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An Assessment of Competitiveness and Productivity Levels – Canadian and U.S. Manufacturing Industries

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ABSTRACT

This paper assesses competitiveness between the Canadian manufacturing sector and its U.S. counterpart. The paper adopts the Jorgensonian framework where both capital and labour inputs are adjusted for differences in composition of the labour force and capital stock. It uses three inputs (capital, labour and intermediate inputs) and their respective purchasing power parities to calculate total factor productivity levels in twenty manufacturing industries for Canada and the U.S. The paper then compares relative output prices in twenty manufacturing industries to assess competitiveness. In 1995, eleven Canadian manufacturing industries were less competitive than their U.S. counterparts. The source of competitive disadvantage for the Canadian manufacturing sector can be traced to higher capital input prices in virtually all Canadian manufacturing industries compared to U.S. counterparts and lower TFP levels for a majority of Canadian manufacturing industries (sixteen). On the other hand, intermediate input prices were virtually the same between Canada and the United States across all manufacturing industries. Labour input prices in all Canadian manufacturing industries were much lower than their U.S. competitors.

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1 Introduction

International comparisons of competitiveness and productivity levels continue to interest economic researchers since these comparisons provide a better understanding of disparities in living standards among countries. Most empirical studies related to competitiveness and productivity assess international competitiveness by comparing unit labour costs across countries (Hooper and Vrankovich, 1995; Lee, 1998) or measure productivity levels by relying on labour productivity estimates (Pilat, 1996; De Jong, 1996; Van Ark, 1995). These studies therefore consider labour as the only input determining either competitiveness or productivity. However, there are some studies that consider other inputs as well. Denny *et al.* (1995) assess total factor productivity (TFP) levels in the two digit manufacturing industries of Canada, Japan and the United States between 1953 and 1986. Harrigan (1997) also compares 1987 total factor productivity levels of some key manufacturing sectors across eleven countries. Jorgenson, Kuroda and Nishimizu (1987), Dougherty and Jorgenson (1997) and Jorgenson and Yip (1999) take a more comprehensive approach in that they compare TFP levels after accounting for differences in quality of capital and labour inputs. Thus, some researchers interpret their TFP levels as differences in technology levels. Jorgenson and Kuroda (1995) and Kuroda and Nomura (1999) also analyze the relationship between competitiveness and TFP levels where competitiveness is defined by relative output prices. Henceforth, their definition of competitiveness reflects differences in relative input prices and TFP levels.

The objective of this study is to compare international competitiveness and total factor productivity levels between twenty Canadian and U.S. manufacturing industries using the Jorgensonian framework on the basis of the data sets that are comparable between the two countries. These are then compared to partial measures of competitiveness and productivity levels (unit labour costs and labour productivity). We focus on the manufacturing sector since it has a more reliable data compared to the services sector and it faces a stiffer international competition at home and abroad.

The remaining sections of the paper are organized as follows. In section 2, we summarize the methodology and data used in this study.   Section 3 is devoted to a comparison of productivity levels and international competitiveness between Canadian and U.S. manufacturing industries. We conclude the paper in section 4.

2 Methodology and Data

This section first summarizes the methodology developed by Jorgenson and Nishimizu (1978) for productivity and international competitiveness comparisons between two countries, and it then briefly discusses the data used in the analysis.

2.1 Methodology

As in Jorgenson and Nishimizu (1978), our theoretical framework for productivity and international competitiveness comparisons between Canada and the United States is based on a translog production function originally introduced by Christensen, Jorgenson and Lau (1971, 1973). Here, output is a translog function of capital, labour and intermediate inputs, as well as a dummy variable equal to one for Canada and zero for the United States, and time as an index of technology for each industry. However, as in Jorgenson and Kuroda (1995) and Kuroda and Nomura (1999), we find that it is more convenient to work with the dual price function of output to analyze international competitiveness and relative TFP levels. The dual price function is derived from the production function under competitive conditions. The price function for the *i*th industry can be represented as:

$$\text{(1)} \quad \begin{aligned} \ln P_i &= \ln P_i^{X'} \alpha_i^X + \alpha_i^t t + \alpha_i^D D + \frac{1}{2} \ln P_i^{X'} \beta_i^{XX} \ln P_i^X + \ln P_i^{X'} \beta_i^{Xt} t \\ &+ \ln P_i^{X'} \beta_i^{XD} D + \frac{1}{2} \beta_i^{tt} t^2 + \beta_i^{tD} tD + \frac{1}{2} \beta_i^{DD} D^2, \end{aligned}$$

where P_i is the output price of the *i*th industry; $ln\, P_i^X$ denotes { $\ln P_i^K \;\; \ln P_i^L \;\; \ln P_i^M$ }, a vector of logarithms of capital, labour and intermediate input prices of *i*th industry; *t* denotes time as an index of technology; and *D* is a dummy variable, equal to one for Canada and zero for the United States.

In this presentation, scalars $\{\alpha_i^t, \alpha_i^D, \beta_i^{tt}, \beta_i^{tD}, \beta_i^{DD}\}$, the vectors $\{\alpha_i^X, \beta_i^{Xt}, \beta_i^{XD}\}$, and the matrix $\{\beta_i^{XX}\}$ are constant parameters. However, these parameters differ among industries, reflecting differences among technologies. Within each industry, differences in technology among time periods are represented by time as an index of technology. Differences in technology between Canada and the United States are associated with the dummy variable.

