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Assessing Economic Performance among North American Manufacturing Establishments, 1870/71: Data, Methodology and Measurement Issues

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Abstract

A number of conceptually robust and empirically practical approaches are available to assess relative economic performance among producers who operate on either side of an international border. In this paper we discuss the impact that data compilation, methodological choice, and variable definitions may have on the quantitative and qualitative assessment of cross-border performance comparisons. As an illustrative example we use manuscript census data from 1870/71 to compare total factor productivity (TFP) among a sample of manufacturing establishments located along the Canada-US border. We briefly discuss issues associated with the preparation of manuscript census data for the measurement of cross-border TFP differentials and the establishment of industry selection criteria. We also review TFP measurement techniques, such as growth accounting calculations, cost and production function index number approaches, and econometric estimation. However, the central focus of the paper is an investigation of the impact that variable definitions have on our assessment of TFP performance. In particular, we probe the relationship between the size of cross-border TFP differentials and the reliance on a variety of common definitions for labour, capital, output, input weights, and prices.

1. Introduction

Total factor productivity (TFP) measures the efficiency of all aspects of a production process simultaneously. It captures the impact of technology, input quality, internal and external scale effects, output composition, organizational structure, market structure, and measurement errors on a producer's ability to convert inputs into output. TFP performance, therefore, can be a proxy for a firm's technical efficiency, international competitiveness, profitability, and ability to sustain economic activity – such as employment, investment, or income generation. A number of conceptually robust and empirically practical ways are available to measure both the TFP performance of an individual producer over time and the relative TFP performance of two producers at a point in time.

Like most studies of early industrialization, Canadian performance has typically been assessed relative to a United States (US) productivity benchmark. (For examples see Inwood and Keay, 2005, Keay, 2000, Denny et al., 1992, Lempriere and Rao, 1992, Baldwin and Gorecki, 1986, or Baldwin and Green, 1986.) Most of these assessments have focused on manufacturing industries, most have relied on data drawn from industrial census in the two countries, and most have used fairly standard index number measurement techniques. Despite the similarities in methodological approach and data sources, the assessments of Canadian relative to US industrial performance have not settled on a set of common, widely accepted definitions for the inputs, outputs, input weights and prices used in their productivity comparisons. Unfortunately, both the quantitative and qualitative conclusions drawn from these assessments are dependent on the definitions used.

In this paper we investigate the impact that various common definitions for inputs, outputs, input weights, and prices have on the measurement of cross-border TFP differentials. As an illustrative example, we use data that have been drawn from the manuscripts of the 1870 US and 1871 Canadian industrial census. These data describe a sample of manufacturing establishments located along the Canada-US border. More specifically, our case study illustrates the need to control for months in operation when comparing Canadian and US labour and capital inputs; we review the impact that gender and age weighting schemes have on labour measurement; we comment on the use of horse power versus value of fixed capital to measure capital inputs; we compare value added and gross value of production as output indicators; we review the available output, intermediate input and capital price deflators; and finally; we discuss eleven different ways to weight inputs in the measurement of TFP. None of the variable definitions we discuss can be dismissed on theoretical grounds and all can easily be derived from historical census data. Inevitably cross-border productivity comparisons depend on the choice of variable definitions. For this reason we must be aware of the sensitivity of our TFP results, and we must be able and willing to defend our definitions.

In Section 2 we briefly comment on the use of manuscript census data in the assessment of relative TFP. In particular, we review the need for some data aggregation, filtration, reconstitution and exclusion to improve cross-border consistency, and we discuss the selection criteria that can be used to construct samples of manufacturing industries for comparison. Section 3 includes a brief summary of the available TFP measurement techniques for both cross sectional and time series productivity comparisons. In the fourth section we illustrate the range of definitions identifying inputs, outputs, input weights, and price deflators that may be reasonably employed in relative TFP calculations. In this section we also investigate the impact definition choices may have on measured TFP differentials. The final section concludes by summarizing and commenting on desirable features one might seek in industry selection criteria, measurement techniques, and input, output, input weights and price definitions.

