CSLS Conference on the Canada – U.S. Manufacturing Productivity Gap

January 21 - 22, 2000   Château Laurier Hotel, Ottawa, Ontario

Centre for the
Study of Living Standards
Centre d'étude des
niveaux de vie

Three Suggestions to Improve Multi-Factor Productivity Measurement in Canadian Manufacturing

Serge Coulombe
University of Ottawa

Session 5 "Can Measurement Problems Account for the Gap?"
January 22   8:30 AM - 10:00 AM

Prepared for the *Centre for the Study of Living Standards* Conference Canada-US Manufacturing Productivity Gap. Ottawa, January 21-22, 2000

Three Suggestions for Improving Multi-Factor Productivity Measurement in Canadian Manufacturing

Serge Coulombe*

* Professor, Department of Economics, University of Ottawa. For further information, contact Serge Coulombe, 613-562-5800#1689, e-mail: **scoulomb@uottawa.ca**

Acknowledgments: Credits should be given to Jean-Pierre Maynard from the Micro-economic Analysis Division, Statistics Canada, for his precious contribution by providing the author with the data on productivity (from both Statistics Canada and the BLS) used in this paper. Some parts of this paper are taken from my recent Research Paper on the Canada-US productivity-growth paradox in the business sector (Coulombe, 2000). The author benefitted from discussions with Pierre Duguay and T.K. Rymes and from the comments of Erwin Diewert. The author is solely responsible for all views expressed in this paper and he is solely responsible for any remaining errors or omissions.

Summary

The paper analyses the consequences of alternative methodologies used to measure labor and capital input changes by Statistics Canada (Statscan) and the Bureau of Labor Statistics (BLS) for MFP growth accounting in both the business and the manufacturing sector. Three measurement problems are analyzed.

First, Statistics Canada's labor force index used to account implicitly for changes in the quality of the labor force appears biased over time which renders it problematic for comparisons with US measures. In the current methodology, Statscan appears to overestimate the contribution of the changes in the labor composition in the 1960s compared with those in the 1980s and the 1990s. MFP growth in the 1960s is therefore underestimated compared with the 1980s and the 1990s.

Second, the concept of capital used by Statistics Canada for MFP growth measurement is too narrow. By excluding land and inventories, which tend to grow at a substantially slower pace than the other components of the capital stock, the Canadian statistical agency tends to overestimate the contribution of capital accumulation to productivity growth. This overestimation is the consequence of using the residual share of profits from national income as a measure of the contribution of capital accumulation to output growth.

Third, the methodology used by the Canadian statistical agency to account for depreciation in estimating the capital stock for MFP measurements appears to be inappropriate. Aggregate effective depreciation rates are extremely high compared with the ones used by the Bureau of Labor Statistics in the US and Statistics Canada seems to systematically underestimate the level and the growth rate of the capital stock in Canada and to substantially overestimate its variability.

The paper proposes methodological changes to address these problems that are very much in line with the methodology used in the US by the Bureau of Labor Statistics.

JEL Classifications: O47, O51, C43, C82, I31

Keywords: Measures of Multifactor Productivity, Solow Residual, Measurements Errors, Canada-U.S. Comparisons

Introduction

This paper analyses the consequences of alternative methodologies used to measure labor and capital input changes by Statistics Canada (Statscan) and the Bureau of Labor Statistics (BLS) for Multifactor productivity (MFP) growth accounting in the business and the manufacturing sectors.[1] Three important methodological differences exist between the approaches taken by each agency: different composition indices are used to account for changes in the quality of the labor force; different definition of the components of the capital stock are used; and finally, the approach used to account for depreciation differs in Canada and the US.

Two conclusions emerge from the analysis. First, using the current methodologies, it is misleading to compare official Canadian and US MFP data in both the manufacturing and the business sectors. Second, it would appear that the more appropriate methodology is used by the BLS and hence, Statscan should thoroughly revise its approach for capturing changes in labor force composition and its methodology for estimating capital inputs for MFP measurements.

The data are discussed in section 1 and the three methodological points dealing with MFP measurements are then analyzed in sections 2 to 4. In section 5, we propose suggestions for improving MFP measurements in Canada.

1 - The Data

The analysis deals with annual data on value-added MFP. In the business sector, we utilize the latest (March 1999 for Canada and February 1999) estimates of MFP produced in Canada by Statistics Canada and in the US by the Bureau of Labor Statistics. US data are for the private business sector. The data bank was constructed by the Micro-economic Analysis Division of Statistics Canada, covering the 1961-1997 period. Time series data for alternative measures of capital stocks with different depreciation approaches are not available in the Canadian business sector. Consequently, we had to rely on Canada-US comparisons to estimate

[1] We abstract from methodological differences associated with the measure of output. Differences in the measurement of output could change the measure of productivity substantially. For example, Gordon (1999) argues that the recent improvements in labor productivity growth in the US might mostly be due to a change in the statistical methodology used to account for the effects of a drop in computer hardware prices on real output.

the bias from alternative depreciation methodologies in the business sector.

In the manufacturing sector, we used the latest value-added MFP estimates from Statscan. Such MFP estimates based on value added are not produced for the manufacturing sector in the US. The Canadian MFP data bank and the BLS capital stock data band were constructed by the Micro-economic Analysis Division of Statistics Canada. We are also using unpublished Canadian capital stock data computed by the Investment and Capital Stock Division in Statistics Canada following the geometric infinite methodology to account for depreciation for the 1962-1998 sample.[2] This approach to model depreciation is used in the US by the Bureau of Economic Analysis (BEA) and is very closely related to the methodology followed by the BLS.

All growth rates and percentage differences are measured as logarithmic differences ($\Delta\%X(t)=\log(X(t)/X(t-1))$).

2 - MFP Measurement and Changes in the Labor Force Composition

2.1 - Basic Growth Accounting

MFP is a measure of productivity derived from an accounting framework in which a fraction of output growth is assigned to the growth of capital and labor inputs. MFP growth is then measured residually from a basic transformation of the production function.

To clarify these concepts, let's consider for illustrating purpose the following Cobb-Douglas production function with constant returns to scale:

$$Y = K^{\alpha}(Le^{gt})^{1-\alpha}. \quad (1)$$

With this notation, output *(Y)* is a function of the capital stock *K*, labor (*L*), labor-augmenting technological progress growing at the rate *g*. Parameters α and $1-\alpha$ are the elasticity of output with respect to capital and labor. The parameter α is measured by the share of profits in national income. This share is obtained residually by subtracting labor income from national income. In Canada, as in the US, the share of profits used by Statscan for the measure of MFP follows a relatively constant trend. For the Canadian business sector, in the 1961-1997 period, it varies

[2]We thank Richard Landry from Statistics Canada Investment and Capital Stock Division for giving to us these unpublished estimates.

between a maximum of 0.39 and a minimum of 0.31 with a mean value of 0.35. In the Canadian manufacturing sector, the mean value of the profit share is 0.33 and it moves between a maximum of 0.43 and a minimum of 0.25.

For computing MFP growth in Canada and in the US, the labor force is measured in hour terms. For the time being, we assume that the labor force is homogeneous and that there is no improvement in the quality of labor. Written in intensive form (per units of labor *L*), the production function becomes:

$$LP = k^{\alpha}(e^{gt})^{1-\alpha},$$

where *LP* stands for labor productivity *Y/L*, and *k* is the Capital / Labor ratio. Taking the time derivative of the logarithms on both sides of this equation leads to the following:

$$GLP = \alpha(\Delta\% k) + (1-\alpha)g. \quad (2)$$

In growth-accounting, the fraction $\alpha(\Delta\% k)/GLP$ of the growth of labor productivity is assigned to the growth rate of capital and the fraction $(1-\alpha)g/GLP$ to technological progress. The parameter $(1-\alpha)g$ is called the **Solow Residual**, or the growth in multifactor productivity. For any given year, MFP growth is computed residually by subtracting from the growth of labor productivity the component $\alpha(t)\Delta\% k(t)$, which is the estimated contribution of the growth in the Capital / Labor ratio to the growth of labor productivity.

2.2 - Composition of the Labor Force and MFP Measurement

Both Statscan and the BLS take account of changes in the composition of the labor force in MFP growth measurement in the business sector. The intent is to account for changes in the quality of the labor force that may affect productivity. Intrinsically, the idea is very interesting because changes in the characteristics of workers play a potentially significant role in explaining changes in living standards. This is particularly important for productivity data on the business sector, which covers around 75% of the economy and provides important information on the evolution of living standards

For MFP measurement in the manufacturing sector, Statscan is using the same methodology than the one used in the business sector to account for changes in labor force composition. The BLS however does not account for changes in labor force composition for MFP measurement in the manufacturing sector.

By accounting for changes in labor force composition, however, one has to bear in mind that the MFP concept is modified. Different methodologies that incorporate different degrees of adjustment for changes in labor characteristics will result in different concepts of MFP growth. In this section, we address this issue with a simple modeling approach that is compatible with the way the two statistical agencies actually account for labor force compositional changes.