Based on the above price function, Jorgenson and Kuroda (1995) and Kuroda and Nomura (1999) show that difference in TFP levels between Canada and the United States for the *i*th industry, $\hat{v}_i^D$, can be expressed as the negative value of the difference between the logarithms of the output prices, less a weighted average of the differences between the logarithms of input prices,

$$\text{(2)} \quad \hat{v}_i^D = -\left\{ \ln\left[\frac{P_i(Can)}{P_i(US)}\right] - \hat{v}_i^K \ln\left[\frac{P_i^K(Can)}{P_i^K(US)}\right] - \hat{v}_i^L \ln\left[\frac{P_i^L(Can)}{P_i^L(US)}\right] - \hat{v}_i^M \ln\left[\frac{P_i^M(Can)}{P_i^M(US)}\right] \right\},$$

where $\hat{v}_i^j = \frac{1}{2}\left[v_i^j(Can) + v_i^j(US)\right]$, the average compensation share of input *j* in Canada and the United States for the *i*th industry. The price ratios are the purchasing power parities for output and inputs.

Under this methodology, the discussion of international competitiveness is straightforward. Following Jorgenson and Kuroda (1995), we measure competitiveness by relative output prices, defined as output purchasing power parities divided by the exchange rate ($CDN per $US). If the relative output price for the *i*th industry is below one, then the industry is more competitive in Canada than in the United States and vice versa. According to Equation (2), the relative output price for the *i*th industry can be expressed as the negative value of the difference in TFP levels between Canada and the United States, plus a weighted average of the differences between the logarithms of relative input prices,

(3) $$\ln RP_i = -\hat{v}_i^D + \hat{v}_i^K \ln RP_i^K + \hat{v}_i^L \ln RP_i^L + \hat{v}_i^M \ln RP_i^M ,$$

where RP_i is the relative price of output; RP_i^K, RP_i^L, and RP_i^M are the relative prices for capital, labour, and intermediate inputs respectively.

2.2 Data

To implement the methodology described above, we use data from output and three inputs (capital, labour and intermediate inputs) based on the production account for each manufacturing industry for Canada and the United States. Gross output and intermediate input (price and quantity indices) for Canadian and U.S. manufacturing are respectively obtained from Statistics Canada's KLEMS database (Durand, 1998) and the Jorgenson's KLEM database which is an update and modification of that found in

Jorgenson, Gollop and Fraumeni (1987). Price and quantity indexes of capital and labour inputs are based on those used in Gu and Ho (2000). In that study, they adjust for capital quality by aggregating the capital stock across four asset types (machinery and equipment, non-residential structure, land and inventories)[1] by means of the rental prices of capital calculated in Gu and Lee (1999) for Canada and Jorgenson and Stiroh (1999) for the United States.[2] At the same time, they combine hours worked by each type of worker using its share of labour compensation to reflect compositional shifts in labour.[3] We use the purchasing power parity estimates of output and inputs constructed in Lee and Tang (2000) to compare levels of output and inputs between Canadian and U.S. manufacturing industries. We will briefly describe the methodology used in Lee and Tang (2000) to construct purchasing power parities for output, capital input, labour input and intermediate input. Purchasing power parities for labour input are discussed last. First, we group the 1992 Canadian and U.S. input-output tables[4] into 249 common commodity groups and 20 manufacturing industries.[5] We then match 201 commodity purchasing power parities[6] at purchasers' prices with commodities in the input-output tables. Among the remaining 48 commodities in the input-output tables, we first identify

[1] To ensure data comparability, we used estimates of capital stock based on alternative estimates of Canada's capital stock for depreciable assets (provided by the Investment and Capital Stock Division of Statistics Canada). These estimates are based on the same declining-balance rates as those described in Fraumeni (1997) for the United States rather than a double declining method as in Statistics Canada's KLEMS database. For land and inventory estimates, see Gu, Lee and Tang (2000).

[2] The rental price of capital input is estimated by taking account of the rate of return on capital, economic depreciation rates, and various tax parameters in each country.

[3] In order to precisely match worker type between two countries, our labour classification is slightly different. We cross-classified workers by two sexes, two employment classes, seven age groups and four educational groups, for a total of 112 types (see Gu and Maynard (1999) and Ho and Jorgenson (1999), respectively, for Canadian and U.S. labour-input data).

[4] The I-O tables from both countries include make, use, final demand, and investment flow matrices.

[5] The Canadian I-O tables are aggregated from 479 commodities and 170 industries; the U.S. tables are aggregated from 541 commodities and 541 industries.

[6] These are 1993 purchasing power parities aggregated on the basis of data on more than 2,000 commodities obtained from Statistics Canada. Statistics Canada uses these data to estimate a bilateral GDP

26 commodities that have close substitutes among the 201 commodities already matched, and then apply to them the purchasing power parities of their close substitutes. In the case of the remaining 22 commodities, we use the 1993 market exchange rate. These commodities are mainly primary goods (such as grain, wheat, copper, steel, and precious metals) that are heavily traded in North American or world markets. The 249 commodity purchasing power parities mapped to 20 manufacturing industries to construct output, intermediate input and investment purchasing power parities for industry *i* using the following expression:[7]

(4) $$ln(PPP_i) = \sum_{j=1}^{249} 1/2\left[v_{i,j}(Can) + v_{i,j}(US)\right] \cdot ln(PPP_j), \ (i = 1,\ldots,20),$$

where, PPP_i is industry purchasing power parities, PPP_j is commodity purchasing power parities and $v_{ij}(S)$ is the value share of commodity *j* in industry *i* in country *S*, estimated from the input-output tables of country *S*.

