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

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

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# The Canada-U.S. Manufacturing Productivity Gap Revisited: New ICOP Results


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Session 2 “How Large is the Canada-U.S. Manufacturing Productivity Gap?”
January  21   11:15 AM - 12:45 PM

# THE CANADA-U.S. MANUFACTURING PRODUCTIVITY GAP REVISITED: NEW ICOP RESULTS

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Paper presented at the CSLS Conference on the
Canada-U.S. Manufacturing Productivity Gap
January 21-22, 2000, Ottawa
(sliightly revised version – 24 January 2000)

Note:
This paper includes some provisional results.
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* We are grateful to Erik Monnikhof with help on the U.S. data and to Andrew Sharpe and Dmitry Kabrelyan for providing the Canadian data for 1997.

**Abstract**

This paper presents the ICOP methodology for industry-of-origin comparisons of manufacturing productivity, and applies it to the study of the manufacturing productivity gap between Canada and the United States. The paper discusses the ICOP method and presents recent refinements to the methodology in order to meet some of the criticisms that were raised earlier. It then presents provisional estimates of a fresh comparison of relative levels of manufacturing productivity between the two countries for 1997. Finally the paper revisits the long term trend of comparative labour productivity between the two countries and compares the outcomes with those from earlier studies.

## 1. Introduction

The widening of the manufacturing productivity gap between Canada and the United States since the mid-1970s has been of considerable concern to observers within and outside the Canada.[1] Indeed earlier estimates from the ICOP (International Comparisons of Output and Productivity) research group at the University of Groningen confirmed the widening productivity gap between the two countries (De Jong, 1996). This paper revisits the issue by providing a new benchmark estimate for Canada vis-à-vis the United States for 1997. The paper also provides a long term perspective by backdating the estimates and comparing the outcomes with earlier alternative estimates, including those from West (1971), Frank (1977) and De Jong (1996).

At the outset of this paper two observations may be made in which our results differ from alternative estimates. Firstly, even though our figures show a rising productivity gap between the two countries, the gap appears somewhat smaller than suggested in other studies. Secondly, even though the increase in the productivity gap relative to the USA has been bigger than elsewhere, other OECD countries (including Australia and the UK) have experienced a widening productivity gap in manufacturing relative to the United States as well (see Table 1). More importantly, in many countries the relative gap has not improved as much since 1987 compared to between, say, 1973 and 1987. Hence the deteriorating productivity performance of Canada's manufacturing sector is only part of the explanation of the widening gap. Of equal interest is the question why the United States has moved so rapidly forward. We will argue that the rapid productivity improvements in the computer and semiconductor industries in the United States are probably mainly responsible for this. We will return to this point when discussing the backward extrapolations of our 1997 benchmark estimate.

In Section 2 of the paper we discuss the ICOP methodology for international comparisons. We review the strengths and weaknesses of using our industry-of-origin unit value ratio (UVR) method relative to the use of ICP (International Comparisons Project) PPPs for converting industry output to a common currency. We also discuss our recent work on further improving the ICOP methodology. In Section 3 of the paper we provide new 1997 Canada-U.S. benchmark results. These estimates are still of a provisional nature as not all the material needed for the comparison is yet incorporated in the estimate. In Section 4 we attempt to backdate the 1997 benchmark results at industry level to earlier years, which clearly indicates the inconsistency of the national time series. This shows the need for regular "re-benchmarking" of manufacturing productivity levels especially for the investment goods industries.

**Table 1**
**ICOP Estimates of Comparative Levels of Labour Productivity in Manufacturing in OECD countries, 1960-1998, USA=100**

| | 1960 | | 1973 | | 1987 | | 1998 | |
|---|---|---|---|---|---|---|---|---|
| | Value Added per Person Employed | Value Added per Hour | Value Added Per Person Employed | Value Added per Hour | Value Added per Person Employed | Value Added per Hour | Value Added per Person Employed | Value Added per Hour |
| Portugal | 15.0 | | 24.2 | | **24.5** | | 23.2 b | |
| Mexico | 37.0 | | 35.5 | | **25.6** | | 25.6 d | |
| Korea | 9.7 a | 6.8 a | 14.9 | 10.8 | **26.3** | 18.2 | 43.3 c | |
| Spain | 15.1 | | 28.5 | | **46.5** | | 39.6 d | |
| Australia | 40.7 | 39.6 | 43.1 | 43.8 | **48.4** | 49.9 | 45.5 | 47.3 |
| United Kingdom | 49.9 | 45.9 | 51.1 | 52.5 | **53.6** | 58.0 | 49.5 | 57.0 |
| Finland | 47.9 | 45.5 | 53.2 | 56.1 | **65.9** | 74.3 | 86.4 d | 103.5 d |
| Sweden | 53.6 | 55.3 | 73.0 | 88.3 | **68.4** | 87.4 | 83.3 | 99.7 |
| West Germany | 63.0 | 57.9 | 75.6 | 79.0 | **70.2** | 82.2 | 68.2 | 86.5 |
| France | 51.8 | 49.8 | 67.6 | 71.4 | **71.2** | 84.0 | 76.5 | 92.8 |
| Japan | 24.9 | 19.9 | 55.0 | 47.5 | **76.4** | 67.5 | 77.4 | 80.0 |
| Canada | 80.4 | 80.2 | 83.9 | 86.0 | **77.5** | 79.4 | 69.2 | 75.2 |
| Belgium | 42.1 | 41.0 | 57.6 | 67.0 | **78.5** | 99.8 | 79.6 | 102.4 |
| Netherlands | 54.4 | 50.2 | 79.3 | 87.0 | **83.3** | 105.4 | 87.3 | 117.1 |
| United States | 100.0 | 100.0 | 100.0 | 100.0 | **100.0** | 100.0 | 100.0 | 100.0 |

(a) 1963; (b) 1995; (c) 1997; (d) 1996.

Notes: Countries are ranked according to their level of value added per person employed in 1987. All estimates have been converted to the USA as the base country.

Sources: Benchmark estimates: Portugal /UK (1984) from Peres (1994), linked to UK/USA (1987) from van Ark (1992); Korea/USA (1987) and Japan/USA (1987) from Pilat (1994), Mexico/USA (1975) from van Ark and Maddison (1994); Spain/UK (1984) from van Ark (1995), linked to UK/USA (1987) from van Ark (1992); Australia/USA (1987) from Pilat, Rao and Shepherd (1993); UK/USA (1987) from van Ark (1992); Finland/USA (1987) and Sweden/USA (1987) from Maliranta (1994); West Germany/USA (1987) from van Ark and Pilat (1993); France/USA (1987) from van Ark and Kouwenhoven (1994); Canada/USA (1987) from de Jong (1996); Netherlands/USA from Kouwenhoven (1993). Extrapolations from benchmark years: mostly from national accounts series on real GDP and employment in manufacturing mostly taken from national statistics, *OECD National Accounts Vol. 2* or BLS, *International Comparisons of Manufacturing Productivity and Unit Labor Cost Trends* (http://stats.bls.gov/news.release/prod4.toc.htm).

[1] See, for example, Sharpe (1998).

## 2. The ICOP Methodology[2]

### *Expenditure versus Industry of Origin Approach*

International comparisons of GDP and per capita income are mostly made by converting national income to a common currency, say U.S. dollars, on the basis of the expenditure-based purchasing power parities (PPPs). These PPPs are obtained by expenditure category (private consumption, investment and government expenditure) and are now provided on a regular basis by Eurostat and the OECD.[3] For comparisons of output, per capita income and productivity at the level of the total economy there is also an academic tradition of using expenditure PPPs. For example, Maddison (1991, 1995, 1998) used such PPPs for historical comparisons, and Kravis, Heston and Summers (1982) and Summers and Heston (1988, 1991) applied PPPs for the construction of the Penn World Tables. Recently, Van Ark and McGuckin (1999) compared relative levels of per capita income and labour productivity for the total economy using labour market indicators for OECD, Asian and Latin American countries.

