A perspective on the U.S.-Canada manufacturing productivity gap

The U.S. advantage over Canada in manufacturing productivity growth during the 1990s, as measured by BLS, was led by dramatic growth in information-technology-related industries and does not appear to be significantly affected by the use of different statistical methods by the two countries

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Over the 1977–98 period, productivity growth in U.S. manufacturing surpassed that of Canadian manufacturing—according to data from the Bureau of Labor Statistics international comparisons program, U.S. manufacturing productivity grew by 3.0 percent per year over the period, while Canadian manufacturing productivity grew by 2.0 percent per year. Of particular interest is the way this differential or gap has grown since the early 1990s. From 1992 to 1998, for example, productivity growth in U.S. manufacturing increased at a rate more than twice that of Canadian manufacturing productivity—4.1 percent per year for the United States versus 2.0 percent per year for Canada.

The gap in productivity performance between the U.S. and Canadian manufacturing sectors is illustrated in Chart 1. The two lines represent each country's output per hour relative to its own performance in 1977. This is the first year for which the comparative data are available for the United States. Policymakers, among others, seek explanations for this gap, and much has been written about it. Concern about the gap led the Centre for the Study of Living Standards to hold a conference in Ottawa in January 2000. This article is an update and revision of a paper presented by the authors at that conference. [1]

One set of comparative measures that indicates the presence of this gap is the BLS series on output per hour. (See the box on page 33.) These comparative measures are based on data from the national accounts of the United States and Canada. Therefore, one may question whether the entire measured gap is real or whether it may be due, at least in part, to differences in procedures used by the two countries to compile the national accounts. The objectives of this study are to determine the extent to which differences in the statistical measurement procedures used by the two countries explain the gap and then to analyze some real factors that may be contributing to the gap.

In this article, we review the procedures BLS uses to produce international productivity comparisons, along with the methods used by each country's statistical agencies to compile the underlying data used by BLS. In general, we find that the methods used by the two countries to construct the components of output per hour are quite similar. Where differences do exist, the differences do not appear to be substantially affecting measured differences in productivity growth over the period of inter-

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est. Some differences tend to reduce the gap, while other measurement differences increase the gap. Finally, we note that both countries revised their methods in 2000, leading to increased comparability for some methods between the data series.

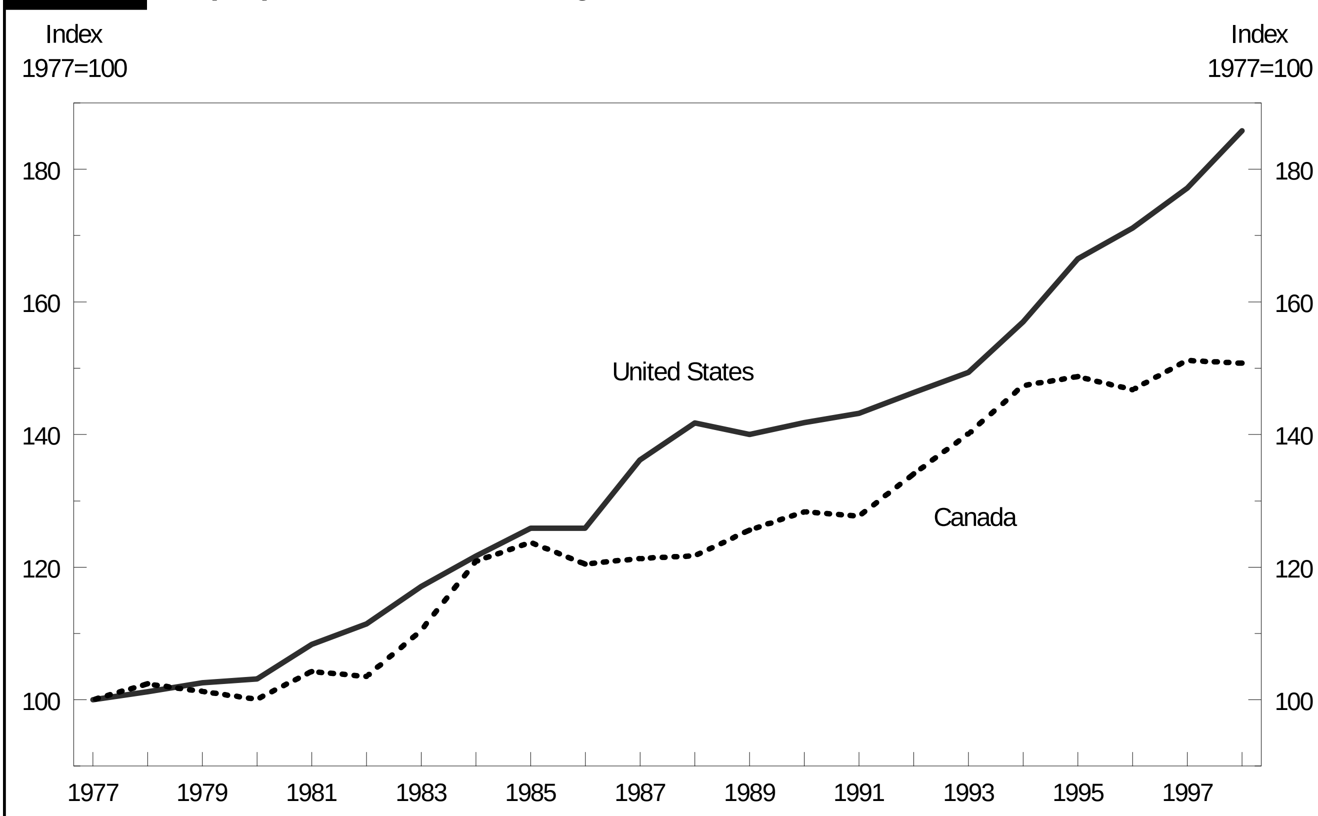
The gap can be partially explained by real factors in the two countries, such as the growth of output and labor input and the performance of output per hour in certain important industries in the manufacturing sector. We find that for certain time intervals, Canadian productivity growth exceeds that of the United States and actually contributes to a closing of the gap. In addition, the differences in trends in labor hours appear to have a significant impact on productivity differences. Further, as other researchers have found, a substantial amount of the difference in productivity performance in the manufacturing sector can be explained by the outstanding productivity growth in the information technology sector of the U.S. economy. This growth was quite pronounced during the 1990s.

In this study, we focus on the period from 1988 to 1998 because it was a period in which dynamic economic activity occurred in certain industries in manufacturing, especially information technology and related industries. Also, this period allows for analysis between an output-peak year (1988), a near-trough year (1992), and a point well into an expansion (1998) for each country. Finally, it is a period, presumably, of more interest to policymakers than earlier or longer periods. Due to data availability, the industry-level analysis is restricted to the 1988–96 period.

The data used by BLS to construct international comparisons of productivity are obtained from the statistical agencies of the United States and Canada. There are differences in the methods used by the two countries, which can affect comparative productivity measures. We examine the U.S. and Canadian methodologies for measuring manufacturing outputs and labor inputs in an attempt to identify differences that can lead to a lack of comparability of the aggregate manufacturing productivity measures. The three possible sources of differences explored in this study are *industrial classification*, concept and estimation of *output*, and estimation of *labor input*.[2] In the following three sections, each of these areas is reviewed in detail, with the objective of identifying differences in methods that may contribute to the gap between U.S. and Canadian productivity.

Many of the issues examined in this study have been raised in the literature on the topic, with some of them becoming more important recently because countries are in the process of adopting new standard systems of national accounts.[3] Although the adoption of the new systems will lead to some convergence in methods and enhanced comparability, the ex-

Chart 1. Output per hour in manufacturing, United States and Canada, 1977–98



The Bureau of Labor Statistics publishes comparative measures of the annual growth in output per hour and unit labor costs for the manufacturing sectors in the United States and in 11 foreign competitor countries. The most current data can be found at **http://stats.bls.gov/flshome.htm**. (Levels of productivity are not included in the series.) The length of the historical series varies by country, but comparisons among all countries may be made from 1977 to 1998.

In addition, BLS publishes quarterly measures of output per hour for U.S. manufacturing in its news release on U.S. productivity and costs. The most current data may be found at **http://stats.bls.gov/lprhome.htm**. This series is based on the concept of sectoral output. Sectoral output is gross output (shipments or sales plus changes in inventories) less intrasectoral sales and transfers. The concept of sectoral output is also used in the production of output per hour and multifactor productivity measures for the U.S. manufacturing sector and component industries.

For the international comparisons series, the value-added concept of output—that is, gross output less intermediate purchases—is used because the data are more readily available in the countries' national accounts, whereas using sectoral output would require a complex estimation procedure. Also, although BLS has determined that sectoral output is the correct concept for U.S. measures of single-factor productivity (output per hour), there are other considerations that may make the value-added concept better for international comparisons, such as differences among countries in the extent of vertical integration. In the value-added series, output per hour in the United States grew by 3.0 percent per year between 1977 and 1998, while in the sectoral output series, output per hour grew by 2.8 percent per year over the same period.

tent to which the countries have chosen or have been able to adopt all aspects of the new systems varies.