The output purchasing power parity is defined as the ratio of the amount of Canadian dollars received by Canadian producers for output sold in Canada, to the amount of U.S. dollars received by U.S. producers for selling the same amount of output in the United States. Thus we first convert commodity purchasing power parities at purchaser's prices into commodity purchasing power parities at producers' prices by peeling off tax and distribution margins (the indirect commodity tax margin and the transportation and trade margins) using the input-output tables of both countries.[8] We

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purchasing power parity between Canada and the United States.

[7] Although these 249 commodities cover all commodities in the input-output tables, some of them may not be used as inputs. In that case, these are not entered into the calculation of input PPPs.

[8] Hooper and Vrankovich (1995) adjust commodity PPPs for international trade in constructing output PPPs. Our analysis shows that incorporating this methodology does not significantly change our results since it is based on two restrictive assumptions: both export and import prices equal world prices; and world prices equal the average of the prices in the two countries, weighted by their expenditures. Since we

then transform 249 commodity purchasing power parities at producers' prices into output purchasing power parities of 20 manufacturing industries using expression (4) where value shares of commodities are based on the make matrices of the input-output tables.

Intermediate inputs include energy, materials, and purchased services. Their purchasing power parities are computed in the same manner as output purchasing power parities, but they are based on commodity purchasing power parities at purchasers' prices, which include tax, transportation, and trade margins. Moreover, the transformation from 249 commodity purchasing power parities at purchasers' prices into intermediate input purchasing power parities is based on the use matrices of the input-output tables in the two countries.

As mentioned earlier, capital input is broken down here into four asset types – machinery and equipment (M&E), non-residential structures, inventories, and land. However, the data available only allow us to construct investment purchasing power parities for M&E and structures. Following Jorgenson and Kuroda (1995) and Kuroda and Nomura (1999), we aggregate 249 commodity purchasing power parities to construct investment purchasing power parities from purchasers' standpoint (including margins) using expression (4) where commodity value shares are estimated from the investment flow matrices of the input-output tables in the two countries.

We derive purchasing power parities for each type of capital input in industry *i* by multiplying the ratio of each type's rental price for Canada relative to the United States by its corresponding investment purchasing power parities. Finally, we determine purchasing power parities for total capital input by aggregating individual capital input PPPs across all capital inputs, using the average compensation in the two countries for

are unable to justify these two assumptions, we use output PPPs without international trade adjustments.

each type of capital input as weights.[9] Thus, in deriving capital input purchasing power parities, we implicitly assume that the relative efficiency of new capital goods in a given industry is the same in both countries. However, the decline in the efficiency of capital input for each component is estimated separately for each country.

For each of the 20 manufacturing industries, labour inputs in Canada and the United States are matched by sex, employment status, age, and education, as shown in Table 1. We estimate the labour input purchasing power parity for industry *i* by aggregating the ratio of hourly labour compensation rates between the two countries over 112 types of labour using labour compensation as weights.

3 A Canada-U.S. Comparison of Competitiveness in Manufacturing Industries

This section presents our results on competitiveness and productivity levels between twenty Canadian and U.S. manufacturing industries. Before we present our results, we first present our estimated purchasing power parities.

3.1 A Summary of Purchasing Power Parities between Canadian and U.S. Manufacturing Industries

Purchasing power parities for output and three types of inputs in 1993 are reported in Table 2. The output purchasing power parities are generally in line with the exchange rate (1.29 in 1993) for most manufacturing industries. However, for tobacco, it is on the lower side.

Capital input purchasing power parities show wide variation across manufacturing industries. These variations stem from the variations in the rental prices of capital input between the two countries since capital investment prices are generally comparable. For

[9] As in Kuroda and Nomura (1999), we implicitly assume that the differences in the asset prices for

instance, the rental price of capital input in the motor vehicles, rubber and plastics, and industrial machinery industries is higher in Canada than in the United States, while the opposite is true in the paper and allied products and petroleum refining industries. A close examination reveals that the substantial differences in the rental prices of capital input noted between Canada and the United States are attributable to large differences in the capital compensation figures from two countries' input-output tables relative to their respective capital stocks.

With respect to the purchasing power parities for labour input, we first observe that all industries' labour input PPPs are smaller than the exchange rate and ten of them are below unity, which is significantly below the exchange rate. In addition, the variation across industries is very small.

Finally, intermediate input purchasing power parities are fairly constant across industries, and more or less equal to the exchange rate for all industries except tobacco. The Canadian tobacco industry pays a higher price for intermediate inputs than does its U.S. counterpart, mainly because of the difference in the taxation on semi-finished tobacco products between the two countries.

3.2 Relative Productivity Levels

Based on equation (2), we first calculate relative TFP levels[10] in Canada and the United States for twenty manufacturing industries. The estimated relative TFP levels by industry are reported in Table 3. In 1995, Canada was less productive than the United States in sixteen of the twenty manufacturing industries. In particular, Canada was much less productive in paper; printing; rubber and plastics; leather; stone, clay, and glass;

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inventory and land reflect the differences in asset prices of M&E and structures between the two countries.

fabricated metals; and industrial machinery. On the other hand, in 1995, Canada was significantly more productive than the United States in tobacco and petroleum refining.