While comparisons for the total economy can be made using an expenditure approach, comparisons for industries (agriculture, industry, and services) should preferably be based on the industry-of-origin approach. Using expenditure PPPs for industry comparisons requires a subjective allocation of PPPs to individual industries. As expenditure not only represents the production value of the industry in question, but also the added value of industries further down the chain, these PPPs require adjustment for taxes and trade and transport margins. While these margins can be "peeled off" as done by, for example, Jorgenson, Kuroda and Nishimizu (1987) and Jorgenson and Kuroda (1990) for Japan vis-à-vis USA, as well as by Lee and Tang (1999) for Canada vis-à-vis USA, this does not solve all problems. Firstly, at industry level, expenditure PPPs should be adjusted to exclude the relative prices of imported goods and include the relative prices of exported goods. Hooper (1996) adjusted expenditure PPPs for margins and import and export prices, but he acknowledges that the latter adjustments involves strong assumptions.[4] Secondly, and most importantly, expenditure PPPs exclude price ratios for intermediate products, which form a substantial part of manufacturing output. Hence the use of these "proxy PPPs"is not straightforward.

The preferable method is to use the industry-of-origin approach. Here one can in practice choose between two methods:

- direct comparisons of physical quantities of output (tons, litres, units).

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2 In this section we discuss the strengths and weaknesses of the ICOP methodology vis-à-vis the ICP methods. Readers who are only interested in the results for the Canada/US comparisons are referred to Sections 3 and 4. For a more detailed exposition see van Ark (1993), van Ark and Pilat (1993) and, more recently, Timmer (1999).

3 Expenditure comparisons were pioneered by Gilbert and Kravis (1954) and Gilbert and Associates (1958). Since the late 1960s surveys were conducted at regular intervals by the International Comparisons Project (ICP). For the latest set of purchasing power parities for OECD countries for 1996, see OECD (1999).

4 Hooper (1996) adjusts the expenditure PPPs by "weighting out" import prices and "weighting in" export prices, assuming the import and export prices equal world prices. World prices are obtained as the output-weighted average of each country's expenditure price levels in dollars. See also Pilat (1996) who uses a combination of UVRs and proxy PPPs (see below).

- converting output by industry to a common currency with a currency conversion factor which approaches cross country differences in producer prices.

Conceptually, the two approaches are the same, but in practice they yield different results because of differences in sampling, weighing and coverage. In the past, international productivity studies often applied the physical quantity method, but recent studies switched to the currency conversion method.[5] The switch is primarily caused by the increase in the number of products and product varieties, so that the percentage of output which can be covered by physical comparisons is much lower than in the past. With price comparisons, the representativity of matched output for non-matched output is greater than for quantity ratios. The physical quantity method is still in use for comparisons at plant level – in which case quality differences can be better accounted for – and for comparisons of output in services.[6]

***The ICOP Method to Obtain Manufacturing Unit Value Ratios***

Since 1983 a substantial research effort has been made at the University of Groningen to revive the industry-of-origin approach as part of the International Comparisons of Output and Productivity (ICOP) project. So far most ICOP studies dealt with comparisons of manufacturing productivity, which now include almost 30 countries in the OECD area, Asia and Latin America.[7] The ICOP studies develop industry-specific conversion factors using producer output data instead of final expenditure information. Ideally, one would like to use specific producer prices to develop "industry PPPs", comparable to the expenditure prices of specified products in ICP. However, internationally comparable producer prices for specified products are usually not available. The alternative applied in the ICOP studies is to use product unit values which are derived from value and quantity information for product groups. By matching as many products as possible, unit value ratios are derived which can be weighted up to industry level. These can then be used to express output for different countries in a common currency. This method is fundamentally different from the pricing technique in the ICP expenditure approach. The latter makes use of prices for specified products. The industry-of-origin technique provides unit values

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5 Rostas (1948) is the best known example of using physical quantity comparisons for a comparison between Britain, the United States and Germany during the second half of the 1930s. Rostas' method was recently revived in a study of British manufacturing productivity in historical perspective by Broadberry (1997). See also Maddison (1952), Heath (1957) and Maizels (1958) for Canada/USA, UK/Canada and Canada/Australia respectively. The pioneering study using currency conversions factors for international comparisons is Paige and Bombach (1959). Such studies for Canada/USA were carried out by West (1971) and Frank (1977).

6 See Maddison and van Ark (1989, 1994) for a review of the two approaches and for a description of the conditions under which these yield the same results. See also Kravis (1976). For recent comparisons of productivity in transport and communication, using quantity measures, see Van Ark, Monnikhof and Mulder (1999) and Mulder (1999).

7 Most of the comparisons for OECD countries are reported in Table 1. For a similar table including most other countries in the ICOP programme, see Van Ark, Monnikhof and Timmer (1999). See Maddison and van Ark (1994) for an overall overview of the ICOP research programme. See also the website of the Groningen Growth and Development Centre (http://www.eco.rug.nl/ggdc) for up-to-date information.

with a quantity counterpart, as quantities times "prices" equal the value equivalent. Details of the ICOP methodology as applied to the 1997 Canada/US benchmark comparison discussed in Section 3 are given in the Appendix.

The most solid basis for industry-of-origin studies is provided when for each country all information can be derived from a single primary source, which in the case of manufacturing is the census of production or industrial survey. These sources contain considerable detail on the output and input structure by industry and information on the sales values and quantities of most products.[8] As the production censuses and industry surveys are only harmonised across countries to a limited extent, the only practical approach is to do the comparisons on a two-country basis. For ICOP comparisons, the United States or West Germany are mostly taken as the "numéraire" (or base) countries. These bilateral comparisons have the advantage that the PPPs comply with the requirement of country characteristicity. However, since each comparison only involves one pair of countries under consideration, the totality of ICOP comparisons lack internal consistency, i.e. they are not transitive.

To multilateralise the results of the ICOP project, Pilat and Rao (1996) constructed a first set of multilateral UVRs by applying various multilateral indices to original binary ICOP results at aggregate levels of branches. While their work is an important step forward in multilateralising the ICOP binary studies, their estimates still suffer from non-transitivity at the branch level. More recently, Rao and Timmer (1999) applied multilateral aggregation procedures at the product level. To this end they constructed a consistent list of 256 manufacturing products for which price and quantity data were available for at least three countries. Then they used several multilateral indices for aggregation of the product detail to total manufacturing.

Table 2 compares manufacturing price levels relative to the United States, which are based on PPPs for total GDP, expenditure PPPs allocated to industries (“proxy PPPs” as in Jorgenson et al. or Lee and Tang (1999), a mix of proxy PPPs and UVRs as in Pilat (1996), and variants of bilateral and multilateral unit value ratios for 1987. For multilateral UVRs both the Geary-Khamis and the weighted EKS variants are shown. The latter multilateral UVR is to be preferred from a theorical viewpoint, but the former is recommended when additivity of the results is required. The table shows that:

- GDP PPPs are distinctly different from UVRs and proxy PPPs.
- proxy PPPs suggest higher price levels relative to the USA than the UVRs and combined UVR/proxy PPPs.
- the differences between the UVRs and the mixed UVR/proxy PPPs were small at the aggregate level for total manufacturing, even though there were bigger differences at branch and industry level.[9]
- The multilateral UVRs do not differ much from the binary UVRs. However, as the multilateralisation was based on a group of only eight countries (i.e., those in the table as well as Australia, Indonesia, Taiwan and South Korea), the effect may be bigger when more

[8] Naturally the derived UVRs can also eventually be applied to the national accounts information on GDP, but the consistency of the price and quantity data for products vis-à-vis the industry output data then disappears.

[9] See Pilat (1996).

countries are included.

**Table 2**
**Comparison of Relative Price Levels for International Comparisons of Manufacturing Output, 1987**

| | Canada | France | Germany | Japan | UK | USA |
|---|---|---|---|---|---|---|
| Exchange Rate (national currency/US$) | 1.33 | 6.01 | 1.80 | 144.6 | 0.604 | 1.00 |
| *Relative Price Levels (currency conversion factor/exchange rate):* | | | | | | |
| ICP Expenditure PPPs for GDP | | | | | | |
| Multilateral (EKS) | 98 | 113 | 122 | 147 | 93 | 100 |
| Bilateral (Fisher) | 96 | 110 | 114 | 136 | 101 | 100 |
| Proxy PPP from ICP | 108 | 134 | 131 | 151 | 131 | 100 |
| Combined UVR/Proxy PPP | 105 | 126 | 128 | 122 | 113 | 100 |
| ICOP Unit Value Ratios (UVRs) | | | | | | |
| Original Binary Fisher UVR | 100 | 120 | 123 | 120 | 117 | 100 |
| Multilateral (Geary Khamis) | 102 | n.a. | 123 | 118 | n.a. | 100 |
| Multilateral (weighted EKS) | 102 | n.a. | 122 | 128 | n.a. | 100 |

Sources: ICP expenditure PPPs, multilateral variant from OECD *National Accounts, vol. I* (1993). ICP expenditure PPPs, bilateral Fisher variant provided by EUROSTAT for 1990 and backdated to 1987 with GDP deflators. Proxy PPP is the "OPR" variant from Hooper (1996) for 1990 backdated to 1987 with manufacturing GDP deflators. Combined UVR/Proxy PPP from Pilat (1996). Original binary ICOP UVRs: see Table 1. Multilateral UVRs from Rao and Timmer (1999).