2. Using Manuscript Census Data

We use manuscript census data from the 1870 US industrial census and the 1871 Canadian industrial census to illustrate the impact that differences in variable definitions can have on our assessment of relative productivity performance. Our investigation, therefore, begins by considering the preparation and compilation of manuscript census data prior to the calculation of cross-border TFP differentials.

Most North American productivity studies have used information drawn from the censuses of manufacturing taken in both Canada and the US since the mid-nineteenth century. The use of data published in aggregated census tables presents some consistency problems for researchers, particularly those interested in the cross-border comparisons. Recently the manuscripts from the enumeration of late nineteenth century industrial establishments in the United States and Canada have become available in machine readable form (Atack, 1985, Inwood, 1994). The establishment-specific manuscript census data allow us to confront many of the shortcomings associated with the use of the published census tables. Through a combination of aggregation, filtration, exclusion and reconstitution of the establishment level data we can significantly improve cross-border consistency.

The census from which we draw data for our illustrative example were undertaken in the United States during June of 1870, and in Canada during April of 1871 (Canada, 1870-71, United States, 1872). The enumeration of industrial establishments was part of the larger framework of a census of population, commodity production, and property and wealth.[1] The design of the Canadian industrial schedule reflects lessons that had been learned in the 1852 and 1861 Canadian enumeration and the longer series of industrial enumeration in the United States. The Canadian ability to learn from US practice undoubtedly helps to explain the similarity between the 1870 and 1871 enumeration. The schedules from both countries identify a proprietor, type of establishment, type of power and force, capital, wages, different categories of labour (men, women, children), months of activity, and values for raw materials and products. These common elements in the US and Canadian data lay the empirical foundations for consistent cross-border TFP comparisons.

Despite the similarities, the enumerators' manuals and the schedules themselves identify a few points of difference (Canada, 1871 and 1870-71, Pg. ix-x, United States, 1870 and 1872, Pg. 373-375). In general, the differences can be easily accommodated prior to the construction of cross-border TFP comparisons. For example, because the Canadian census had an extra category for both labour (distinguishing boys from girls) and capital (distinguishing fixed from variable capital), and the US census provided detail on the number and nature of machines, some aggregation across input types is necessary to ensure a consistent comparison. Perhaps the most important difference in

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[1] The Canadian Census enumerated property using physical measures rather than wealth. The report of capital on the industrial schedule was the only Canadian attempt to value an asset in 1871. The US Census, by contrast, asked for information on personal wealth. The larger context of the two Census is chronicled in Anderson 1988 and Curtis 2001.

the two schedules is that the US census did not enumerate industrial establishments selling less than $500 of output, whereas Canadian enumerators received instructions to include any workplace that transformed raw materials, regardless of the scale of production. Admittedly, Canada did not succeed in its attempt to enumerate all establishments regardless of size, just as the US census allegedly missed some firms exceeding its threshold size (Inwood, 1995, Jentz, 1982, United States, 1872, Pg. 373). Nevertheless, because the Canadian census enumerated smaller firms than in the United States, a cross-border comparison requires that we exclude establishments in the former country reporting less than $500 of products (Inwood and Sullivan, 1993).[2]

Additional complications arise from poorly documented differences in census administration or enumerator practice. Fortunately the use of manuscript census data allows us to identify and remove entries that appear unusual or idiosyncratic. Some enumerators stated explicitly that the information for some establishments was unreliable or imprecise, either because it seemed implausible to the enumerator, or because the proprietor was absent, dead, deranged or did not maintain useful records. In addition to these obviously unreliable entries, we have employed data filters designed to exclude:

(i) Information from establishments under construction for part of the year, in rented premises, or intermittently active (because of reduced confidence in the value of fixed capital).

(ii) Information which suggests an elevated risk of imprecision in other information (for example a specified jointness with non-industrial activity or evidence of inventory fluctuations).

(iii) Information with evidence of cost-based valuation (products valued as the sum of material, or material plus labour costs).

(iv) Information that seems implausible (negative value added, or capital productivity less than one-tenth or more than ten times the average for that industry).