Previously, labor *L* was assumed of constant quality. Now let's suppose that the index number *C*, called the **composition of the labor force index**, accounts for the aggregate improvement in the quality of the labor force *L*. Equation (1) can now be written as:

$$Y = K^{\alpha}(CLe^{gt})^{1-\alpha}. \qquad (3)$$

Again, the derivative of the logarithm on both sides of this equation, written in intensive form per unit of labor *L*, yields the following relationship between labor productivity growth and MFP growth:

$$GLP = \alpha\Delta\% k + (1-\alpha)\Delta\% C + \Delta\% MFP. \qquad (4)$$

For a given labor productivity growth (*GLP*), a positive $\Delta\%C$ will decrease the estimation of MFP growth ($\Delta\%MFP$).

The BLS approach for MFP measurement in the business sector is to account for improvements in the quality of labor through investment in education. Consequently, the measure of $\Delta\%C$ is positive on average. For MFP measurement in the manufacturing sector however, the BLS does not account for changes in *C*. Consequently, *ceteris paribus*, MFP growth in the US should be smaller in the business sector than in the manufacturing sector simply because $\Delta\%C$ is positive in the former and null by definition in the later.

2.3 - Canada-US Comparisons

For MFP growth computation in the business sector, both Statscan and the BLS use a composition/quality-improvement factor for measuring the labor force. The two statistical agencies produce a **Laspeyres Index** measure of labor, which is a straightforward summation of hour works, and a **Fisher Index** measure, which captures compositional changes. In the framework of equation (3), we define the composition of the labor force index C as being:

$$C = F / L.$$

L is the Laspeyres Index and F is the Fisher Index measure of labor.

The way the adjusted labor force F is measured by the two statistical agencies differs considerably. For Statscan, F is derived by weighting labor with relative wages by industries. This index is designed to capture implicitly some of the changes in the quality of the labor force from changes in the labor composition across industries.[3] In the US however, F is measured with a more sophisticated statistical methodology that accounts explicitly both for composition changes from gender composition and experience, and for improvements in the quality of the labor force from education.[4] Consequently, the index $C(t)$ in the US should be increasing on average since the mean educational level of the US labor force has tended to increase for decades. *A priori*, $C(t)$ in Canada might not be increasing in the long run since industrial shifts might be only transitory.

The composition index C is directly available from the BLS MFP growth data bank. As for Statscan, we have computed the implicit composition of the labor force index by simply dividing the Fisher index measure by the Laspeyres index measure. The original data and the HP trend are depicted in Figure 1 and the trend growth rates in Figure 2. For the US, data are available from 1949 and are portrayed in Figure 2 from this date to present a historical perspective.

---

[3] Refer to Wells, Baldwin and Maynard (1999) page 3.2 and endnote 4 regarding the way Statistics Canada relates its labor force adjustment to changes in quality.

[4] For methodological details on the BLS measure of labor force composition changes, refer to Bureau of Labor Statistics (1999a).

Insert Figures 1 and 2 here

In the business sector, the trend growth rate of the US time series is always positive since 1949 which indicates that the composition index effectively captures the long-run improvement of the labor force with the increase in educational attainment. The decline between 1965 and 1980 in the trend growth rate of the composition index reflects the changes in the mean experience of labor with the massive entry of the baby boom cohort into the labor market. Similarly, the increase in the trend growth rate thereafter is primarily the consequence of the gradual aging of the baby boom cohort. Being more experienced, the efficiency of the typical baby boom worker is improving.

By comparison, the evolution of the Canadian time series appears extremely surprising for two reasons. First, during the 1960s, the growth rate of the composition index in Canada considerably exceeds that of the US. This is puzzling since Statscan does not capture explicitly educational improvements with this index. On average in the long run, the difference between the two time series should be attributed to the trend increase in education captured by the US index and not captured by the Canadian index. The 1960 Canada-US comparison result is puzzling because the occurrence of three following factors would explain it. First, the pure compositional changes in Canada would have to be extremely different to what was observed in the US. Second, the shifts in the 1960s would have to lead to a substantial improvement in the quality of the Canadian labor force. Third, the difference between the two countries in pure compositional changes would have to offset, by a substantial margin, the effect of increasing educational attainment in the U.S. captured by the BLS. We don’t believe this is a realistic scenario.

The second problem pertains to the time series consistency of the Canadian index. The level of the composition index in Canada, not the growth rate, peeks in the mid-1970s and decreases up to the early 1990s, as shown in Figure 1. As shown in Figure 2, this leads to a negative growth rate for the composition index between 1977 and 1989. The composition index in 1997 is 107.0, compared to100 in 1961, and the 1997 number is still slightly below its historical high of 107.7 reached in 1977. In our views, this portrays a biased picture of Canadian labor market developments. Since 1951, reliable census data are available on educational achievements and these suggest that there has been a substantial improvement in the quality of the Canadian workforce. Between 1976 and 1996, the proportion of the population 15 years and over with at least a university degree has increased from 6.4% to 13.3%. During the same period, the proportion of the population 15 years and over with at least a grade 9 has increased from 74.6% to 87.6%. From an historical perspective, a measure indicating that Canadian labor force efficiency improved at a rapid pace in the 1960, but slightly decreased in the last twenty years is clearly unacceptable.

Statscan's current labor force composition effect depends on structural shifts across industries. *A priori*, since the manufacturing sector is more disaggregated than the business sector, the compositional effect should be less pronounced. Furthermore, since the BLS does not account for changes in the composition of the labor force in the manufacturing sector, we could assume that the implicit index *C* is constant for the US with a trend growth rate equal to zero. The two indices are depicted in Figure 3 and 4.

Insert Figures 3 and 4 here

From 1961 to 1982, the labor force composition index in the Canadian manufacturing sector increases from 100 to 102.5 and, since the early 1980s, the index is trending downward (Figure 3). The trend growth rate in the Canadian manufacturing index is positive prior to 1980 and negative since then. Figures 3 and 4 (and their relation with Figures 1 and 2) illustrates three points regarding MFP analyses and comparisons.

First, MFP growth measures in the manufacturing sector in Canada and the US cannot be used for cross-sectional comparison because of significant methodological differences in measuring labor input changes between Statscan and the BLS. Roughly 2/3 of the composition of the labor force growth rate is withdrawn from labor productivity growth to get MFP growth. Consequently, with the current methodologies used by the two statistical agencies, MFP growth in the manufacturing sector is slightly underestimated in Canada compared with the US prior to 1980 and slightly overestimated thereafter. However, the bias stemming from different labor composition indexes is less pronounced in the manufacturing sector than in the business sector.

Second, the problem regarding the time series consistency (comparing the 1960s and the 1970s with the 1980s and the 1990s) of the Canadian index in the manufacturing sector is less pronounced than in the business sector but is still there.

Third, since by definition industrial shifts are less important within a sub-sector than within a more aggregated sector, by construction, the Canadian composition index does not reflect the same changes in labor quality for a sub-sector than for the whole economy. Consequently, in Canada, MFP data in the manufacturing sector cannot be compared with MFP data in the business sector. For example, in the 1960s and the 1970s, the growth rate in the composition index is much higher in the Canadian business sector than in the Canadian manufacturing sector. This does not indicate that labor quality was improving at a more rapid pace in the former than in the later. This is simply a statistical artifact.

3 - The Components of the Capital Stock and the Residual Share of Profits

MFP growth accounting relies critically on the measure of the growth in the capital stock. From a statistical point of view, the capital stock is one of the most intrinsically complicated concepts to measure. In this section, we show that the way the capital stock is defined, narrowly or broadly, has important quantitative implications for the estimation of MFP growth.

The capital stock for MFP measurements in both the business and the manufacturing sector is defined differently by the BLS and Statscan. The American agency adopts a broad definition of the capital stock by including five components in the business sector: equipment, structures, rental residential capital, inventories, and land. Rental residential is not included in the manufacturing sector. The Canadian agency uses a narrower definition by excluding land and inventories. Intrinsically, on methodological ground, there is nothing wrong with the Canadian approach. However, there is a basic problem in using a narrow concept of capital given the way the contribution of capital accumulation to economic growth is measured in current TFP growth accounting practices in the two statistical agencies.

The problem is illustrated with a look at the detailed US data on the business sector capital stock. From BLS official estimates, we have computed an adjusted aggregate capital stock that excludes land and inventories.[5] We depict in Figure 5 the relationship between the official measure of the capital stock used by the BLS, our adjusted measure that excludes land and inventories, and the difference between the two, which accounts for the capital stock from land and inventories.

Insert Figure 5 here

The adjusted measure, which corresponds to the narrow concept used by Statscan, tends to grow at a faster rate than the official measure. This is not surprising since land and inventories, which are excluded from the adjusted measure, are growing at a slower rate than the total capital stock. A look at the actual data from the BLS indicates that the share of equipment in the total capital stock tends to rise continuously since 1948, the first year for which the data are available.