To give another perspective on this issue, we also present gross-output based labour productivity in the same table. The Canada-U.S. productivity gap based on gross-output labour productivity[11] was much larger for most manufacturing industries. In fact, with the exception of lumber & wood and rubber & plastics, all other Canadian manufacturing industries' labour productivity levels (gross-output based) relative to their U.S. counterparts were lower than their relative TFP levels. The difference is mainly attributable to lower capital intensities[12] in most Canadian manufacturing industries relative to those in the United States.[13] For instance, in 1995, the capital intensity (PPP based) in Canada was only 73 per cent of that in the United States in total manufacturing.

3.3 International Competitiveness at the Industry Level

This section assesses differences in competitiveness between Canadian and U.S. manufacturing industries and relates them to their TFP levels based on equation (3). The relative prices for output, for capital, labour, and intermediate inputs, and relative TFP levels in 1995 are reported in Table 4. In 1995, about half of Canadian manufacturing industries had a lower relative output price and thus more competitive than their U.S. counterparts.

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[10] These are quality adjusted TFP levels.

[11] Some analysts also devise labour productivity measures based on value-added with additional restrictions on the production function. The Canada-U.S. productivity gap based on the value-added concept is larger for most manufacturing industries.

[12] Canada's capital intensity is based on an alternative set of capital stock estimates from the Investment and Capital Stock Division of Statistics Canada. These alternative capital stocks are estimated using the same declining-balance rates as those in the United States. Capital intensity for Canada would be much lower if we used capital stock data from Statistics Canada's KLEMS database.

[13] In addition, differences in capital and labour quality are also responsible for the difference between the estimated TFP levels and gross-output based labour productivity levels. However, differences between

With respect to capital input, Canada had higher capital input prices than the United States in all manufacturing industries except for leather. In particular, Canadian capital input prices were substantially higher than U.S. prices in textiles, apparel, furniture, paper, rubber and plastics, primary metals, motor vehicles, other transportation equipment, and miscellaneous manufacturing in 1995. As discussed earlier, it is helpful to keep in mind that differences in relative capital input prices reflect differences not only in capital investment prices but also in the rental price of capital input.

In contrast with the situation regarding capital input prices, all Canadian manufacturing industries had an advantage over their U.S. counterparts in terms of labour costs, and the variations in relative labour input prices across industries were very small in 1995. As a result of this difference in labour costs, the production structures of the two countries in the manufacturing sector are also different. Canadian manufacturing industries are generally more labour-intensive, while their U.S. counterparts tend to be more capital-intensive.

Finally, most Canadian industries paid almost the same price for their intermediate inputs as did their U.S. counterparts.

When examining the links between competitiveness, relative TFP levels, and relative input prices, a simple correlation among these variables is a good starting point for discussion. The correlation coefficient between relative output prices and relative TFP levels across manufacturing industries is -0.75 based on 1995 data, while in the case of capital, labour, and intermediate inputs, the coefficients stand at 0.32, 0.38, and -0.26,

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Canadian and U.S. manufacturing industries in quality levels of capital and labour inputs are not large as shown in Table A.1 in the Appendix.

respectively[14]. These coefficients indicate that variations in relative output prices across manufacturing industries are strongly related to inter-industry differences in relative TFP levels.

We summarize the relationship between output prices and TFP levels by plotting relative output prices against relative TFP levels for 1995 across manufacturing industries in Canada and the United States, as shown in Figure 1. To better illustrate the relationship between competitiveness and relative TFP levels, we divide the figure into four quadrants. In quadrants I and II are found those Canadian manufacturing industries which are less competitive than their U.S. counterparts, while quadrants III and IV show Canadian manufacturing industries that are more competitive than their U.S. equivalents. At the same time, Canadian manufacturing industries in quadrants II and III are more productive than their U.S. competitors, while relatively less productive manufacturing industries in Canada are located in quadrants I and IV.

In 1995, 11 Canadian manufacturing industries were less competitive and less productive than U.S. manufacturing industries (quadrant I). In seven manufacturing industries (food, textiles, apparel, paper, printing, rubber and plastics, and primary metals), lower productivity combined with higher input prices (including all three types of inputs) to reduce competitiveness. Low input prices in four of the remaining manufacturing industries were not strong enough to offset the effects of lower productivity and make these manufacturing industries more competitive. No industry was less competitive but more productive than its U.S. counterpart (quadrant II).

[14] Unlike the partial correlation coefficient between output prices and TFP levels, the three partial correlation coefficients for input prices are not significantly different from zero at the 5% level.

An examination of quadrant III reveals that four Canadian manufacturing industries were more competitive and more productive than U.S. manufacturing industries. Two of these – lumber & wood and petroleum refining – were identified as having relatively lower input prices than their U.S. counterparts. The remaining two manufacturing industries – tobacco and motor vehicles – had higher input prices than their U.S. competitors, but the difference was not large enough to make them less competitive than the U.S. manufacturing industries.

And last, quadrant IV shows those manufacturing industries where Canada was more competitive but less productive than the United States – chemicals, leather, industrial machinery, electrical machinery and miscellaneous manufacturing. Canada's competitive position in those cases stemmed from lower input prices rather than higher TFP levels. Thus it appears that the main factor behind variations in international competitiveness across manufacturing industries is the gap in relative TFP levels.