Over the years the results from ICOP studies have been critizised for various reasons, of which the most important three are discussed below. These include output coverage, quality adjustment and double deflation.

***The Output Coverage of Unit Value Ratios***

For many industries, unit value ratios are based on a limited sample of items, and rather farreaching assumptions are employed concerning their representativity for non-measured price relatives. For example, in ICOP studies the average percentage of the total manufacturing output value covered by product matches varies between 15 and 40, with between 60 and 450 product matches. UVRs for matched items are assumed to be representative for non-matched items. Moreover, the product groups that are matched tend to be biased towards relatively homogeneous, less sophisticated products, for which values and quantities are more readily available from the industry statistics.[10] For example in basic goods industries, such as pulp and paper, wood products, metallic and non-metallic mineral products, and in transport and communication, output coverage is usually large and there are few quality differences between countries. However, product matching is more difficult in manufacturing industries which produce durable consumer goods and investment goods. In these industries, the percentage of

10 See, for example, Lichtenberg (1993) in his comment on Van Ark and Pilat (1993), and Collier (1999) is his comment on Van Ark, Monnikhof and Timmer (1999).

output covered by UVRs is often below 10 per cent.

Indeed industry statistics suffer, and increasingly so, from lack of information on quantities of heterogeneous products. In recent comparisons we have therefore begun to use information from secondary sources, for example for cars, to complete our matchings. In our new Canada/US benchmark comparison for 1997 we use unit value ratios for more than one benchmark year which are extrapolated to the same year with producer price indices (see Section 3). An alternative is still to use (proxy) expenditure PPPs for areas where the coverage with unit value ratios is insufficient, referred to above as the "combined UVR/proxy PPP" method. Pilat (1996) adjusted UVRs from ICOP comparisons by combining those with proxy PPP measures including, for example, furniture, printing and publishing measures and various industries in machinery and equipment. This combination method may be useful in areas where the effect of import and export prices, for which an adjustment is must be made, is small and where the expenditure PPPs themselves are of sufficient quality (see Van Ark, 1996). However, the reliability of expenditure PPPs is questionable in particular in the case of furniture and investment goods.[11] As we will discuss in more detail in Section 3 we have reservations about using expenditure PPPs in these areas.

***Adjustments for Product Mix and Quality***

Comparisons of unit values are affected by differences in product mix and product quality. The "mix" problem is caused by the fact that industry statistics often include quantity and values for product groups rather than for specified products. In international comparisons the problem aggravates because of the lack of a harmonised product coding system, so that items need to be further aggregated in order to obtain a correct match between countries.[12] The problem can be partly resolved by using more detailed information from secondary trade and industry sources (see Gersbach and Van Ark, 1994). Again, using ICP PPPs for specified products is not necessarily a step forward, as there is a clear trade-off between output coverage by unit value ratios and the detail of product specification in the expenditure PPPs. Hence there is a big question mark on the representativity of the narrowly specified items for total output in ICP.

But even after adjustments for product mix, the "quality" problem remains because of differences in unit values which are due to factors not directly observed in the price differentials. In comparisons by the McKinsey Global Institute of selected industries between the United States, Japan and Germany, quality adjustment were made for cars, computers, and some products in the machinery industry (McKinsey Global Institut, 1993). Even though these adjustments were substantial at a detailed level, they were not always in the same direction. Hence the effect on the total measure of manufacturing productivity differentials remained small but uncertain.[13] The best way forward on the quality issue is to

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[11] See the "Castles report" (1997), pp. 25-27.

[12] For comparisons across European countries output coverage by product matches is likely to be increased substantially in the future using product information from a European data base, called PRODCOM, which provides quantity and value information using the same product classification for EU member states.

[13] For a full report of the adjustments in the McKinsey Global Institute study on manufacturing productivity, see Gersbach and Van Ark (1994). The MGI study explicitly based quality

make greater use of hedonic price measurement for international price comparisons. Instead of observing the prices of products themselves, the hedonic method obtains the price of a bundle of characteristics of a product through regression analysis. For example, the use of a country-product dummy (CPD) method, which regresses the price of a product on its characteristics and on a dummy variable for the country of origin, makes it possible to pull off the quality adjusted-unit value ratio from the coefficients of the dummy.[14]

To provide a formal test of the reliability of unit value ratios, Timmer (1996, 1999) measured the samping variance of UVRs by branch. Statistically, large variations in unit value ratios signal increased unreliability of the measures. By adjusting the variance for a finite population correction, it is ensured that with an increasing coverage of products, the variance goes down. Together with measures of the Paasche/Laspeyres spread between unit value ratios, which indicate differences in production structure between countries, measures of output covered by matched products, and the number of product matches, the variance of UVRs gives a reasonably good view on the reliability of the unit value ratios.[15]

***UVRs for Gross Output versus Value Added***

Whatever concept of PPP or UVR is chosen, the main problem in industry of origin comparisons is that ideally one not only requires a currency conversion factor for output but also for inputs. Preferably industry productivity should be measured as gross output per unit of input. The approach requires comprehensive measurement of output and intermediates in an input-output framework, which has been developed most extensively by Dale Jorgenson and associates in the KLEM growth accounting research, and is also represented in the study by Lee and Tang (1999) on Canadian versus U.S. economic performance. For this work comparative measures of labour inputs (weighted for differences in age, sex and education) and capital services and intermediate inputs are needed as well. Proxy PPPs for output, intermediate inputs, capital input and labor input are derived separately.

ICOP comparisons differ from the KLEM methodology as they apply output-weighted unit value ratios to value added. This may be referred to as the “single deflation” method, which implictly uses one and the same UVR for output and for intermediate inputs.[16] The reason why this relatively simple

adjustments on the "resource cost" criterion: UVRs are adjusted only when recognised by consumers in such a way that they are willing to pay a price premium, and when these are the result of differences in the product and production process. Remaining notions of quality (which were the result of advertising, taste, etc.) were treated as differences in consumer preferences which may explain differences in productivity and which can improve the competitive situation of companies and industries, but which are not used in adjusting the productivity measure itself.

14 See Van Mulligen (2000) who provides first results of a comparison of unit value ratios for cars between selected European countries.

15 See the Appendix for the methodology and Table 3 in Section 3 for results of the reliability tests for the new 1997 Canada/US comparison of manufacturing productivity.

16 See, for example, Jorgenson (1993) for the most explicit criticism of this approach in his comment on Van Ark and Pilat (1993). Of course, the use of gross output may causes double counting when aggregating the results, but this can be largely resolved by using a Domar weighting system (see Gullickson and Harper, 1999).

method still has useful application in international comparisons is due to measurement problems related to the prices of intermediate inputs. Earlier attempts to change ICOP studies from “single deflation” to “double deflation” (i.e., deducting UVR-deflated intermediate inputs from UVR-deflated gross output) led to volatile results because the estimates were sensitive to the weights used in the index. Timmer (2000) largely overcame this problem by using translogarithmic indexes which are based on average value shares of two countries in each binary comparison. Still, adequate measurement of the value and quantities of intermediate inputs requires larger coverage percentages for inputs than for output, as in one and the same industry the output is more homogenenous than inputs. In particular when intermediate inputs make up a large part of gross output, small measurement errors show up strongly in the end results of value added (in the ICOP case) or in the contribution of intermediate inputs to gross output (as in the case of Jorgenson and associates). Hence the deflation problem is not any less serious in using the proxy PPP approach for productivity measures than in a "double deflation" procedure. In practice therefore the single deflation method still provides more robust results for international comparisons than the double deflation method when applied to value added, or the separate estimation of intermediate input PPPs or UVRs.

**3. A New Canada-US Benchmark of Manufacturing Productivity Levels in 1997**

In this section we provide provisional results for a new benchmark comparison of labour productivity levels in Canada and the United States in 1997. We use the ICOP industry-of-origin approach as discussed in the previous section and the Appendix. This new benchmark estimate differs from previous comparisons in the ICOP project as, for the first time, it makes use of product data for several years instead of only one year. For this comparison we used a combination of unit value ratios for 1987, 1992 and 1996/1997 to take full account of all available data.[17] Unit value ratios for 1987 and 1992 were updated to 1997 by using industry-level producer price indices for both countries.[18] For Canada we had, for this moment, only access to the 1996 product data and Canadian unit values were therefore updated to 1997 as well. As more data comes available, more precise matches can be made and the set of matched products can probably be further expanded. Hence the results presented here should be interpreted with some caution.