The difference in the growth rates of the two capital concepts is substantial. Over the 1961-1997 period, the narrower measure of the capital stock (excluding land and inventories) has grown on average at an annual rate of 4.10%, compared with only 3.77% for the broader concept. The cumulative growth rate differential between the two concepts over the period is 15.3%.

For measuring MFP growth, both Statscan and the BLS estimate the capital share (α in the equations of section 1.3) residually after having extracted the share of labor income from national income. For the 1961-1997 period, the business sector capital share averages 0.35 in Canada compared to 0.32 in the US. The capital share multiplied by the Capital / Labor ratio growth is then subtracted from labor productivity growth to compute the Solow residual. If the narrower

[5] From a statistical perspective, the exclusion of land and inventories from BLS official measure of the capital stock is not a trivial exercise. For aggregating capital inputs, the BLS uses a chained Tornqvist (Divisia) aggregation index at the industry and at the sector level. We followed the procedure described in the BLS Handbook of Methods for the Tornqvist aggregation procedure (that could be consulted on the WEB at: http://stats.bls.gov/opub/hom/homch10_c.htm#Data Sources and Estimating Procedures on page 4 of 6). First, we tested the procedure by reconstructing the total asset capital stock from the aggregation of its five components. Second, we produced the adjusted estimate by aggregating only the first three components following the same chained Tornqvist in aggregation procedure. We thank Jean-Pierre Maynard again from Statistics Canada for his valuable help in this delicate exercise.

concept tends to grow faster than the broader one, MFP measurements would differ, given the definition of what should be included in the capital stock.

Based on the cumulative growth rate differential observed in the US between the broad and the narrow concept in the business sector, we could estimate the quantitative implications of excluding land and inventories from the definition of the capital stock. Compared with the broad concept, the use of the narrow capital stock, coupled with a profit share of 1/3, would have produced a systematic underestimation of annual MFP growth rates of around 0.1 of 1 percentage point in the 1961-1997 period. This is a small number but remember that MFP annual growth rates are small numbers too, typically around 1% in the business sector. Consequently, the underestimation represents roughly 10% of total MFP growth.[6]

In the manufacturing sector, we have estimated the bias from excluding land and inventories from the capital stock for MFP measurement using exactly the same methodology. The bias is smaller, roughly 0.6 of 1% in the 1961-1997 period. Then, the bias on MFP measurements is relatively less important in the manufacturing sector since MFP numbers are typically higher in this sector than in the business sector.

Which capital concept, the narrow or the broad, should be used to account for capital accumulation in MFP growth measurements? On theoretical ground, one should use that capital whose return corresponds to the residual share of profits. The form of capital that earns the residual share of profits obtained by subtracting labor income from national income includes land and inventories. The return to land and inventories are certainly not measured in labor income. Consequently, on methodological ground, the BLS approach has to be preferred to the Canadian approach.

---

[6] Diewert and Lawrence (1999), from a completely different methodology and using Canadian data only, arrive exactly to the same number. They estimate that the exclusion of land and inventories as input decreases multifactor productivity growth in Canada by .1% per year.

4 - Depreciation Rates and the Growth in the Capital Stock

4.1 - Different Approaches to Account for Depreciation

From a statistical point of view, depreciation is not a straightforward concept to measure. Different methodologies could be used to account for depreciation: Linear, hyperbolic, geometric truncated or geometric infinite.[7] The different approaches lead to substantial differences in the measures of capital stock. Statscan uses the geometric truncated approach for MFP measurement. The BLS closely follows a methodology developed by the Bureau of Economic Analysis (BEA) of the US Department of Commerce.[8] Depreciation rates used by both Statscan and the BEA are based on recent empirical evidence but BEA rates are lower than the Statscan's depreciation rates.

However, the key difference between the Statscan and the BLS methodologies is their treatment of capital retirement. For MFP measurement, Statscan uses the geometric truncated approach in which a retirement pattern, independent of depreciation, specifies the age at which an asset is discarded or retired. The BLS uses the hyperbolic approach which produces very similar results to the geometric infinite approach used by the BEA. With the hyperbolic or the geometric infinite, the infinite pattern of depreciation is assumed to account for retirement. The truncated model is known to generate a higher aggregate effective depreciation rate than the infinite geometric or the hyperbolic and a much lower level for the capital stock. Interestingly, Statscan produces estimates of the capital stock with alternative methodologies for modeling depreciation (hyperbolic and linear). The hyperbolic approach produces lower aggregate effective depreciation rates and is much closer to the approaches used by the BEA and the BLS.

Over the 1961-1997 period, the effective aggregate depreciation rate used for MFP measurements to estimate the growth of the business sector capital stock in Canada is around

---

[7] We thank Peter Koumanakos and Richard Landry from *Statistics Canada*, Investment and Capital Stock Division, for providing to us useful information on Statistics Canada methodology to account for depreciation.

[8] For a detailed description of the BLS's methodology for measuring capital input for MFP growth, refer to BLS (1999b).

10%.[9] In the US, implicit aggregate depreciation rates for the business sector are published on a time-series basis by the BLS. Remember again that the capital stock concept in the US includes land and inventories. We have computed the implicit aggregate depreciation rate in the US business sector for a capital concept comparable with Canada by excluding land and inventories. Time series for both the official measure of the US capital stock and our estimate excluding land and inventories are shown in Figure 6.

Insert Figure 6 here

Interestingly, the aggregate depreciation rate, for both capital concepts, shows a clear tendency to increase over the 1961-1997 period. Two factors explain this phenomenon. First, depreciation rates on equipment and rental residential capital have slightly increased during the time period. Second, and this is the most significant factor from a quantitative point of view, the share of equipment in the aggregate capital stock, the class of capital goods with highest depreciation rates, has continuously increased during the period under study.

Regarding the manufacturing sector, we computed the aggregate implicit effective depreciation rate for the geometric truncated (current) approach to depreciation from the CANSIM series data base.[10] We used Statistics Canada Investment and Capital Stock Division recent estimates of the Canadian manufacturing capital stock and depreciation using the BEA infinite geometric approach. This approach to depreciation is very closely related to the one used by the BLS for producing MFP estimates in the US. Time series for both the implicit aggregate depreciation rates from the current methodology and the BEA methodology are shown in Figure 7.

---

[9] Aggregate depreciation rates for the business sector are not published by Statscan. This number was computed at our request, based on the mean asset lives, by Tarrek Harchaoui, from the Micro-economic Analysis Division of Statistics Canada. It should be interpreted as an estimation of the mean implicit aggregate effective depreciation rate on the capital stock for all assets (again excluding land and inventories) in the Canadian business sector over the 1961-1997 period.

[10] CANSIM series D993717 divides by series D993721(-1).

Insert Figure 7 here

Between 1961 and 1997, the aggregate effective depreciation rate averages 19.3% with the current geometric truncated methodology compared with 6.7% with the BEA-type methodology to account for depreciation. This is a big difference, to say the least. Such a difference in aggregate depreciation rates could translate into very important differences in the time series behavior of the Canadian and the US capital stocks and could have a major impact on measures of MFP growth.

4.2 - Slow Growth for Canadian Capital Inputs

What are the consequences of using higher depreciation rates on the behavior of the Capital / Labor ratio? To answer this question, we have to rely on economic growth theory. The Solow-Swan neo-classical growth model is well suited to analyzing the impact of different depreciation rates on the evolution of the capital stock. In this model, the saving rate, and thus the investment rate, are fixed. If the depreciation rate is changed, agents don't adjust their behavior, as they will do in a growth model with consumer optimization.

To start with, it is important to note than, in steady state in the Solow-Swan model, the growth rate of the Capital / Labor ratio is independent of the methodology used to account for depreciation. In the long run, the growth in the Capital / Labor ratio is only determined by the growth rate of technological progress. However, the growth of the Capital / Labor ratio depends critically on the methodology used to measure depreciation during the convergence process toward steady state. As demonstrated in Barro and Sala-i-Martin (1995, section 1.2.5), the growth of the Capital / Labor ratio and the growth in the capital stock are inversely related to the depreciation rate during the convergence process toward steady state from an initial situation below steady state. Then, higher depreciation rates could translate into a different mean growth rate in the Capital stock for long periods of time. This theoretical prediction is corroborated by the comparative analysis of the Canadian and US data.

In a recent (September 1999) working paper, Koumanakos et al. (1999) recognizes the dramatic consequences that would result from switching to the BEA methodology for geometric depreciation. The authors show that, using the BEA methodology for depreciation, the growth rate in the Canadian capital stock (all industries) would have been substantially higher, around 1% per year since 1980. Regarding more directly the business sector, comparison with US adjusted data for the Capital stock excluding land and inventories indicate that the capital stock used for MFP measurement in the Canadian business sector is growing abnormally too slowly. In the 1961-1997 period, the cumulative growth of the US Capital / Labor ratio was 49.9% higher (logarithmic percentage change) than its Canadian counterpart. Since during the entire period, the annual growth rate in labor productivity in Canada was slightly higher on average than in the US (2.1% versus 1.9%), this big difference in Capital / Labor growth is certainly the consequence of a statistical artifact rather than different economic fundamentals.

