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The Canada-US Productivity Growth Paradox: An Economic or a Statistical Puzzle?

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ISSN: 0225-3860

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January 2000

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Acknowledgments: Credits should be given to Jean-Pierre Maynard from Micro-economic Analysis Division, Statistics Canada, for his precious contribution at providing the author the data banks on productivity (from both Statistics Canada and the BLS) used in this paper. The author benefitted from discussions with Pierre Duguay and T.K. Rymes and comments of Erwin Diewert on a previous version of this paper. The author is solely responsible for all views expressed in this paper and he remains solely responsible for any remaining errors or omissions.

ABSTRACT

Productivity data on the business sector, which covers around 75% of the economy, provide important information on the evolution of living standards. The data on multifactor productivity (MFP) growth and labor productivity growth produced by the official statistical agencies in Canada (Statistics Canada) and the US (the Bureau of Labor Statistics, or the BLS) send mixed signals regarding the comparative evolution of living standards in the two countries. Since the early 1980s, Statistics Canada's MFP growth measures for the business sector indicate that the Canadian economy has outperformed the US economy while labour productivity data produce a reverse picture. This is the Canada-US Productivity Paradox. In this study, we investigate the Productivity Paradox with an analysis of Canadian and US business sector productivity data since 1961. The main finding of our analysis is that business sector MFP growth estimates provided by Statistics Canada in March 1999 are misleading. Statistics Canada's MFP estimates should not be used either for cross-country comparisons or for historical comparisons of productivity trends in Canada. Our analysis identifies three significant problems with the methodology used by Statistics Canada for estimating MFP growth. First, Statistics Canada's labor force index is biased. The agency appears to significantly 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 appears too narrow for MFP growth measurement. 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. Third, Statistics Canada appears to systematically underestimate the transitory growth rate and the level of the capital stock in Canada. This underestimation of the capital stock stems from the methodology used by the Canadian statistical agency to account for depreciation. The bias engendered by the underestimation of the growth in the capital stock (third problem) more than offsets the bias generated by the narrow definition of the capital stock (second problem). As a result, Statistics Canada overestimates MFP growth by approximately a quarter of a percentage point annually. Our conclusion is that Statistics Canada should thoroughly revise its methodology for estimating the capital stock and for measuring changes in labor force composition. The paper proposes methodological changes to address these problems.

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

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

RÉSUMÉ

Le paradoxe de productivité canado-américain : problème statistique ou économique? Les mesures de la productivité dans le secteur des entreprises, qui constitue environ 75 % de l'ensemble de l'économie, fournissent des indications importantes sur l'évolution des niveaux de vie. Les données sur la productivité multifactorielle (PMF) et la productivité du travail produites par les deux organismes officiels au Canada

(Statistique Canada) et aux États-Unis (le 'Bureau of Labor Statistics') envoient des signaux contradictoires concernant l'évolution comparative des niveaux de vie entre les deux pays. Depuis le début des années 1980, la mesure de la PMF de Statistique Canada dans le secteur des entreprises indique que l'économie canadienne a connu une croissance supérieure à celle de l'économie américaine tandis que les données sur la productivité du travail indiquent le contraire. C'est ce que nous appelons le Paradoxe de la productivité canado-américain. Dans la présente étude, nous abordons le Paradoxe de la productivité avec une analyse des données sur la productivité dans le secteur des entreprises depuis 1961. Le principal résultat qui ressort de l'analyse est que les données sur la PMF produites par Statistique Canada en mars 1999 brossent un tableau trompeur de la réalité. Les estimations de la PMF de Statistique Canada ne devraient pas être utilisées pour des comparaisons internationales ou pour des comparaisons historiques portant sur l'évolution tendancielle de la productivité au Canada. Notre analyse fait ressortir trois problèmes significatifs relatifs à la méthodologie employée par Statistique Canada pour les estimations de la PMF. Premièrement, l'indice de composition de la main-d'oeuvre employé par l'organisme canadien apparaît biaisé. Statistique Canada semble systématiquement surestimer, dans une large mesure, l'amélioration de la qualité de la main-d'oeuvre dans les années 1960 par rapport aux deux dernières décennies. Ainsi, la croissance de la PMF est sous-estimée dans les années 1960 par rapport aux années 1980 et 1990. Deuxièmement, il appert que Statistique Canada utilise un concept de capital trop étroit aux fins de la mesure de la PMF. En excluant la terre et les stocks de produits, deux composantes qui ont tendance à croître plus lentement que les autres composantes du stock de capital, l'organisme de statistique canadien surestimerait systématiquement la contribution de l'accumulation du capital à la croissance de la productivité. Troisièmement, nous croyons que Statistique Canada sous-estime systématiquement la croissance et le niveau du stock de capital au Canada. Cette sous-estimation serait imputable à la méthodologie utilisée pour rendre compte du phénomène de la dépréciation. Le biais engendré par ce problème fait plus que compenser celui noté précédemment concernant la définition du concept de capital. Ainsi, l'organisme canadien aurait tendance à surestimer la croissance de la productivité multifactorielle dans un ordre de grandeur de 1/4 de point de pourcentage annuellement. En conclusion, nous suggérons que Statistique Canada devrait revoir en profondeur sa méthodologie relative à la mesure de la croissance de la productivité multifactorielle. Nous proposons un ensemble de suggestions à cet effet.

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

Mots clés: Mesures de la productivité multifactorielle, résidu de Solow, niveaux de vie, erreurs de mesure, comparaisons Canada-États-Unis

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Introduction: The 1973 Recession

In January 1974, I was unhappy with my studies in physics at university and planning to switch to meteorology. This plan was altered, however, when I heard an economist, now very well known, talking on TV about the 1973 recession in Canada. With panache, the economist was explaining the cause of the recession and its consequences, and arguing for fiscal and monetary action to reduce the economic and social costs of the downturn. I was fascinated by the analysis and I decided to pursue the study of economics.

The 1973 recession provides a classic example of the importance of data revisions. Revisions to quarterly output data often slightly alter the historical picture of events. The 1973 recession was gradually smoothed out through subsequent revisions and, ultimately, completely eliminated from Canadian records. We know today that there were no recession in Canada in 1973!

Even though misleading data are usually corrected, they can have important consequences. Most importantly, policymakers could take inappropriate actions, or abstain from taking appropriate ones. Less importantly, economists could publish papers based on unrevised data that turn out to be statistical artifacts. Sometimes decisions based on misleading data have long-term consequences - with my career in economics, for example, being one of the long-term consequence of the 1973 statistical recession.

This paper discusses the multifactor productivity (MFP) growth measure released by Statistics Canada in March 1999. We think that Statcan's MFP data are misleading and will, necessarily, be substantially revised in the future.. The MFP growth measures provide a picture of the comparative evolution of living standards in Canada and the US that conflicts with the image created by measures of Labor productivity. From a statistical point of view, labor productivity growth is a much more straightforward measure of productivity improvements than MFP growth. The statistical estimation of MFP growth depends on input measures, such as the growth in the capital stock and the changes in the composition of the labor force, that are intrinsically extremely difficult to calculate. Any mismeasurement in input changes will necessarily lead to mismeasurements of MFP growth.[1] Consequently, if the two productivity measures send mixed signals, the cautious observer would be inclined to give more credit to the straightforward measure. In this paper, we will show that the cautious approach is the correct one.

The purpose of the analysis is twofold. First, we want to assess if MFP growth measures in Canada and the US can be used for cross-sectional comparison, i.e., if we can compare MFP growth measures between the two countries. The answer to this question is no. Because of significant methodological differences in measuring input changes between Statscan and the BLS, MFP growth estimates from these statistical agencies should not be used for cross-sectional comparison.

Second, we want to assess the consistency of MFP growth measures provided by the two statistical agencies for the business sector. The main finding of our analysis is that the BLS's MFP estimates appear consistent, whereas Statscan estimates appear inconsistent. This evaluation is based on the analysis of the measures of labor and capital input changes used by the two statistical agencies in estimating MFP growth.

We argue that Statscan should thoroughly revise its measure of the capital stock and its approach for capturing changes in labor force composition. Until Statscan has revised its estimation of MFP growth, economists and policy makers should primarily focus on the labor productivity concept to compare productivity changes in Canada on a time-series and on a cross-country basis.

The data, the stylized facts, and the growth accounting framework are discussed in the background section 1. The three problems with MFP measurements are then analyzed in sections 2 to 4. In section 5, we conclude that, contrary to the picture drawn by the latest MFP growth measures released by Statscan, the US economy has outperformed the Canadian economy since the early 1980s. As Fortin (1999) has recently highlighted, the most important differences between the two economies might not be related to a difference in productivity growth rates but, rather, to difference in productivity levels. Canada appears to have converged to a steady-state growth path below the US growth path in

[1] Diewert and Lawrence (1999) demonstrate how alternative measures of input changes effect the estimate of multifactor productivity in Canada.

terms of productivity levels and living standards. We review the statistical puzzle resulting form current measures in section 6 and put forward suggestions to improve MFP measurements in Canada.

1. Background

1.1 - The Data and the Filtering Process

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. We are using yearly data over the 1961-1997 period. Up to section 5, the analysis focuses on business sector data in Canada and private business sector data in the US. MFP measures are produced for these two sectors in Canada and the US. In section 5, we use labor productivity data for the business sector in both countries for cross-sectional comparison purposes.

The analysis in this paper concentrates on long-run trends. One way to extract the business cycle from the observed data is to compare the evolution of variables in different sub-periods. We realized, however, that this approach is sensitive to slight changes in the choice of starting and ending sub-period years. Productivity growth data are extremely volatile and the comparative picture might change by taking the 1989-1997 period instead of the 1990-1997 period.

We chose to use an alternative approach in which long-run trends are identified by smoothing the original data. We adopted the Hodrick-Prescott Filters (HP Filter) with a smoothing parameter of 100 to estimate the trend from actual level data. The HP filter is the most popular smoothing procedure used by macroeconomists. Long-run growth rates are measured as logarithmic difference ( ) %X(t)=log(X(t)/X(t-1)) of the smoothed series. The original and smoothed series are described in Appendix II.

1.2 - The Canada-US Productivity Paradox

The Canada-US productivity paradox is illustrated in Figures 1 and 2, which compare the trend growth rates of MFP (Figure 1) and labor productivity (Figure 2) in the business sector in

Canada and the private business sector in the US. For the measure of labor productivity, labor inputs are measured in hours using a Laspeyres index.

Insert Figure 1 and 2

The slowdown in productivity growth from the 1960s to the 1970s and the 1980s is strikingly illustrated in both figures. From the perspective of this paper, the most interesting point is the relationship between MFP growth trends in the two countries. MFP growth is always higher in Canada than in the US. Since 1961, for the original growth rate data, the MFP annual growth rate averages 1.21% in Canada compared with 1.02% in the US. Since 1980, Canada has continued to outperform the US with a MFP growth rate mean of 0.60%, compared with only 0.31% in the US. According to these estimates, Canada does not have a relative productivity problem vis-à-vis the US. Even if the productivity level in Canada is still below that of the US, this country's faster productivity growth leads Canada's MFP to convergence towards the US level.