3.4 International Competitiveness and Productivity Levels in Total Manufacturing

This section discusses competitiveness and productivity levels for the manufacturing sector as a whole. Figure 2 compares competitiveness and relative TFP levels between 1979 and 1995. The Canadian manufacturing sector was as competitive as the U.S. sector in 1979. However, the Canadian manufacturing sector's relative competitive position worsened between 1979 and 1995 where its relative output price increased by about 4%. All three relative input prices increased between 1979 and 1995. Specifically, relative capital input price rose by 45% and relative labour and intermediate input prices, respectively, increased by 22% and 9% despite the depreciation of the Canadian dollar by 17% between 1979 and 1995. Thus, without the depreciation of the

Canadian dollar, the Canadian manufacturing sector's competitive position would have been worse. Meanwhile, the TFP gap in the manufacturing sector increased from 1% to 7% between 1979 and 1995 thereby worsening the competitive position of the Canadian manufacturing sector.

Many analysts often compare unit labour costs to assess competitiveness. Differences in this measurement reflect differences in labour productivity, labour compensation per hour and the exchange rate. For the purpose of illustration, we compare our measure of competitiveness with both gross-output based unit labour costs and value-added based unit labour cost in Figure 3. Based on both measures of unit labour costs, the Canadian manufacturing sector was more competitive than the U.S. manufacturing sector in 1995. The underlying reason behind this is that these measures only consider labour input in determining competitiveness whereas our measure of competitiveness considers all three inputs. On the productivity side, all three measures show that there was a productivity gap between the Canadian and the U.S. manufacturing sector in 1995. As mentioned earlier, the productivity gap based on TFP is smaller than the productivity gap based on a gross-output labour productivity due to a lower capital intensity in the Canadian manufacturing sector relative to the U.S. The productivity gap based on a value-added labour productivity[15] is larger than the gross-output based labour productivity gap since the share of intermediate goods in gross-output in the Canadian manufacturing sector is larger than that in the U.S. manufacturing sector.

[15] The value added purchasing power parity for total manufacturing is 1.34, based on weighted industry value added purchasing power parities. The industry value added purchasing power parities are implicitly derived from gross output and intermediate input purchasing power parities by applying the formula in Jorgenson, Gallop and Fraumeni (1987, p52) to a bilateral country model.

4 Summary and Conclusion

This paper illustrates that it is critical to use purchasing power parities rather than the market exchange rate to assess the relative productivity levels and international competitiveness of two countries. Purchasing power parities vary across manufacturing industries as well as over types of output and inputs. Based on a common framework using comparable data sets, sixteen of the twenty Canadian manufacturing industries had lower TFP levels compared to their U.S. counterparts in 1995. Relative TFP levels are an important element in determining international competitiveness. Our analysis indicates that Canadian manufacturing industries with high relative productivity compared to their U.S. counterparts tend to be more competitive. Over time, however, movements in the exchange rate remain as another important factor behind international competitiveness.

This study shows that one's perception of competitiveness change depending on the measures used to assess competitiveness. For instance, this study demonstrates that a partial measure of competitiveness based on one input such as unit labour costs could yield a different result. In fact, based on unit labour costs, Canada's manufacturing sector was more competitive than its U.S. counterpart in 1995, since Canada's labour costs were substantially lower than those of the U.S. However, once we include other inputs, the Canadian manufacturing sector is slightly less competitive than the U.S. manufacturing sector.

Future research should focus on understanding underlying factors behind competitiveness between Canadian and U.S. manufacturing industries. In particular, assessment of factors such as technology adoption rates, management practices, institutional settings and innovation may help us to better understand competitiveness at the industry level. In addition, case studies focusing on major industries in both countries where there is a large productivity gap may also prove to be fruitful.

Appendix: Measuring Capital and Labour Inputs, and Their Quality

This appendix first compares relative levels of capital and labour input quality in Canada and the United States and assesses their implications for relative TFP levels. Following Dougherty (1992), we estimate capital input, $K_i\ (S)$, for industry *i* in country *S*, Canada or the United States, with each country's asset type (M&E, structures, land, and inventories) weighted by the average compensation share in two countries:

$$\text{(A.1)} \quad \ln[K_i\ (S)] = \sum_{k=1}^{4} \frac{1}{2}\left[v_{i,k}^K(Can) + v_{i,k}^K(US)\right]\ln[A_{i,k}(S)],$$

where $v_{i,k}^K(S)$ is the capital compensation share of type *k* capital asset in total capital compensation in industry *i* in country *S*, and $A_{i,k}(S)$ is the net stock of type *k* capital asset in industry *i* in country *S*.

The quantity index of capital input is then indexed in such way that its value in the base year (1993) equals total capital compensation in that year. The capital input price index for using the total capital service, P_i^K, is then defined as the ratio of total capital compensation to the quantity index of capital input.[16]

As Dougherty (1992), the relative capital quality levels for industry *i* between Canada and the United States can be estimated by

$$\text{(A.2)} \quad \ln\left[\frac{q_i(Can)}{q_i(US)}\right] = \sum_{k=1}^{4} \frac{1}{2}\left[v_{i,k}^K(Can) + v_{i,k}^K(US)\right]\ln\left[\frac{A_{i,k}(Can)}{A_{i,k}(US)}\right] - \ln\left[\frac{A_i\ (Can)}{A_i\ (US)}\right],$$

where $A_i\ (S) = \sum_{k=1}^{4} A_{i,k}(S)$ denotes the total capital stock in industry *i* in country *S*.