In Table 3 we present the unit value ratios for each manufacturing branch. The unit value ratio for total manufacturing is close to the exchange rate, but price levels in manufacturing branches differ considerably from 1.19 Can$/US$ in textiles to 1.69 Can$/US$ in electrical machinery. This implies that Canadian producer price levels varied from between 89 per cent and 125 per cent of the U.S. price level in these industries. A major advantage of the ICOP method is that, in contrast to the ICP method, it is possible to assess the reliability of the various unit value ratios. Table 3 gives details on the number of matches, the percentage of output covered and the coefficient of variation of

[17] This approach was also necessary because the US census for 1997 displays much less detailed quantity data for products than the previous censuses of manufactures.

[18] In total 38 matches for 1987, 9 matches for 1992 and 82 matches for 1996/1997 are used. At this stage, the product weights used in the aggregation procedure for 1987 and 1992 UVRs

the UVRs in the various branches.[19] As is shown, the average unit value ratio for total manufacturing is based on 129 product matches. These products account for about 14 per cent of shipments in the US and 20 per cent in Canada. Even though this matching percentage is somewhat low compared to other ICOP studies, our weighting system reduces the overrepresentation of relatively large matches. The number of unit value ratios varies considerably between the branches. For some branches, for example food manufacturing, a fairly large number of UVRs could be calculated while for other branches a few matches could be made. The coefficients of variation in Table 3 indicate for each branch the variation of the product UVRs around the mean. A high level of variation indicates a low reliability of the corresponding UVR. It appears that the UVRs for wood products, rubber and plastics and especially electrical machinery are relatively unreliable.

Given the relatively high UVR for electrical machinery, its small number of matches and its high unreliability, we considered to use an expenditure PPP instead of an ICOP UVR for the electrical machinery branch, as provided by Lee and Tang (1999). Whether this is a good alternative depends on the reliability of the underlying ICP data. An important disadvantage of ICP PPPs is that no indication of reliability can be given. Moreover, as a large part of the electrical machinery branch consists of intermediate products, such as semi-conductors which by definition are not measured for expenditure PPPs, the expenditure approach seems not particularly attractive in this case. Nevertheless, to investigate the impact on relative productivity levels we present the ICP PPP for electrical machinery in the bottom rows of Table 3. The ICP PPP for electrical machinery and equipment is about 30 percent lower than our UVR.

The second step in deriving comparative labour productivity levels is a reconciliation of the different concepts and definitions used in the national censuses. Both the Canadian *Annual Survey of Industries* and US *Census of Manufacturing* use a similar concept of value added which still includes purchased services from outside manufacturing such as business services. Therefore the concept is more ’gross’ than the national accounts concept of value added (van Ark, 1993). Employment figures in the US census reports are exclusive of working proprietors and head office employment and have been adjusted to conform the Canadian concept of employment. An important advantage of using these industrial statistics instead of national accounts is that output and labour input come from one and the same primary source. Industrial classifications have also been matched in detail between the two countries. For example, to conform to the time series from the US national accounts, which are used in the backdating procedure in the next section, the computer and peripherals industry has been allocated to the machinery and transport equipment branch in both countries.

Tables 4 and 5 show the gross value of shipments, value added and employment in manufacturing branches in Canada and the US. This data is combined with the unit value ratios of Table 3 to calculate relative levels of value added and labour productivity, which are shown in Table 6.

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were not be adjusted to 1997.

**Table 3**
**Unit value ratios and reliability indicators by manufacturing branch, Canada/United States, 1997**

| | Unit value ratio (Can$/US$) | | | Coefficient of variation | | Matched output as % of total | | Number of product matches |
|---|---|---|---|---|---|---|---|---|
| | US quantity weights | Canadian quantity weights | Geome -tric average | US quantity weights | Canadian quantity weights | USA | Canada | |
| Food, beverages and tobacco | 1.66 | 1.50 | 1.58 | 0.0401 | 0.0486 | 29.4 | 35.1 | 39 |
| Textile mill products | 1.26 | 1.12 | 1.19 | 0.0837 | 0.0940 | 46.3 | 12.2 | 4 |
| Wearing apparel | 1.67 | 1.57 | 1.62 | 0.0328 | 0.0400 | 67.1 | 62.0 | 15 |
| Leather products | 1.44 | 1.00 | 1.20 | 0.1690 | 0.2919 | 61.7 | 21.5 | 6 |
| Wood products | 1.82 | 1.43 | 1.61 | 0.2877 | 0.1939 | 16.7 | 24.4 | 7 |
| Paper, printing & publishing | 1.27 | 1.25 | 1.26 | 0.0670 | 0.0276 | 44.2 | 46.6 | 4 |
| Chemical products | 1.36 | 1.47 | 1.41 | 0.0236 | 0.0447 | 41.8 | 47.1 | 24 |
| Rubber and plastic | 1.35 | 1.32 | 1.33 | 0.1634 | 0.1709 | 9.8 | 9.3 | 2 |
| Non-metallic mineral | 1.22 | 1.19 | 1.20 | 0.0072 | 0.0054 | 25.0 | 33.0 | 7 |
| Basic & fabricated metal | 1.44 | 1.45 | 1.44 | 0.0709 | 0.0566 | 13.7 | 23.3 | 8 |
| Machinery & transport equipment | 1.26 | 1.26 | 1.26 | 0.1209 | 0.1379 | 14.3 | 17.3 | 9 |
| Electrical machinery and equipment | 1.79 | 1.59 | 1.69 | 0.3815 | 0.5721 | 1.1 | 2.2 | 4 |
| Other manufacturing | 1.45 | 1.36 | 1.40 | - | - | 0.0 | 0.0 | 0 |
| Total manufacturing | 1.45 | 1.36 | 1.40 | 0.0748 | 0.0614 | 14.4 | 20.2 | 129 |
| *Pro memoria* | | | | | | | | |
| Electrical mach. and eq. from ICP (a) | 1.24 | 1.24 | 1.24 | | | | | |
| Total manufacturing (incl. ICP for electrical machinery and equipm (a)) | 1.38 | 1.34 | 1.36 | | | | | |
| Exchange rate | 1.35 | 1.35 | 1.35 | | | | | |

Note: (a) PPP from Lee and Tang (1999, Table 5.2) based on ICP benchmark 1993, updated to 1997.
*Source*: Based on a combination of ICOP UVRs for 1987 (from De Jong 1996), 1992 and 1997 based on Statistics Canada, Manufacturing Commodity Publications various issues, and Bureau of the Census, *Census of Manufacturing*, various issues. See also the text

**Table 4**
**Basic data for Manufacturing branches, Canada 1997**

| | Total number of employees | Value of shipment (mil C$) | Value Added (mil C$) | Value added per employee ('000 C$) |
|---|---|---|---|---|
| Food, beverages and tobacco | 224,302 | 70,141 | 24,213 | 108 |
| Textile mill products | 48,571 | 8,168 | 3,511 | 72 |
| Wearing apparel | 83,957 | 7,585 | 3,730 | 44 |
| Leather products | 11,035 | 1,139 | 484 | 44 |
| Wood products | 188,997 | 34,773 | 13,598 | 72 |
| Paper, printing & publishing | 237,694 | 49,595 | 23,304 | 98 |
| Chemical products | 98,799 | 58,898 | 18,129 | 183 |
| Rubber and plastic | 92,632 | 19,124 | 7,639 | 82 |
| Non-metallic mineral | 45,635 | 9,384 | 4,625 | 101 |
| Basic & fabricated metal | 262,727 | 54,330 | 23,330 | 89 |
| Machinery & transport equipment (a) | 361,891 | 145,270 | 43,009 | 119 |
| Electrical machinery and equipment (a) | 108,506 | 27,010 | 11,785 | 109 |
| Other manufacturing | 76,177 | 10,071 | 5,312 | 70 |
| Total manufacturing | 1,840,923 | 495,488 | 182,668 | 99 |

(a) Computers and peripheral are included in the machinery branch.
Source: Statistics Canada, Manufacturing Industries of Canada: National and Provincial Areas, 1997, cat. no. 31-203-XPB, Table 4.