The picture changes completely if we consider the trends in labor productivity growth (Figure 2). For the overall period, the growth rate of labor productivity in Canada averages 2.07% which is slightly higher than the 1.97% US growth rate. However, the Canadian economy outperforms the US economy only during the period prior to 1980. After 1980, the annual growth rate of labor productivity in the US averages 1.24% and exceeds its Canadian counterpart of 1.05%. Since 1990 however, the growth of labor productivity is virtually equal between the two countries, averaging 1.2%. According to this description of circumstances, convergence of Canadian productivity levels toward US levels was a phenomenon of the 1960s and the 1970s. If, as we will see in Section 14, Canadian labor productivity levels are still below US levels, the trends observed in the last 20 years indicate that the Canadian economy would trail behind the US economy, if nothing changes.

How could we have such a different picture described by two alternative productivity indicators? In the remaining sections of the paper, we will show that the paradox is merely the consequence of a statistical puzzle. Statistics Canada measures of TFP growth appear to provide a misleading portrait of the evolution of the Canadian economy..

1.3 - MFP 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, or the Solow residual, is then measured residually from a basic transformation of the production function.

To clarify these concepts, let's consider the following general neoclassical (concave) production function with constant returns to scale:

$$Y(t) = F(K(t), A(t)L(t)). \quad (1)$$

With this notation, output *(Y)* is a function (*F*) of the capital stock *K*, labor (*L*), labor-augmenting technological progress *A* (growing at the rate *g*), and time (*t*). 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. These two factors will be analyzed with a less general framework in Section 2. According to Romer (1996, p. 26), it could be demonstrated that the growth-accounting framework compatible with this general neoclassical production framework is:

$$GLP(t) = \alpha(t)(\Delta\%k(t)) + R(t). \quad (2)$$

Here, *GLP(t)* is the percentage growth in labor productivity *Y(t)/L(t)*, α(t) is the elasticity of output with respect to capital and Δ*%k(t)* is the (percentage) change in the Capital / Labor ratio *K(t)/L(t).* The parameter α(t) 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 many countries, 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 between a maximum of 0.39 and a minimum of 0.31 with a mean value of 0.35.

The parameter *R(t)* is called the **Solow Residual**, or the growth in multifactor productivity. For any given year, *R(t)* is computed residually by subtracting from the growth of labor productivity the component α(t)Δ*%k(t),* which is the estimated contribution of the growth in the Capital / Labor ratio to the growth of labor productivity.

The purpose of growth accounting is to identify the effect of technological progress on output growth. How could we reconcile the concept of MFP growth, or the Solow Residual *R(t)*, with the concept of technological progress? Remember that technological progress is the growth rate *g(t)* of the efficiency parameter *A(t)* in equation (1). The exact relationship between technological progress *g* and the Solow residual could be derived with the following Cobb-Douglas specification of equation (1):

$$Y = K^{\alpha}(Le^{gt})^{1-\alpha} \,. \quad (3)$$

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*. Taking the time derivative of the logarithms on both sides of this equation leads to the following:

$$GLP = \alpha(\Delta\%k) + (1-\alpha)g. \quad (4)$$

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. But in steady state, the only source of growth of the Capital / Labor ratio *k* is technological progress.[2] In this situation, $\Delta\%k$ = g and 100% of the growth rate of per capita output should be attributed to technological progress.

Since the purpose of MFP growth is to estimate the contribution of technological progress to labor productivity growth, it is important to correct the estimation of MFP growth to account for the effect of technological progress on the growth in the Capital / Labor ratio. This adjusted MFP concept (R_A), which is the measure of labor augmenting technological progress, is simply:

$$R_A(t) = g(t) = \frac{R(t)}{1-\alpha} \quad (5)$$

This adjusted MFP growth concept is used as a measure of technological progress by Jones

[2] For an exhaustive examination of neoclassical growth models, refer to Barro and Sala-i-Martin (1995)

(1997) in a cross-country empirical study on economic growth. The use of adjusted MFP growth concepts has long been advocated by T.K. Rymes as a better approximation of technological changes than usual MFP growth concept. The adjusted concept was called **Harrod Neutral Multifactor Productivity Growth** by Rymes (1971).[3]

2. Accounting for Improvements and Changes in the Labor Force Composition

2.1 - 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. The intent is to account for changes in workers' characteristics that may affect productivity - i.e changes over time in the proportion of male/female workers, in work experience and in education. Intrinsically, the idea is very interesting because changes in the characteristics of workers play a potentially significant role in explaining changes in living standards. 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. In Appendix I, we model the change in the quality of the labor force in an alternative way based on recent neoclassical growth models and we derive the Harrod Neutral MFP concept associated with human capital accumulation.

Previously, labor *L(t)* was assumed to be homogeneous and of constant quality. Now let's suppose that the index number *C(t)*, called the **composition of the labor force index**, accounts for the aggregate improvement in the quality of the labor force *L(t)*. Equation (3) can now be written as:

$$Y = K^{\alpha}(CLe^{gt})^{1-\alpha} . \qquad (6)$$

Again, the derivative of the logarithm on both sides of this equation, written in intensive form per unit of

[3] Barro and Sala-i-Martin (1995, section 10.4.6) summarized the idea that the usual MFP growth concept underestimates the contribution of technological changes on labor economics growth.

labor L, yields the following relationship between labor productivity growth and MFP growth:

$$GLP = \alpha \Delta \%k + (1 - \alpha) \Delta \%C + R(t). \qquad (7)$$

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

If a statistical agency modifies its measure of the composition of the labor force to account for improvements in the quality of labor through investment in education and on-the job training, the measure of $\Delta\%C$ would be positive on average. This change in the statistical measure of C will necessarily generate a decrease in the estimated measures of MFP growth *R(t)*.

2.2 - What the Data Show

We have reviewed sufficient theory and we are now ready to undertake a particularly revealing first exercise using Canada and US MFP growth data. 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 (6), 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. It is important to point out however that 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 the changes in effective quality of the labor force from changes in the labor composition across industries. 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,

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

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 3a and the trend growth rates in Figure 3b. For the US, data are available from 1949 and are portrayed in Figure 3b from this date to present a historical perspective.

Insert Figures 3a and 3b here

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 puzzling for two reasons. First, during the 1960s, the growth rate of the composition index in Canada considerably exceeds that of the US. This is very surprising since Statscan does not capture explicitely educational improvements with this index. In the long run, abstracting from business cycle compositional changes, 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 results depend on the occurrence three factors. 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 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 3a. As shown in Figure 3b, 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. This clearly portrays a biased picture of Canadian labor market developments. 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.

From an economic point of view, it is impossible to demonstrate analytically that Statscan's composition index is biased. In this case, the assessment relies on one's judgement. In our judgement, Statscan's methodology to account for labor force composition changes needs to be thoroughly revised. The pure composition effect appears to have been overestimated in the 1960s compared with the last twenty years. Furthermore, 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 both from a policy and from an economic perspective to measure the effects of education on labor productivity growth with a sophisticated composition index. 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. For example, 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%.

The analysis of this section highlights a statistical puzzle with the measure of MFP growth produced by Statscan. The index of labor force composition used by Statscan for computing MFP growth follows an erratic time path that is extremely difficult to associate with any realistic story regarding labor market developments in Canada. Certainly, based on the comparison with the US, the analysis of this section demonstrates that it is misleading to compare MFP growth measure between the two countries. But more interestingly, the analysis underlines that, on a time-series basis, the improvement in labor force composition in Canada appears overestimated in the 1960s compared with the last twenty years. According to equation 7 above, this would lead to an underestimation of MFP growth in Canada in the 1960s compared with the last twenty years. Consequently, we think that Statscan MFP growth measures of the business sector should not be used for either cross-sectional comparisons (with the US) or for time-series comparisons (the 1960s versus today) until they are re-estimated using a labor force composition index that more accurately captures the historical evolution of the Canadian labor force.

2.3 - MFP Growth Estimates Abstracting From Changes in the Labor Force Composition

We present in this section, for illustrative purposes only, MFP growth measures in Canada and the US that exclude labor force composition changes. In doing this, we wish to highlight the bias created by the use of disparate methodologies for computing the composition index by Statscan and the BLS.

We have extracted changes in the composition of the labor force for MFP computation using equation (7). For this purpose, we have added the component $(1-\alpha)\Delta\%C$ to official MFP growth measures in Canada and the US. From the adjusted MFP growth rate series, we have computed an index for the level of MFP series. Then we have smoothed the adjusted MFP level series with the HP filter. The trend growth rates for the adjusted MFP series are depicted in Figure 4.

Insert Figure 4 here

At first glance, the Productivity Paradox disappears! Canada has outperformed the US only in the first part of the period under study. From the end of the 1970s to the early 1990s, the US has outperformed Canada. In the remaining sections of the paper however, we will show that two other statistical puzzles are hidden in Statscan's estimates of MFP growth. The two problems are related to the measure of the capital stock.

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 is defined differently by the BLS and Statscan. The BLS adopts a broad definition of the capital stock by including five components: equipment, structures, rental residential capital, inventories, and land. Statscan uses a narrower definition, including only the first three components. Intrinsically, on methodological ground, there is nothing wrong with the Canadian approach. However, we demonstrate in this section that 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.

To demonstrate the problem, we 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

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[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.

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 (" 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 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, 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%.

Consequently, the underestimation represents roughly 10% of total MFP growth.[6]

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.

Thus, one could think that Statistics Canada tends to systematically underestimate MFP growth in Canada. That would be the case if the problem identified in this section was the only problematic aspect of capital stock measurement. But this is not the case. In the following section, we will see that Statscan tends to systematically underestimate the growth in the (narrow) capital stock. While these two problems could conceivably cancel each other out, resulting in a reasonable overall measurement of Canada's capital stock, we will see that this is not the case.

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, leading to substantial differences in the measure of the capital stock. For measuring the growth of the capital stock in the business sector, the BLS closely follows a methodology developed by the Bureau of Economic Analysis (BEA) of the US Department of Commerce.[7] Depreciation rates used by the BEA are based on recent empirical evidence and are considerably lower than the depreciation rates that Statscan uses to estimate changes in the capital stock. Furthermore, depreciation could be modeled in different ways: Linear, hyperbolic, geometric

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[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.

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

truncated or geometric infinite.[8] Whereas Statscan uses the geometric truncated approach for MFP measurement, the BLS uses the geometric infinite model. The key difference between the two methodologies is their treatment of capital retirement. In Statscan's methodology, a retirement pattern, independent of depreciation, specifies the age at which an asset is discarded or retired. In the BEA methodology, the infinite geometric pattern of depreciation is assumed to account for retirement. The geometric truncated model is known to generate a higher aggregate effective depreciation rate than the infinite geometric or the hyperbolic.