[16] Capital input price should be distinguished from the acquisition price of buying all capital assets. Capita input rice equals the average rental price of all capital assets while the acquisition price equals their purchasing price.

Likewise for capital input, labour input $L_i(S)$, for industry *i* in country *S*, Canada or the United States, can be expressed as:

$$\text{(A.3)} \quad \ln[L_i(S)] = \sum_{j=1}^{112} \frac{1}{2}\left[v_{i,j}^L(Can) + v_{i,j}^L(US)\right]\ln[H_{i,j}(S)],$$

where $v_{i,j}^L(S)$ denotes the labour compensation shares of type *j* workers in industry *i* in country *S*, and $H_{i,j}(S)$ denotes the hours worked by workers of type *j* in industry *i* in country *S*.

The quantity of labour input is then indexed in such way that its value in the base year (1993) equals total labour compensation in that year. The labour input price index, P_i^L, is defined as the ratio of total labour compensation to the quantity index of labour input.

As with capital quality, relative labour quality levels are estimated by:

$$\text{(A.4)} \quad \ln\left[\frac{q_i^L(Can)}{q_i^L(US)}\right] = \sum_{j=1}^{112} \frac{1}{2}\left[v_{i,j}^L(Can) + v_{i,j}^L(US)\right]\ln\left[\frac{H_{i,j}(Can)}{H_{i,j}(US)}\right] - \ln\left[\frac{H_i(Can)}{H_i(US)}\right],$$

where $H_i(S) = \sum_{j=1}^{112} H_{i,j}(S)$, the total hours worked by all types of workers in industry *i* in country *S*.

We then use the relative quality levels of capital and labour inputs to estimate relative raw TFP levels (commonly referred to as relative Solow residuals). The relationship between the relative raw TFP levels and our estimates of relative TFP levels is given below:

$$\text{(A.5)} \quad \hat{\varphi}_i^D = \hat{v}_i^D + \hat{v}_i^K \ln\left[\frac{q_i^K(Can)}{q_i^K(US)}\right] + \hat{v}_i^L \ln\left[\frac{q_i^L(Can)}{q_i^L(US)}\right],$$

where $\hat{\varphi}_i^D$ is the raw TFP, $\hat{v}_i^D$ is the TFP, and $\hat{v}_i^K$ and $\hat{v}_i^L$ are the average capital and labour compensation shares of the two countries in industry *i*, as in equation (2).

In Table A.1, we report relative quality levels of capital and labour inputs and assess their implications for relative TFP levels. Generally speaking, there are some variations in the relative levels of capital quality across manufacturing industries between Canada and the United States. On the other hand, labour quality in Canada is slightly lower than in the United States in almost all manufacturing industries. In most cases, the effect of capital quality is offset by labour quality, resulting in a slight difference between relative raw TFP levels and the estimated TFP levels that incorporate capital and labour input quality differences.

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Table 1
Classification of the Canadian and U.S. Work Force

Worker characteristics	Number of categories	Type
Sex	2	Female; Male
Employment status	2	Paid employees; Self-employed[1]
Age	7	16-17;[2] 18-24; 25-34; 35-44; 45-54; 55-64; 65+
Education	4	0-8 years grade school; Some or completed high school; Some or completed post-secondary school; University or higher

1. U.S. self-employed includes unpaid workers.
2. The age group is 15-17 for Canada.

Table 2
Purchasing Power Parities by Industry, 1993 (U.S. = 1.00)

Industry	Output	Capital input	Labour input	Intermediate Input
1. Food	1.42	2.13	1.11	1.36
2. Tobacco	0.74	2.23	1.05	1.57
3. Textile	1.46	2.36	1.06	1.35
4. Apparel	1.34	2.29	0.96	1.38
5. Lumber & wood	1.25	1.88	1.21	1.24
6. Furniture	1.36	2.41	0.93	1.35
7. Paper	1.55	0.75	1.16	1.30
8. Printing	1.52	2.45	1.12	1.35
9. Chemicals	1.28	1.19	0.81	1.32
10. Petroleum refining	1.13	0.47	0.99	1.29
11. Rubber & plastics	1.58	2.73	1.02	1.31
12. Leather	1.32	0.83	1.06	1.27
13. Stone, clay & glass	1.41	2.08	1.01	1.32
14. Primary metals	1.28	1.10	1.07	1.26
15. Fabricated metals	1.40	1.85	0.89	1.29
16. Industrial machinery	1.30	2.55	0.85	1.28
17. Electrical machinery	1.17	1.70	0.92	1.23
18. Motor vehicles	1.23	3.59	0.76	1.35
19. Other trans. equip.	1.35	2.19	0.97	1.31
20. Misc. manufacturing	1.29	2.40	0.80	1.30
Total manufacturing	1.33	1.48	0.96	1.31

Table 3
Relative TFP and Labour Productivity Levels in Canada, 1995 (U.S. = 1.00)

Industry	TFP	GLP[1]
1. Food	0.96	0.66
2. Tobacco	2.06	0.90
3. Textile	0.98	0.64
4. Apparel	0.99	0.61
5. Lumber & wood	1.01	1.04
6. Furniture	0.96	0.61
7. Paper	0.83	0.71
8. Printing	0.88	0.60
9. Chemicals	0.93	0.78
10. Petroleum refining	1.15	1.22
11. Rubber & plastics	0.85	0.61
12. Leather	0.83	0.71
13. Stone, clay & glass	0.87	0.77
14. Primary metals	0.96	0.94
15. Fabricated metals	0.84	0.64
16. Industrial machinery	0.88	0.84
17. Electrical machinery	0.98	0.87
18. Motor vehicles	1.07	0.92
19. Other trans. equip.	0.98	0.80
20. Misc. manufacturing	0.92	0.54

[1] Gross output per hour worked.