**Table 5**
**Basic data for Manufacturing branches, USA 1997**

| | Total number of employees | Value of shipment (mil US$) | Value Added (mil US$) | Value added per employee ('000 US$) |
|---|---|---|---|---|
| Food, beverages and tobacco | 1,640,178 | 519,937 | 220,844 | 135 |
| Textile mill products | 564,858 | 75,843 | 31,769 | 56 |
| Wearing apparel | 693,202 | 66,698 | 32,905 | 47 |
| Leather products | 60,708 | 6,803 | 3,599 | 59 |
| Wood products | 978,295 | 134,995 | 58,595 | 60 |
| Paper, printing & publishing | 1,411,615 | 248,303 | 128,456 | 91 |
| Chemical products | 984,233 | 587,101 | 263,503 | 268 |
| Rubber and plastic | 1,025,940 | 159,287 | 81,516 | 79 |
| Non-metallic mineral | 491,435 | 83,949 | 47,102 | 96 |
| Basic & fabricated metal | 2,381,340 | 470,942 | 202,488 | 85 |
| Machinery & transport equipment (a) | 3,485,077 | 920,663 | 401,982 | 115 |
| Electrical machinery and equipment (a) | 2,016,102 | 437,914 | 265,423 | 132 |
| Other manufacturing | 717,493 | 98,239 | 60,333 | 84 |
| Total manufacturing | 16,450,476 | 3,810,675 | 1,798,515 | 102 |

(a) Computers and peripheral are included in the machinery branch.
Source: Bureau of the Census, *1997 Census of Manufacturing*, Washington DC, Industry reports.

**Table 6**
**Comparative levels of labour productivity (value added per employee) in manufacturing branches, Canada as a percentage of the USA, 1997**

| | Value added<br>Canada as % of US | Employment (a)<br>Canada as % of US | Value added per employee<br>Canada as % of US |
|---|---|---|---|
| Food, beverages and tobacco | 7.0 | 12.6 | 55.1 |
| Textile mill products | 9.3 | 8.3 | 112.8 |
| Wearing apparel | 7.0 | 11.8 | 59.6 |
| Leather products | 11.2 | 17.3 | 64.9 |
| Wood products | 14.4 | 18.9 | 76.1 |
| Paper, printing & publishing | 14.4 | 15.9 | 90.8 |
| Chemical products | 4.9 | 7.9 | 61.6 |
| Rubber and plastic | 7.0 | 8.7 | 81.0 |
| Non-metallic mineral | 8.2 | 8.8 | 93.0 |
| Basic & fabricated metal | 8.0 | 10.7 | 74.7 |
| Machinery & transport equipment | 8.5 | 9.6 | 88.5 |
| Electrical machinery and equipment | 2.6 | 5.0 | 52.7 |
| Other manufacturing | 6.3 | 10.1 | 62.2 |
| Total manufacturing | 7.2 | 10.4 | 69.3 |
| *Pro memoria* | | | |
| Electrical mach. and eq. (ICP) | 3.6 | 5.0 | 71.8 |
| Total manufacturing (incl. ICP for elec) | 7.5 | 10.4 | 71.4 |

(a) US employment adjusted for employment at head office and auxiliaries by applying ratios of total employment to production workers from Bureau of the Census (1990), *1987 Census of Manufacturing*, Washington DC.
Sources: Tables 4 and 5. Value added converted by Fisher unit value ratios from Table 3.

The first column of Table 6 indicates the level of value added in Canada as a percentage of the USA. The total manufacturing sector accounts for only 7 per cent of the US. The electrical machinery branch is particularly small, i.e. accounting for only 3 per cent of US output. On the other hand, Canada has relatively large wood and paper industries (more than 14 per cent of the US value added).

With respect to labour productivity, there is a considerable gap between Canada and the US. Value added per employee in total manufacturing is about 70 per cent of the level in the US. Branch performance varies but in all manufacturing branches – except textiles – labour productivity is lower in Canada than in the USA. The highest relative labour productivity levels are recorded in the textile industry, non-metallic mineral industry and the paper and printing industry.[20] Canada has particularly low labour productivity in food manufacturing, wearing apparel and electrical machinery (all below 60 per cent of the US level). The result for electrical machinery may seem surprising and the high unit value ratio might be blamed for it. When the ICP PPP is used the relative level increases to the manufacturing average. However, as discussed above, the ICP PPP has no a priori superiority and appears implausible when used in an extrapolation exercise. Moreover, there are indications that,

[20] Given the high unreliability of the UVR measure for textiles, the product matches for this industry need to be further reviewed.

when measured in own country prices, the semiconductor industry – which is part of the electrical machinery branch – is very productive in the United States. For example, the ratio of labour productivity relative to all electrical machinery and equipment is 1.25 in the United States versus 1 in Canada.

One reason for the low level of labour productivity in Canadian manufacturing relative to the United States might be that manufacturing labour in Canada is mainly concentrated in branches with relatively low levels of labour productivity. In the USA labour might be concentrated more in capital-intensive industries with higher labour productivity levels. If this is true, structural differences between Canada and the USA can help to explain the labour productivity gaps found in the previous section. To test this hypothesis, we use the shift-share method in an interspatial perspective.[21]. Let superscripts A and B denote countries, with B the base country, in this case the USA. The difference in labour productivity levels (the productivity gap) at the aggregate manufacturing level ($LP^B$-$LP^A$) is then decomposed into two parts:

$$LP^B - LP^A = \sum_{i=1}^{n} (LP_i^B - LP_i^A)\tfrac{1}{2}(S_i^A + S_i^B) + \sum_{i=1}^{n} (S_i^B - S_i^A)\tfrac{1}{2}(LP_i^A + LP_i^B) \qquad (1)$$

where LP is the labour productivity level and $S_i$ the branch share in employment. If the two countries do not differ in their employment structure, the second term of the right hand side of equation (1) (the structure effect) is zero and the total labour productivity differential is solely due to intra-branch productivity differences. If branch productivities are equal, the first term (the intra branch effect) equals zero. In that case, differences in employment structures explain the entire gap in labour productivity.

Table 7 shows the results of the decomposition of the Canada-U.S. gap in manufacturing labour productivity using equation (1).[22] It can be seen from the first column, that the major part of the labour productivity gap in 1997 is due to differences in labour productivity levels in each branch. Intra-branch effects account in total for 88 per cent of the gap in aggregate productivity and this effect is positive for all branches, except textiles (which is the only branch in which Canada has a higher productivity than the USA). The remaining 12 per cent of the gap is explained by differences in the employment structure. Canada has lower employment shares in high productive industries, such as electrical machinery and chemicals, and is more specialized in resource-intensive industries which have on average low levels of labour productivity. This can be seen from the large negative structure effects for the wood and paper branch. However, this difference in specialization pattern does not go a long way in explaining the aggregate labour productivity gap between Canada and the USA. Looking at the contribution of the individual branches to the aggregate gap in the last column, it follows that the electrical machinery branch contributed for 37 per cent of the gap in aggregate manufacturing, partly because it is much smaller (the positive structure effect) and because the labour productivity level is relatively low in Canada vis-à-vis the USA (the positive intra-branch

[21] See Timmer (1999) for an extensive discussion.

[22] Labour productivity levels have been put on a comparable basis using Fisher unit value ratios as given in Table 3 and 6. As Fisher-type indices are not additive, sectoral contributions may not add up to total. Therefore they have been normalised.

effect).

**Table 7**
**Decomposition of manufacturing labour productivity difference between Canada and the USA, 1997 (in percentage of total gap)**

| | Intra branch effect | Structure effect | Total effect |
|---|---|---|---|
| Food, beverages and tobacco | 20.3 | -6.6 | 13.7 |
| Textile mill products | -0.7 | 1.3 | 0.6 |
| Wearing apparel | 2.6 | -0.6 | 2.0 |
| Leather products | 0.3 | -0.4 | 0.0 |
| Wood products | 3.7 | -7.8 | -4.1 |
| Paper, printing & publishing | 2.8 | -11.9 | -9.1 |
| Chemical products | 16.5 | 9.6 | 26.1 |
| Rubber and plastic | 2.6 | 2.3 | 4.9 |
| Non-metallic mineral | 0.6 | 1.3 | 1.9 |
| Basic & fabricated metal | 9.6 | -0.8 | 8.8 |
| Machinery & transport equipment | 8.3 | 5.7 | 14.0 |
| Electrical machinery and equipment | 17.2 | 19.6 | 36.8 |
| Other manufacturing | 4.2 | 0.3 | 4.5 |
| | | | |
| Total manufacturing | 87.9 | 12.1 | 100.0 |

*Source:* Decomposition of difference in labour productivity levels between Canada and the USA into part due to differences in branch levels (intra-branch effect) and differences in branch shares in employment (structure effect) using equation (1). Data from Tables 4-6.