Industrial classification

Aggregate manufacturing data for the United States are published according to the 1987 Standard Industrial Classification system (US-SIC87).[4] The aggregate manufacturing data for Canada conform to the Canadian 1980 Standard Industrial Classification system (C–SIC80).[5] At the aggregate level, the classifications of the manufacturing sector for the United States and Canada are quite similar.[6] The main difference between the two systems is the treatment of the logging industry, which is a component of the manufacturing sector in the U.S. system but not in the Canadian system.[7]

To investigate the significance of the difference in the classification of the logging industry on manufacturing performance, we made two comparisons. First, we adjusted the U.S. aggregate measures to exclude logging, and then we adjusted the Canadian aggregate measures to include logging.[8] Annual trends in output per hour for U.S. manufacturing, Canadian manufacturing, and the adjusted series for the United States and Canada are shown in the following tabulation:

	United States		*Canada*	
	As published	*Adjusted*	*As published*	*Adjusted*
1988–96	2.4	2.4	2.4	2.3
1982–92	0.8	0.8	2.5	2.3
1992–96	4.0	4.0	2.3	2.2

Notice that trends for the two U.S. series are identical, while the Canadian series differ slightly. The logging industries in the United States and Canada both demonstrate negative productivity growth. However, the relative size of logging in the adjusted Canadian measures is significantly larger than its share in U.S. manufacturing. The logging industry accounts for approximately 3.7 percent of Canadian adjusted 1996 manufacturing value added and less than 0.3 percent of 1996 value added in U.S. manufacturing. Thus, the adjusted measure of productivity in Canada grew by approximately 0.1 percentage points less than the published Canadian measure during the 1988–96 period. Based on the adjustments we were able to make, it appears that including logging in the Canadian measure of aggregate manufacturing productivity would increase the gap between the U.S. and Canadian productivity measures a small amount, while excluding it from the United States would have no effect.

Output

Primary data sources. For the U.S. international productivity comparisons, output data are taken from the Bureau of Economic Analysis (BEA) series "Gross Product Originating by Industry," a value-added measure of output.[9] Data for benchmark years (1977, 1982, 1987, and 1992) are based primarily on data from the input-output accounts. Data for nonbenchmark years are interpolated between benchmark years and extrapolated from the last benchmark (1992) forward. Interpolators and extrapolators are based on shipments and inventory-change data from the Bureau of the Census Annual Survey of Manufacturers and the 1996 annual input-output tables.[10]

For Canada, output data are based on measures of real GDP by industry published by the Industry Measures and Analysis Division of Statistics Canada.[11] The underlying data on gross output and detailed intermediate purchases are based on data from the input-output tables derived from the Canadian Annual Survey of Manufacturers and their 5-year Census of Manufacturers. The latest input-output table underlying the data in this study is for 1996. Statistics Canada estimates the current 2 years of data on real GDP by industry using monthly data.[12] These monthly estimates are based on proxy indicators such as gross output and the assumption that the relationship between inputs and outputs is fixed.

Output valuation. The United States and Canada differ in the concept of prices used to value gross output in the value-added measures used by BLS for international comparisons of productivity. Real value-added data for both countries is measured with the double deflation procedure; the real value of intermediate purchases of materials, energy, and services are subtracted from the real value of gross output.[13] BEA measures gross output at market prices, while Statistics Canada measures gross output at basic prices.[14]

The main difference between output valued at market prices versus basic prices is the treatment of taxes and subsidies. The value of output at market prices is the amount receivable by the producer from the purchaser for a unit of a good produced. The value of output at basic prices is the value of output at market prices, less any tax payable, and plus any subsidy receivable on that unit as a consequence of its production or sale. The different treatment of taxes and subsidies among countries has been raised as a source of noncomparability in international comparisons.[15]

We found that the different treatment of subsidies between the United States and Canada is not a major issue. From 1987 forward there have been no subsidies assigned to manufacturing in the United States;[16] further, in Canada subsidies have accounted for less than 1.0 percent of manufacturing income. Thus, the current difference in practices concerning subsidies in each country does not lead to substantial differences in productivity growth.

Although taxes are a component of nominal output in the United States, the BEA measurement technique ensures that a change in taxes would not be reflected in the growth of real output. Prices for the BLS producer price indexes, which are used extensively for deflation, are collected exclusive of taxes. These producer price indexes are applied to shipments data that do not include taxes. BEA then makes an adjustment so that real shipments plus taxes grow at the same rate as real shipments. Using this technique removes the effect of the tax change from the growth of the real value of shipments. Thus, we conclude that the U.S.-Canada productivity gap is not affected by the different valuation of output.

Aggregation index. As a result of the revision to the Canadian output series in May 2000, Canada and the United States now use similar methods to aggregate output components. Real output is constructed for very detailed components within manufacturing, and these components are then aggregated together to arrive at a measure of output for the entire manufacturing sector.[17] The United States and Canada use a chained Fisher index to aggregate components of real gross output, intermediate inputs, and value added in manufacturing.

The Fisher index is a geometric mean of the conventional fixed-weight Laspeyres index and a fixed-weight Paasche index. The Fisher index is calculated using price weights for both periods of comparison, thus avoiding the substitution bias that exists in measures employing price weights for a single year (fixed-weight indexes). Substitution bias refers to the inability of a fixed-weight index to account for substitutions made in response to changes in relative prices over time. This substitution bias is particularly an issue in manufacturing, because the decline in computer prices has had a major impact on relative prices.[18]

In order to construct an historical series, adjacent-year Fisher indexes are "chained" (multiplied) together. The United States adopted the chain-type annual-weight (Fisher) output index in the comprehensive revision of 1996. In a study following the adoption, BEA indicated that over the 1987–93 period, the annual growth rate of real value added for manufacturing was revised downward approximately 0.9 percentage points. Previous measures for this period were constructed with a fixed-weight index with a 1987 base year. BEA stated that the change in index formula was a major factor in this downward revision of manufacturing real value added.[19]

Canada adopted the chained Fisher output index in May 2000, revising data back to 1961. This change resulted in a slight downward revision to growth of real value added in manufacturing for the 1988–98 period. Prior to the revision, Canada measured real GDP in manufacturing using a fixed-base-volume index, in which the base year was updated periodically, approximately every 5 years.[20]

In the BLS productivity comparisons prior to May 2000, different aggregation indexes were being used to construct the underlying data for the United States and Canada. A productivity gap can be defined as the ratio of the U.S. index of output per hour to the Canadian index of output per hour. In the tabulation that follows, a comparison is presented showing the annual growth of the current published productivity gap and the growth of the gap as measured prior to May 2000—with Canada using the fixed-weight index and the United States using a Fisher index. Positive values indicate faster growth (or slower decline) of the U.S. variable relative to the Canadian variable, thus widening the gap; negative values indicate that the U.S. variable either rose slower or fell faster than its Canadian counterpart, closing the gap.

	As published	Pre-2000
1988–98	0.6	0.4
1988–92	–1.6	–1.8
1992–98	2.1	1.9

The data indicate that adopting the chained Fisher index formula resulted in slower annual growth in value added in Canada, thus expanding the U.S.-Canada productivity gap by approximately 0.2 percentage points per year. However, because the two countries now use the same aggregation index formula, this measurement issue no longer affects current productivity comparisons.

Treatment of Software. The United States and Canada treat software differently in the national accounts.[21] However, because software plays a very small role in manufacturing value added in both countries, the different treatment has only a slight effect on the productivity gap.

Prior to October 1999, the United States and Canada measured software purchases and production in a similar manner within their national accounts—both countries treated software as an intermediate input in production. In the 1999 comprehensive revision of the U.S. national income and product accounts,[22] BEA recognized business and government expenditures for software as fixed investment—that is, as an asset that produces flows of services lasting more than one year. This revision is consistent with recommendation 10.92 of the United Nations *System of National Accounts 1993*.[23] To date, Statistics Canada has been unable to incorporate the United Nations recommendation for the treatment of software; the agency currently is evaluating the feasibility of adopting this recommendation.

The new treatment of software by the United States affected both components of real value added. The reclassification of software purchases decreased real intermediate inputs,[24] and the recognition of own-account software production as part of gross output increased real gross output. These changes resulted in an upward revision to real value added for the U.S. economy.

There was very little impact on manufacturing industries,[25] where value added was revised upward by about 1 percent, only slightly affecting trends. The small effect on U.S. manufacturing value added is due to the small size of software as an input to manufacturing. Although software's share of intermediate purchases has been increasing rapidly—more than doubling from 1988 to 1998—it still was only about 0.5 percent in 1998 for the United States.[26] (The industries most affected by the new treatment of software were outside of manufacturing: wholesale trade; retail trade; finance, insurance and real estate; and services.)

Using BEA data for tangible wealth investment, it is possible to estimate value added for U.S. manufacturing to reflect the prior treatment of software as expenditures. We recalculated real value added by adding software purchases back to real intermediate inputs and removing own-account software production from real gross output.[27] The results of this simulation affected the annual growth of the productivity gap as follows:

	As published	Adjusted
1988–98	0.6	0.5
1988–92	–1.6	–1.8
1992–98	2.1	2.0

The data show that the growth in the U.S.-Canada productivity gap has widened approximately 0.1 percentage point as a result of the new treatment of software by the United States.

Data were not available to adjust the Canadian data to the U.S. basis; however, we did confirm that software plays a similar minor role in Canadian manufacturing. Intermediate inputs of software in Canadian manufacturing account for about 0.5 percent of 1996 intermediate purchases.[28] Thus, we conclude that the different treatment of software by the United States and Canada is having only a small impact on the productivity gap in manufacturing. If software continues to grow substantially, the different treatment by the two countries could become more of an issue in the future.

Prices of information technology products The general procedures used by the United States and Canada to measure price change for important information technology products are fairly similar, although the actual results for semiconductors vary substantially. Since 1996, the methods used by the two countries for these products have become more similar, but the historical series still are affected by the pre-1996 differences.

The category of information technology products can be specified to include computers and communications hardware, as well as the software and associated services required to effectively use that hardware.[29] Because this specification includes a broad range of products, we have chosen to limit the present discussion to certain types of computers and communications hardware that have been discussed in the literature as posing international comparability problems or that have displayed rapid price change in national accounts statistics. Three information technology products within the manufacturing sector were selected: computers, telephone switching equipment, and semiconductors. These products were selected because the industries that produce them play a significant role in explaining the productivity gap in the manufacturing sector (as will be discussed later in this article). Also, a BEA study of industry price measures noted that declines in gross output prices in certain information technology industries between 1992 and 1996 were primarily for prices for these three products.[30] Finally, semiconductors are important inputs into several industries, and thus value-added output is affected when they are removed.