In a recent (September 1999) working paper (Koumanakos et al. 1999), Statistics Canada recognizes the dramatic consequences that would result from switching to the BEA methodology. The authors show (p. 13) that in 1998 the capital stock in Canada would be 2.5 times larger if depreciation was calculated according to the BEA approach rather than using the agency's current methodology. Furthermore, using the BEA methodology for depreciation, the growth rate in the Canadian capital stock would have been substantially higher, around 1% per year since 1980. 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 closer to the approach used by the BEA.

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

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[8] 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.

[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.

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, show 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.

For the capital concept that excludes land and inventories, the aggregate implicit effective depreciation rate averages 4.4% between 1961 and 1997 compared with 10% in Canada. 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 stock and have a major impact on measures of MFP growth.

4.2 - The Canadian Capital Stock Is Growing Too Slowly

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. In this section, we focus on the consequences of using a higher aggregate effective depreciation rate on the growth rate of the Capital / Labor ratio, which is of primary importance for the estimation of MFP.

To start with, it is important to note, as shown in section 1.3, that, 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. The decrease in the trend growth rate of labor productivity as pictured in section 1.2 is an indication of convergence from an initial situation below steady-sate. Then, a higher depreciation rate would translate into a lower mean growth rate in the Capital / Labor ratio. This theoretical prediction is corroborated by the comparative analysis of the Canadian and US data.

The actual (non-smoothed) data for the adjusted Capital / Labor ratio in the US excluding land and inventories and the Capital / Labor ratio series used by Statscan for business sector MFP computations are displayed in Figure 7, with labor measured in hours.

Insert Figure 7 here

Both series have been normalized at 100 in 1961. The picture corroborates the previous analysis based on the Solow-Swan model. The Capital / Labor ratio in Canada is growing at a much slower pace than in the US. Between 1961 and 1997, the cumulative growth of the US index is 152.8 percentage points compared with only 92.8 percentage points for the Canadian index. The cumulative growth of the US Capital / Labor ratio in this period 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%), clearly this big difference in Capital/Labour growth is the consequence of a statistical artifact rather than different economic fundamentals.

A close analysis of actual time series data on the Canadian Capital / Labor ratio highlights another interesting point. Between 1984 and 1997, the growth of the Capital / Labor ratio in Canada almost came to a halt. The growth rate, averaging 0.18 of 1 percentage point, is not significant and the median growth rate is negative at -1.0%. Again, this could not be reconciled with the historical records of broad economic indicators for this period. During this sub-period, the growth rate in labor productivity in Canada averaged 1.1%. It is difficult to find an economic model where steady growth in labor productivity over a 14 year period is compatible with a stable Capital / Labor ratio. The analysis suggests that the high aggregate effective depreciation rate that Statscan uses to account for depreciation generates a systematic underestimation of the growth in the capital stock.

4.3 - Consequences for MFP Measurements

But what happens now with the measurement of MFP growth? 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.[10] To assess whether the two problems do cancel each other out, we plot, on Figure 8, the evolution of the narrow Capital / Labor ratio in Canada and the US Capital / Labor including land and inventory.

Insert Figure 8 here

Even though the Canadian capital concept excludes the slow growing components of land and

[10] This analysis underlines the fact that it is always better to do two opposing errors, rather than just one, in measuring one concept. The corollary of this theorem is that if Statscan wants to improve its measurement of MFP growth, it should fix the two problems at the same time. Correcting just one problem could worsen the measurement of MFP growth.

inventories, the Capital / Labor ratio in Canada is growing at a much slower pace than in the US. This is puzzling 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 is 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).

The Canadian statistical agency is making two partly offsetting errors in measuring the growth of the capital stock, but these mistakes do not cancel each other out. The second error appears to be the larger of the two and, therefore, notwithstanding its use of a definition that excludes land and inventories, Statcan is likely underestimating the contribution of capital to economic growth. Consequently, **Statistics Canada appears to systematically overestimate the growth in multifactor productivity in Canada.**

Through a comparison with the US capital stock data including land and inventories, we can roughly assess the overall degree of overestimation of MFP growth in Canada. For the 1961-1997 period, the cumulative increase in the narrow capital stock is 30 percentage points smaller than the increase in the broad US stock . With a capital share of roughly 1/3, we get a cumulative overestimation of MFP growth of 10 percentage points between 1961 and 1997. On a yearly basis, that implies an overestimation of MFP growth by Statscan of a little more than 1/4 percentage point. Even though this number is small, we repeat that MFP growth numbers are small numbers too, typically between ½ and 1 percentage point in recent years.

Our calculation of the underestimation of capital stock growth resulting from the current methodology is consistent with the findings of Koumanakos et al. (1999). Since 1982, the growth rate in the capital stock 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%.

4.4 - Indications of Mismeasurements in The Canadian Capital Stock

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.

Again, the Solow-Swan model is useful to assess, on theoretical ground, the consequences of alternative depreciation rates for the long-run capital stock. With a benchmark value of 0.04 for the growth rate of the economy in the long run, a saving rate of 0.2, and a profit share of 1/3, and using a Cobb-Douglas production function, we can predict that the long-run capital stock will be 75% higher (logarithmic percentage) with a depreciation rate of 4.4 % instead of 10%.

The previous analysis suggests that, for a comparable concept of capital, the variability in the growth rate of the capital stock should be substantially higher in Canada than in the US. This prediction could easily be tested since we have constructed a time series for the adjusted US capital stock excluding land and inventories. Over the 1961-1997 period, the standard deviation in the growth rate of the adjusted US capital stock is 1.10%. In Canada, the standard deviation for the growth rate of the capital stock is 1.89%. The Canadian series is 54% (logarithmic percentage) more variable than the US series. Again, this increased volatility is not the result of different economic fundamentals. It is merely a statistical artifact.

A direct way to test for a mismeasurement in the capital stock is to look at the correlation between MFP growth and the growth in the capital stock.[11] 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

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

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 observe a positive or a null contemporaneous correlation between MFP growth and the growth in the capital stock.

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, 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 so small, and not significantly different from zero, that they could not be taken as indications of mismeasurement. In Canada 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. The striking negative correlation, significantly different from zero well below the 1% level, is a clear indication of mismeasurement in the Canadian capital stock. Figure 9 illustrates the clear contemporaneous negative correlation between MFP growth and the growth in the capital stock.

Insert Figure 9 here

5. We Do Have a Productivity Problem

In previous sections, we focused on business sector data for Canada and private business sector data for the US because MFP measures are produced by Statscan and the BLS for these two slightly different levels of aggregation. Since the results of our analysis suggest that Statscan MFP growth measures are not adequate for cross-sectional and time-series comparison, we now focus on labor productivity measures for the business sector in both countries. This level of aggregation provides a more appropriate basis for comparison.

Again, the actual data were smoothed using the HP filter and the trend growth rates were computed from logarithmic changes of the HP trend. The trend growth rates of labor productivity in the business sector in both countries are depicted in Figure 10 for the 1961-1998 period.

Insert Figure 10 here

Essentially Figure 10 tells the same story as Figure 2, where the same variables were depicted for the business sector in Canada and the private business sector in the US. Labor productivity in Canada was growing faster than in the US until 1980, but not thereafter. However, a close look at the two figures reveals two small differences. First, the trend labor productivity growth in the US business sector paralleled that in Canada in the early 1960s, contrarily to what was observed in Figure 2. Second, since 1993, the gap between the trend growth rates in both countries is a little larger in Figure 10. In the 1980-1998 period, the gap between the Canadian and the US trend growth rates appears roughly constant. Since 1980, actual data indicate that labor productivity annual growth rate averages 1.28% in the US compared with 1.03% in Canada. Thus, over the last 18 years, private sector labor productivity growth in the US has exceeded that in Canadian by 1/4 of 1 percentage point. One could argue that such a small difference is not significative because even the relatively straightforward measurement of labor productivity poses some statistical problems. 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.

From a quantitative point of view, analyses of labor productivity growth rates have to be complemented with analyses of labor productivity levels to obtain a complete comparative picture. Official measures of labor productivity levels in the business sector are not available from either the Canadian nor the US statistical agency. Furthermore, for international comparison, it is necessary to adjust productivity levels using a purchasing power parity (PPP) index.

For illustrative purposes only, Figure 11 provides a simple and rough estimate of the evolution of the Canada / US ratio of labor productivity in the business sector over the 1961-1998 period. Our simple construction of labor productivity levels is based on the crude assumption that in 1961, the Canada-US labor productivity level percentage differential was equal to the percentage differential observed for the PPP- adjusted GDP per capita. For this estimate, we are using as an initial value the 1961 estimate of real GDP per capita in constant dollars adjusted for changes in the terms of trade taken from the Summers-Heston database.[12] This database is widely used in cross-country growth studies. So the 1961 number, which is 0.7104, is the Canada / US ratio taken from the Summers-Heston data base. In following years, the ratio changes (exponentially) according to the Canada-US difference in the trend growth rate in labor productivity depicted in Figure 11. Consequently, we produced with this simple technique an estimate of productivity levels based on trend labor productivity growth and with the initial value anchored to the Summers-Heston's estimates of PPP- adjusted GDP per capita.[13]

Insert Figure 11 here

Prior to 1980, Canada was converging toward the US productivity level. However, the gap was such in 1961 that by 1980, after 19 years of convergence, less than 1/4 of it was closed. From a qualitative point of view, this analysis is certainly accurate. What is less clear, howeve,r is the exact proportion of the gap that still existed in 1980. The exercise illustrates that convergence is a slow phenomenon. However, convergence came to a halt in 1980 and, for the last 18 years covered by the data, the labor productivity gap is slightly increasing.

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[12] The Summers-Heston data set could be consulted on the Web at http://www.nuff.ox.ac.uk/Economics/Growth/summers.htm

[13] The crude assumption in this estimation is that the initial gap in productivity levels equals the 1961 gap in per capita GDP after adjusting for PPP, estimated by Summers-Heston. It is relatively realistic however to assume that after 1961, the gap changes on average according to the law of motion specified in the analysis. The Canada-US differential in the trend growth rates in labor productivity should replicate relatively accurately the evolution of the Canada / US productivity levels ratio in the long run. On a qualitative point of view, Fortin (1999) draws the same picture on Canada-US productivity level differential using an alternative approach.

This analysis underlines that it is essential in such a comparative exercise to examine data both on growth rates and levels. Although the best available data indicate that, since 1980, productivity growth rates were equal in Canada and in the US, productivity improvement should have been an important policy issue in Canada.

A clear message emerges from this simple exercise: Compared with the US, Canada does have a productivity problem. As Fortin (1999) points out, at best, Canada appears to have a **level problem** since productivity levels in Canada are smaller than in the US and the gap is not closing. One could argue that the mean difference in growth rates since 1980 is statistically insignificant, given the inherent statistical difficulties in measuring real output, as pointed out above. At worst, the productivity level in the Canadian business sector is lower than in the US and the gap is increasing.