## 4. The Trend in the Canada/US Manufacturing Labour Productivity Gap

***Measurement issues***

The 1997 estimate of comparative manufacturing productivity can be backdated to earlier years to obtain the trend in relative levels between Canada and the United States. For this purpose use can be made of time series on real GDP and employment in manufacturing for both countries, which are then linked to the 1997 benchmark. Table 8 shows the indices of labour productivity based on the national accounts estimates in both countries. Overall manufacturing productivity growth has been faster in the U.S. than Canada, but the distribution of the relative gains and losses has been very unequal across sectors. For example, since 1987 food products, wood products, chemicals and basic and fabricated metal products have shown faster productivity growth in Canada. Wearing apparel, rubber and plastic products, leather products and footwear, machinery and transport equipment, and in particular electrical machinery and equipment, have experienced faster growth rates in the U.S.. Labour productivity in the latter industry, increased more than twice as fast in the U.S. than in Canada.

An important question is whether the difference in growth rates between Canada and the US in electrical machinery and equipment is real or due to inconsistencies in measurement of the time series. For this purpose it is useful to check the plausibility of the time series by using them to backdate our 1997 benchmark estimates of labour productivity. Table 9 shows some important results. Clearly the high productivity level for textiles needs to be reconsidered, probably mainly for its relatively level in the benchmark year. But apart from textiles, the comparative productivity levels for machinery and transport equipment and in particular electrical machinery and equipment in earlier years are also of concern. The extrapolation for electrical machinery and equipment suggests a collapse from a more than 20%-productivity advantage for Canada in 1987 to half the US productivity level in 1997.[23] This seems a very unlikely estimate, and suggests inconsistensies between the time series used both countries. One possibility is that the Canadian national accounts do not use hedonic price measures as extensively as the U.S. national accounts. For example it is not clear whether the Canadian accounts use hedonic price measures for semiconductors, and this needs to be further analysed.

**Table 8**
**Time Series of Labour Productivity Growth (Real GDP per Employee) in Canadian and US Manufacturing, 1976-1997**

| | Canada | | | United States | | |
|---|---|---|---|---|---|---|
| | 1976 | 1987 | 1997 | 1976 | 1987 | 1997 |
| Food, Beverages and Tobacco Products | 93.9 | 100.0 | 114.6 | 82.9 | 100.0 | 102.4 |
| Textile Mill Products | 87.7 | 100.0 | 136.4 | 65.2 | 100.0 | 139.5 |
| Wearing Apparel | 87.8 | 100.0 | 98.2 | 78.9 | 100.0 | 146.8 |
| Leather Products and Footwear | 74.4 | 100.0 | 94.8 | 85.9 | 100.0 | 153.7 |
| Wood Products, Furniture and Fixtures | 78.7 | 100.0 | 104.1 | 86.4 | 100.0 | 88.8 |
| Paper Products, Printing and Publishing | 91.9 | 100.0 | 94.7 | 97.1 | 100.0 | 95.8 |
| Chemicals, Petroleum and Coal Products | 61.5 | 100.0 | 135.9 | 69.3 | 100.0 | 121.3 |
| Rubber and Plastic Products | 68.7 | 100.0 | 138.6 | 65.4 | 100.0 | 157.1 |
| Non-Metallic Mineral Products | 83.1 | 100.0 | 102.5 | 88.2 | 100.0 | 124.4 |
| Basic and Fabricated Metal Products | 95.6 | 100.0 | 129.4 | 83.1 | 100.0 | 124.5 |
| Machinery and Transport Equipment (a) | 89.8 | 100.0 | 142.3 | 75.3 | 100.0 | 156.7 |
| Electrical Machinery and Equipment (a) | 58.5 | 100.0 | 151.3 | 59.6 | 100.0 | 351.8 |
| Other Manufacturing Industries | 98.9 | 100.0 | 92.1 | 84.4 | 100.0 | 92.6 |
| Total Manufacturing | 82.1 | 100.0 | 123.5 | 74.5 | 100.0 | 132.9 |

(a) computers in Canada were transferred from electrical machinery to non-electrical machinery to match the US time series according to SIC 1987.
Source: Canada from underlying data on output and employment from the productivity database of the Centre for for the Study of Living Standards (http://www.csls.ca/index.html). Output data are Gross Domestic Product data in constant 1992 dollars. Labour input data are from the Labour Force Survey of Statistics Canada. US data are from BEA, National Income and Product Accounts. GPO from 1947-1987 is at fixed 1982 prices but is reweighted at current dollar GPO every five years (1947, 1952, 1957, etc.). The series from 1987-1997 are chain weighted-series at 1992 dollars obtained from BEA (http://www.bea.doc.gov/bea/dn2.htm). Employment is full-time and part-time employees plus self-employed persons.

23 Note that when using the ICP PPP for electrical goods from Lee and Tang (1999) the resulting productivity advantage for Canada/US in this industry would have been even higher by about 40%!

**Table 9**
**Comparative Levels of Labour Productivity in Canadian Manufacturing, Relative to US Manufacturing, 1976-1997**

| | Extrapolation from 1997 | | |
|---|---|---|---|
| | 1976 | 1987 | 1997 |
| Food, Beverages and Tobacco Products | 55.8 | 49.3 | 55.1 |
| Textile Mill Products | 155.2 | 115.3 | 112.8 |
| Wearing Apparel | 99.2 | 89.1 | 59.6 |
| Leather Products and Footwear | 91.1 | 105.2 | 64.9 |
| Wood Products, Furniture and Fixtures | 59.1 | 64.9 | 76.1 |
| Paper Products, Printing and Publishing | 86.9 | 91.8 | 90.8 |
| Chemicals, Petroleum and Coal Products | 48.9 | 55.0 | 61.6 |
| Rubber and Plastic Products | 96.5 | 91.8 | 81.0 |
| Non-Metallic Mineral Products | 106.3 | 112.8 | 93.0 |
| Basic and Fabricated Metal Products | 82.7 | 71.9 | 74.7 |
| Machinery and Transport Equipment (a) | 116.0 | 97.4 | 88.5 |
| Electrical Machinery and Equipment (a) | 120.4 | 122.6 | 52.7 |
| Other Manufacturing Industries | 73.2 | 62.5 | 62.2 |
| Total Manufacturing | 82.1 | 74.6 | 69.3 |
| *Counterfactual using US time series on labour productivity in electrical machinery and equipment for Canada as well:* | | | |
| *Total Manufacturing* | *75.9* | *69.1* | *69.3* |

(a) computers in Canada were transferred from electrical machinery to non-electrical machinery to match the US time series according to SIC 1987.
Source: 1997 benchmark from Table 6. Time series from table 8

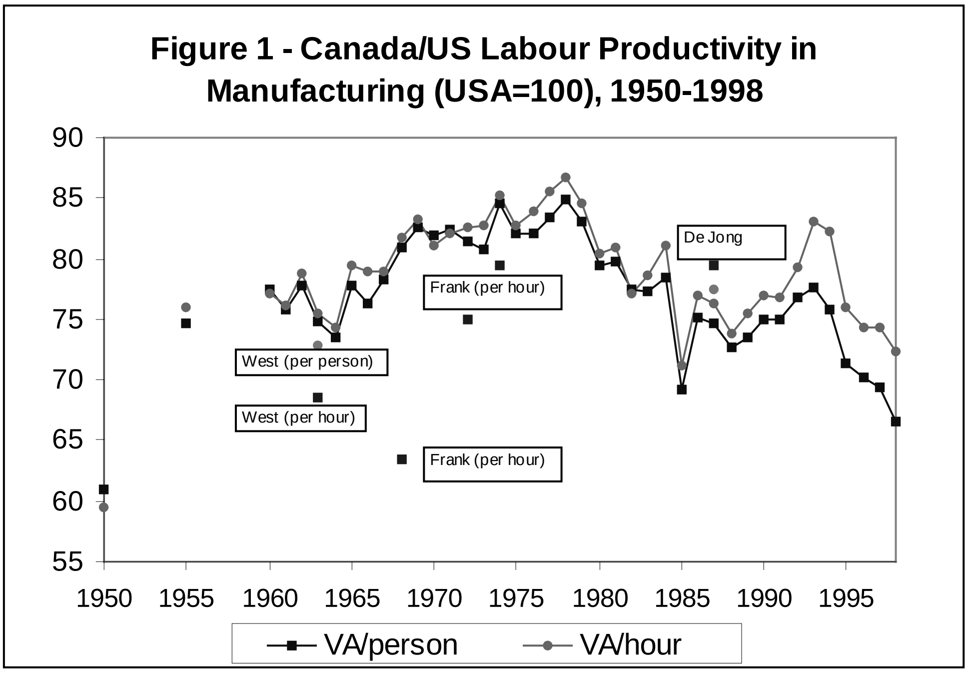
The measurement issue is important because, as is shown at the bottom of Table 9, it fundamentally affects the issue of the rising productivity gap between Canadian and U.S. manufacturing. If one would assume, on a purely counterfactual basis, that the productivity growth in Canadian electrical machinery and equipment would be the same as in the United States, there would have been no further rise in the productivity gap between the countries from 1987 to 1997.