(v) Information that suggests a description of customary activity, even though the establishment was inactive during the census year.

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[2] The threshold in Canada is set at $400 because of the 20% depreciation of the US dollar during the US census year.

(vi) Information that seems to duplicate other records.

(vii) Information from establishments that fell outside the bounds of manufacturing.

(viii) Information from establishments that listed no employees and no wages or salaries.

One additional stage of data preparation arises when using manuscript census data because some multi-process establishments were divided or decomposed for enumeration and reporting purposes. Today we think of industrial activity as being organized in firms or companies that are defined in terms of independent management or ownership. Nineteenth century census staff, however, viewed the establishment as a spatially distinct production unit and, to some extent, a technologically distinct process. This conception facilitated product specific tabulations of information. Francis Walker, Superintendent of the US Census, commented on the processing of data from firms with products that could be classified into distinct industries:

> "One of the first difficulties encountered in the compilation of Industrial Statistics is found in the fact that in the same establishment frequently carried on two or more industrial processes which are distinct in idea, and in general practice, are separately pursued." (United States, 1872, Pg. 382-83)

The US census compiled reports of individual industries, according to Walker, by processing the records of multi-process establishments on the principle that industrial processes that could and did exist on their own would be regarded as independent establishments. Two or more milling activities appearing in every visible respect as a single firm – sharing a single power source, the same premises, common management and ownership – would be recorded in published tabulations as if they were separate establishments, even if they had been enumerated jointly. A joint saw and grist mill, for example, appears in the US published compilation as two distinct establishments with no warning that a single industrial return had been divided during the processing of the data (United States, 1872, Pg. 383).[3]

[3] Walker reports the frequency of decomposition in the leather and iron-working industries. In one county enumerators returned twenty establishments currying leather, three tanneries, and sixteen establishments that combined tanning and currying. The census office compiled and published this information as nineteen tanners and thirty-six curriers (Pg. 388-89). In the same manner foundries were separated from furnaces, mining from milling, and so on.

The decomposition of multi-process establishments could not be made, of course, in the absence of information about the individual lines of production. Perhaps for that reason enumerators were encouraged to use as many lines of their worksheet as were needed to detail the different products of large firms (United States, 1870, Pg. 20). If the enumerator failed to provide sufficient information, the decomposition was based on correspondence with the proprietors of the establishments, so far as they were disposed to release the information, or the Census Office had the force to acquire it. In the remaining cases, the decomposition was accomplished through an analysis, somewhat arbitrary in form, but conducted according to carefully obtained and approved formulae, at the Census Office (United States, 1872, Pg. 384).

Scholars working with the US industrial manuscripts have confirmed that the post-enumeration editing of manuscripts included, in some cases, the division of multi-process establishments into distinct entries (Atack, 1985, Pg. 49-55, Walsh, 1970 and 1971). A similar process is apparent in the Canadian records, particularly for rural mills.[4] Nevertheless, the Canadian case is particularly complicated because many multi-process establishments did not provide sufficient information about individual product lines to permit decomposition. The nineteenth-century authorities had to leave these records as multi-process establishments even though other establishments could be and were decomposed in a manner similar to that of the US. We eliminate the potentially serious inconsistency through a reconstitution of the divided records in both countries (Inwood, 1995). To complete the preparation of manuscript census data for our illustrative example we have organized records from both countries using a common industrial classification system, that of the 1890-91 Canadian census (Canada, 1890-91, Inwood, 1994).[5]

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[4] There are no visible indications of US influence although Canadian census staff had the opportunity to learn from their US counterparts. Walker's explanation of the 1870 US Census was published and available to the Canadians more than a year before they began their own industrial compilations in 1873. It is also known that the Canadian census staff collected reports of enumeration elsewhere (see NAC RG 17, Volume 49 #4669, Dixon to Dunkin, July 10 1871). Of course, the desire to produce tabulations of individual industries almost inevitably drove Canadian officials to divide the information returned by multi-process firms, for the same reasons as in the United States.

[5] The 1891 classification system was the most elaborate used in Canada until the 1920s.