6. Concluding on the Statistical Puzzle

In this paper, we have identified three problems in the Canadian statistical agency's methodology to estimate business sector MFP growth. First, the changes in labor force composition captured in Statscan's estimates of labor input growth seem inconsistent with our knowledge of the historical pattern of labor force evolution in Canada. The data look odd. It is difficult to accept that improvements in the compositional quality of the Canadian labor force exceeded by such a wide margin compositional improvements in the US in the 1960s, given that the BLS, unlike Statcan, accounts for human capital improvement from education. Furthermore, improvements in the Canadian labor force in the 1960s appear to have been overestimated by comparison with the 1980s and 1990s. Statscan should thoroughly revise its methodology for measuring changes in the composition of the labor force. It should account for human capital accumulation in the same way as the BLS and it should fix its techniques for measuring pure compositional changes to tackele the apparent overestimation of the 1960s.

The second statistical problem pertains to the concept of capital used by Statscan for measuring MFP growth. By excluding land and inventories from the capital stock, two slowly growing components which are included in the US capital concept, the Canadian statistical agency overestimates the contribution of capital accumulation to labor productivity growth. This overestimation is a consequence of the fact that Statscan uses a capital share computed residually by deducting labor income from national income. Such a capital share is consistent with a broader concept of capital. If the broader concept of capital displayed the same time-series behavior as the narrower concept, Statcan's approach would not have significant consequences. We have found, however, that this is not the case. Based on BLS data for the US, we found that over the 1961-1997 period, a narrower measure of the capital stock (excluding land and inventories) grew on average at a much faster rate than the broader concept.

Two alternative methodological adjustments could be undertaken by Statscan to correct this second problem. First, 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 (0.35) 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 in the aggregate capital stock. The second way to fix this problem is to continue using the residual share of profits in national income but to switch to a broad capital concept that includes land and inventories, following the approach of the BLS.

The third problem affecting Statscan's estimation of MFP growth relates to the agency's measurement of capital accumulation. The growth of the Capital / Labor ratio appears to have been systematically underestimated leading to a systematic overestimation of MFP growth. This problem is related to the way the Canadian statistical agency accounts for depreciation. The aggregate effective depreciation rate in Canada is more than twice that in the US, using a comparable capital concept, and such a difference has major implications. Which approach to depreciation works best? The analysis presented in section 4.4 clearly indicates that the Canadian capital stock is mis-measured. In the US however, we found no indication of mismeasurement. Consequently, we believe that the US methodology is superior and should be adopted by Statcan.

Problem two, which implies that Statcan undestimates MFP growth, and problem three, which points towards overestimation, partly offset each other. Our calculations indicate that the impact of overestimation from problem three is substantially greater than the effect of underestimation from problem two. On a yearly basis, overall, the overestimation of MFP growth by Statscan is around 1/4 percentage point.

In addressing this statistical puzzle, Statistics Canada must attempt to resolve problem three at the same time or before it corrects problem two. By fixing problem two and not correcting problem three, the agency would increase the bias in its MFP estimates. In the meantime, in the absence of the important methodological revisions needed to rectify the three identified methodological problems, it is important to recognize that Statistics Canada Multifactor Productivity data on the business sector send misleading signals regarding the evolution of living standards in Canada.

Appendix I. Growth Accounting with Human Capital Accumulation

From a quantitative point of view, what is the potential effect of accounting for investment in education on TFP measures? To answer this question, we adopt the concept of **human capital** as modeled in new growth theory like in Mankiw, Romer and Weil (1992). Let's consider the following 'new-growth theory' neoclassical production function:[14]

$$Y = K^{\alpha} H^{\beta} (Le^{gt})^{1-\alpha-\beta},$$

where *H* is the human capital stock and β is the elasticity of output with respect to human capital accumulation. Contrarily to Section 5, the improvement in the labor force quality is here modeled as an independent factor of production *H* that could be accumulated, like physical capital *K*, by investment (in education). Using the same methodology as before, one gets the following equation relating the growth of labor productivity, the accumulation of capital, and the Solow Residual:

$$GLP = \alpha \Delta \%k + \beta \Delta \%h + (1 - \alpha - \beta)g. \quad \text{(A1)}$$

Here, *h* stands for the Human Capital / Labor ratio (*K/L*). The Solow residual *R(t)* is now only $(1-\alpha-\beta)g$. Similarly to α which is measured by the share of profits in national income, profits being the return to physical capital, β could be measured as the share of the returns of human capital investment in national income. Unfortunately, the return of human capital accumulation is not measured separately in national accounting procedures. From a statistical point of view, the return to human capital is hidden in the wage component of national income. The estimation of the human capital share in national income is a subject of research in new-growth theory. For example, Mankiw (1995) for the US and Coulombe and Tremblay (1999) for the case of Canada, using completely different statistical methodologies, have estimated that the parameter β is in the neighborhood of 0.5. Since the share of wages in national income is roughly 2/3, this estimation of β implies that more than 70 % of wages is an implicit return to human capital accumulation. If these estimates were accurate, and statistical agencies were fully accounting in their labor composition index for human capital accumulation, not much would be left for

[14] Romer (1997, chapter 3) uses a production function of this type in its presentation of the new-neoclassical growth model with human capital.

the Solow Residual $(1-\alpha-\beta)g$ in growth accounting. With $\alpha=1/3$ and $\beta=1/2$, the Solow Residual (official MFP growth measures) would capture only 1/6 of technological progress as seen in equation (8).

Following the discussion of section 4, this underestimation of technological progress by growth accounting stems from the fact that, in the neoclassical growth framework, on steady state, technological progress g is the only source of the growth in the Human capital/ labor ratio h. This comes from decreasing returns to capital accumulation that hold as long as $\alpha+\beta<1$.

When decreasing returns apply, without technological progress, the net return to investment on education eventually voids and on steady state, the Human Capital / Labor ratio is constant. With positive technological progress, on steady state, the Human Capital / Labor ratio is growing at the rate g. By extracting from the growth of labor productivity the portion imputed to the growth of factors, growth accounting underestimates the effect of technological progress on labor productivity since a substantial part of factor accumulation, the totality of the accumulation per unit of labor in the long run, is caused by technological progress. Following equation (5), with human capital accumulation measured in growth accounting, the Solow Residual should be corrected for the purpose of fully estimating the contribution of technological progress to labor productivity in the following way. The adjusted MFP (Rymes' Harrod Neutral MFP)concept R_{AA} is:

$$R_{AA}(t) = g(t) = \frac{R(t)}{1-\alpha-\beta} \quad \text{(A2)}$$

Appendix II. Actual Data and HP Trend: Some Examples

We present in the appendix some figures that illustrate the smoothing technique, from Hodrick-Prescot Filter, used in this paper. In each figure, the actual data are plotted with the smoothed series.

Insert Figure A1 to A5 here

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Figure 1: Trend in MFP growth, Canada and the US