***The Long Run Change in the Manufacturing Productivity Gap between Canada and the USA***

At the level of total manufacturing, the measurement problems are not as important as for individual branches, partly because many of the issues are localized in particular industries, and because the biases are not all in the same direction and therefore cancel out to some extent. For example, whereas our new benchmark comparison for 1997 suggests a labour productivity level in 1987 of 75.1 per cent when extrapolated backwardly, the previous ICOP study by De Jong (1996) showed that manufacturing output per employee stood at 77.5 per cent in 1987 (see also Table 1). This small difference suggests that a backward extrapolation of the measure of labour productivity in total manufacturing for 1997 is feasible.

Figure 1 shows our extrapolation from the 1997 benchmark comparison and compares it with alternative benchmark estimates from De Jong (1996) for 1997, Frank (1977) for 1967, 1972 and 1974 and West (1971) for 1963. Whereas De Jong's procedures were more or less the same as ours, West and Frank used very different procedures. They both calculated unit value ratios for sales, but also for materials and supplies and for fuel and electricity. They both covered 33 industries which accounted for about three quarters of output of all industries. Even though these studies do not report the exact number of products matched, these can be estimated at about 150 products covering about 38 per cent of Canadian shipments. Whereas De Jong's measures are close to ours, those of West and Frank are lower. In particular Frank's estimates also show a much more rapid growth between 1967 and 1974 than our estimates.

The long run estimates show that the increase in the manufacturing productivity gap started around the late 1970s. Between 1985 and the early 1990s the productivity gap narrowed somewhat, and then began to increase again. The most recent widening of the gap, however, is not due to a slowdown in Canadian manufacturing productivity growth, but to a rise in U.S. growth of labour productivity. In fact the U.S. has outperformed many other OECD countries on manufacturing productivity since 1992, including Australia, Germany and the United Kingdom.



## 5. Conclusion

This paper aimed to revisit the manufacturing productivity gap between Canada and the United States using the ICOP "industry of origin" methodology. It is argued that the ICOP methodology has important advantages over studies that attempt to measure productivity differences with proxy PPPs, which are obtained by allocating expenditure PPPs to individual industries. Most importantly, ICOP unit value ratios cover prices of final as well as intermediate products. We described various refinements in our measurement procedures that help us to reduce biases due to low output coverage of product matches in particular industries. We also described the introduction of better measures to test the reliability of our UVRs. This helps in assessing the areas where further improvements in our measures are most urgent. Such tests are not possible in the ICP procedure, where one basically has to "live with what one gets".

In this paper we presented provisional estimates of the Canada-US manufacturing productivity gap in 1997. Our reliability tests of the unit value ratios show some areas where the measures need to be further improved, either with new product matches or quality adjustments. However, the most problematic issue, which falls outside the immediate scope of the ICOP methodology, concerns the time series of labour productivity that are used to backdata the benchmark results to earlier years. In particular in the case of electrical machinery and equipment, the time series look very implausible. The consistency of the time series between the countries needs to be investigated in greater detail. Meanwhile comparisons of changes in relative productivity levels may perhaps be better done by regular "re-benchmarking" of the relative productivity levels. For example, the ICOP estimate of comparative labour productivity in electrical engineering between the 1987 and the 1997 benchmark estimates suggests a fall in Canadian productivity relative to the US of about 20 percentage points (see De Jong, 1996 and this study), which is much more plausible than the 70 percentage points fall according to the backward extrapolation procedure (see Table 9).

In this paper we have dealt exclusively with comparisons of labour productivity. A complete account of factors other than labour contributing to the productivity differentials is needed to get the whole story.[24] In 1976, Kravis concluded that because of the wide range of problems in TFP measurement, the best strategy for international comparisons would be to concentrate on labour productivity comparisons. In his view factor inputs and intermediate inputs should be treated as external variables which may explain the results (Kravis, 1976). Even though much progress has been made in a limited number of countries, including Canada and the United States, measurement of TFP is still problematic in many other countries and a big research effort is required to get these countries up to speed.[25] Meanwhile Kravis' suggestion still has much validity. Even though capital stock measures now exist for most OECD countries, these are rarely available at a sectoral or industry level, and there are legitimate concerns about their international comparability. In practice many studies still rely on investment-output ratios, which only under very strict assumptions can be seen as a good proxy for capital stock. Human capital is often approximated by student enrollment rates or at best by years of

[24] For ICOP comparsions of TFP see, for example, Van Ark and Pilat (1993) and Timmer (1999).

[25] See Timmer (2000).

schooling, without distinctions between different types of education. Direct measures of technology, such as the stock of R&D, licenses or patents are only available on a limited scale, and suffer from important problems in terms of international comparability. Finally, measurement of intermediate inputs is not well developed. Better measurement of inputs in the framework of input-output tables, together with further development of reliable output and input UVRs, therefore deserves priority in order to improve productivity measures.

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## Appendix - ICOP industry-of-origin approach[26]

The aim of the ICOP method is to derive industry-specific conversion factors on the basis of relative product prices. As a first step, unit values (uv) are derived by dividing ex-factory output values (o) by produced quantities (q) for each product i in each country

$$uv_i = \frac{o_i}{q_i} \qquad (1)$$

The unit value can be considered as an average price, averaged throughout the year for all producers and across a group of nearly similar products. Subsequently, in a bilateral comparison, broadly defined products with similar characteristics are matched, for example ladies' shoes, cigarettes, cheese and car tyres. For each matched product, the ratio of the unit values in both countries is taken. This unit value ratio (UVR) is given by

$$UVR_i^{xu} = \frac{uv_i^x}{uv_i^u} \qquad (2)$$

with x and u the countries being compared, u being the base country, usually the USA. The product UVR indicates the relative producer price of the matched product in the two countries.

Product UVRs are used to derive an aggregate UVR for manufacturing branches and total manufacturing. This requires the choice of a particular weighting scheme. The most simple aggregation method would be to weight each product UVR by its share in output. However, according to stratified sampling theory, estimates of aggregates can be made more precise if a heterogeneous population is divided into more homogeneous subpopulations, called strata. Strata have to be defined as non-overlapping. Together they should comprise the whole of the population. Within ICOP, the total manufacturing sector is subdivided into more homogeneous branches, which are subsequently subdivided into industries. This is illustrated by Appendix Figure 1.

**Appendix Figure 1 Simplified representation of the four levels of aggregation within ICOP**

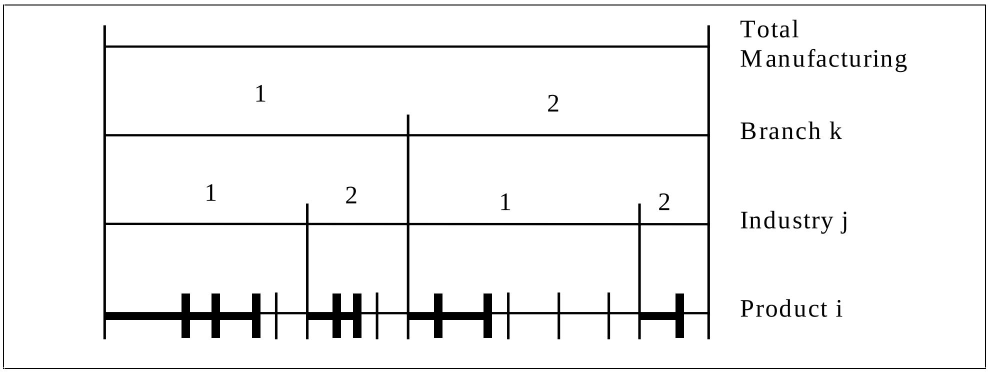


Figure 1 shows the four levels which are being distinguished within ICOP: products, industries, branches and total manufacturing. These levels correspond with the levels distinguished in the International Standard Industrial Classification (ISIC).[27] ICOP industries consist of one or more four-digit ISIC industries, and ICOP

[26] The procedure explained here slightly differs in its aggregation procedures from earlier ICOP comparisons, including the Canada/U.S. study by De Jong (1996). See also Van Ark (1993). The differences between the old and the new method are generally very small, but the present method is preferred from a theoretical and statistical perspective.