The sequence of aggregations, exclusions, filters and reconstitutions leads to a data set composed of common variables for US and Canadian manufacturing establishments from all industries and regions in the two nations. However, if our objective is the calculation of manufacturers' relative productivity performance, we must consider which industries, regions and establishments make the cross-border comparison meaningful. For a complete and accurate comparison we would like coverage to be both extensive and representative. However, if we wish to construct comparisons relatively free of geographic, cultural and structural differences in composition, then we should confine our comparison to regions in which producers on both sides of the border shared input and output markets, information networks, transportation corridors, and environmental conditions.[6] Compositional considerations, therefore, restrict the regional extent of any meaningful comparison. For our illustrative example we examine the industrial establishments throughout Ontario, northern New York, northern Ohio, northern Pennsylvania and eastern Michigan.[7] Almost all of the Ontario industrial returns have survived, but here has been considerable loss of industrial schedules for in the border states. We use all available data from the 38 border and near-border US counties in the lower Great Lakes region whose industrial returns have survived intact.

In addition to considerations regarding regional composition, a meaningful cross-border TFP comparison must also concern itself with the criteria used to select common industries for inclusion. Again, the objective is to maintain an extensive and representative sample of establishments. There are two reasonable criteria with which one might select industries for comparison.

One approach is to compare industries that were large in terms of their output generation. If we follow this approach, we would establish an industry gross output or value added threshold; any industries that fell below this threshold would not be

[6] For a detailed discussion of the need to isolate TFP comparisons from differences in the composition of national aggregates, see Inwood and Keay 2005.

[7] Michigan counties: Genesee, Huron, Ingham, Lapeer, Lenawee, Livingston, Macomb, Monroe, Oakland, St. Clair, Saginaw, Sanilac and Shiawassee. New York counties: Fulton, Genesee, Herkimer, Montgomery, Niagara, Ontario, Orleans, St. Lawrence, Saratoga, Schenectady, Scholarie, Schuyler, Seneca, Washington and Wayne. Ohio counties: Cuyahoga, Erie, Fulton, Geauga, Huron, Sandiusky and Seneca. Pennsylvania counties: Crawford, Venango and Warren.

included, any above the threshold would be included. This approach, therefore, would capture industries with many small firms and industries with a few very large firms (probably vertically and/or horizontally integrated). The latter industries would lack sufficient degrees of freedom for any meaningful analysis. From a sample construction perspective, these industries would not be regionally or sectorally representative since in 1870 only a handful of industries were fully integrated. Virtually all of these industries were concentrated in small, well defined regions in the United States. This implies that even though these industries generated a considerable proportion of aggregate manufacturing value added, they were atypical. The inclusion of these industries would substantially undermine one's ability to comment on the relative productivity performance of a representative, or average producer in the two countries. The inclusion of highly concentrated industries would strongly bias the mean results, and more significantly, the biases would be different in Canada relative to the US.

A second approach to industry selection employs an establishment threshold criteria that will include industries with many firms. If we follow this approach, we choose a minimum number of establishments as a threshold; any industries that fall below this threshold are not included, any above the threshold are included. This approach, therefore, captures industries with many firms, be they large or small. Relative to the use of an output threshold, this approach generates a sample that is more representative from a regional and sectoral perspective and ensure a minimum sample size for each industry.

For our illustrative example we use a threshold of 50 establishments in each country. With this threshold we are able to consider 25 matching industries. Specifically, we examine the impact of alternate variable definitions on an assessment of TFP performance using the manuscript census records from 13,126 Canadian producers and 8,461 US producers that remain after our aggregations, exclusions, filters, reconstitutions and industry selection process.[8] Table 1 reports the number of establishments, aggregate gross output and aggregate value added for the 25 largest

[8] The Canadian establishments included in our sample generated approximately 31% of all domestic manufacturing GNP in 1871. The highly concentrated industries that would have been included in our illustrative example had we used an output threshold, rather than an establishment threshold, include distilleries, oil refineries, sewing machine factories, soap and candle makers, and musical instrument makers.

Canadian industries using a gross output, value added or establishment threshold to determine industry inclusion.