Table 4
Relative Prices[1] and TFP Levels by Industry, 1995 (U.S. = 1.00)

Industry	Output	TFP	Capital input	Labour Input	Intermediate Input
1. Food	1.05	0.96	1.21	0.78	1.03
2. Tobacco	0.61	2.06	1.74	0.69	1.29
3. Textile	1.10	0.98	3.26	0.77	1.05
4. Apparel	1.01	0.99	2.34	0.72	1.05
5. Lumber & wood	0.96	1.01	1.20	0.98	0.92
6. Furniture	1.01	0.96	3.17	0.67	1.01
7. Paper	1.39	0.83	2.99	0.84	1.07
8. Printing	1.16	0.88	1.96	0.80	1.05
9. Chemicals	0.97	0.93	1.01	0.59	1.01
10. Petroleum refining	0.85	1.15	1.21	0.75	0.99
11. Rubber & plastics	1.23	0.85	2.20	0.79	1.04
12. Leather	0.99	0.83	0.48	0.72	1.01
13. Stone, clay & glass	1.06	0.87	1.49	0.71	0.95
14. Primary metals	1.09	0.96	2.24	0.79	1.05
15. Fabricated metals	1.08	0.84	1.54	0.66	0.98
16. Industrial machinery	0.96	0.88	1.12	0.64	0.96
17. Electrical machinery	0.90	0.98	1.35	0.64	0.92
18. Motor vehicles	0.95	1.07	3.50	0.56	1.02
19. Other trans. equip.	1.01	0.98	2.70	0.70	1.02
20. Misc. manufacturing	0.97	0.92	2.48	0.55	1.00

1. PPP denominated price index denominated by exchange rate.

Table A.1
Relative Capital and Labour Quality Levels and TFP Levels, 1995 (U.S. = 1.00)

Industry	Capital Quality	Labour Quality	TFP	Raw TFP
1. Food	1.00	0.95	0.96	0.95
2. Tobacco	0.95	1.01	2.06	2.02
3. Textile	0.98	1.01	0.98	0.98
4. Apparel	1.00	0.97	0.99	0.98
5. Lumber & wood	1.06	0.97	1.01	1.01
6. Furniture	0.99	0.98	0.96	0.96
7. Paper	1.11	1.00	0.83	0.84
8. Printing	0.93	0.96	0.88	0.86
9. Chemicals	1.01	0.96	0.93	0.92
10. Petroleum refining	0.74	0.99	1.15	1.12
11. Rubber & plastics	1.12	0.97	0.85	0.86
12. Leather	1.11	0.95	0.83	0.83
13. Stone, clay & glass	1.07	0.98	0.87	0.88
14. Primary metals	1.20	0.97	0.96	0.97
15. Fabricated metals	1.05	0.98	0.84	0.84
16. Industrial machinery	1.04	0.96	0.88	0.87
17. Electrical machinery	0.87	0.98	0.98	0.96
18. Motor vehicles	1.67	0.94	1.07	1.09
19. Other trans. equip.	0.88	0.95	0.98	0.95
20. Misc. manufacturing	0.93	0.91	0.92	0.88
Total manufacturing	1.04	0.98	0.93	0.93

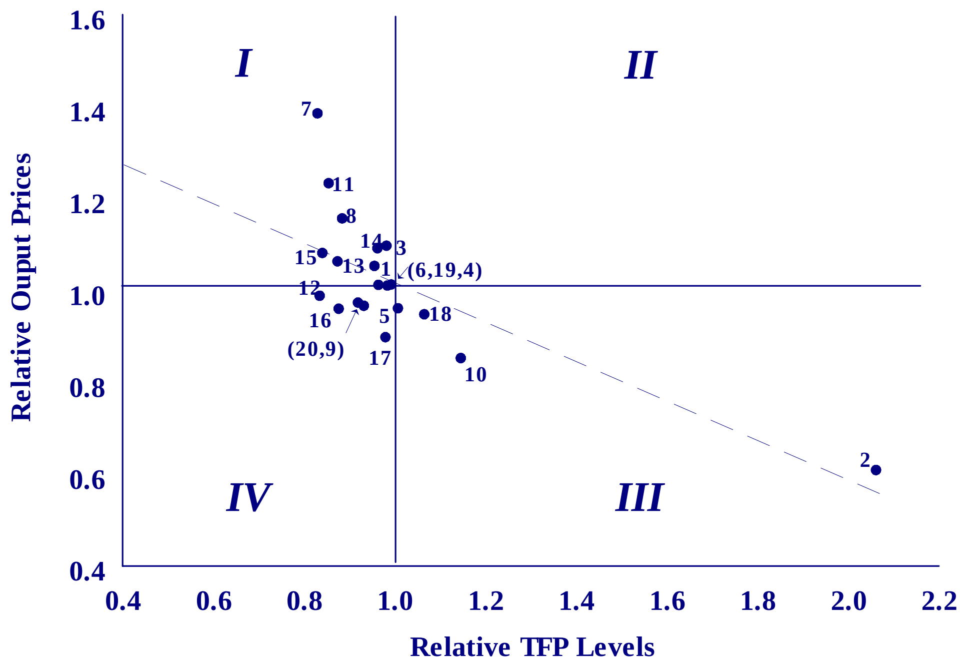

Figure 1
Relative Output Prices Against Relative TFP Levels, 1995
Note: Numbers in this figure refer to those industries listed in table 2.