The effect of alternative methodologies to account for depreciation in the manufacturing sector is illustrated with a comparison of the capital stock time series computed by Statscan using the geometric truncated (current Statscan methodology) and the BEA-type approach.[11] The two time series are depicted in Figure 8.

Insert Figure 8 here

The two methodologies produce enormous differences in the estimated levels of the net capital stock for the Canadian manufacturing sector. We come back to the question related to these levels in section 4.4 below. But, more importantly for MFP measurements, the growth rates in the net capital stock is lower with the current Statscan methodology than with the BEA-type methodology. In the 1961-1998 period, the annual growth rate of the capital stock averages 2.5% with the current methodology compared to 3.0% with the BEA-type methodology. In the 1980-1998 period, the difference is more important, with a mean growth rate of the capital stock of 1.4% using the current methodologies compared with 2.2% using the BEA approach.

[11] Up to the 1990s, the Statscan's hyperbolic approach and its BEA-type estimate two time series of the Canadian capital stock that are almost identical. In the 1990s, the growth rates between the two estimates are slightly diverging. We come back to this point latter.

4.3 - Consequences for MFP Measurements

When the growth in the Capital / Labor ratio is underestimated, MFP growth, which is calculated residually, should be systematically overestimated. But because of a further problem discussed in section 3 - namely the Canadian statistical agency's use of a narrow capital stock definition (excluding land and inventories) combined with its computation of the residual share of profits by subtracting labor income from national income - if Statscan was appropriately measuring the growth of the capital stock, it would be overestimating MFP growth. Only if, on average, these two statistical problems cancel each other out, would the problems of systematic overestimation and underestimation be avoided.

We evaluate whether the two problems do cancel each other out for the business sector by comparing the evolution of the narrow Capital / Labor ratio in Canada and the US Capital / Labor including land and inventory depicted in figure 9.

Insert Figure 9 Here

Even though the Canadian capital concept excludes the slow growing components of land and inventories, the Capital / Labor ratio in Canada is growing at a much slower pace than in the US. This is an indication of measurement problems since, during the whole period, labor productivity has been growing at a slightly faster rate in Canada than in the US. Consequently, the underestimation of capital stock growth appears to more than compensate for Statscan its use of a capital concept that excludes land and inventories. Between 1961 and 1997, the cumulative growth rate of the broadly measured US Capital / Labor ratio exceeded that of the narrow Canadian measure by 32.2% (35.2 percentage points). With a capital share of 1/3, we get a rough overestimation of MFP growth by Statscan in the business sector of a little more than 1/4 percentage point annually.

This estimation of the underestimation of capital stock growth resulting from the current geometric truncated methodology in the business sector is consistent with the findings of Koumanakos et al. (1999). Since 1982, the growth rate in the capital stock (for all industries) in Canada would have been 1.1% higher on average using the BEA methodology for calculating depreciation. Again, with a capital share of 1/3, this implies that MFP growth has been overestimated by .37%. If we subtract the underestimation of 0.1% from the exclusion of land and inventories, we get an overall overestimation of 0.27% in the Canadian business sector.

For the Canadian manufacturing sector, we could measure directly the incidence of alternative methodologies by comparing MFP estimates using alternative measures of the capital stocks given by Statscan. We computed MFP growth in the Canadian manufacturing sector using all actual Statscan data with the exception of the capital stock. We substituted the BEA-type, the hyperbolic, and the geometric truncated to the actual capital stock data used for MFP measurements. The geometric truncated data from the Capital stock division differ from the actual data used for MFP estimation because the two series are not aggregated in the same way. So the following experiment isolates the incidence of alternative depreciation methodologies on MFP measurement. The results are presented in Table 1.

Insert Table 1 Here

For the whole 1962-1998 period, the use of the geometric truncated methodology instead of the BEA-type or the hyperbolic produces a slight overestimation of MFP growth in the Canadian manufacturing: .17% compared with the BEA-type and .09% compared with the hyperbolic. However, maybe more importantly, the bias is much more important in the 1990s: .48% and .28%. Interestingly, in the 1980s, The geometric truncated approach produces an MFP estimates smaller than the one produced by the hyperbolic approach.

In conclusion, in the manufacturing sector, the bias resulting from the use of the geometric truncated approach is not constant through time. It is more significant however in the 1990s. Compared with the BEA-type or the hyperbolic, the geometric truncated approach currently used by Statistics Canada for MFP measurement tends to significantly overestimate MFP growth in the 1990s. Figure 10 strikingly illustrates why we get this result in the 1990s. The time-series behavior of the capital stock from the geometric truncated approach differs considerably from the behaviors of the other two approaches of accounting for depreciation.

Insert Figure 10 Here

4.4 - The Canadian Capital Stock is Too Variable

As clearly depicted in figure 8, another consequence of using an excessive depreciation rate is that the level of the capital stock is underestimated. This, by itself, does not lead to a bias in the estimation of MFP growth since growth accounting methodology relies on the growth rate of the capital stock instead of its level. However, the growth rate of the capital stock is simply the ratio of net investment to the capital stock. If the capital stock is underestimated, the variability of the capital stock growth rate should be much higher in Canada for a given variability of net investment flows This increased variability in the capital stock would translate into an increased variability in MFP growth.

In the business sector, over the 1961-1997 period, the standard deviation in the growth rate of the adjusted US capital stock (excluding land and inventories) is 1.10%. In Canada, the standard deviation for the growth rate of the capital stock is 1.89%. The Canadian series is 54% more variable than the US series. In the Canadian manufacturing sector, in the 1961-1997 sample, the standard deviation in the growth rate in the actual capital stock used for MFP measurement is 3.30% compared to only 1.64% in the US. The Canadian capital stock is 70% more variable than in the US.

Again, this is purely a statistical artifact. Using the data on the Canadian manufacturing sector from Statscan Investment and Capital Stock Division, we have computed the standard deviation in the capital stock growth rate in the 1962-1998 sample from alternative depreciation approaches. The capital stock from the geometric truncated approach is much higher: 3.69% versus 1.95% and 2.09% for the BEA-type and the hyperbolic approaches respectively. Figure 10 already pictured the high variability in the capital stock growth rate intrinsically related with the geometric truncated approach in the 1990s.

4.5 - Evidences of Mismeasurement in the Canadian Capital Stock

A way to test for mismeasurements in the capital stock is to look at the correlation between MFP growth and the growth in the capital stock.[12] On theoretical ground, the correlation between MFP growth and the growth in the capital stock should be positive. In neo-classical growth models, the causality goes from technological progress to the capital stock and in endogenous growth models, the causality is reversed. However, the relationship between changes in technological progress and the growth in the capital stock is not necessarily contemporaneous. In both models, the positive relationship between MFP growth and the growth in the capital stock would follow a dynamic relationship with lags. So, *a priori*, one should not observe a negative contemporaneous correlation between MFP growth and the growth in the capital stock.[13]

As mentioned before, being a residual concept, any mismeasurement of inputs translates into a mismeasurement of MFP. Since capital growth is subtracted from output growth to get the Solow residual, any mismeasurement in the capital stock would translate into a negative contemporaneous correlation between MFP growth and the growth in the capital stock.

For the US business sector, the contemporaneous correlation between MFP growth and the growth in the capital stock is -0.017 in the 1948-1997 period and -0.059 during the 1961-1997 period. Such correlations are not significantly different from zero. In the Canadian business sector however, between 1961 and 1997, the correlation between MFP growth and the growth in the capital stock is -0.450. Between 1980 and 1997, the negative correlation is even more important at -0.744. In the Canadian manufacturing sector, the correlation between MFP growth and the growth in the capital stock is -0.555 between 1962 and 1998 and -0.704 in the 1980-1998 sample. These striking negative correlations, significantly different from zero at well

---

[12] Credits should be given to Pierre Duguay for the following argument.

[13] One could argue that by construction (MFP growth accounting) an increase in the growth rate of the capital stock, holding the growth rate of output constant, decreases MFP growth and leads to a negative correlation between the growth in the capital stock and MFP growth. However, output growth could not be hold constant since an increase in the growth rate of the capital stock leads to an increase in the growth rate of output. Consequently, the negative correlation does not follow by construction in the MFP growth framework.

below the 1% level, suggest the presence of mismeasurement problems in the Canadian capital stock.

Figure 11 illustrates the clear contemporaneous negative correlation between MFP growth and the growth in the capital stock in the Canadian manufacturing sector.

Insert Figure 11 here

5 - Three Suggestions

Certainly the analysis presented in this paper highlights the fact that MFP growth measures produced by Statscan and the BLS cannot be used for comparing productivity growth between the two countries. There are many significant methodological differences in measuring input changes between the two statistical agencies that effect the measurement of MFP.[14] On this point, the contribution of the paper is to measure the quantitative implications of different methodological approaches to the measurement of MFP.