Insert Table 1

3. Choosing an Appropriate Methodological Approach

Robert Solow (1957) demonstrated that output growth generated by a general production technology could be expressed as a weighted average of input growth and a residual. The unexplained output growth has become known as the 'Solow Residual', or total factor productivity (TFP). TFP includes the contributions to output made by factors that are not captured by standard quantitative input measurement techniques. For example, TFP may be attributed in part to improvements in the quality of the inputs, changes in the physical technological employed, internal and external organizational changes, and under some specifications of the underlying production technology, scale effects and economic profits from resource rents or market power. TFP is commonly used as a proxy for technological change, but this is a narrow interpretation. It is more accurate to define TFP as the efficiency of all aspects of a production process measured simultaneously. In addition to technological change, the other components of TFP may be identified in isolation if adequate data exist. It is clear that if we know how efficiently a production unit can convert its inputs into output, we also know much about its economic performance. A wide range of methodological approaches are available for the measurement of TFP. Here we focus on just three of the more common techniques.

In his seminal paper on the topic, Solow (1957) reported results from an illustrative example that demonstrated how to implement his generalized TFP measurement technique. He used a constant returns to scale Cobb-Douglas production function and data from the US industrial census to show that an arithmetic weighted average of labour and capital could only explain approximately 40% of the observed US income growth over the first half of the twentieth century. Although his basic calculation method has been refined considerably over time, Solow's general approach, known as 'growth accounting', continues to be common in empirical studies that do not focus primarily on TFP measurement. Traditional growth accounting exercises were designed to calculate rates of change in TFP over time for individual production units, rather than comparing the TFP performance of two matched production units at a point in time. In addition, traditional growth accounting exercises relied on production function specifications and, therefore, required physical measures for inputs and outputs. The standard CRS, Cobb-Douglas growth accounting approach takes the form:

$$A^* = VA^* - (\alpha L^* + \beta K^*) \qquad (1)$$

Where A is the TFP parameter, VA is value added, α is the elasticity of output with respect to labour, β is the elasticity of output with respect to capital, and an * denotes a variable expressed as a rate of change over time. Under the constant returns to scale assumption ($\alpha + \beta$) must sum to one. This implies that any scale effects will be captured by the TFP parameter.

A second common measurement technique uses the results from econometric estimates of production and/or cost functions to determine the rate of change in a production unit's TFP over time. The inclusion of time parameters into regression equations allows one to measure the change in output, or cost, that cannot be explained by changes in measured inputs, or input prices. The estimated regression coefficients associated with the time parameters indicate the rate of change in TFP over time. Woolf (1984) provides an example of the use of econometric estimation to measure TFP growth for a sample of US manufacturing industries during the late nineteenth and early twentieth centuries. Econometric estimation of TFP growth introduces greater flexibility into the choice of production technology that can be considered, including the use of cost functions. The added flexibility associated with the use of cost function estimates allows researchers to employ price data to derive TFP estimates in the absence of information about physical inputs and outputs. In addition, econometric estimation of TFP growth facilitates rigorous statistical testing of the results. However, like growth accounting, econometric approaches are much better suited to the measurement of rates of change in TFP over time for single production units, rather than a comparison of TFP across production units. Another constraint on the use of econometric techniques for the measurement of TFP is quantity of data required to generate meaningful results with sufficient statistical confidence.

Diewert (1976) showed that various methods for calculating TFP indices were consistent with specific production technologies. For example, a Laspeyres or Paasche index is consistent with Leontief production technology; a geometric mean implies Cobb-

Douglas production technology; a Fisher ideal index implies square root-quadratic technology; and a Tornqvist index implies translog production functions. Diewert argued that it is desirable for index number calculation techniques to be consistent with 'flexible and superlative' production or cost functions. These flexible and superlative functions are simply second order approximations of more specific and restrictive production technologies. The most common examples of flexible and superlative production and cost functions include translog and generalized Leontief specifications. Allen (1983) provides empirical examples using data from US and UK steel mills to demonstrate the measurement of cross-border productivity differentials using various index number techniques.