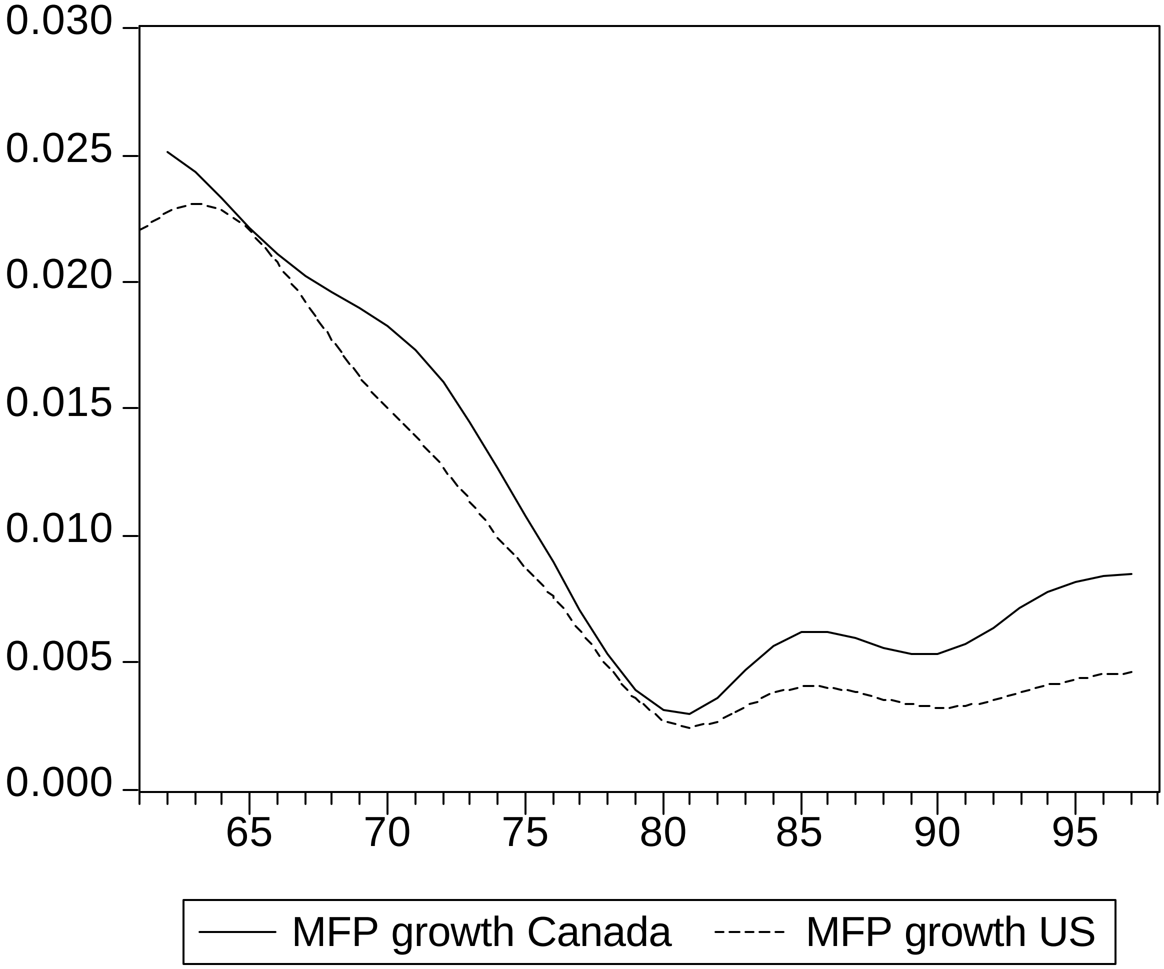


Figure 2: Trend in Labor Productivity Growth, Canada and the US

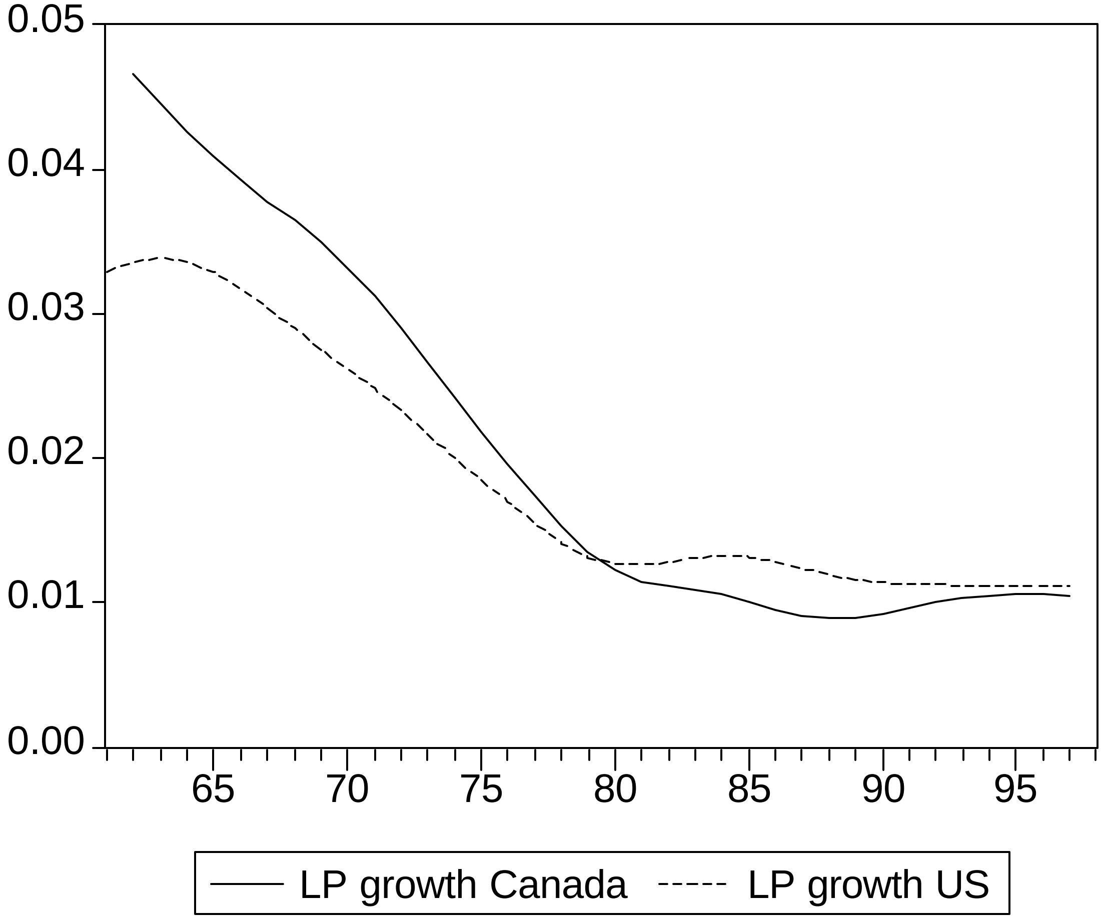
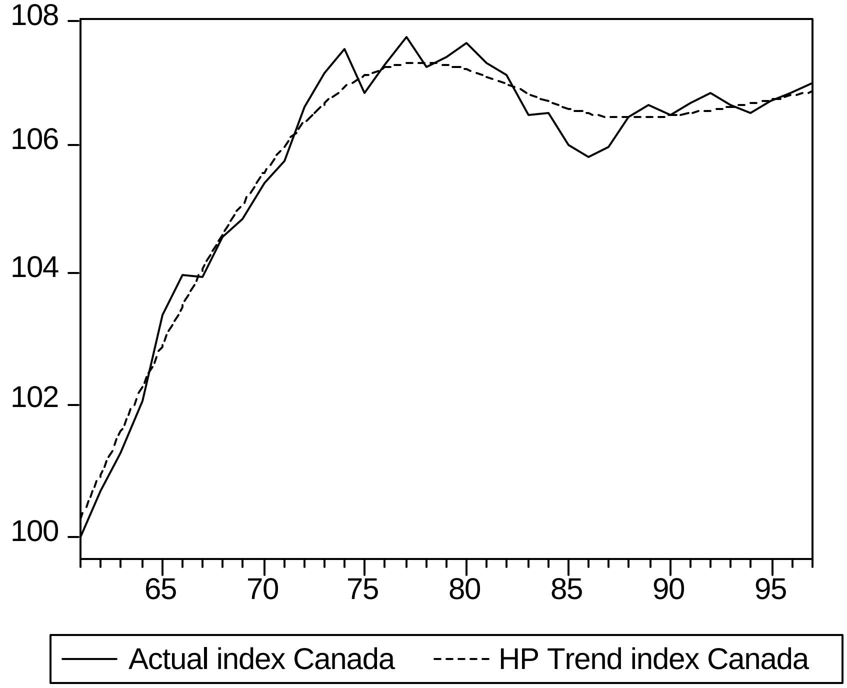


Figure 3a: Actual and HP Trend Composition of the Labor Force Index



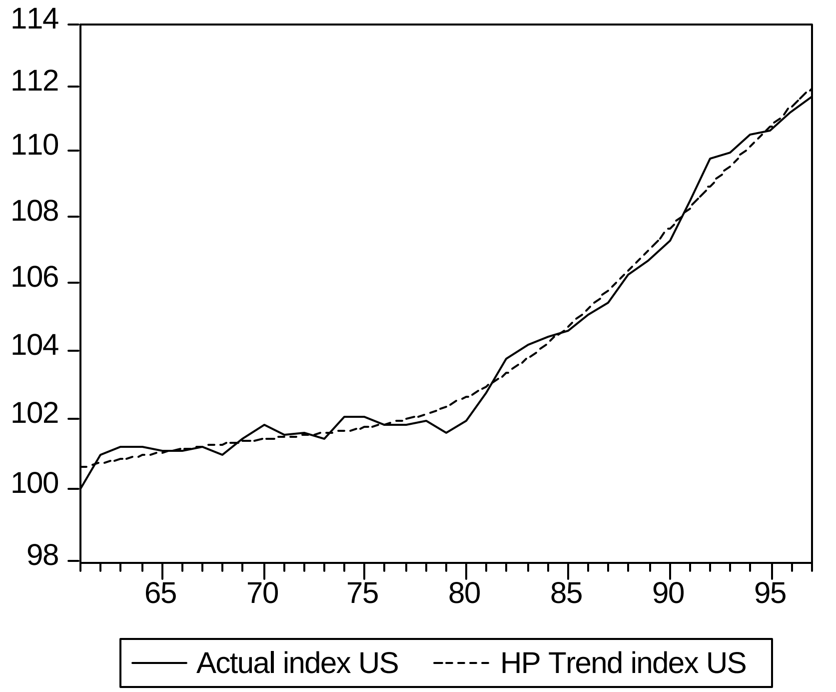


Figure 3: Trend Growth Rate in the Composition of the Labor Force Index
Canada and the US

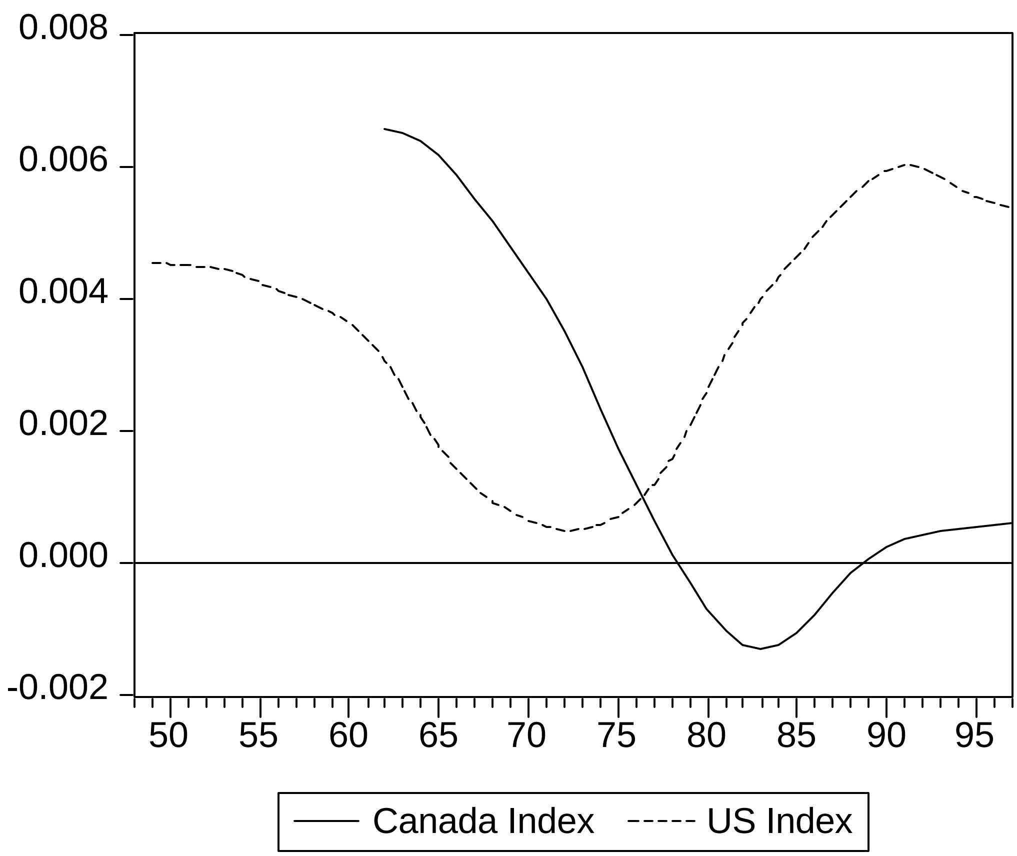


Figure 4: Adjusted Trend MFP Growth Estimates, Canada and the US
(excluding labor force composition changes)

