two productivity measures

Change in output(Q) = Change in labour(L) + Change in capital(K) + Change in technology(T)*

or:

$\triangle Q = \triangle L + \triangle K + \triangle T$

therefore,
LABOUR PRODUCTIVITY is

$\triangle Q - \triangle L = \triangle K + \triangle T$

and
MULTIFACTOR PRODUCTIVITY is

$\triangle Q - \triangle L - \triangle K = \triangle T$

* *or productivity*

Note: This is a simplified form of the detailed equation shown in Technical notes.

idly than the multifactor productivity index. In other words, the faster growth in labour productivity since 1960 has occurred in large measure because workers have been increasingly well equipped.

Long-term trends

The trends in both the multifactor and the labour productivity index confirm that the productivity growth rate began to slow in 1975 (see *Why has productivity growth slowed?*). However, the severity of the decline depends on which indicator is used.

Since 1975, the Canadian economy has gone through two complete economic cycles: from 1975 to 1982 and from 1982 to 1991. The growth rate of the multifactor index improved during the second cycle, although it did not equal the performance of 1961 to 1975. The labour index, on the other hand, declined slightly since 1982 (Table 1).

The improvement in the performance of the multifactor productivity index between 1982 and 1991 results from a higher average annual increase in real output combined with a drop in the growth of capital stock. The small drop in the growth rate of the labour productivity index stems primarily from the relatively greater growth in hours worked compared with output.

Sources of growth

One of the advantages of the multifactor productivity index is that it helps to identify the sources of output growth: productivity, capital and labour. For example, from 1961 to 1991, capital appears to have been the main component of growth in business output (as measured by the increase in real GDP). Between 1961 and 1975, the contributions of capital, labour and productivity were relatively strong and fairly

Why has productivity growth slowed?

Since 1975, the growth rates of both multifactor and labour productivity have declined, a situation that it is not unique to Canada. The phenomenon has occurred in all industrialized nations and has been no worse here than elsewhere. Many researchers have attempted to pinpoint the causes, but after 20 years of research, the debate continues.

Of all the hypotheses put forward to explain this decline, two seem most plausible. According to the first, the oil shock in the 1970s and the restrictive policies that accompanied it were largely responsible for the decline in productivity. This explanation, however, is less popular today, as productivity has not improved substantially despite lower prices for raw materials.

A second explanation is the "convergence" theory, which holds that countries tend to reach the same overall income and productivity levels in the long run. According to this theory, it is not the current slowdown that is unusual, but rather the rapid growth following World War II. During the "Dirty Thirties" and the war, many new technologies were developed, but their implementation into regular production had to wait until after the war. Because of the exceptional economic climate of the time, American firms were well positioned to draw on the backlog of new technology and hence experienced remarkable productivity improvements in the post-war years. Subsequently, other industrialized countries adopted these new technologies, prompting their own productivity explosions and bringing their levels of productivity closer to that of the U.S. In fact, the lower a country's productivity level in 1960, the greater the increase achieved.

Once the new technologies had been completely adopted in the U.S., the rate of productivity growth slowed as technical advances were developed and implemented at a more "normal" pace and as the exceptional post-war conditions gradually ceased to exist. As other industrialized countries in turn implemented the new technologies, their productivity growth also slowed (Abramovitz, 1991; Fortin, 1994; Denny and Wilson, 1993).

similar, and output had its highest growth rate. However, between 1975 and 1982 and between 1982 and 1991, growth was dominated by capital (Chart B).

Cyclical trends in the two productivity measures

Multifactor productivity is much more sensitive to economic cycles than is labour productivity. As a result, the multifactor index drops more markedly during recessions.

This sensitivity stems from different short-term characteristics of the two main factors: capital and labour. Capital is considered downwardly rigid because a business will rarely get rid of its capital stock during an economic slowdown, tending instead to decrease its use of capital. Also, since investment decisions are made well in advance, capital stock usually continues to increase even when production declines. Labour, however, is considered to be less rigid because it is possible, within certain limits, to reduce the hours worked.

When an economic slowdown occurs, businesses usually decrease the quantity they produce, primarily by reducing hours of work and the degree to which capital is used. Consequently, the multifactor productivity index tends to decline because less is being produced with a capital stock that is continuing to increase, at least in the short term. However, the downward adjustment in the number of hours is generally made more quickly, so labour productivity (as measured by output per hour worked) decreases less abruptly.