For our illustrative example we use a Tornqvist calculation technique. This technique relies on the assumption that industries in the two nations employed constant returns to scale, industry and nation specific translog production functions. The Tornqvist index is among the most common calculation techniques in the TFP measurement literature[9], it is flexible and superlative, it can be used in a time series and cross sectional context, it can be implemented with both production and cost functions, and, although the results cannot support statistical tests in the same manner as econometric estimates, the data requirements are much less restrictive. Another desirable feature of our measurement approach is that, aside from the required input and output price comparisons, all of the data needed to implement the Tornqvist technique are available from the 1870/71 industrial census. For each industry included in our illustrative example the Tornqvist TFP calculation technique takes the form:

$$\frac{A_{CDA}}{A_{US}} = \left(\frac{Q/L_{CDA}}{Q/L_{US}}\right)^{0.5\,(SLC+SLU)} \bullet \left(\frac{Q/K_{CDA}}{Q/K_{US}}\right)^{0.5\,(SKC+SKU)} \bullet \left(\frac{Q/M_{CDA}}{Q/M_{US}}\right)^{0.5\,(SMC+SMU)} \qquad (2)$$

Where A_j = Hicks neutral total factor productivity in country j; $Q/\mathbf{X}_j$ = partial factor productivity of input **X** in country j; and S**X**j = input elasticity of input **X** in country j.[10]

[9] Some Canadian examples that use the Tornqvist calculation technique include Caves and Christensen (1980), Baldwin and Green (1986), Denny et al. (1992), and Keay (2000).

[10] If Q represents value added, then the shares; SLj and SKj; are income shares, rather than cost

To implement equation (2) we must have access to physical measures of output, labour inputs, capital inputs, intermediate inputs (assuming we use gross, rather than net, output figures), and we need input elasticities. All of these variables must be commonly defined and measured for each Canadian and US industry in our sample. This need for common and well defined numerators and denominators brings us to the primary focus of this paper – because a qualitative and quantitative assessment of Canadian relative to US TFP performance depends on the variable definitions used in equation (2), we must employ defensible definitions, and we must investigate the sensitivity of our results.

4. Common Variable Definitions and Their Impact on TFP

4.1 Gross and Net Output

The numerators used in equation (2) represent the output generated by manufacturing establishments in Canada and the US. We can measure output in two ways – value added (the sum of income payments to labour and capital, or equivalently, gross output less the value of all raw materials and intermediate inputs used in production) or gross output (the total value of production). Both measures have been used to compare twentieth century Canadian relative to US productivity performance.[11] The use of value added as an output measure allows one to avoid inconsistencies in the enumeration of intermediate and raw material inputs in Canada and the US, and one need not worry about the absence of reliable intermediate input prices in the two countries during the late nineteenth century. In addition, historical TFP comparisons based on value added output measures generate results that are consistent with modern national accounting techniques which, in turn, implies that value added output measures facilitate the investigation of questions associated with national income or welfare generation. However, there are some issues associated with the use of value added that may encourage us to carefully consider the gross output alternative.

When we use value added as numerators in equation (2) we explicitly exclude any recognition of differences in intermediate and raw material input intensity among

shares, and the intermediate input productivity ratio is not included.

[11] For an example using value added see Baldwin and Gorecki, 1986. For an example using gross output see Denny et al., 1992.

the Canadian and US producers (Lempriere and Rao, 1992, Pg. 5). From table 5 we can see that for both the Canadian and US industries in our study intermediate and raw material inputs consistently account for the largest share of total cost, and that the shares differ for all 25 industries in our sample. This implies that excluding these inputs in the calculation of TFP may have a subsidiary impact on the weights we assign to remaining labour and capital inputs. The resultant changes in the input weights may be of particular concern in Canada-US comparisons because the exclusion of intermediate inputs seems to have a disproportionately large impact on the Canadian establishments in our bi-national sample.