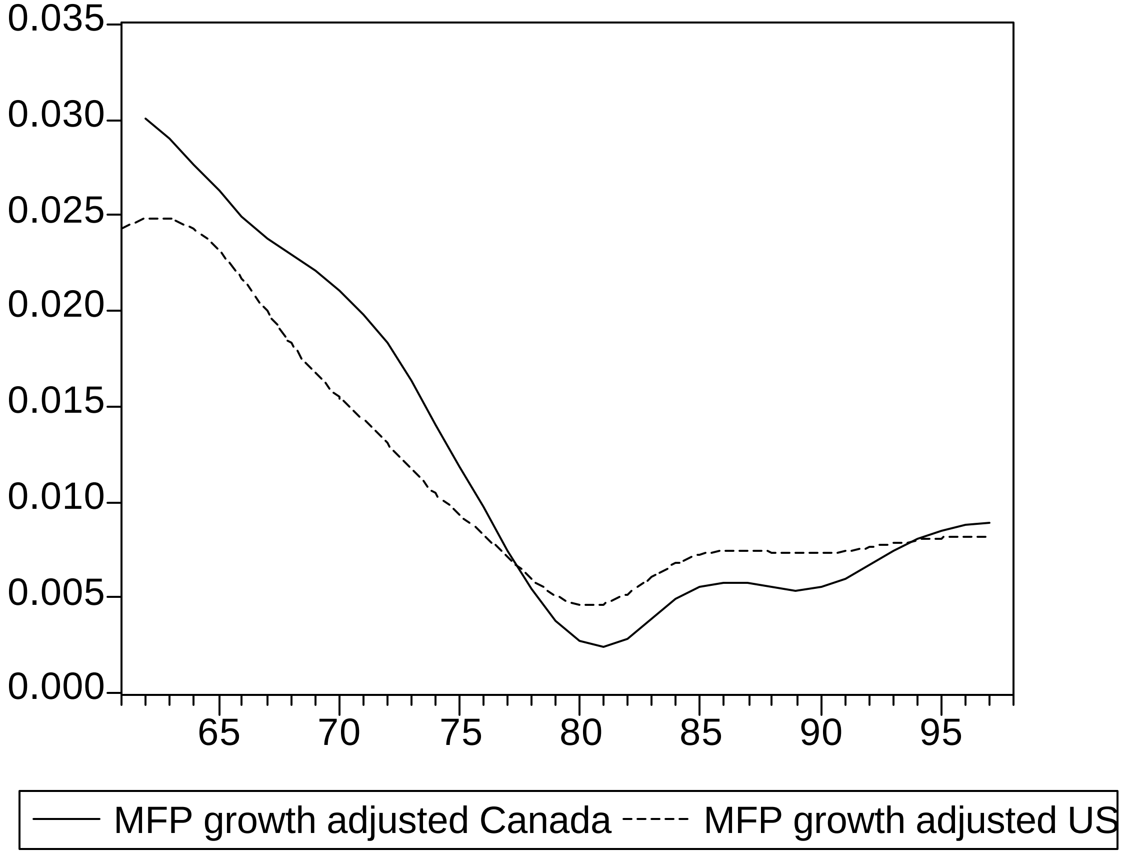


Figure 5: Official and Adjusted Measures of the Capital Stock in the US

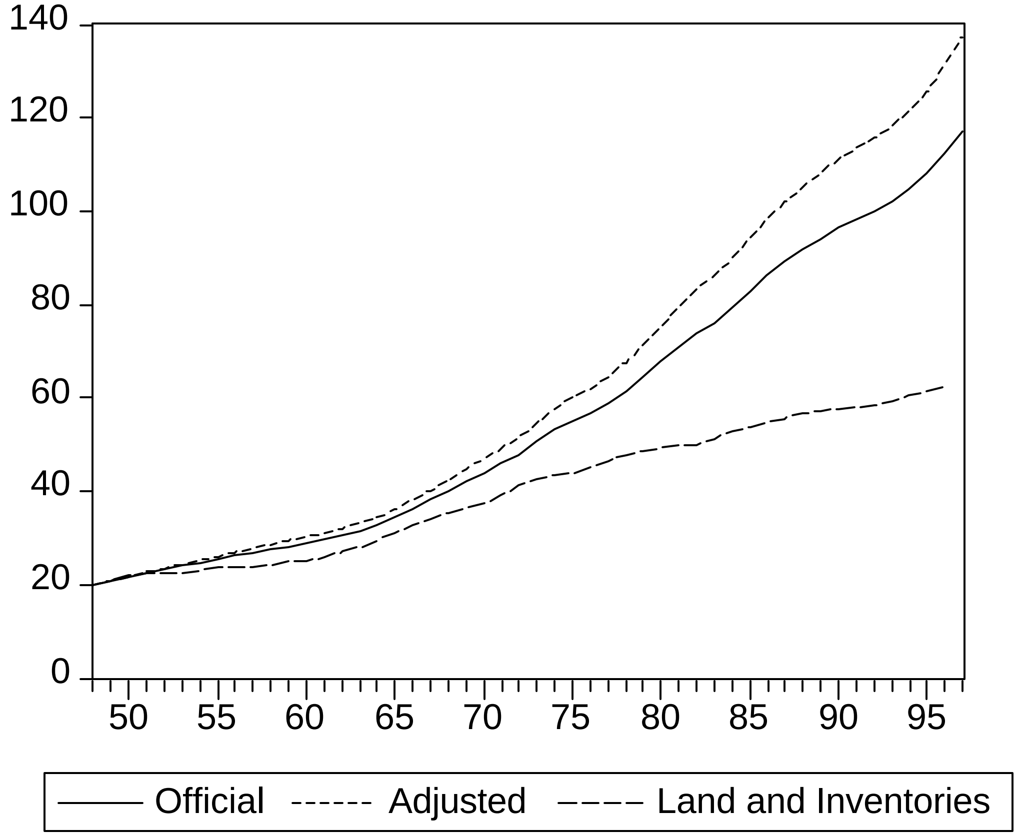


Figure 6: Aggregate Effective Depreciation Rate, US Business Sector

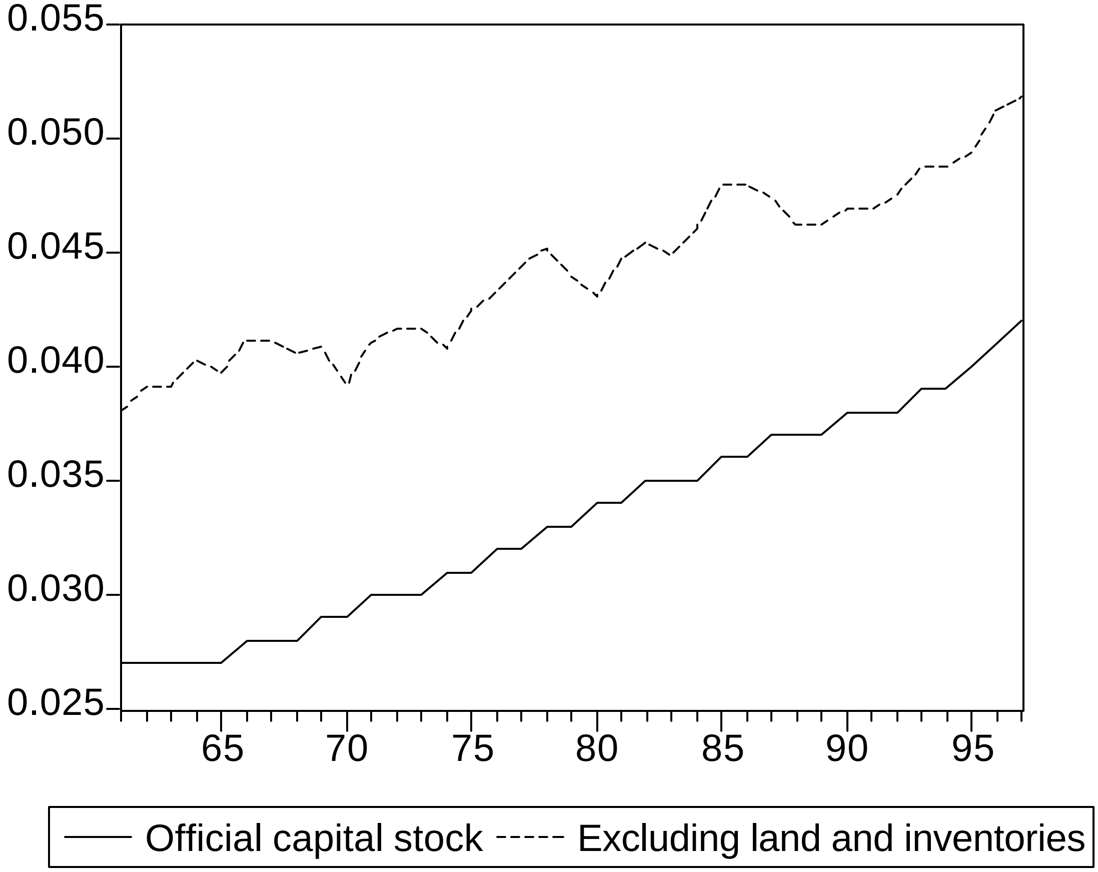
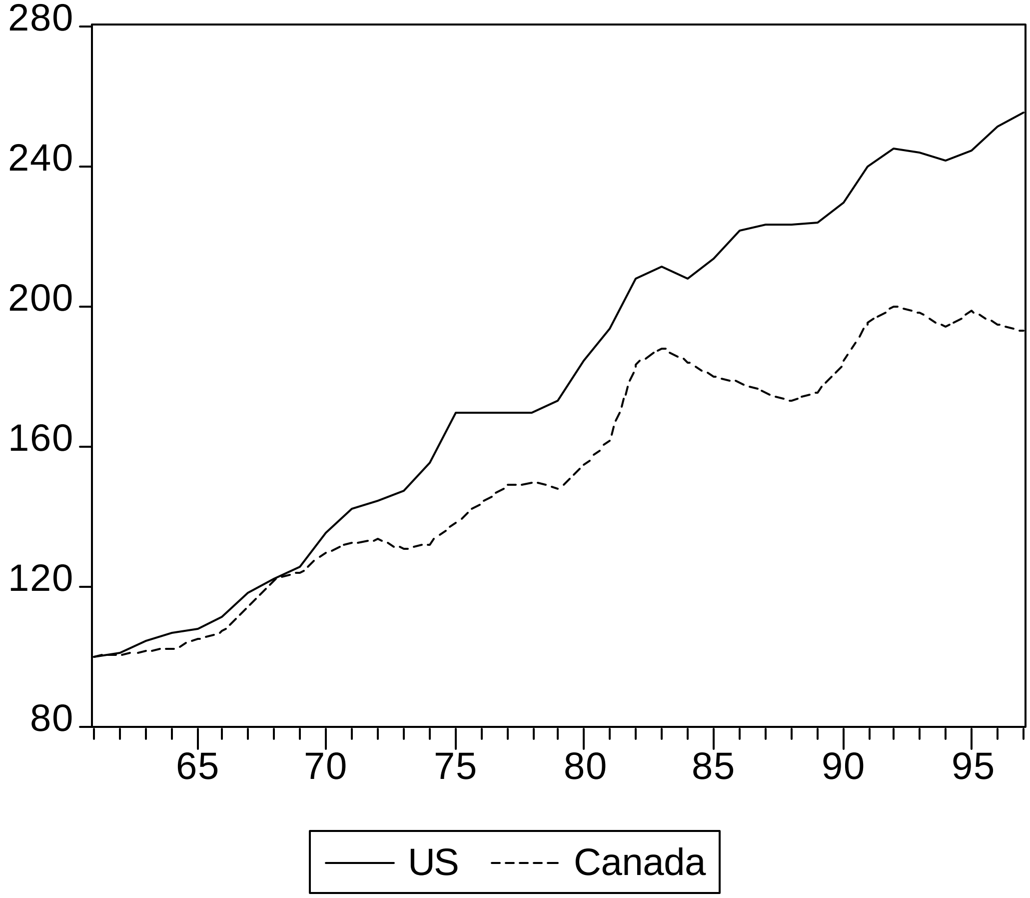
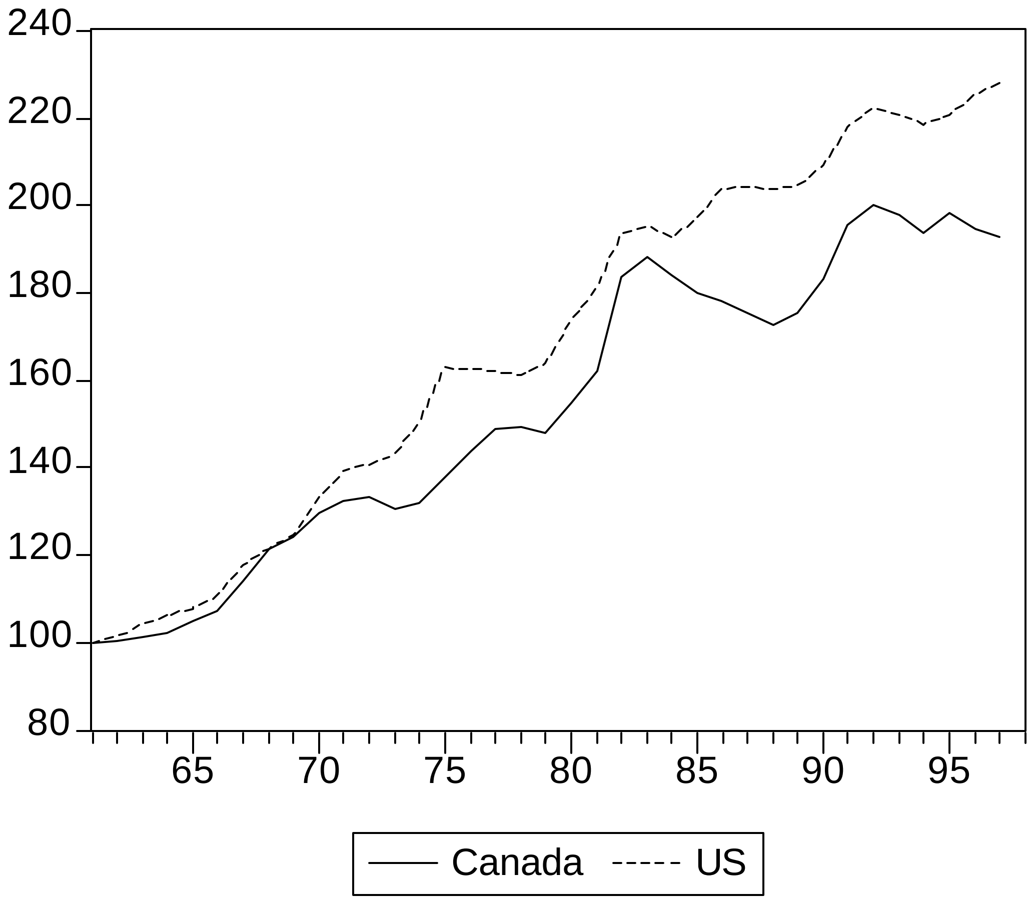