As products change over time, it is crucial that their price indexes accurately account for changes in product quality. One traditional way to adjust for quality change is to assume that an increase in the quality of a product is associated with an increase in the cost of producing it. This cost increase can be used to determine how much of the item's price change is due to quality change. For information technology products, however, the cost and price of the improved version often fall below those of the previous lower quality versions.[31]

Several statistical techniques exist that can be used to construct price indexes for information technology products. Two commonly noted techniques are the *matched model* technique and the *hedonic regression* technique. The matched model technique controls for quality by measuring price change only for products or models that exist in two periods. Traditionally, when the technique was applied, only prices for models that existed in both periods were used in the index. The price of any nonmatched model was disregarded. An alternative application calls for an attempt to estimate the missing price in some manner—for example, by using the price change for another appropriate model as a proxy.

The hedonic regression technique regresses the price of a product against a list of product characteristics thought to influence (or provide a proxy for) quality. There are actually various ways the technique can be employed, including estimating a price index from regression coefficients for variables representing specific time periods or estimating missing prices for particular models derived from a cross-sectional hedonic equation. In the latter case, when the quality of the product changes, as reflected in changes in one or more of its characteristics, an adjustment can be made to the product's price to account for this quality change.

The matched model technique and hedonic technique also can be used in combination. Hedonic regressions have been used to estimate prices for those models not available in both periods of comparisons, and then the prices estimated with the hedonic equation are combined with the prices of other available models in a matched model procedure.

The use of these two techniques by different countries has been cited often as a reason for noncomparability of international comparisons. For example, Andrew A. Wyckoff examines computer price methodologies for several countries and finds that both the matched model and the hedonic techniques are employed. He argues that the difference in price behavior can be significant, depending upon the technique chosen. Further, based on the results of studies of U.S. data, he notes that typically the matched model index falls at a slower rate than the hedonic index; sometimes it even increases.[32]

To assess the comparability of prices for information technology products in specific countries, it is necessary to look beneath the dichotomy of the matched model and the hedonic techniques. There can be considerable variation in the actual implementation of the same general technique, whether it be the hedonic or the matched model technique. Alternative applications of the same technique, even within the same country, may yield different results. Further, it is also possible that particular applications of the two different techniques may produce similar results.[33]

Without knowing the exact application of either technique, it is difficult to argue a priori that the use of the same technique in each country yields more comparable results than the application of different techniques. Given this difficulty, we proceeded as follows. For each information technology product, we examined the two countries' uses of the hedonic technique and the matched model technique, and we also looked at the price behavior between 1992 and 1996 of the four-digit industries producing these products.[34] Where the countries used different techniques or the price behavior appeared substantially different, we attempted to assess the impact on the productivity gap.

Computers and related products. The value-added output measures for the United States and Canada are based on the use of similar techniques to measure prices for computers and related devices.[35] Both countries employ the hedonic technique to account for quality change. The implicit prices or price indexes[36] of the industries producing these products are as follows:

	United States	*Canada*
1992	100.0	100.0
1996	50.0	63.3

The prices for computers and related devices in both countries fell considerably between 1992 and 1996. In the United States, prices fell about half, while in Canada, they fell by about a third.

BEA uses a hedonic procedure to capture quality change in prices for computers, as well as for printers, displays, direct access storage devices, and tape drives.[37] The resulting price indexes for five-digit product classes are then linked to the BLS producer price indexes that became available in 1990 and are also based on the hedonic technique.

The Canadian price index incorporates some prices from the U.S. series, as well as some from Canada. From 1981 forward, the Canadians have used a weighted average of the BEA series for computers, direct access storage drives, printers, and displays, using weights based on Canadian production levels. The BEA tape drive index was not used because the output of this product is small in Canada. The BEA series were incorporated into the Canadian price index through 1992, at which point, price indexes for microcomputers and printers were based on prices collected in Canada and adjusted with a hedonic procedure. The BEA series were adjusted for exchange rate variations in order to express the indexes in terms of Canadian prices.

Because Canada has actually incorporated some U.S. price data and is using the same general hedonic technique for microcomputers and printers, measurement differences in this industry do not seem to be contributing to the gap. This is reinforced by the large price declines in both countries. Presumably, the differences in the prices are due to the different relative importance of the products within the aggregate category of computers and related devices, as reflected in the Canadian reweighting of the BEA prices. The Canadian adjustment for exchange rates could contribute to the difference as well.

Telephone switching equipment. The United States and Canada use different procedures to measure prices for telephone switching equipment,[38] a product within telephone and telegraph apparatus. Through 1996, the United States employed the hedonic technique, while Canada employed the matched model technique. The implicit prices or price indexes for the industries producing these products are as follows:

	United States	*Canada*
1992	100.0	100.0
1996	82.9	105.6

Over this period, U.S. prices fell by a little less than 20 percent, while Canadian prices increased a small amount—not an insignificant difference.

BEA produced a hedonic price index for telephone switching equipment until 1996.[39] Canada produces a price series for telephone switching equipment based upon purchased prices collected from Canadian telephone companies. In Canada, the matched model technique is used. Despite these differences in techniques and the resulting price differences, the impact on the manufacturing productivity gap is probably fairly small. In 1992 and 1996, the nominal output of the telephone and telegraph apparatus industry in the United States and the corresponding industry in Canada accounted for about 1 percent of shipments in the respective manufacturing sectors of each country. Of this 1 percent, the telephone switching equipment industry in the United States represented less than half.[40]

Semiconductors. The United States and Canada used similar techniques to construct prices for semiconductors[41] in constructing value-added output through 1996. The differences in results are due more to the differences in source data, rather than to the use of different techniques. The implicit prices or price indexes for the industries producing these products in the two countries are as follows:

	United States	*Canada*
1992	100.0	100.0
1996	32.6	100.4

Prices for this industry fell by about two-thirds in the United States, while remaining unchanged in Canada—a striking difference.

A major component of the U.S. output series[42] is based on a price index for semiconductors developed by BEA. This index employs a mixture of the hedonic technique for microprocessors and the matched model technique for memory chips through 1996. (Microprocessors, a type of integrated circuit, and memory chips are products of the semiconductor industry.) Beginning with 1996, a link was made to the appropriate BLS producer price index.

Canada does not collect prices for semiconductors, but rather uses BLS producer price indexes for several products within the semiconductor industry to proxy as deflators for integrated circuits and semiconductors and parts. The BLS producer price indexes for semiconductors are constructed using a matched model technique. As is the case for computers, the producer price indexes are adjusted by Statistics Canada for exchange rate variations.

Because the hedonic technique is used only to estimate missing prices for some microprocessor observations in the BEA application of the matched model procedure,[43] the difference in price behavior for the entire semiconductor industry is not primarily due to the BEA's use of the hedonic technique. A discussion with members of the BLS staff who work on the producer price indexes indicated that most of the difference between the BEA and BLS price indexes through 1996 was due to BEA's use of secondary price data covering important producers not included in the BLS indexes.[44] Beginning in 1997, BLS began using new secondary source data for its producer price indexes.

The very different price behavior of the BEA and BLS series, combined with the importance of this industry to understanding the productivity gap between the two countries, led us to explore further the impact of the use of different deflators. Semiconductors are produced in the manufacturing sector and are also consumed by industries in manufacturing, such as the computer industry.[45] Thus, the growth in semiconductor gross output increases value added of the manufacturing sector, while the growth in semiconductor consumption reduces it. To the extent that consumption and output of semiconductors are the same within a country's manufacturing sector and similar prices are used to deflate output and inputs, the choice of a deflator will not affect manufacturing value-added growth. In other words, if output and consumption were equal within a given country, the choice of deflators would not influence the productivity gap.

Such a complete offset is not the case, however, in either country. Our review of 1992 data from the input-output tables for the United States indicates that consumption of semiconductors in manufacturing is about two-thirds of output. Our corresponding review of the data from Canada indicates that 1992 consumption levels were 33 percent greater than output. Because there is less than a full offset in the United States and more than an offset in Canada, the impact on value added from the use of different semiconductor deflators should not be dismissed.

To assess the impact of the different prices on the gap, we accepted the BEA choice of deflator for estimating semiconductor growth. We replaced the real semiconductor outputs and inputs in the Canadian real value-added series with values constructed with an exchange-rate-adjusted BEA price series.[46] The results of this simulation affected the annual growth of the productivity gap as follows:

	As published	*Adjusted*
1988–96	0.0	0.1
1988–92	–1.6	–1.6
1992–96	1.7	1.8

For the 1992–96 period, this adjustment increased the productivity gap by about 0.1 percentage point. The much more rapid price decline of the BEA price index makes both output and intermediate inputs grow faster. Because semiconductors occupy a greater share of Canadian manufacturing as an input rather than as an output, adjusted Canadian value-added output grows slower and contributes slightly to a widening of the gap.

In summary, the difference in techniques for estimating prices for information technology products in the two countries is not substantially affecting the gap in manufacturing productivity growth. For computers, the techniques are similar. The Canadians actually use the same prices as BEA, with the exception of their estimate of microcomputers and printers after 1992. Not surprisingly, the resulting price series for computers show similar major price declines. The general techniques and resulting price series for telephone switching equipment in the two countries are different. However, the importance of this product is relatively small in both countries and thus probably does not affect the aggregate manufacturing productivity gap. Finally, although the same general technique is used by both countries for semiconductors, the resulting prices are very different—primarily because the United States uses a BEA-produced deflator, while Canada uses the BLS producer price index. Our simulation indicated that using the same prices for semiconductors in both countries would have a slight impact on the manufacturing sector productivity gap.

Labor input

Productivity measures for the United States and Canada are derived from data on hours and employment from different types of surveys—a potential source of at least part of the difference in growth of labor input. Total labor hours inputs are measured as the product of average hours and employment, and U.S.-Canada ratios represent the gaps in these measures. The importance of the growth of the gap in each of these measures in explaining the annual growth of the gap in total hours can be seen in the following tabulation:

	Total hours	*Average hours*	*Employment*
1988–98	0.1	0.2	–0.1
1988–92	3.3	.7	2.5
1992–98	–1.9	–.2	–1.7

Positive values indicate faster growth (or slower decline) of the U.S. variable relative to the Canadian variable, thus widening the gap. Negative values, on the other hand, indicate that the U.S. variable either rose slower (or fell faster) than its Canadian counterpart, thus closing the gap. Looking at these ratios, one may easily conclude that the gap in employment between the two countries is responsible for the majority of the gap in total hours. In this section, we examine the methods underlying both average hours and employment and analyze the impact of using different types of surveys.