The other contribution of the paper deals with an evaluation of the methodological consistency of the approach to MFP measurement in Statistics Canada. Not only does the Statscan methodology differ from the one used by the BLS, but we argue in this paper that the approach used by the Canadian statistical agency is inferior to that used by its US counterpart. We conclude this paper with three suggestions for improving Statistics Canada methodology for MFP measurement.

First Suggestion - Statscan should thoroughly revise its methodology for measuring changes in the composition of the labor force. In our view, Statscan should not weight hours with relative wages at the industry level since this approach produces a biased pictured of improvements in the Canadian labor force. Regarding business sector data, it would be interesting to account for labor force composition changes in the same way as the BLS so that the MFP growth measures of the two statistical agencies are more comparable. It is important

[14] This point was already acknowledged in a September 1999 study published by Statscan (Wells et al., 1999).

both from a policy and from an economic perspective to measure the effects of education on labor productivity growth with a sophisticated composition index. In the manufacturing sector, Statscan could adopt the same BLS-type approach for measuring changes in the composition of the labor force, but official MFP data abstracting from compositional changes should be published for comparisons with the US.

Second Suggestion - Statscan could continue to use the narrow capital concept that excludes land while adjusting the share of profits to a fraction smaller than the number obtained by subtracting the share of labor income from national income. Specifically, the share of the return going to land should be deducted. With this approach, inventories should be included in the narrow concept. Inventories contribute to profits, they are easy to measure since they do not depreciate, and their inclusion would slightly reduce the growth measure in the aggregate capital stock. Alternatively, Statscan could continue using the residual share of profits in national income if a broaded capital concept that includes land and inventories is used.

Third Suggestion - The geometric truncated approach to account for depreciation should not be used for MFP measurement purposes. This approach produces a biased estimated of MFP growth and a capital stock that is too variable on a year to year basis. Statscan should adopt the hyperbolic approach used by the BLS to facilitate comparisons with the US.

Bibliography

Barro, R. and X. Sala-i-Martin, 1995, *Economic Growth*, McGraw-Hill, New York.

Bureau of Labor Statistics,1999a, "Changes in the Composition of Labor for BLS Multifactor Productivity Measures, 1999", US Bureau of Labor Statistics, available to download from the WEB at **http://stats.bls.gov/mprlabor.htm** .

_____________________, 1999b, "Revisions to Capital Inputs for the BLS Multifactor Productivity Measures", US Bureau of Labor Statistics, available to download from the WEB at **http://stats.bls.gov/mprcaptl.htm** .

Coulombe, S., 2000, "The Canada-US Productivity Growth Paradox: An Economic or a Statistical Puzzle?", Department of Economics, University of Ottawa Working Paper #0001E, January.

Diewert, W.E., and D.A. Lawrence, 1999, "Progress in Measuring the Price and Quantity of Capital", Discussion paper 99-17, Department of Economics, University of British Columbia.

Gordon, R.J., 1999. "Has the 'New Economy' Rendered the Productivity Slowdown Obsolete?" Department of Economics working paper. Evanston, Ill.: Northwestern University.

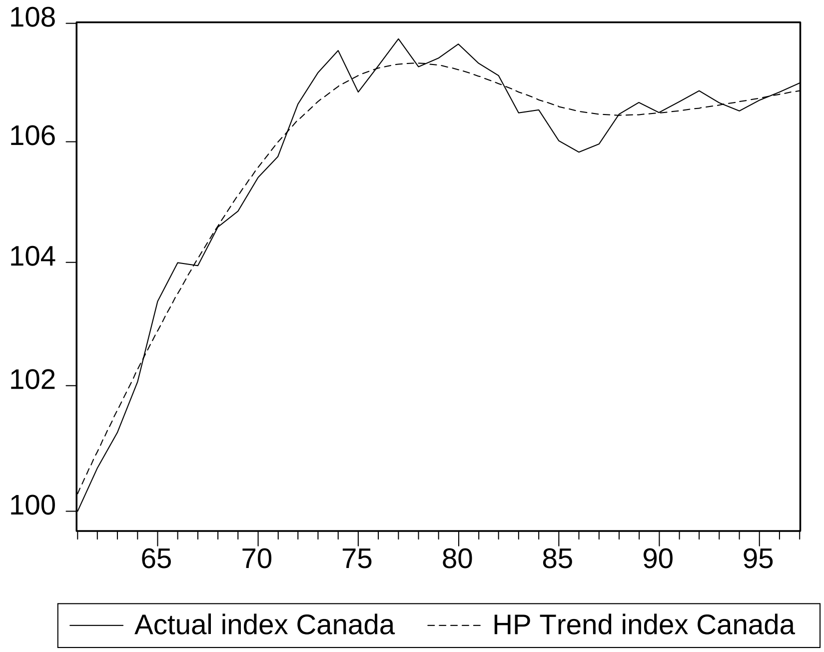
Koumanakos, P., R. Landry, K. Huang, and S. Wood, 1999, "Canadian net capital stock estimates and depreciation profiles: A comparison between the existing series and a test series using the US (BEA) methodology", *Statistics Canada*, Investment and Capital Stock Division, Working Paper, September 30, 1999.

Wells, J.S., J. Baldwin and J.-P. Maynard, 1999, "Productivity Growth in Canada and the United States", *Canadian Economic Observer*, Statistics Canada, September.

Table 1: MFP Estimates of the Canadian Manufacturing Sector from Alternative Methodologies Accounting for Depreciation

	1962-1998	1962-1979	1980-1989	1990-1998
BEA-TYPE	1.92	2.55	1.23	1.43
HYPERBOLIC	2.00	2.55	1.34	1.63
GEOMETRIC TRUNCATED	2.09	2.63	1.25	1.91

Sources: Author's estimates from Statistics Canada Investment and Capital Stock Division in the Business Sector



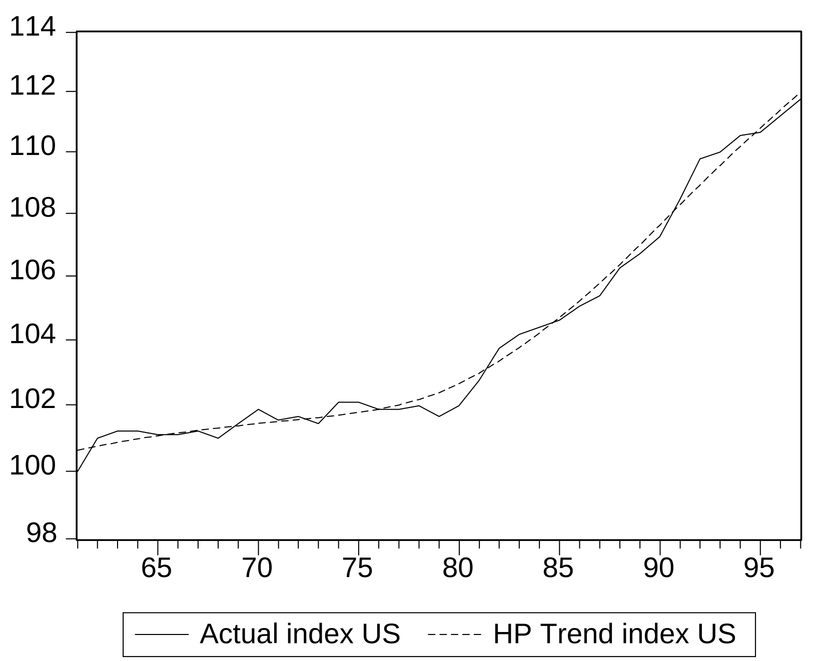
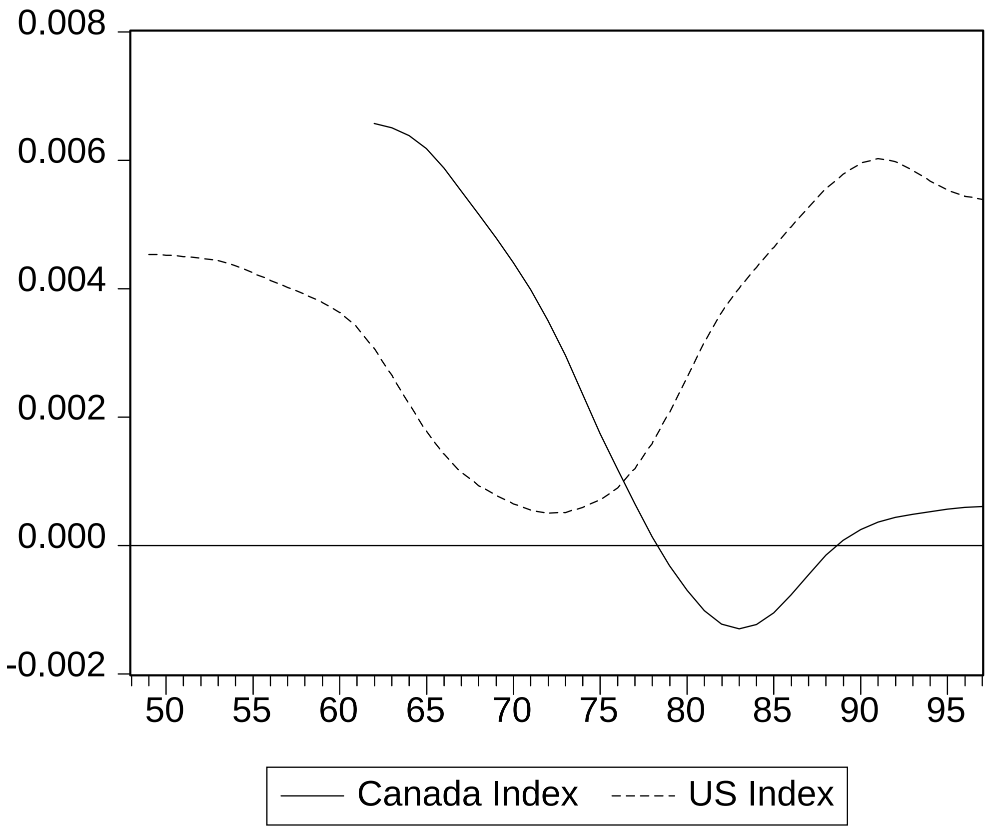