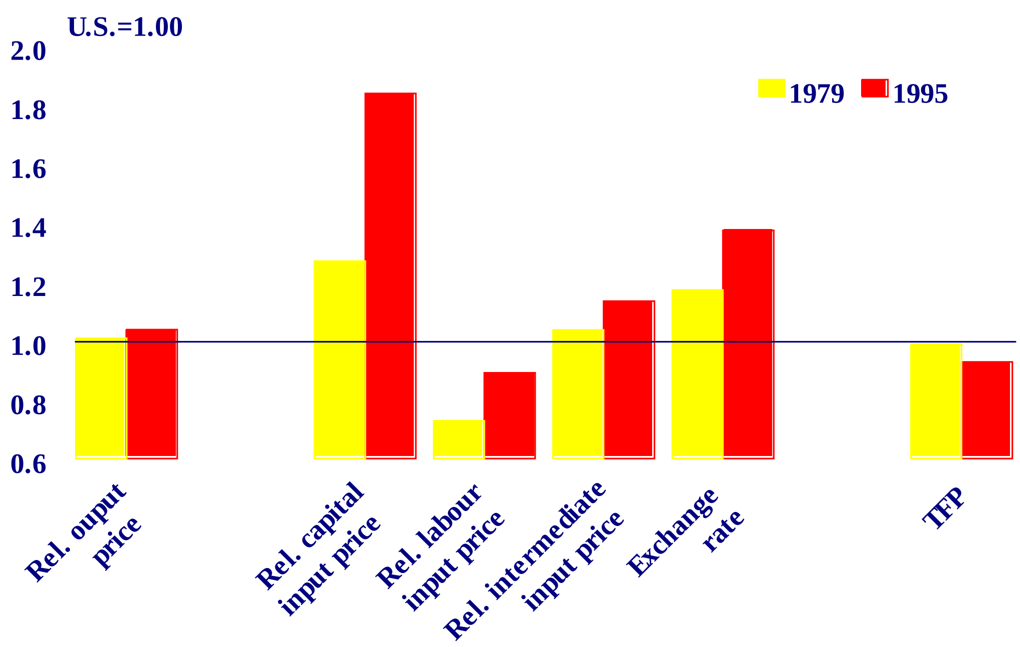

Figure 2
Relative Prices and Productivity between Canada and the United States for the Manufacturing Sector

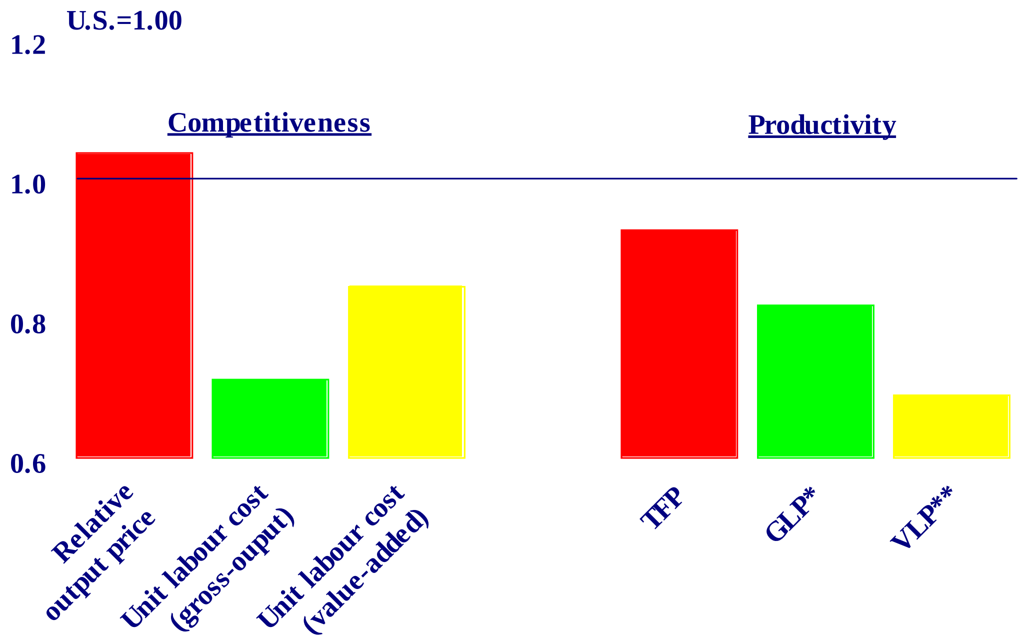

Figure 3
A Comparison of Competitiveness and Productivity between Canada and the United States for the Manufacturing Sector, 1995

Note: * GLP refers to gross output based labour productivity
** VLP refers to value-added based labour productivity.