Hours concept. The appropriate labor input for measuring output per hour is hours worked, rather than hours paid. For the United States, the measure of hours at work excludes all forms of paid leave, but includes paid time to travel between job sites, coffee breaks, and machine downtime. Similarly, Canada's measure of hours worked excludes time lost due to strikes, holidays, vacations, illness, maternity leave, or personal reasons, but it includes normal hours, overtime, coffee breaks, on-the-job training, and time lost to unanticipated interruptions. For productivity measurement, a measure of the labor input of all employed persons is appropriate. All employed persons include production workers, nonproduction workers, and unpaid workers.[47]

Primary data sources. Total hours data for the United States are derived from the BLS series on average hours and employment underlying its quarterly productivity statistics. Statistics Canada publishes measures of total jobs and hours worked for total jobs.

The primary data source for the U.S. estimates of average hours paid for production workers is the BLS Current Employment Statistics (CES) survey, which is an establishment survey.[48] For the period from 1977 forward, average weekly hours paid for nonproduction workers are extrapolated using trends in the workweek of production workers from CES data and from BLS studies of wages and supplements in manufacturing.[49] These studies provide data from prior to 1978 on the regularly scheduled workweek of white-collar employees.[50] Data from the BLS Hours at Work Survey are used to convert average weekly hours paid to an hours-at-work basis.[51] In the United States, average hours data for self-employed workers are obtained from the household-based Current Population Survey (CPS).[52] In Canada, data on average hours worked (including unpaid overtime) for all employed persons are collected in the Canadian Labor Force Survey, which also is a household survey.[53]

For the United States, employment data for production and nonproduction workers are obtained from the CES. For Canada, employment data for production and nonproduction workers are collected in the Canadian Annual Survey of Manufacturing, an establishment-based survey. However, this series is benchmarked to an adjusted version of employment from the Canadian Labor Force Survey, which causes the Canadian series to grow at a rate similar to that shown by data from the labor force survey.[54] In both countries, employment data for unpaid workers are obtained from labor force surveys.

Differences in average hours. Studies have shown that trends in average hours may differ considerably when they are derived from household labor force surveys as opposed to establishment surveys.[55] It is possible to compare trends of average hours from the two types of surveys by analyzing alternate data from the United States and Canada. In the United States, BLS collects data on average hours for wage and salary workers in the CPS,[56] as well as in its establishment survey. In Canada, too, average hours data are collected not only from a household survey, but also from an establishment survey, the Survey of Establishment Payroll and Hours (SEPH).[57] Using these alternative data sources, we estimated the U.S.-Canada gap in average hours from comparable data sources. There have been numerous methodological changes to the SEPH since 1990, and the sample size prior to 1998 was relatively small.[58] The simulation results for 1988–98 based on the Canadian establishment data are affected by these limitations.

The impact on the annual growth of the U.S.-Canada gap in average hours is shown in the following tabulation:

	Published data	*Establishment data*	*Household data*
1988–98	0.2	0.1	0.1
1988–92	.7	.3	.4
1992–98	–.2	.0	–.2

The results show that if both countries use source data from establishment surveys, the gap in U.S.-Canada average hours would grow more slowly than the published series for the 1988–92 period, and more rapidly for the 1992–98 period. Alternatively, if both countries use source data from household surveys, the gap in average hours would grow more slowly for the 1988–92 period, and about the same for 1992–98.[59] The largest change occurred during the 1988–92 period, where adopting the U.S. establishment basis reduced the gap in average hours by 0.4 percentage point, and adopting the Canadian household basis reduced the gap by 0.3 percentage point. Hence, the choice of the type of survey used does appear to affect the growth in the gap in average hours between the United States and Canada.

Differences in employment. Even though the United States and Canada both use establishment data to measure employment in the manufacturing sector, the Canadian data are benchmarked to a labor force survey. Employment trends estimated from a labor force survey often differ from employment trends estimated from an establishment survey. Using alternative data from the United States and Canada, one can estimate the impact of adopting the same survey types. We adjusted the published U.S. employment series to grow at the rate of the CPS and compared this series with the published Canadian measure. Alternatively, we adjusted the Canadian data to remove the household survey benchmark and then compared the data to the published U.S. series.[60]

The impact on the annual growth of the U.S.-Canada gap in employment is illustrated in the following tabulation:

	Published data	*Establishment data*	*Household data*
1988–98	–0.1	–0.2	–0.1
1988–92	2.5	2.1	2.6
1992–98	–1.7	–1.7	–1.9

The results show that if both countries had used employment data from an establishment survey, the gap in U.S.-Canada employment would have grown more slowly during the 1988–92 period, and it would have remained the same during the 1992–98 period. Alternatively, if both countries had used employment data from household surveys, the gap would have grown somewhat more rapidly during the 1988–92 period, and it would have declined more rapidly during the 1992–98 period.[61] Again, we noticed that the adjustment for the 1988–92 period was the most dramatic. During this period, shifting the Canadian employment series from a labor force basis to an establishment basis reduced the employment gap by 0.4 percentage point. For the other periods, the adjustments had relatively little effect.

Comparing total hours and productivity. Because total hours are contingent on trends in both average hours and employment, we combined the results of the analysis on these two measures.[62] Using the resulting alternate trends in total hours, we then re-estimated productivity growth. The following tabulation compares the annual growth of the productivity gap based on the published data with the gaps associated with using comparable methods to measure total hours in the two countries:

	Published data	*Establishment data*	*Household data*
1988–98	0.6	0.8	0.7
1988–92	–1.6	–.7	–1.4
1992–98	2.1	1.8	2.2

Adopting comparable methods for either country led to a small increase in the productivity gap over the 1988–98 period. For the 1992–98 period, however, adopting the U.S. establishment basis decreases the gap, while adopting the Canadian labor force survey basis increases the gap. Notice that, particularly for the 1988–92 period, shifting the Canadian hours series to a U.S. basis results in the greatest change in the productivity gap, reducing it by 0.9 percentage point.

From our analysis, we conclude that measurement procedures used by the two countries to construct labor input are contributing to the productivity gap. However, if comparability is achieved, the adjustment to the gap will depend on the basis selected.[63] In the United States, BLS favors using hours data from the establishment survey in estimating U.S. productivity growth. Statistics Canada has chosen not to use establishment survey data to measure hours. To the extent that this choice implies limitations in the alternative establishment-based data from Canada, we are reluctant to interpret our findings as precise measures of the impact of using different survey types on the U.S.-Canada productivity gap.

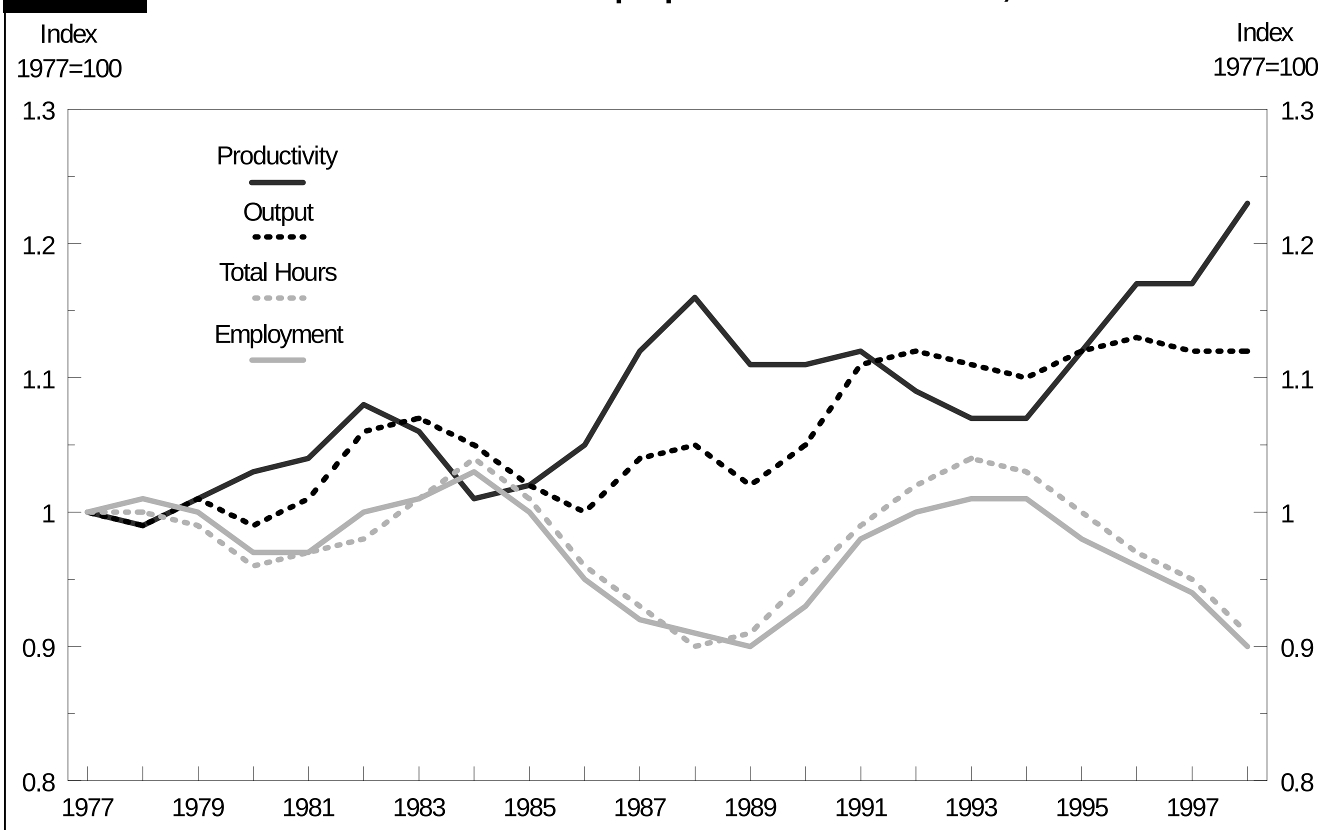
Real Factors

Since 1979—a peak year for output in each country—there has been a gap in relative productivity performance between the United States and Canada. However, there have been two major periods in which the gap narrowed before increasing again. From 1982 to 1984, Canadian productivity grew faster than U.S. productivity, contributing to a decline in the gap before a slower growth rate in Canada increased it again through 1988. From 1988 to 1992, the gap began to decline again. Since the early 1990s, however, there has been a much more rapid increase in U.S. productivity relative to Canadian productivity.