Figure 7: Evolution of the Capital / labor ratio, Canada and the US



Note: 1961 arbitrarily fixed to 100 for both countries; excluding land and inventories from private business sector capital stock data in the US.

Figure 8: Evolution of the Capital / Labor Ratio, Canada and the US



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

Figure 9: Negative Correlation Between MFP Growth and the Growth in the Capital Stock in Canada

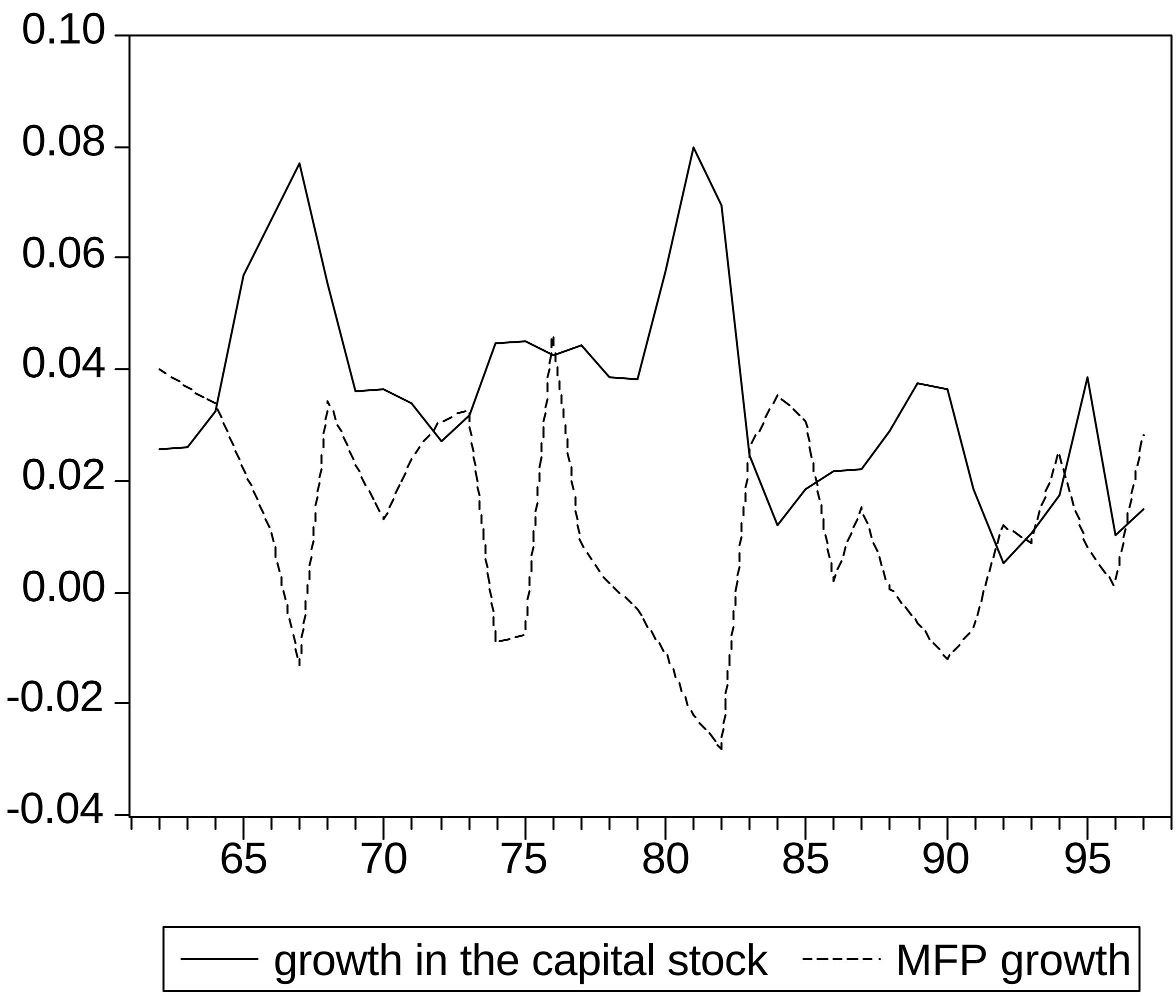