Keay (2000) illustrates that the use of value added, rather than gross output, as numerators in equation (2) generates a considerably more pessimistic picture of early twentieth century Canadian relative to US TFP performance. Because lower numerators in equation (2) lead to more pessimistic TFP ratios for the Canadian producers, we can see from table 2 that this potential bias may also hold for our 1870/71 sample. Among our establishments Canadian relative to US gross output figures are higher than Canadian relative to US value added figures for 16 of the 25 industries, and on average Canadian gross output was only 23.9% lower than US gross output, while Canadian value added was 32.1% lower. The figures in table 2 indicate that in 1870/71 Canadian manufacturers were faced with proportionately higher intermediate input costs than their US counterparts, due to some combination of higher intermediate input prices and more intensive intermediate input use. This, in turn, suggests that suppressing an explicit consideration of relative intermediate input productivity may result in an incomplete assessment of Canadian relative to US performance.

Insert Table 2

4.2 Labour

For the measurement of the first of the denominators used in equation (2) – labour –we must address two issues. The first is the treatment of months in operation. The second is the treatment of female and child labour. From table 3 we can see that on average the Canadian industries in our study operated for nine months and 27 days per year. The US industries operated for slightly more than one additional day, on average. The average across industries masks much of the cross sectional variation.

While only seven of the industries had differences in their months in operation in excess of 5%, some industries – lime, cut stone and wool mills, for example – differed in their input utilization much more dramatically. If we did not adjust our labour measures by months in operation, we would implicitly be assuming that Canadian and US producers operated for the same number of months, and therefore, we would be biasing our productivity ratios against the Canadian establishments.

Insert Table 3

The issue of female and child labour is similar. Again, from table 3 we can see that on average the Canadian establishments included in our illustrative example employed 0.195 women for every male employee and 0.106 children for every male employee. The US establishments, in contrast, employed only 0.158 women per male and 0.053 children per male. For some industries – boot and shoe producers, clothing makers, flour and grist mills, furriers, shingle makers and wool mills, for example – the gender and age composition of the Canadian and US work forces were very different. If we simply used an unweighted aggregation of male, female and child labour we would again be biasing our average productivity assessment against the Canadian establishments, assuming that these three categories of labour are not equivalent in terms of productive capacity. To account for differences in productive capacity we can apply weights to the male, female and child labour figures for each establishment. The question then becomes; "What weights best control for gender and age specific productive capacity?" In his study of manufacturers in the southern US states in the late nineteenth century Tchakerian (1994) multiples female employees by 0.5 and children by 0.0 to adjust for reduced productive capacity. The origin of these weights is unclear, and it seems extreme to assume that child labour added nothing to the productive capacity of manufacturing establishments. Goldin and Sokoloff (1982) report that during the last half of the nineteenth century in the US women earned approximately three quarters as much as men and children earned approximately half as much as adult men. If we assume that relative wages reflect relative productive capacity, then it seems reasonable to generate a labour input measure by multiplying male employees by 1.00, female employees by 0.75 and children by 0.50. If we multiply this weighted average by the number of months in operation, we can then generate male equivalent months in operation as a measure of the labour input to be used in the denominators of equation (2).

4.3 Capital

Studies that rely on data from manufacturing census have problems with the measurement of the second of the denominators used in equation (2) – capital. Canadian census enumerators collected information on the 'value of fixed capital' employed by manufacturing establishments, the 'type of power' – human, animal, water, or steam – and total 'horsepower' employed. For the measurement of TFP we would like to define capital as the value of land, plant, machinery and equipment employed in production, net of depreciation and denoted in current 1870/71 dollars for every establishment. Although the 'value of fixed capital' comes close to this definition, we cannot claim with confidence that depreciation has been consistently removed from all reported values, nor can we know if values have been consistently reported in current, rather than historic, replacement, or scrap costs. Virtually all other productivity studies using Canadian or US manuscript census data have used 'value of fixed capital' as their capital measure[12], and deviations from modern depreciation and valuation techniques may have been similar in the Canadian and US data, implying that these deviations would cancel each other out in Canada-US comparisons. However, an even more compelling reason to use 'value of fixed capital' as a capital measure is that the alternative is more problematic, rarely reported, and further from our ideal definition.