Chart 2 presents U.S.-Canada ratios of indexes of output per hour, as well as indexes of output and labor input. These ratios represent the gap that exists for each variable. An increase in a ratio indicates faster growth (or slower decline) of that variable in the United States relative to Canada. A declining ratio indicates that the U.S. variable either rose more slowly or fell more rapidly than the Canadian variable. Although the behavior of the productivity gap between 1988 and 1998 can be explained in part by the different growth rates of output, the interesting finding is that the gap in productivity performance is a near mirror image of the gap in employment. The increase in the productivity gap between 1992 and 1998 is driven by more rapid growth in Canadian employment.

The following tabulation shows the annual growth in the U.S.-

Chart 2. Ratio of U.S.-Canada indexes of output per hour and related series, 1977–98



Canada ratios of output per hour, output, and hours:

	Output per hour	*Output*	*Hours*
1988–98	0.6	0.7	0.1
1988–92	–1.6	1.6	3.3
1992–98	2.1	.1	–1.9

It can readily be seen that over the 1988–98 period, productivity growth in the United States was 0.6 percentage point greater than it was in Canada. However, as depicted in Chart 2, the two subperiods reveal more dynamic results. The growth of the ratio of U.S.-Canadian output per hour compared with the growth in the U.S.-Canada ratios for output and hours, underscores the importance of relative output and labor movements in each country. For the 1988–98 period, the productivity gap appears to be resulting mainly from a gap in output. However, for the two subperiods, the gap in hours is the force behind the productivity differentials.

As discussed earlier, the gap in employment is mainly responsible for the gap in hours. Because measurement differences only play a small role in explaining the U.S.-Canada employment gap, there also are real economic factors driving the gap in hours.

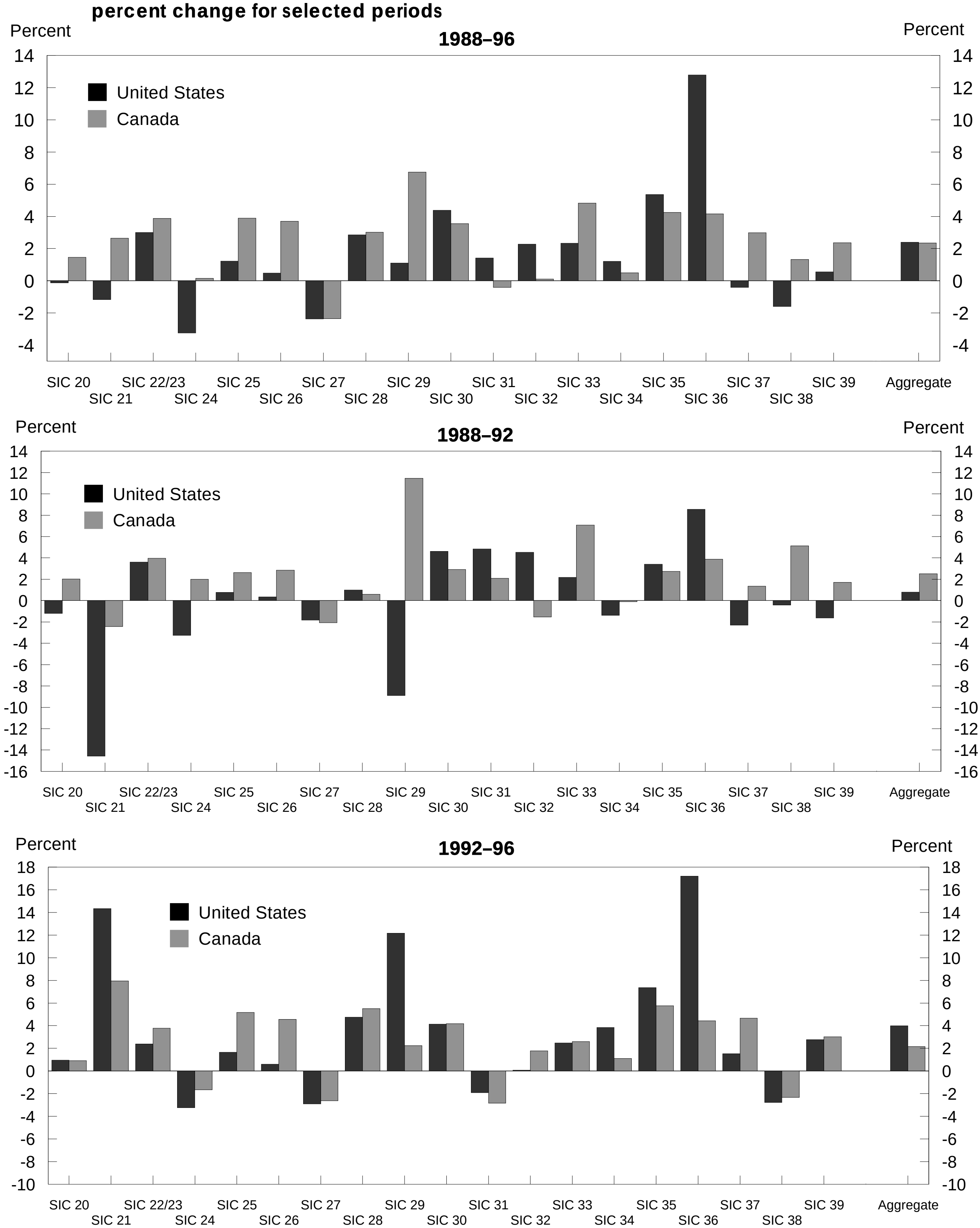
A decomposition of productivity into its input and output components provides useful information concerning the U.S.-Canadian productivity gap. However, additional information can be gained by looking at the productivity performance of the individual industries that make up the manufacturing sector. Industry-level data allow us to identify industries that contribute substantially to a country's growth in manufacturing output per hour.

Industry measures. Because BLS has obtained data for both Canada and the United States, we are able to measure productivity trends through 1996 for approximately 19 two-digit industries within manufacturing. Using these data, we compare each country's productivity performance by industry and then analyze the contribution made by specific industries to the growth in manufacturing output per hour. These data are consistent with the aggregate manufacturing series. To the extent possible, we have adjusted the Canadian two-digit industry data to conform to the 1987 U.S. Standard Industrial Classification (US-SIC87).[64] For brevity, we refer to industries with a short rendition of the full title given in the *Standard Industrial Classification Manual: 1987.* (A mapping of the full

Exhibit 1. Mapping of abbreviations and full titles of manufacturing industries in the 1987 U.S. Standard Industrial Classification system

SIC code	Short title	Full title
20	Food	Food and kindred products
21	Tobacco	Tobacco products
22/23	Textiles and apparel	Textile mill products, and apparel and other finished products made from fabrics and similar materials
24	Lumber	Lumber and wood products, except furniture
25	Furniture	Furniture and fixtures
26	Paper	Paper and allied products
27	Printing	Printing, publishing, and allied industries
28	Chemicals	Chemicals and allied products
29	Petroleum	Petroleum refining and related industries
30	Rubber and plastic	Rubber and miscellaneous plastic products
31	Leather	Leather and leather products
32	Stone and clay	Stone, clay, glass and concrete products
33	Primary metals	Primary metal industries
34	Fabricated metals	Fabricated metal products, except machinery and transportation equipment
35	Machinery and computers	Industrial and commercial machinery and computer equipment
36	Electronics	Electronic and other electrical equipment and components, except computer equipment
37	Transportation equipment	Transportation equipment
38	Instruments	Measuring, analyzing, and controlling instruments; photographic, medical, and optical goods; watches and clocks
39	Miscellaneous	Miscellaneous manufacturing industries

Chart 3. **U.S. and Canadian productivity growth in manufacturing by industry, annual average percent change for selected periods**



titles and their abbreviated versions is shown in exhibit 1 on page 41.)

Productivity by industry. Chart 3 presents a comparison of growth in output per hour for 19 industries over the 1988–96 period (top panel) and two subperiods (bottom two panels). Over the longer period, growth in output per hour in the United States was particularly strong in the electronics industry and in the machinery and computers industry. The rubber and plastics industry can also be considered a strong performer in the United States. However, over the same period, the lumber, printing, and instruments industries recorded the poorest performances. In Canada over the 1988–96 period, the petroleum and primary metals industries showed the greatest growth in output per hour, while the machinery and computers industry and the electronics industry also had strong growth over this period. Canada has experienced declining productivity growth in the printing, lumber, and leather industries.

For the 1992–96 subperiod, the United States experienced strong productivity growth in the tobacco and petroleum industries, as well as the electronics industry and the machinery and computers industry. Within this subperiod, the lumber, printing and instruments industries continued to have the most significant declines in growth in output per hour. In Canada, the tobacco industry and the machinery and computers industry are also productivity leaders, along with the chemicals industry. For this subperiod, productivity growth declined most significantly in the printing and leather industries.