Figure 2: Trend Growth Rates in the Composition of the Labor Force Index in the Business Sector



Manufacturing Sector

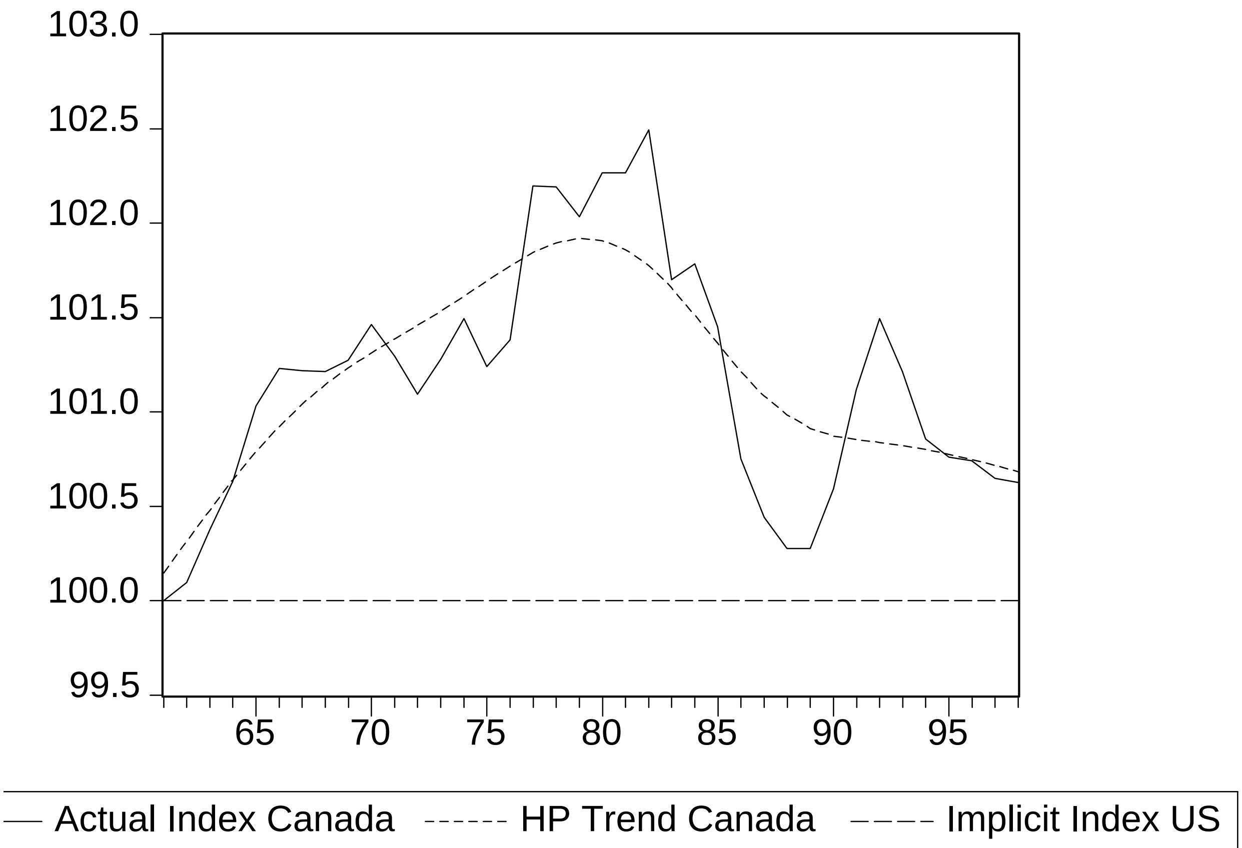


Figure 4: Trend Growth Rates in the Composition of the Labor Force Inde
Manufacturing Sector