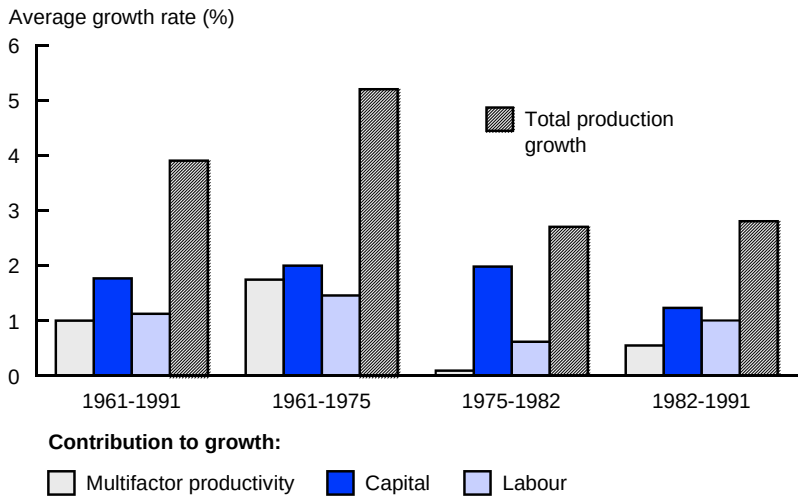
However, when the economy recovers, the multifactor productivity index rises rapidly because output increases more quickly than capital stock (machinery, materiel and plants). The relatively weak growth in capital stock occurs because investment decisions lag behind the economic cycle, so that even if output begins to recover, it will take longer for capital stock to follow suit. This time lag can sometimes lead to a more rapid increase in the multifactor index than in the labour index, as happened in 1984 and 1985.

Table 1
Average* rates of business sector growth from 1961 to 1991

	Multifactor productivity**	Labour productivity	Hours worked	Capital stock	Real output (GDP)
			%		
1961-1975	1.7	3.3	2.3	5.3	5.4
1975-1982	0.1	1.5	0.9	5.5	2.5
1982-1991	0.5	1.2	1.6	3.4	2.9

Source: Input-Output Division
* *Geometric average calculated from the trough of each business cycle*
** *Based on value-added production*

Chart B
In every period since 1961, capital has contributed the most to business sector growth.



Source: Input-Output Division

The multifactor productivity index increased from 1983 to 1987. The decreases observed between 1988 and 1991 resulted in part from under-use of capital. Capital stock grew at a high rate from 1986, whereas the degree of use of capital began to decline in 1989. Output decreased as capital stock kept increasing, which exerted downward pressure on the multifactor productivity index. The index increased slightly in 1992 and 1993, however, because of an upturn in output (Table 2).

Labour productivity rose from 1983 to 1989. The decline of 1.6% between 1989 and 1990 was caused mainly by a drop in output. The decrease was only temporary, however, because it was followed by three consecutive increases. These movements reflect the late adjustment by businesses to changes in aggregate demand.

Is better productivity synonymous with employment growth?

Canadian firms have become more aware of the need to improve their productivity. On the other hand, the country has an increasing problem with underemployment – people unemployed or working fewer hours than they would like (Noreau, 1994). But what is the relationship between productivity and employment?

Overall, between 1961 and 1991, changes in the multifactor productivity index paralleled those in employment. From 1961 to 1975, multifactor productivity and hours worked[6] climbed relatively quickly, whereas in the following two cycles (1975 to 1982 and 1982 to 1991) both multifactor productivity and hours worked rose more slowly (Chart B).

At the industry level, however, the relationship is not as clear over the entire period (1961 to 1991[7]). In some industries, such as agriculture, an increase in multifactor productivity coincided with a decrease in hours worked. In contrast, community, business and personal services and finance, insurance and real estate (other services) showed a decrease in productivity, yet posted the largest increase in number of hours worked (Table 3).[8]

Table 2
Annual rates of business sector growth from 1982 to 1993

	Real output (GDP)	Multifactor productivity*	Labour productivity	Hours worked	Capital stock	Capital utilization rate**
			%			
1982	-5.6	-4.0	-0.8	-4.8	7.1	-10.2
1983	3.5	3.9	4.1	-0.6	1.6	3.0
1984	7.0	4.0	3.6	3.4	1.2	6.4
1985	5.6	0.8	0.5	5.0	2.3	4.5
1986	3.5	0.8	1.5	1.9	3.6	-1.0
1987	5.0	0.9	1.1	3.8	3.6	2.8
1988	4.9	-0.1	0.8	4.1	4.4	1.3
1989	2.4	-0.4	0.9	1.4	5.5	-2.0
1990	-1.5	-3.4	-1.6	0.1	5.3	-3.6
1991	-3.2	-1.4	1.1	-4.2	3.1	-3.7
1992	0.3	0.1	1.7	-1.4	3.8	-1.3
1993	3.2	0.9	0.9	2.3	1.8	1.8