When comparing industry performance between countries, we found that over the 1988–96 period, the United States demonstrated stronger productivity growth than Canada in 6 of the 19 industries. The largest gap between U.S. and Canadian growth in output per hour appears in the electronics industry and in the stone and clay industry. Canada demonstrates faster productivity growth in 13 of the 19 industries. The largest differences appear in the petroleum, tobacco and transportation equipment industries. Over the 1992–96 period, the United States demonstrated superior performance in 8 of the industries, while Canada demonstrated stronger growth in 11 industries. The United States outperformed Canada most notably in the electronics and petroleum industries, while Canada outperformed the United States most notably in the paper, furniture, and transportation equipment industries.

Chart 3 enables us to identify differences in productivity performance across industries within each country and to compare an industry's performance between the two countries. However, in order to assess an industry's contribution to aggregate productivity growth, the industry's relative importance must be taken into account.

Productivity growth by industry. To examine the contribution made by an industry to the growth in manufacturing output per hour, we weighted the industry's productivity growth rate to reflect the industry's relative importance in the manufacturing sector. In the case of measures of output per hour, a relevant weight is the industry's share of the manufacturing sector's labor hours.

Determining the contribution made by an industry to manufacturing productivity and to the gap between the two countries is not a precise determination. Further, it should be noted that some industry contributions are negative; thus, positive contributions from other industries will sum to more than 100 percent. However, we estimated these contributions simply to identify the industries that are most important to productivity growth in each country.[65] We caution against interpreting the

Table 1. Contributions to growth in manufacturing output per hour for the United States and Canada, 1988–96

Industry (US-SIC87)	1988–96		1988–92		1992–96	
	United States	Canada	United States	Canada	United States	Canada
Food	.0	.08	–.10	.14	.03	.04
Tobacco	.0	.0	–.03	.0	.01	.01
Textiles and apparel	.11	.14	.30	.18	.06	.11
Lumber	–.06	–.05	–.12	–.07	–.04	–.04
Furniture	.01	.06	.02	.04	.01	.06
Paper	.01	.09	.01	.09	.01	.10
Printing	–.09	–.07	–.14	–.08	–.07	–.07
Chemicals	.07	.06	.05	.02	.08	.11
Petroleum	.0	.02	–.07	.05	.03	.01
Rubber and plastics	.10	.07	.20	.06	.06	.07
Leather	.0	.0	.03	.01	.0	–.01
Stone and clay	.03	.0	.12	–.02	.0	.02
Primary metal	.04	.11	.08	.20	.03	.05
Fabricated metal	.04	.02	–.09	.0	.09	.03
Machinery and computers	.27	.14	.34	.10	.25	.16
Electronics	.51	.12	.67	.14	.44	.10
Transportation equipment	–02	.17	–.21	.09	.04	.24
Instruments	–.03	.01	–.02	.02	–.04	.0
Miscellaneous	.01	.03	–.03	.04	.02	.02

Table 2. Industry contribution analysis, United States and Canada, 1988–96

Industry (US-SIC87)	1988–96		1988–92		1992–96	
	United States	Canada	United States	Canada	United States	Canada
Machinery & computers						
Contribution	0.27	0.14	0.34	0.10	0.25	0.16
Output per hour growth	5.36	4.25	3.40	2.75	7.37	5.77
Output growth	5.61	4.46	1.21	–3.87	10.20	13.51
Hours growth	.23	.72	–2.12	–4.94	2.64	6.71
Labor share	11.29	7.21	10.91	6.54	11.17	6.96
Transportation equipment						
Contribution	–.02	.17	–.21	.09	.04	.24
Output per hour growth	–.40	2.99	–2.29	1.34	1.52	4.67
Output growth	–1.78	3.02	–5.33	–2.26	1.89	8.59
Hours growth	–1.39	.03	–3.11	–3.56	.36	3.75
Labor share	10.09	12.50	10.19	12.13	9.77	12.78
Electronics						
Contribution	.51	.12	.67	.14	.44	.10
Output per hour growth	12.79	4.15	8.55	3.88	17.21	4.43
Output growth	12.25	.75	4.80	–1.59	20.22	3.15
Hours growth	–.48	–3.17	–3.45	–4.62	2.57	–1.71
Labor share	8.86	5.99	8.58	6.40	8.53	5.91

NOTE: Contributions in table 1 have been normalized to sum to one; therefore, the product of the shares and productivity growth will not necessarily equal the contribution.

results as exact estimates of the contributions.

Each industry's contribution to productivity growth in aggregate manufacturing is shown in table 1 (page 43). Notice that a low positive productivity growth within an industry can contribute considerably to aggregate productivity performance because of a large weight. The food industry in Canada during the 1988–92 period is an example. Conversely, a relatively high productivity growth rate combined with a small relative importance leads to a small contribution. The tobacco industry in both countries between 1992 and 1996 is an example.

Over the 1988–96 period, two industries stand out as top contributors to U.S. productivity growth—the electronics industry and the machinery and computers industry. The textiles and apparel industry also appears to contribute significantly to U.S. performance over this period. These industries, along with the transportation equipment industry, were also the largest contributors in Canada. The greatest differences in contributions between the two countries are observed for the electronics, the transportation equipment, and the machinery and computers industries.

For the 1992–96 period, the electronics industry and the machinery and computers industry remained dominant forces in the United States, while the transportation equipment and machinery and computers industries contributed the most to productivity growth in Canada. The chemicals industry and the fabricated metals industry in the United States, and the chemicals industry and the textiles and apparel industry in Canada also are significant contributors. During this period, the largest differences between the countries were for the electronics and transportation equipment industries.

Table 2 presents some details underlying the contributions of three key industries. The machinery and computer industry is one of the major contributors to productivity growth in both the United States and Canada, although the contribution in the United States is considerably larger. Over all three periods, the two countries' productivity performance was fairly similar for this industry, but the industry's importance was much larger in the United States. Productivity growth in this industry was somewhat stronger in the United States because of stronger growth in output and slower growth in hours over the entire 1988–98 period; from 1992–96, more rapid growth in hours in Canada offset its advantage in output growth.

The transportation equipment industry contributed significantly more to manufacturing sector productivity in Canada than in the United States. Given that this industry has a relatively large but similar labor share in both countries, the difference in contribution is due to the Canadian industry experiencing much higher productivity growth than its U.S. counterpart—the United States actually experienced negative productivity growth over the entire 1988–96 period. In Canada, output and hours in the transportation equipment industry have been growing faster than in the United States; however, output has outpaced hours. This strong performance in the Canadian transportation equipment industry helped reduce the gap in U.S.-Canadian manufacturing productivity.

The largest disparity in contribution between the two countries was in the electronics industry. This is a result of the superior productivity growth that the U.S. industry demonstrated, compared with its Canadian counterpart, as well as the fact that the U.S. labor share is about 50 percent larger than the Canadian share. In the United States, output has far outpaced the growth in hours, and output in the United States has been growing significantly faster than in Canada. During the 1992–96 period, output in the United States electronics industry grew at a phenomenal rate of 20 percent per year, compared with 3 percent in Canada.

In summary, the transportation equipment and the machinery and computer industries had an offsetting impact on the gap over the period covered by this study. The small advantage in importance of the transportation equipment industry combined with stronger productivity growth in Canada was offset by the considerably larger share and somewhat stronger productivity growth enjoyed by the United States in the machinery and computers industry. The real contribution disparity occurs in the electronics industry. Both a larger share and much stronger productivity growth in the United States caused the electronics industry to widen the U.S.-Canada gap in manufacturing productivity.

IN THIS ARTICLE, WE REVIEWED the procedures BLS uses to produce international productivity comparisons, along with the methods used by each country's statistical agency to compile the underlying data used by BLS. We explored differences between the two countries in industrial classification, concepts and estimation of real value-added output (including valuation of prices, index aggregation formula, treatment of software and information technology deflation), and the estimation of labor hours worked.

In general, we found that the methods used by the two countries to construct the components of output per hour are quite similar. Although some differences exist, they do not appear to be substantially affecting measured productivity growth over the study period. Some differences tend to reduce the gap, while other measurement differences increase the gap. In our exploration of deflation techniques used to construct real value-added measures for certain products within the information technology sector, we found that there are some important similarities in methods but a substantive difference in the actual implementation of the semiconductor pricing methodology. When we combined our findings regarding all nonlabor methods reviewed, we found that they made only a small contribution to the size of the gap. The following tabulation of annual growth rates summarizes our findings with respect to the effect on the productivity gap of these measurement differences:

	1988–96	*1988–92*	*1992–96*
Published productivity gap	0.0	–1.6	1.7
Measurement issue:			
Industrial classification ..	.1	.2	.1
Software	–.1	–.2	–.1
Semiconductor prices	.0	.0	.1
Adjusted productivity gap .	.0	–1.7	1.8

Although real factors are responsible for the majority of differences in labor hours, hours derived from establishment surveys and labor force surveys behave differently, and thus have an impact on productivity comparisons. The United States favors the use of establishment survey data for measuring hours used for BLS productivity statistics. Statistics Canada has chosen not to use establishment survey data to measure hours. To the extent that this choice implies limitations in the alternative establishment-based data from Canada, we are reluctant to interpret our findings as precise measures of the impact of using different survey types on the U.S.-Canada productivity gap.

Among the real factors, the gap was substantially affected by the different growth rates of manufacturing employment in the two countries. Further, as other researchers have found, our review of productivity data at the two-digit level indicated that a substantial amount of the difference in productivity performance can be explained by the outstanding productivity growth in the information technology sector of the U.S. economy. In the United States, the electronics industry and the machinery and computers industry were the largest contributors to productivity growth, while in Canada, the transportation equipment industry played a major role in holding down the size of the gap. □

Notes

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[1] "Investigating the Canada-US Productivity Gap: BLS Methods and Data," presented at the Centre for the Study of Living Standards Conference on the Canada-US Manufacturing Productivity Gap, Ottawa, January 21-22, 2000. Conference papers can be obtained on the Internet at **http://www.csls.ca**, under the heading "recent events." More current data are included in the present article, as well as substantive revisions in the two countries' series that have taken place since January 2000.