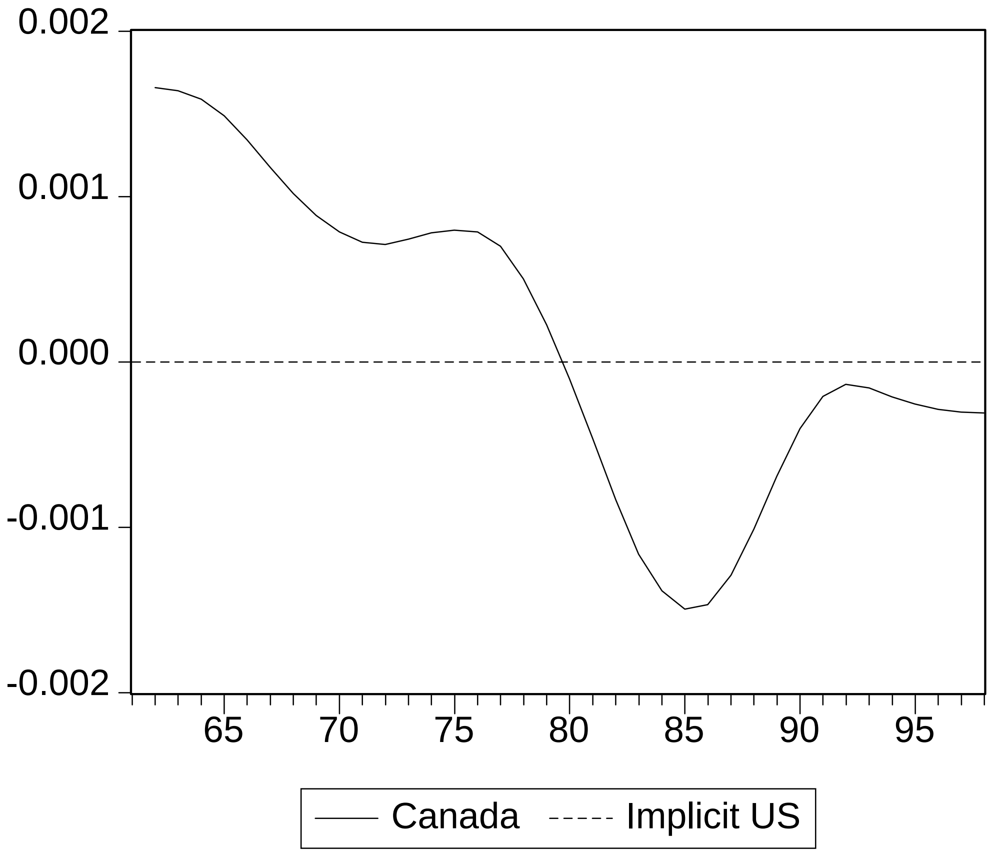


Figure 5: Official and Adjusted Measures of the Capital Stock in the US

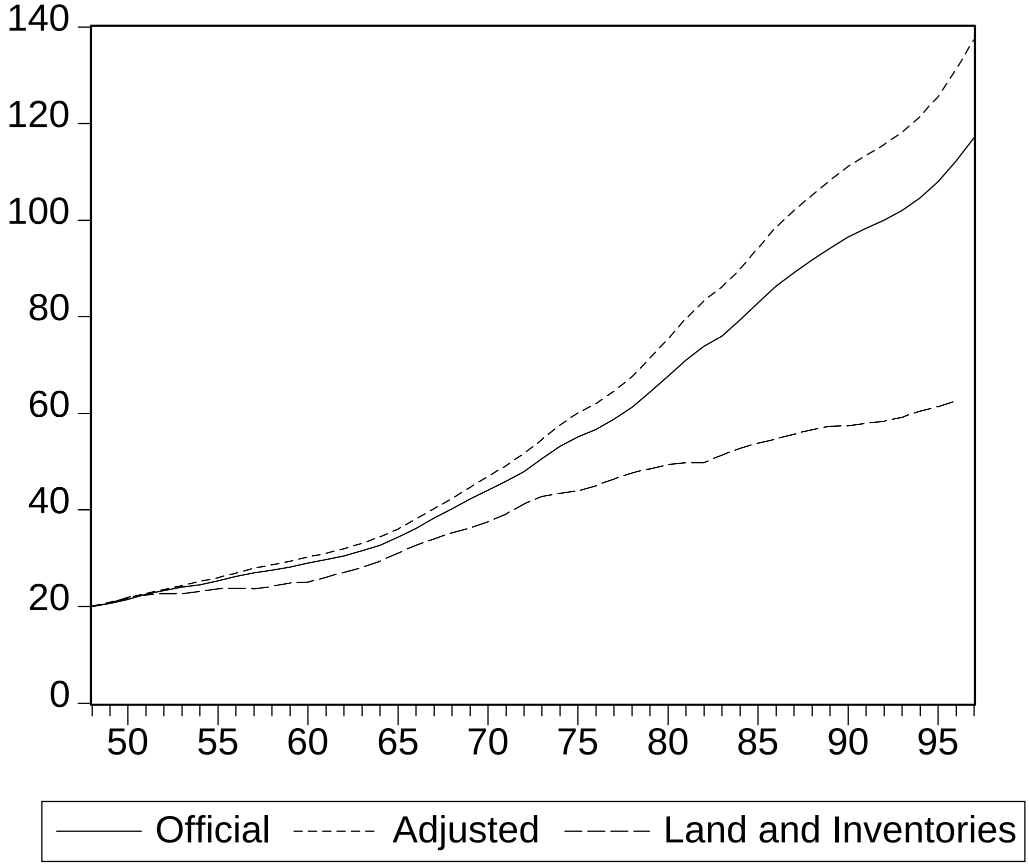


Figure 6: Aggregate Effective Depreciation Rates, US Business Sector

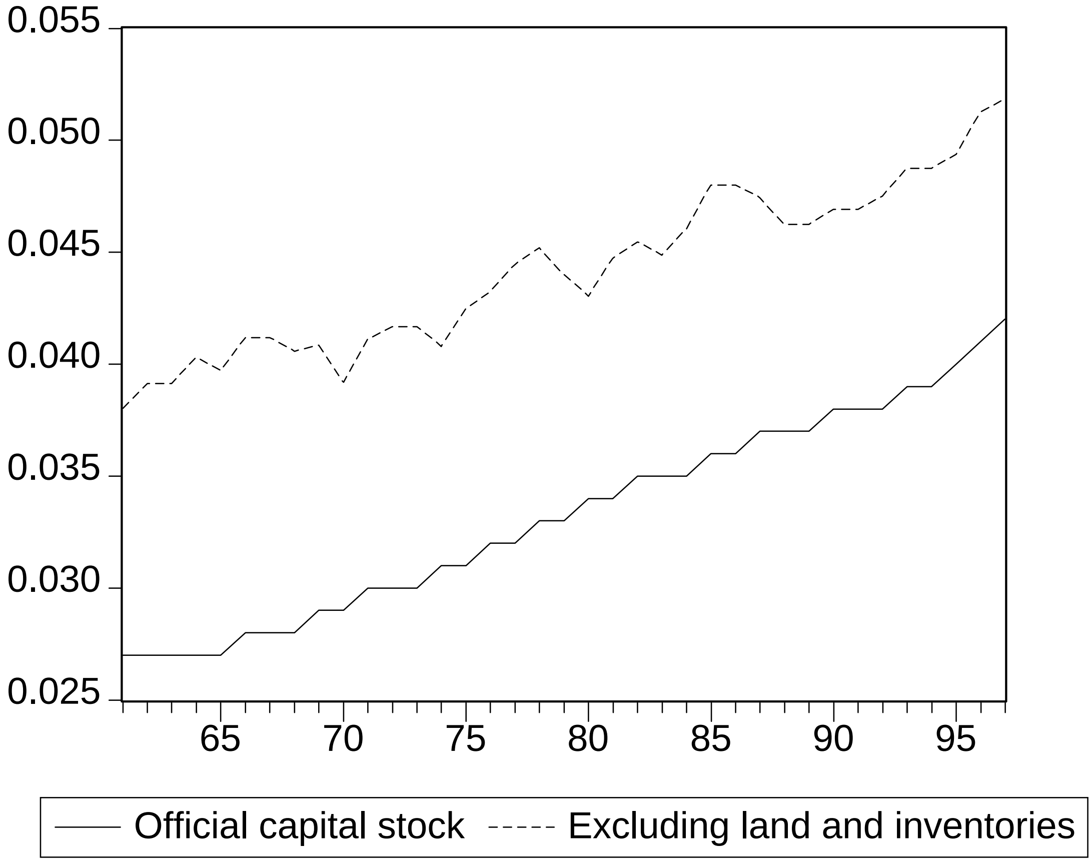


Figure 7: Aggregate Effective Depreciation Rates in the Canadian Manufacturing Sector with Alternative Methodologies Accounting for Depreciation