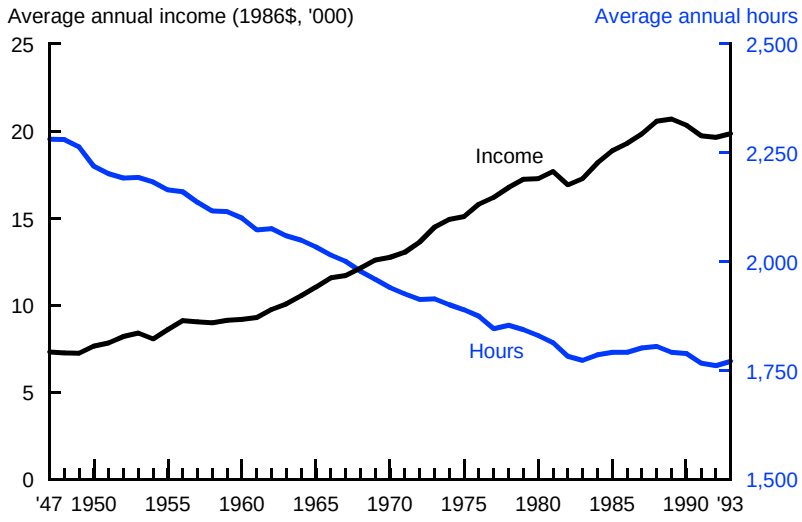
Source: Input-Output Division
* *Based on value-added production*
** *Based on total non-farm goods-producing industries*

Table 3
Average rates of growth from 1961 to 1991; proportion of hours worked and gross domestic product, 1991

	Average* rates of growth 1961-1991				
	Multifactor productivity**	Hours worked	Capital stock	Proportion of hours worked (1991)	Proportion of GDP (1991)
	%				
Goods sector					
Agriculture	1.5	-1.9	-0.2	6.2	3.0
Other primary	-0.2	0.3	3.7	2.8	6.6
Manufacturing	0.6	0.7	3.7	19.8	24.2
Construction	0.3	1.4	4.6	8.7	8.3
Electricity, gas	1.2	3.0	4.8	1.2	4.4
Service sector					
Transportation	1.5	0.9	1.2	5.5	5.8
Communication	3.8	1.9	4.6	2.2	5.2
Wholesale trade	1.4	3.1	3.7	7.5	7.7
Retail trade	1.2	1.9	1.0	14.8	8.2
Other services †	-0.9	4.5	7.4	31.2	26.6

Source: Input-Output Division
* *Geometric average*
** *Based on gross output*
† *Includes community, business and personal services, and finance, insurance and real estate*

Chart C
With increased productivity, per capita income has increased overall while hours of work have generally declined.



Source: Input-Output Division

What do productivity gains in an industry mean?

New jobs will not necessarily be created in an industry with efficiency gains. In fact, efficiency gains can have multiple effects depending on the prevailing conditions when the gains are realized.

The relationship between employment and productivity must be examined in a broader sense and over a longer period. A significant rise in productivity in a given sector eventually leads to reallocation of resources, as occurred in the transition to the industrial age. A large proportion of the population used to be engaged in agricultural activity, but today this industry accounts for a relatively small share of employment. As a result of improved productivity in agriculture, workers could shift to other industries, such as manufacturing.

Reallocation of resources is not painless, especially when the resources are workers. Human and non-human resources idled by the increased efficiency of production could remain unused for some time if aggregate demand is temporarily saturated or if they are unsuited to other industries.

Productivity and the standard of living

Despite temporary disruption, the long-term effect of improved productivity is always an increase in the standard of living. A general increase in productivity implies the same output at a lower cost (or higher output at the same cost). That translates into lower consumer prices and/or increased returns to the factors of production (including wages and salaries).

If technical advances served only to improve efficiency in producing the same outputs, employment would not increase. But growth in collective wealth stimu-

Technical notes

Calculation method

Productivity is derived as follows:

$Q = F(K,L,T)$

where

Q = Output L = Labour

K = Capital T = Technological change (or productivity)

Growth in output is represented by

$q = \alpha k + \beta l + \tau$

$\tau = q - \alpha k - \beta l$

where

q = increase in output l = Increase in labour

k = increase in capital τ = increase in technology

α, β = shares of capital and labour in output

The increase in multifactor productivity is calculated as the difference between the increase in output and the contribution of additional quantities of the factors of production.

Labour productivity is derived in a similar fashion. The growth in labour productivity (P_l) is defined as:

$$P_l = q - l$$

The growth in labour productivity actually represents efficiency gains (growth in multifactor productivity) plus the contribution of increases in capital stock.

Since $q = \alpha k + \beta l + \tau$ and $P_l = q - l$

$$P_l = \alpha k + \beta l + \tau - l$$

$$P_l = \tau + \alpha k + (\beta - 1) l$$

because $\alpha + \beta = 1$ then $\beta - 1 = -\alpha$

$$P_l = \tau + \alpha k + (-\alpha l)$$

$$P_l = \tau + \alpha (k - l)$$

where $(k - l)$ is the change in capital relative to labour, that is, the ratio of capital to labour.