[2] The list is not exhaustive but includes issues thought to be most important. It should be noted that there are limitations associated with the quality of

the particular data available for estimating the variables used in productivity measurement, as well as with the practical procedures that must be used when data are not available. It is not feasible to review all of the limitations. For example, accurate price deflators necessary to determine the real input of purchased services are rare. Because this problem is not unique to either country, we did not attempt to explore the issue.

[3] A standardized system being adopted, at least in part, by many countries is the *System of National Accounts 1993*, which has been undertaken under the joint responsibility of the United Nations, the International Monetary Fund, the Commission of the European Communities, the Organization for Economic Co-operation and Development, and the World Bank. See *System of National Accounts 1993*, Series F, Number 2 (United Nations Statistics Division, 1993); for more information, visit the United Nations Statistics Division website, on the Internet at **http://www.un.org/Depts/unsd/**.

[4] *Standard Industrial Classification Manual: 1987* (Executive Office of the President, Office of Management and Budget, 1987).

[5] More information on Canada's 1980 Standard Industrial Classification system can be found on the Internet at **http://www.statcan.ca/english/Subjects/Standard/standard_classifications.htm**.

[6] In 1997, Canada completed a major revision to the national accounts. This historical revision did not result in any changes to the classification of the manufacturing sector or to two-digit industries within manufacturing; however, the numbering structure for industries within manufacturing was modified. Both countries, along with Mexico, are in the process of converting to a common industrial classification known as the North American Industrial Classification System (NAICS). At this time, manufacturing data on a NAICS basis are scheduled to be released in Spring 2001 for Canada and not before 2004 for the United States.

[7] There are several other components of Canadian manufacturing that are not in U.S. manufacturing that we were unable to adjust for. These include portions of photo finishing (C-SIC80 2821), vehicle engine repair services (C-SIC80 3081, 3261), and clay products (C-SIC80 3511, 3512, 3591).

[8] Output and hours for the Canadian logging industry (C-SIC80 w-5) were obtained from Statistics Canada. Output and hours for the five-digit US logging industry were obtained from the BLS Division of Industry Productivity Studies. The consistency in aggregation theorem was used to construct the adjusted series. (See W. E. Diewert, "Superlative Index Numbers and Consistency in Aggreagation," *Econometrica*, July 1978, pp. 883–900.) Under the 1997 North American Standard Industrial Classification System (NAICS), the logging industry will not be included in the manufacturing sector.

[9] For more information, visit BEA's website, on the Internet at **http://www.bea.doc.gov/**.

[10] Sherlene K. S. Lum, Brian C. Moyer, and Robert E. Yuskavage, "Improved Estimates of Gross Product by Industry for 1947–98," *Survey of Current Business*, June 2000, pp. 24–54. Note that prior to the June 2000 revisions, the U.S. data relied upon information from the 1987 input-output table. This raised concern at the Conference regarding comparability with Canadian data. The authors addressed that point in a revised paper prepared for the Conference volume.

[11] Statistics Canada is the Canadian national statistical agency; the agency publishes statistics organized into three broad subject matter areas: demographic and social, socioeconomic, and economic. For more information, visit the official Statistics Canada website, on the Internet at **http://www.statcan.ca/start.html**.

[12] See "Gross Domestic Product by Industry," Catalogue no. 15-001-XPB, (Statistics Canada, October 1997) pp. vii-xxvi.

[13] In both countries deflation is conducted at the most detailed level possible. In the United States, current dollar gross output is deflated primarily using BLS producer price indexes. Notable exceptions are price indexes constructed by BEA for computers, telephone-switching equipment, selected semiconductor products, and government purchases. Intermediate purchases are deflated with prices based largely on those used to prepare constant dollar gross output and imported intermediate inputs are deflated mainly using BLS import price indexes. In Canada, current dollar gross output and intermediate purchases are deflated with producer price indexes. In general, the two countries use similar deflation techniques to measure real output and inputs.

[14] The *System of National Accounts 1993* recommends the use of basic prices or modified basic prices to value gross output. Prior to 2000, Statistics Canada valued output at factor costs.

[15] Kishori Lal, "Value Added by Industry: A Problem of International Comparison," OECD Meeting of National Accounts Experts, Paris, (Statistics Canada, September 21–24, 1999).

[16] Prior to 1987, subsidies in U.S. manufacturing never accounted for more than .05 percent of nominal gross output in manufacturing.

[17] BEA implements the aggregation procedure at a product level while Statistics Canada implements it at a higher industry level. Because the adoption of the new aggregation formula by the Canadians led to small overall differences at the manufacturing level, it is presumed that implementing the method at a more detailed level would also have a small impact on the aggregate manufacturing sector.

[18] Robert E. Yuskavage, "Improved Estimates of Gross Product by Industry, 1959–94," *Survey of Current Business*, August 1996, pp. 133–155, especially p. 138.

[19] *Ibid.*, pp. 138–39.

[20] For any given interval between base periods, Canada constructed a fixed-weight Laspeyres output index. Since 1981, the base year of this index was updated every 5 years (1981, 1986, and 1992). See Kishori Lal, "Remaining Differences Between the 1997 Canadian System of National Accounts and the 1993 International System of National Accounts," OECD Meeting of National Accounts Experts, Paris, France, September 22–25, 1998 (Statistics Canada), p 23.

[21] Software enters the national accounts as purchases of software and as own-account software production. Own-account software refers to software produced by a business or government for its own use. Purchased software is produced by the computer programming and the prepackaged software industries (US-SIC87 7371 and 7372) in the service sector.

[22] For a detailed discussion of the revision, see Brent R. Moulton, Robert P. Parker and Eugene P. Seskin, "A Preview of the 1999 Comprehensive Revision of the National Income and Product Accounts: Definitional and Classificational Changes," *Survey of Current Business*, August 1999, pp. 7–20.

[23] *System of National Accounts 1993* (United Nations Statistics Division, 1993); see also note 3.

[24] Nominal GPO is measured as the sum of the distribution by industry of the components of gross domestic income (GDI). The new treatment of software as fixed investment increased proprietor's income and profit within GDI by eliminating the deductions for software purchases and by adding the value of the production of own account software. These effects were only partially offset by the deduction of the consumption of fixed capital on both purchased software and own-account software production. Thus, this change increased nominal GDI. To calculate real GPO, nominal intermediate purchases are constructed as gross output less GDI. The new treatment of software increased both gross output and GDI; however, the impact on GDI was greater, and thus the result was decreased nominal intermediate purchases. Consequently, real GPO was revised upward slightly.

[25] See Lum, Moyer, and Yusgavage, "Improved Estimates of Gross Domestic Product, 1947–98," June 2000.

[26] At the industry level, software accounts for slightly larger shares in some industries: 2.7 percent in printing, publishing and allied industries (US-SIC87 27) and in industrial and commercial machinery and computer equipment (US-SIC87 35); 2.2 percent in measuring, analyzing, and controlling instruments, photographic, medical and optical goods, watches and clocks (US-SIC87 38); and 2 percent in electronic and other electrical equipment and components, except computer equipment (US-SIC87 36).

[27] Consistency in aggregation theorem; see Diewert, "Superlative Index Numbers," July 1978.

[28] Statistics Canada.

[29] This specification is used in *Information Technology in the Service Society*, a report prepared by the National Research Council (Washington, DC, National Academy Press, 1994); see p. 23, note 1.

[30] See Robert E. Yuskavage, "Gross Product by Industry Price Measures, 1977–96," *Survey of Current Business*, March 1998, pp. 17–25, especially p. 22. In the United States, within the US-SIC87 two-digit industry electronic and other electrical equipment and components, except computer equipment, the prices of more than half the value of the products' shipments fell somewhat or greatly between 1992 and 1996. However, most did not fall to the extent the information technology items we reviewed fell. Further, by 1996, the information technology products that we reviewed in this industry made up about a third of the output of the electronics industry.

[31] See Bruce T. Grimm, "Price Indexes for Selected Semiconductors, 1974–96," *Survey of Current Business*, February 1998, pp. 8–24; see p. 9 for a brief discussion of the issues associated with the measurement of output and prices for high-tech goods.

[32] Andrew A. Wyckoff, "The Impact of Computer Prices on International Comparisons of Labour Productivity," in *Economics of Innovation and New Technology*, vol. 3 (Amsterdam, Overseas Publishers Association, 1995), pp. 277–93, especially page 282.

[33] See, for example, Ernst R. Berndt and Zvi Griliches, "Price Indexes for Microcomputers," in Murray F. Foss, Marilyn E. Manser, and Allan H. Young, eds., *Price Measurements and Their Uses*, National Bureau of Economic Research Studies in Income and Wealth, no. 57 (Chicago, University of Chicago Press, 1993), pp. 63–93, especially table 2.1.

[34] The price data are not strictly comparable because the U.S. implicit price series is a chained annual-weighted price index; the Canadian implicit price index is not.

[35] Computers, storage devices, terminals, and peripherals (US-SIC87 3571, 3572, 3575, and 3577) in the United States and electronic computing and peripheral equipment (C-SIC80 3361) in Canada. In 1992 and 1996, respectively, these industries accounted for 2.1 percent and 2.6 percent of manufacturing nominal shipments in the United States. The comparable figures for Canada were 1.2 percent and 1.6 percent.

[36] The U.S. price index is calculated by weighting the respective industry price changes by shipments shares.

[37] BEA constructed a hedonic price index for personal computers in 1987.

[38] Telephone switching equipment (US-SIC87 36611) in the United States accounted for about 41 percent of telephone and telegraph apparatus (US-SIC87 3661) in 1992. We do not have information on the relative importance of telephone switching equipment in Canada, but telephone equipment accounted for 90 percent of telecommunications equipment (C-SIC80 3351) in 1992 (Statistics Canada). In 1992 and 1996, the shares of nominal shipments for telephone and telegraph apparatus within the manufacturing sector in the United States were 0.7 percent and 0.9 percent, respectively. The comparable values in Canada for C-SIC80 3351 were 1.3 percent and 1.2 percent.