[27] The ISIC is based on both the supply-side and the demand-side approach to the classification of economic activities (Triplett 1990). In the supply-side approach activities are classified according to similarities in the production processes. The demand-side approach on the other hand yields a classification

branches consist of two- or three-digit ISIC divisions. The four horizontal level lines in the figure can be thought of as representing manufacturing output value. The total manufacturing output is the sum of branch output, which is the sum of industries' output value. The output value of an industry is the sum of the value of output of its products. In a binary comparison some of these products can be matched, but not all. This is because of lack of value or quantity data, difficulties in finding well-corresponding products, the existence of country-unique products *etc.* Bold lines at the product level in the figure indicate the total output value of the matched products in the different industries. Thus, matched products in an industry can be seen as a sampled subset of all the products within an industry in a multi-staged stratified-sampling framework.

*Aggregation Step One Industry Level UVRs*

The industry UVR ($UVR_j$) is given by the mean of the UVRs of the sampled products. Product UVRs are weighted by their output value as more important products should have a bigger weight in the industry UVR:

$$UVR_j = \sum_{i=1}^{I_j} w_{ij} UVR_{ij} \tag{3}$$

with i=1,.., $I_j$ the matched products in industry j; $w_{ij} = o_{ij} / o_j$ the output share of the i[th] commodity in industry j; and $o_j = \sum_{i=1}^{I_j} o_{ij}$ the total matched value of output in industry j. In bilateral comparisons the weights of the base country (u) or the other country (x) can be used. The use of base country value weights leads to the Laspeyres index. Substituting base country weights in (3) gives:

$$UVR_j^{xu(u)} = \sum_{i=1}^{I_j} w_{ij}^{u(u)} \; UVR_{ij} \tag{4}$$

with $w_{ij}^{u(u)} = o_{ij}^{u(u)} / o_j^{u(u)}$; $o_j^{u(u)} = \sum_{i=1}^{I_j} o_{ij}^{u(u)}$; and $o_{ij}^{u(u)} = uv_{ij}^u q_{ij}^u$. Using (1), (4) can be rewritten as

$$UVR_j^{xu(u)} = \frac{\sum_{i=1}^{I_j} uv_{ij}^x q_{ij}^u}{\sum_{i=1}^{I_j} uv_{ij}^u q_{ij}^u} \tag{5}$$

with $UVR_j^{xu(u)}$ indicating the Laspeyres index which is the unit value ratio between country u and x weighted at base-country quantities indicated by the u between brackets.

For the Paasche index, weights of the other country quantities valued at base country prices are used in formula (3). This gives

$$UVR_j^{xu(x)} = \sum_{i=1}^{I_j} w_{ij}^{u(x)} UVR_{ij} \tag{6}$$

with $w_{ij}^{u(x)} = o_{ij}^{u(x)} / o_j^{u(x)}$; $o_j^{u(x)} = \sum_{i=1}^{I_j} o_{ij}^{u(x)}$; and $o_{ij}^{u(x)} = uv_{ij}^u q_{ij}^x$. Using (1), (6) can be rewritten as

system based on similarities in the use of the produced goods. In theory, a classification based on the supply-side approach solely would be more useful for the aggregation of UVRs (Timmer 1996).

$$UVR_j^{xu(x)} = \frac{\sum_{i=1}^{I_j} uv_{ij}^x q_{ij}^x}{\sum_{i=1}^{I_j} uv_{ij}^u q_{ij}^x} \qquad (7)$$

with $UVR_j^{xu(x)}$ indicating the Paasche index which is the unit value ratio between country u and x weighted at the quantities of the other country (x).

*Aggregation Step Two Branch Level UVRs*

The theory of stratified sampling suggests that if in each industry (stratum) the sample estimate of the mean is unbiased, then the industry-weighted mean of all industries' UVRs in a branch is an unbiased estimate of the branch mean ($UVR_k$). Use of output weights from the base country and the industry UVRs at base country weights, gives the Laspeyres index for branch k.

$$UVR_k^{xu(u)} = \sum_{j=1}^{J_k} w_{jk}^{u(u)} UVR_{jk}^{xu(u)} \qquad (8)$$

with j=1,.., $J_k$ the number of industries in branch k for which a UVR has been calculated (the sample industries); $w_{jk}^{u(u)} = o_{jk}^{u(u)} / o_k^{u(u)}$; and $o_k^{u(u)} = \sum_{j=1}^{J_k} o_{jk}^{u(u)}$. To arrive at the Paasche index, the industry output of country x valued at base prices is substituted. This gives

$$UVR_k^{xu(x)} = \sum_{j=1}^{J_k} w_{jk}^{u(x)} UVR_{jk}^{xu(x)} \qquad (9)$$

with $w_{jk}^{u(x)} = o_{jk}^{u(x)} / o_k^{u(x)}$; and $o_k^{u(x)} = \sum_{j=1}^{J_k} o_{jk}^{u(x)}$, which can be alternatively rewritten in terms of industry output of country x at own prices instead of base-country prices, using (1) and (2)

$$UVR_k^{xu(x)} = \frac{\sum_{j=1}^{J_k} o_{jk}^{x(x)}}{\sum_{j=1}^{J_k} \frac{o_{jk}^{x(x)}}{UVR_{jk}^{xu(x)}}} \qquad (10)$$

*Aggregation Step Three Total Manufacturing UVRs*

The total manufacturing sector consists of the manufacturing branches. Similar reasoning as used for the aggregation of UVRs from industry to branch level applies to the aggregation from the branch to the total manufacturing level. Base country output weights are used to arrive at the Laspeyres index, and the other country quantities valued at base prices are used to arrive at the Paasche index. The Laspeyres and Paasche indices are combined into a Fisher index when a single currency conversion factor is required. It is defined as the geometric average of the Laspeyres and the Paasche.

*Reliability measure*

Variance of the UVRs is measured as follows (see Timmer 1996 for full discussion). The sample variance of the UVR for total manufacturing is given by the quadratic output weighted average of corresponding branch UVR variances.

$$\mathrm{var}[\mathrm{UVR}] = \sum_{k=1}^{K} w_k^2 \,\mathrm{var}[\mathrm{UVR}_k] \tag{11}$$

In a similar vein, the estimated variance of the UVR in branch k is given by

$$\mathrm{var}[\mathrm{UVR}_k] = (1 - f_k) \sum_{j=1}^{J_k} w_{jk}^2 \,\mathrm{var}[\mathrm{UVR}_{jk}] \tag{12}$$

with $f_k$ the share of branch output which is covered by the matched products within a branch. Branch variance is thus defined as a weighted average of the estimated variances of the industry UVRs, var[$\mathrm{UVR}_{jk}$], corrected by the finite population correction (fpc). The fpc is normally stated as one minus the number of products sampled divided by the total number of products in the population. Here I use the output share of sampled products rather than the number of products to account for the difference in importance of products. The fpc ensures that with an increasing coverage of products, the variance goes down. Thus, branch variance depends on the variance of the industry UVRs, but also on the coverage of branch output. If the coverage ratio is lower, the variance will be higher, and if the variance of the industry UVRs is higher, then branch variance will be higher as well.

The variance of the industry UVR is given by the mean of the weighted deviations of the product UVRs around the industry UVR:

$$\mathrm{var}[\mathrm{UVR}_j] = \frac{1}{I_j - 1} \sum_{i=1}^{I_j} w_{ij} \,(\mathrm{UVR}_{ij} - \mathrm{UVR}_j)^2 \tag{13}$$

with $I_j$ the number of products matched in industry j. Formulae (11) to (13) can be applied to either the Laspeyres or Paasche UVR using output value weights of the base country for the variance of the Laspeyres, and quantity weights of the other country valued at base prices for the variance of the Paasche.