Figure 10: Trend in Labor Productivity Growth, Canada and the US
Business sector

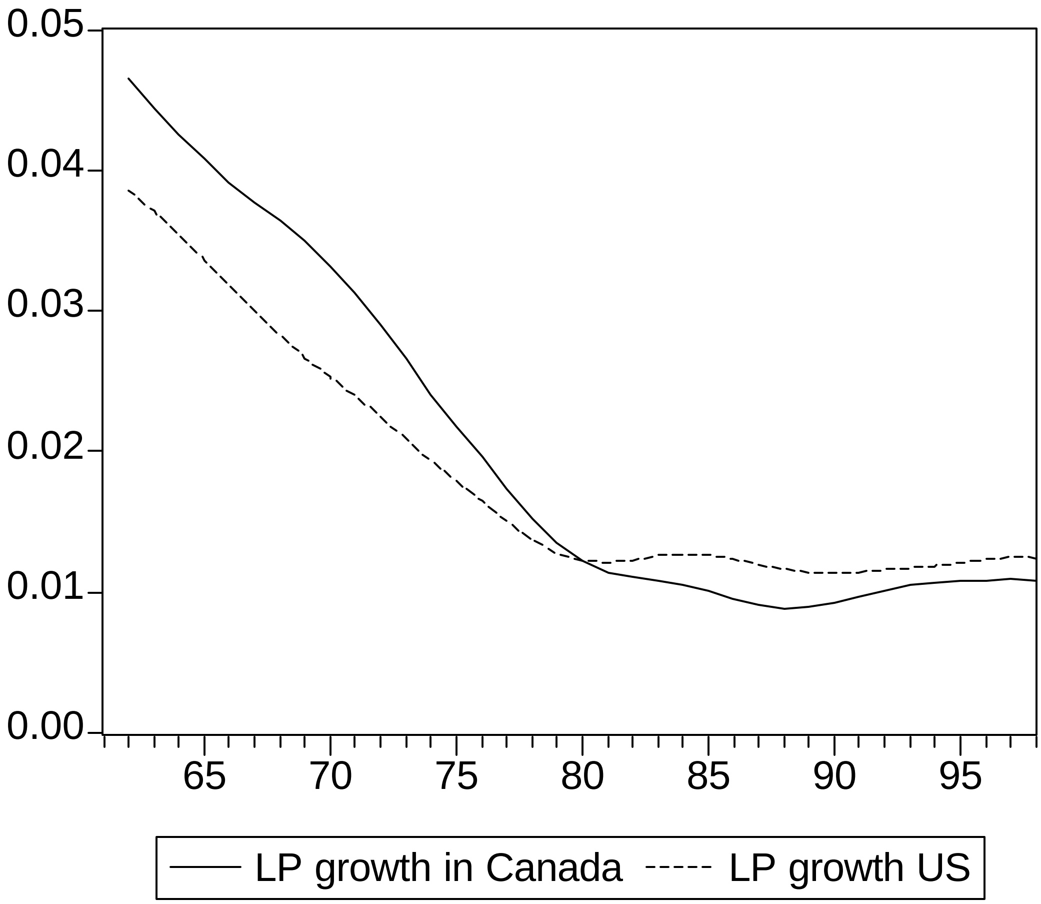


Figure 11: Estimated Trend in Labor Productivity Levels

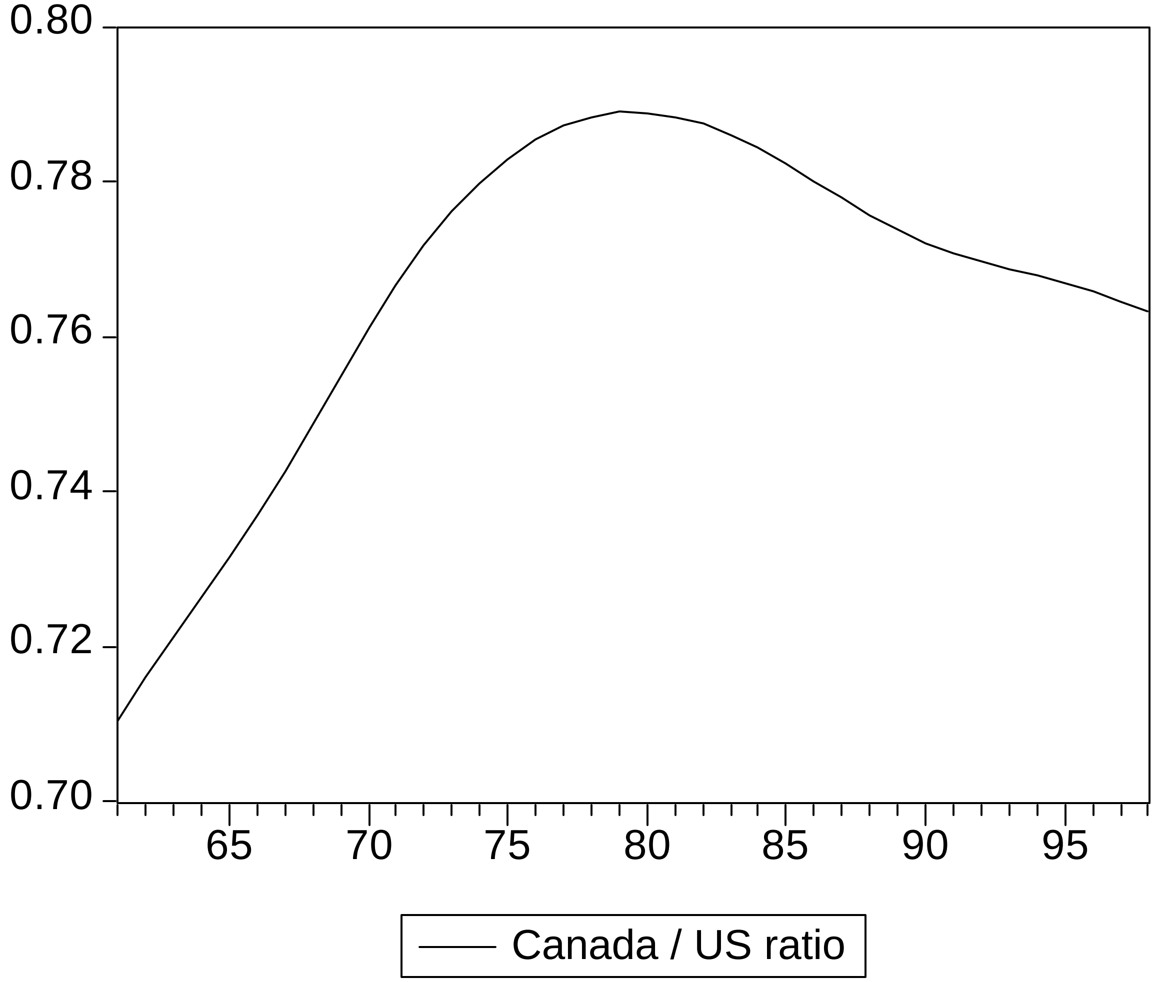
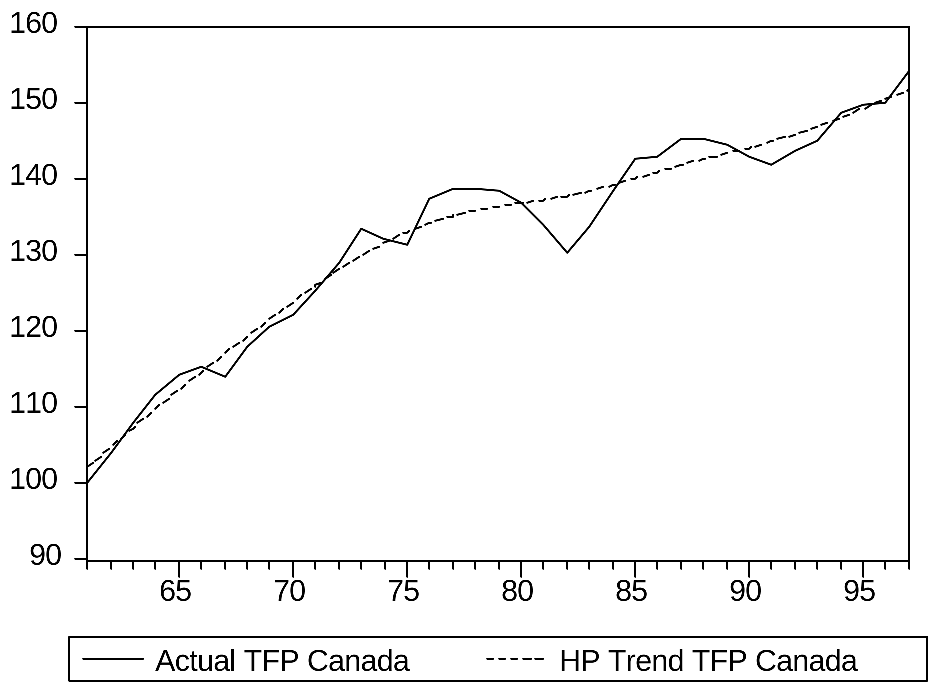


Figure A1: Actual and HP Trend TFP



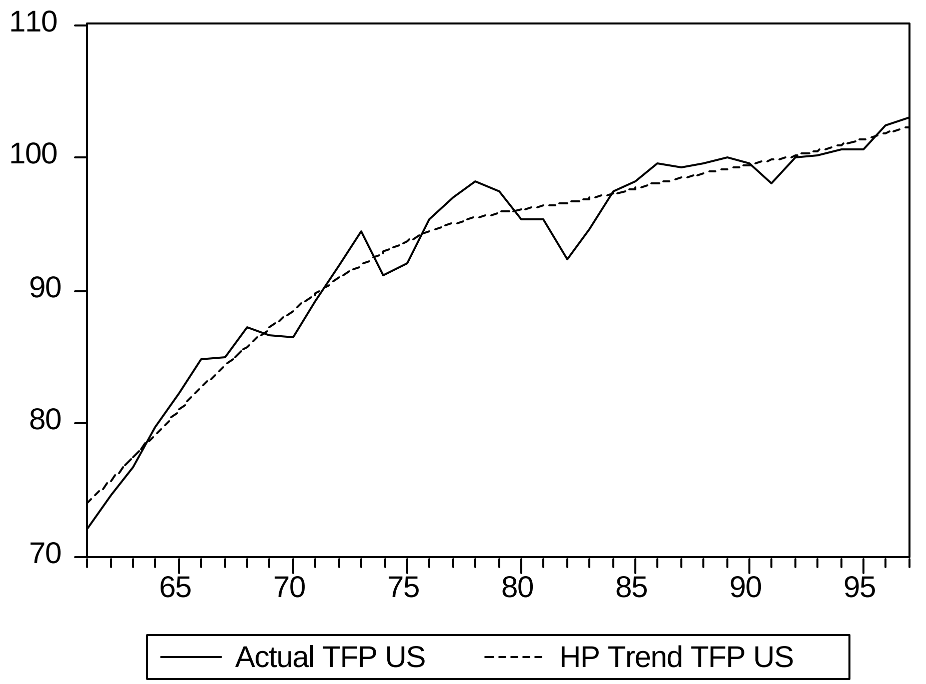


Figure A2: Actual and HP Trend Labor Productivity

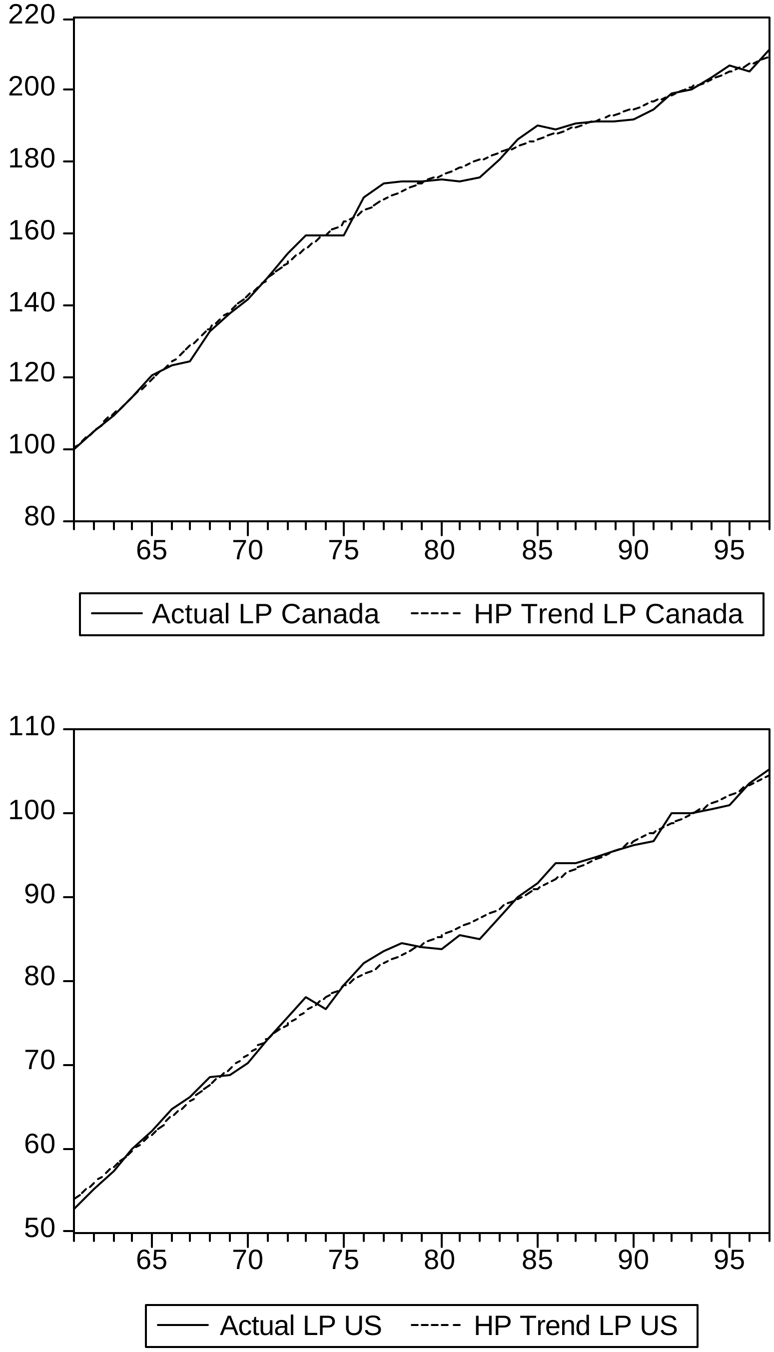


Figure A3: Adjusted TFP Estimates (excluding labor force composition changes)