[39] After 1996, the BEA price series were linked to the appropriate BLS producer price index series. The producer price index series are based upon a matched model technique.

[40] To estimate the possible magnitude of the impact from the different techniques, we accepted the BEA choice of deflator for estimating telecommunications equipment growth. We replaced the real telecommunications equipment outputs and inputs in the Canadian real value added series with values constructed with an exchange-rate adjusted BEA price series. The results for the 1992–96 period indicated that the productivity gap between the United States and Canada would be slightly reduced (0.1 percent). Telephone switching equipment, where the different techniques are employed, accounts for less than half of the telephone and telegraph apparatus industry in the United States. We would expect the impact, therefore, to be even smaller than 0.1 percent.

[41] In the United States, the industry group is semiconductors and related devices (US-SIC87 3674). In Canada, two components of the electronic parts and equipment industry (C-SIC80 3352), semiconductors and integrated circuits, are equivalent to the U.S. industry and will be referred to as semiconductors. Semiconductors account for 72 percent of the output in C-SIC80 3352 in 1996 (Statistics Canada). In 1992 and 1996, the shares of nominal output of semiconductors within the manufacturing sector in the United States were 1.1 percent and 1.9 percent, respectively. The comparable shares in Canada for C-SIC80 3352 were 1.2 percent and 1.4 percent.

[42] The industry is US-SIC87 36741, integrated micro circuits (including semiconductor networks, microprocessors, and MOS memories).

[43] The hedonic method was used to adjust for missing prices for matched models for 32 percent of one type of microprocessor and 7 percent of a second type of microprocessor. See Bruce T. Grimm, "Price Indexes for Selected Semiconductors, 1974–96," p.22.

[44] For 1996, the BEA implicit price index for shipments of industry US-SIC87 3674 is 32.6; the BLS producer price index for that industry is 86.2 (both with 1992 = 100.0).

[45] Consumption may be from semiconductors produced in the domestic manufacturing sector or from imports.

[46] Real semiconductor output growth was removed from real value added and real semiconductor input growth was added to real value added. Then real gross output and inputs of semiconductors were re-estimated with an exchange-rate-adjusted BEA price index. The adjusted real output growth was added and the adjusted input growth was subtracted to arrive back at a measure of real value added for Canadian manufacturing. Information on the procedures used to adjust the Canadian data is available from the authors upon request. The consistency in aggregation theorem was used to make this adjustment; see Diewert, "Superlative Index Numbers," July 1978.

[47] Unpaid family workers are negligible in U.S. manufacturing and are not included in the BLS estimates of U.S. employment and hours. The Canadians use the term "other-than-paid" for the concept of unpaid workers.

[48] In this survey, jobs rather than persons are counted. Hours of labor input are treated as homogeneous units; no distinction is made among workers with different skill levels or wages. For more information on the Current Employment Statistics (CES) program, see *BLS Handbook of Methods*, Bulletin 2490 (Bureau of Labor Statistics, April 1997), pp. 15–31.

[49] See *Employee Compensation in the Private Nonfarm Economy, 1977*, Summary 80–5 (Bureau of Labor Statistics, April 1980).

[50] The direction and magnitude of any bias created by this estimation technique is not clear. Data from the CPS suggest that nonproduction workers may work more hours than production workers, in which case the estimation technique may understate hours. (See Marilyn Manser, "U.S. Labor Market Data and Issues in Comparing Goods and Services,"prepared for the 10th meeting of the Voorburg Group on Service Statistics, September 11–15, 1995.) However, the fact that production workers tend to work more paid overtime relative to nonproduction workers may cause the use of production worker hours in the estimation process to offset the issue of unpaid hours. For a bias to exist, there would have to be some change in these relationships.

[51] For nonproduction workers, the ratio hours-worked to hours-paid is only available for durable and nondurable groups within manufacturing. Therefore, industry data on hours paid are adjusted with a ratio for the appropriate group. For information on the Hours at Work Survey, see Kent Kunze, "A New BLS Survey Measures the Ratio of Hours Worked to Hours Paid," *Monthly Labor Review*, June 1984; see also *BLS Handbook of Methods*, Bulletin 2490 (Bureau of Labor Statistics, April 1997), pp. 89–102.

[52] For more information on the Current Population Survey (CPS), see *BLS Handbook of Methods*, Bulletin 2490, pp. 4–14.

[53] The Canadian Labour Force Survey (LFS) underwent a comprehensive revision in January 2000. See "Improvements in 2000 to the LFS," on the Internet at **www.statcan.ca/english/concepts/method.htm**.

[54] Labor force survey data are adjusted to a jobs basis. For completeness, estimates for Armed Forces, the Territories, and Indian reserves are added to the LFS data. Industry data are adjusted to remove own-account construction and noncommercial activities.

[55] Katharine G. Abraham, James R. Spletzer, and Jay C. Stewart, "Divergent Trends in Alternative Wage Series," in John Haltiwanger, Marilyn E. Manser, and Robert Topel, eds., *Labor Statistics Measurement Issues*, National Bureau of Economic Research Studies in Income and Wealth, no. 60 (Chicago, University of Chicago Press, 1998), pp. 293–324.

[56] The CPS collects data on a per-person basis, while the CES collects data on a per-jobs basis. Using data on multiple jobholders in manufacturing, we constructed an adjusted CPS series that converts the hours data to a jobs basis. This is consistent with efforts employed by Statistics Canada to convert the LFS data to a jobs basis. For 1998, this adjustment reduces the CPS average weekly hours for wage and salary workers from 42.2 to 41.5. Growth rates for the adjusted CPS series do not differ greatly from those of the published CPS.

[57] The SEPH collects average hours paid, rather than hours worked. Trends in SEPH data are a reasonable approximation for this comparison if it is reasonable to assume that the ratio of hours worked to hours paid did not fluctuate dramatically over the 1988–98 period.

[58] Statistics Canada.

[59] Growth of the adjusted Canadian average hours series is virtually unchanged for the 1988–98 period. The adjusted Canadian series is 0.4 percent higher for 1988–92, and 0.2 percent lower for 1992–98 than the original series. Growth of the adjusted U.S. average hours series is 0.1 percent lower for 1988–98, 0.3 percent lower for 1988–92, and 0.1 percent higher for 1992–98 than the published series.

[60] Because Statistics Canada does not use data from the Annual Survey of Manufacturers without such benchmarking, we presume that there are limitations associated with our establishment-based comparisons.

[61] The growth of the adjusted Canadian employment series is revised upward 0.2 percent for 1988–98 and 0.4 percent for 1988–92, and is unchanged for 1992–98. The growth rate of the adjusted U.S. employment series does not change for the 1988–98 period, and is revised upward 0.1 percent for 1988–92 and downward 0.2 percent for 1992–98.

[62] The growth of the adjusted Canadian series for total hours is revised upward 0.1 percent for 1988–98 and 0.9 percent for 1988–92, and revised downward 0.3 percent for 1992–98. The growth rate of the adjusted U.S. series is revised downward 0.2 percent for the periods 1988–98 and 1988–92, and revised downward by 0.1 percent for the 1992–98 period.

[63] These results indicate a fairly limited impact on the productivity gap due to the two countries' uses of different data sources for the labor hours measures for the entire 1988–98 period. However, we found that these results are sensitive to the time frame selected for analysis. For example, if the Canadian data for aggregate hours were constructed on an establishment basis, the 1992 to 1996 growth in hours would be 1.1 percent rather than the published 1.7 percent. In this case, the choice of the source for hours affects the measured gap in a substantial way.

[64] As discussed earlier, the aggregate manufacturing sectors in the United States and Canada are very similar, with the major exception of the treatment of logging. However, within the manufacturing industries, there are additional classification differences that must be taken into account. Using data supplied by Statistics Canada and BEA, we constructed 19 comparable two-digit industries. These reflect the US-SIC87, with the exception of textile mill products (US-SIC87 22) and apparel and other finished products made from fabrics and similar material (US-SIC87 23) that we were forced to combine. To make these adjustments, the consistency in aggregation theorem (Diewert, "Superlative Index Numbers," July 1978) was employed for both countries.

We were unable to match industries perfectly, but made every effort to adjust components of industries that were significant in size, and for which data could be obtained. An industry concordance was constructed based upon four-digit industry descriptions. Where these descriptions were vague, the NAICS concordance was used as a bridge to map US-SIC87 to C-SIC80. We also reviewed the publication produced jointly by the United States and Canada which presented industry concordances. See *International Concordance between the Industrial Classifications of the United Nations and Canada, the European Union, and the United States* (Bureau of the Census, Statistics Canada, and EUROSTAT, undated).

Of the 19 two-digit industries that are compared in this paper, 8 industries were considered one-to-one matches (tobacco; furniture; printing and publishing; chemicals; leather; stone and clay; primary metals; and transportation equipment). Food and rubber and plastics required aggregation of Canadian industries, while textiles and apparel required aggregation of both U.S. and Canadian industries. For the remaining industries, we obtained data from Statistics Canada at approximately the three-digit level to move components among industries. The following adjustments were made: asphalt roofing (Canada L–51) was moved from the paper industry to the petroleum industry; machine shop (Canada L–69) was moved from fabricated metals to machinery; office equipment (Canada L–86), which includes computers, was moved from electronics to machinery and computers; logging (Canada L–3) was added to lumber; and scientific instruments (Canada W–154 and 155) was separated out of miscellaneous to become the instruments industry.

[65] The weighted growth rates were calculated as

$$\left[\frac{a_i^1}{a_i^0} - 1\right] w_i^{1,0}$$

where $a_i^1 / a_i^0 - 1$ represents an industry's productivity growth, and where $w_i^{1,0}$ is the average hours share for periods 1 and 0. Because industry contributions can be constructed in different ways, we also estimated industry productivity shares as output-share weighted productivity growth and as output-share-weighted output growth less labor-share-weighted labor growth—these alternatives resulted in the same industries contributing significantly to the aggregate measures.