In the short or medium term, this method of measuring productivity can lead to interpretation errors. In fact, in the short term, an increase in measured productivity can reflect something other than changes in efficiency. It also reflects everything that cannot be quantified using current measurement techniques.

Other factors, whose contribution should be included with the inputs if measurement techniques allowed, will produce an upward bias in measured productivity. Changes in the degree of use of machinery and equipment or in economies of scale are two examples. Since collection methods are not perfect, measurement errors or omissions can also bias the productivity measure upward or downward and consequently over- or underestimate the improvement in efficiency.

Capital

Productivity measures the quantity produced per unit of input. It is impossible to define a unit of capital, however, because it is not a homogeneous factor. The only data available are based on the real purchase values of machinery and equipment, which are written off over time to account for depreciation. Ideally, the measure used in calculating multifactor productivity should relate to the theoretical concept of the service provided by the capital, e.g., "machine-hours." Such a measure would be similar to that used for labour (hours worked).

Converting quantities into dollars and prices

For a given business, it is usually possible to determine changes in the quantities of inputs used and goods and services produced. For a chair manufacturer, for example, a chair is a unit of production. At the national level, however, variations in quantities are more difficult to determine because of the many types of inputs used and goods and services produced, as well as the difficulty in finding a common unit of measurement. This is why inputs and outputs are expressed in dollars.

However, because of inflation, dollar values generally increase more quickly than quantities. Price deflation makes it possible to convert to measures in quantities and still retain a common unit of measurement.

Exchange rate

Because Canada trades goods and services with other countries, Canadian businesses must cope with fluctuations in the exchange rate. That rate affects the price of goods and services traded between countries. If the Canadian dollar has a low value compared with the American dollar, Canadian goods and services sold in the United States will be more attractive because they cost less. If, in addition, productivity gains are passed on to the consumer in the form of a lower price for a particular good, this will give the product a further advantage on the American market. However, productivity gains could be offset by a high Canadian dollar because the price decrease in Canada (resulting from increased efficiency) would be nullified on the American market by the high exchange rate.

Different measures of multifactor productivity

There are two types of multifactor productivity measure: industry measure and inter-industry measure. Statistics Canada publishes three industry measures (based on value added, gross output, and gross output net of intra-industry sales) and one inter-industry measure.

The measure based on value added is the most appropriate for analyzing the productivity of the business sector as a whole, and was used here for long-term trends and cyclical trends. Gross output was used for productivity by industry.

For further information, consult *Aggregate Productivity Measures*, Catalogue 15-204E.

lates new demands. As well, improvements in efficiency demand more sophisticated inputs. Meeting these new demands requires resources, which can be provided through the reallocation of resources made available by efficiency gains in other areas. In this way, productivity is linked to the standard of living and employment.

Productivity increases in primary industries and, later, in secondary industries have made substantial contributions to the growth of GDP and the overall wealth of the country. Among other things, this has translated into a major increase in real per capita income along with a decrease in the hours of work (Chart C). In addition, increased leisure, the possibility of postponing labour force entry, and the option of early retirement are all benefits of the increased collective wealth.

Summary

Increased productivity is a key component of economic growth. Improvements in productivity represent technical progress in the broad sense of the term, without which national output would increase only with larger quantities of the factors of production (labour and capital).

Labour productivity, the most commonly used measure of productivity, is only a partial measure. Since 1989, a broader measure – multifactor productivity – has been available. By definition, this measure grows more slowly than labour productivity and is more sensitive to recessions.

Although overall, changes in employment and multifactor productivity followed the same pattern between 1961 and 1991, on an industry-by-industry level, increases in productivity sometimes coincided with decreases in hours worked (or employment). This reflects in part the adjustments that must be made when production becomes more efficient. Hence the relationship between employment and productivity must be analyzed from a broader perspective and over a longer period. Under these conditions, overall increases in productivity lead to an improved standard of living and usually coincide with widespread employment growth. □

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Notes

1 Also included in the factors of production are intermediate goods and services such as energy and raw materials. However, for ease of presentation, this article deals with labour and capital only.

2 For further information, see *Technical notes.*

3 Changes in labour productivity (like changes in multifactor productivity) also result from economies of scale and changes in the degree of use of capital.

4 Because data are not sufficiently precise, the residual portion of growth still includes more than just efficiency gains. For further information, see *Technical notes.*

5 Productivity data are usually presented in index form.

6 Employment is represented in this study by the number of hours worked.

7 The data by industry are available only up to 1991.

8 Linking employment and productivity requires analytical techniques more sophisticated than the one used here. Table 3 serves only to place the discussion that follows in context.

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