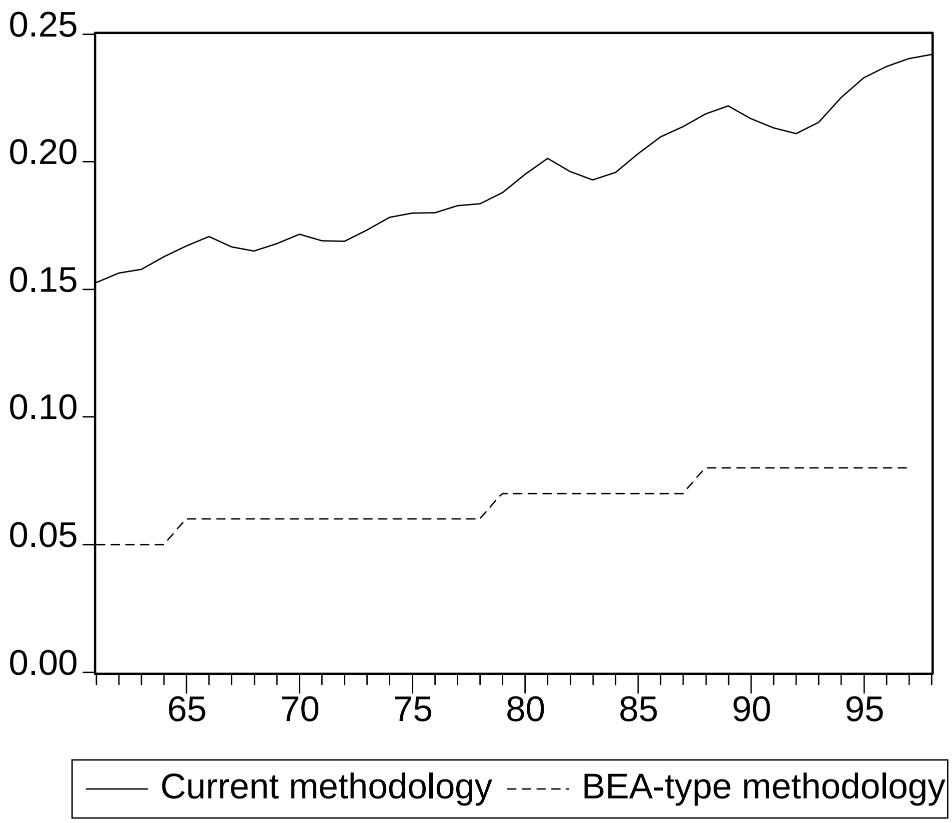
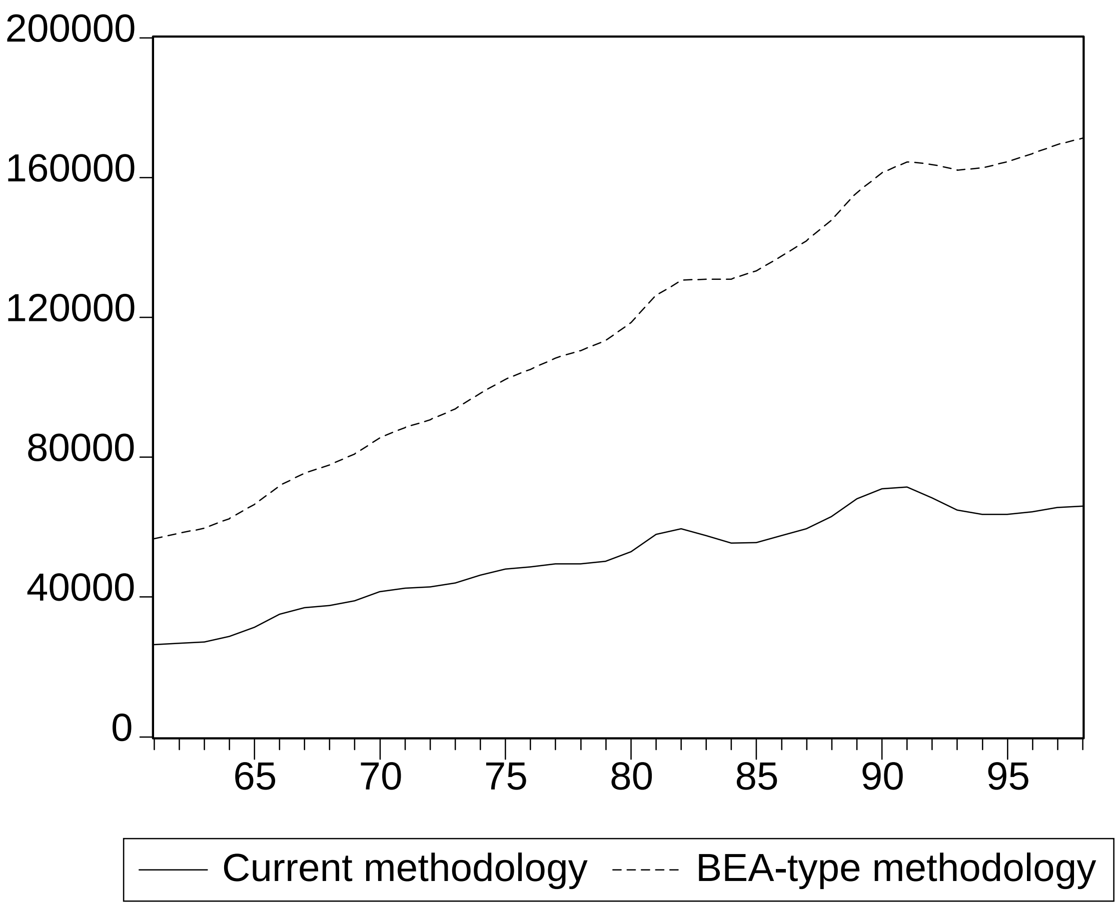
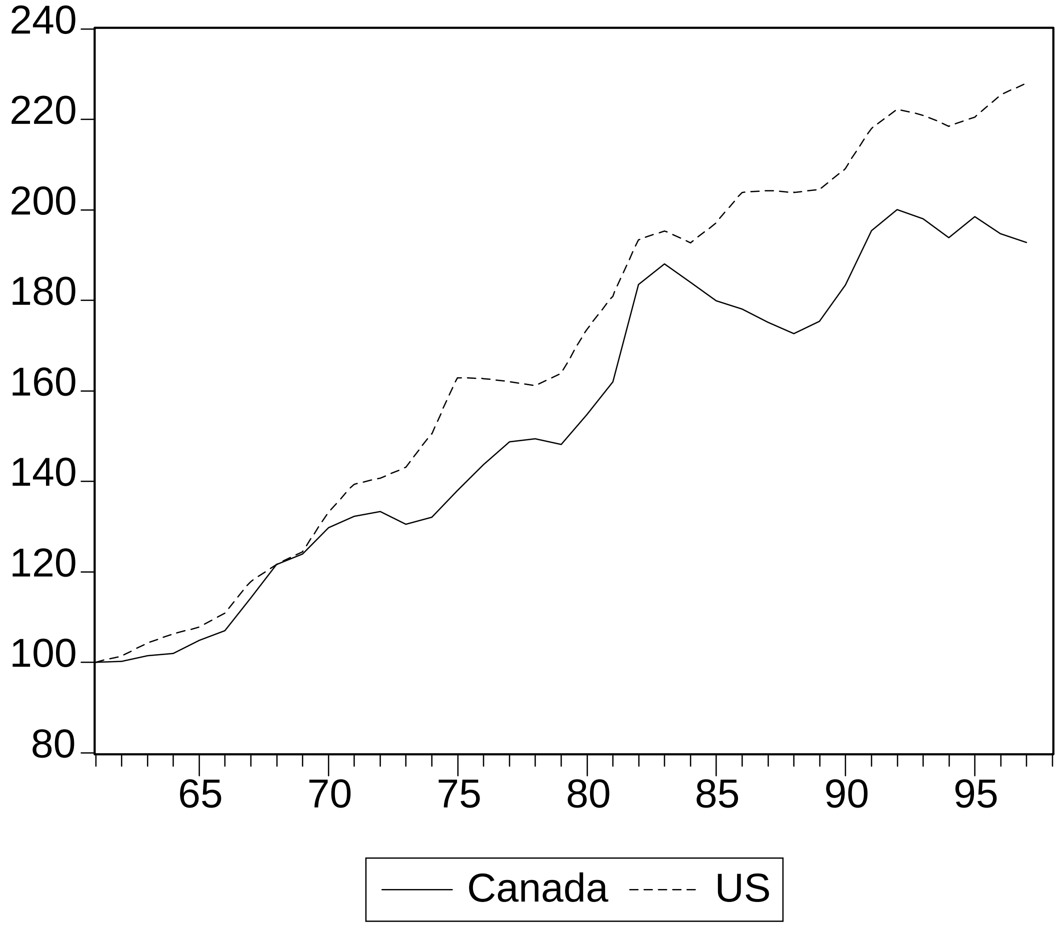


Figure 8: Net Capital Stock in the Canadian Manufacturing Sector with Alternative Methodologies Accounting for Depreciation



Note: In millions of 1992 constant dollars.

Figure 9: Evolution of the Capital - Labor Ratio, Business Sector



Note : 1961 arbitrarily fixed to 100 for both countries; including land and inventories for the US, excluding land and inventories for Canada.

Figure10: Estimated Growth Rates in the Capital Stock
Canadian Manufacturing (and Associated MFP growth rate)
Alternative Depreciation Methodologies, 1990-1998

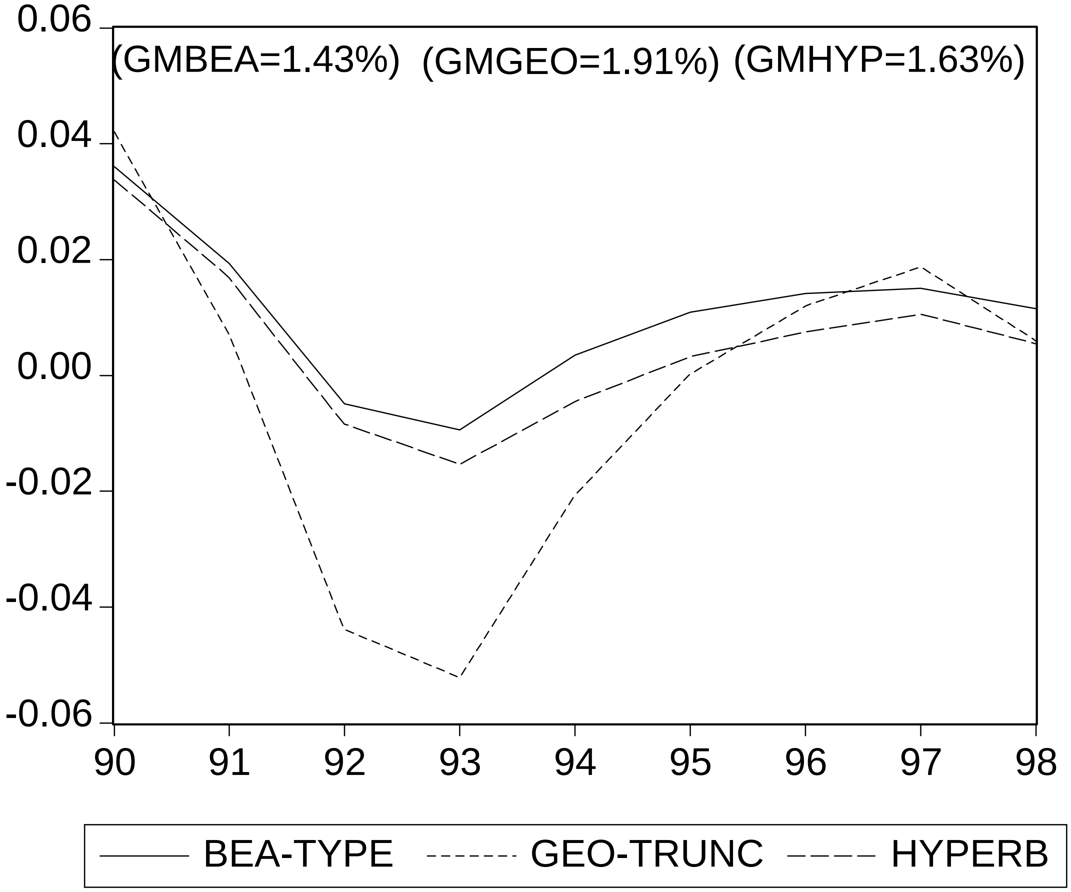


Figure 11: Negative Correlation Between MFP Growth and the Growth in the Capital Stock of the