From table 4 we can see that on average across all 25 Canadian industries only 32.6% of the establishments that reported a positive value for fixed capital reported a positive value for horsepower, more than 20% of the establishments that reported a positive value for fixed capital also reported a positive value for horsepower among only 10 of the 25 Canadian industries, and among four of the 25 industries no establishments reported positive values for horsepower. It is apparent that for many establishments included in the 1870/71 manuscripts there is very little horsepower reported, despite that fact that virtually all report some value for fixed capital. Typically, this problem is more prevalent among Canadian establishments, and it suggests that horsepower may

[12] For example see Sokoloff (1984) Pg. 363, Tchakerian (1994) Notes to Table 4, or Inwood and Keay (2005).

be a poor proxy for the type of capital that was most commonly employed by manufacturers in 1870/71.

Insert Table 4

As a final note regarding capital measurement, similar to the discussion regarding adjustments made to labour figures, differences in Canadian and US months in operation imply that it is desirable to multiply capital inputs by months in operation to control for cross-border differences in seasonal capital utilization.

4.4 Price and Currency Comparisons

To avoid any confusion associated with changes in nominal values versus real efficiency gains, all time series and cross sectional productivity studies must control for movements in prices. When one wishes to construct cross-border comparisons, and the data employed have been drawn from industrial census, then the need to carefully convert nominal values into real input and output measures is particularly acute. With our illustrative example there are two issues associated with the conversion of nominal to real values that we must consider. The Canadian census provides information on gross output, the value of intermediate inputs and the value of fixed capital in Canadian dollars and at Canadian prices. The US census provides these data in US dollars and at US prices. If the data employed were drawn from the period just prior to 1860, between 1879 and the 'great depression', or during the Bretton Woods era, then because the Canadian and US currencies were linked to a gold standard during these periods, there would be no need to worry about currency exchange. However, in 1870/71 the US was in the midst of the 'greenback' inflationary period, during which the value of the US dollar was driven down relative to gold backed currencies, including Canada's, because the US government attempted to facilitate a post-Civil War recovery through currency devaluation. On average during 1870 $1.00 US could be exchanged for less than $0.83 Canadian (Prados, 2000, Table 9).

If differences in currency values were our only concern, then it would be a simple matter to convert US nominal values into Canadian equivalent dollars and continue with our cross-border productivity comparison. However, the second and more substantive problem is price variation between Canada and the US.[13] Maddison (1995) uses a 1970 purchasing power parity (PPP) measure, in conjunction with annual wholesale price indices, to convert the general price level in Canada into a US currency and price equivalent at 10 year intervals through most of the nineteenth and twentieth centuries. Maddison's PPP estimate suggests that, after controlling for currency exchange and price differences, $1.00 US could buy less than $0.75 Canadian in 1870. Prados (2000) has used a more sophisticated econometric technique to derive out-of-sample predictions of Canada-US PPP measures in an effort to improve on Maddison's G.D.P. per capita comparisons. Prados' PPP estimate suggests that, after controlling for currency exchange and price differences, $1.00 US could buy less than $0.62 Canadian in 1870. The lower prices in Canada relative to the US implicit in Maddison's and Prados' PPP measures have persisted over most of the nineteenth and all of the twentieth centuries. If we do not adjust for these price differences, then all of the differences between nominal values in the two countries will be inaccurately attributed to efficiency differences. There are a number of approaches one may adopt in an effort to convert nominal input and output values into real measures for use in equation (2).

(i) First, we could use no currency or price conversion. This approach assumes that at the time our data was collected Canadian and US currencies were of equal value and there were no price differences between the two nations. All of the available empirical evidence suggests that both of these assumptions have been invalid throughout the nineteenth and twentieth centuries.

(ii) Second, we could use the official exchange rate to convert US values into Canadian equivalents. This assumes that there have been no price differences between the two nations, but that the currencies have had different values. Again, empirical evidence suggests that price differences between Canada and the US have been persistent and substantial.

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[13] Prices vary not only between Canada and the US, but also between the individual establishments within each industry and nation. This suggests that to truly control for price differences in our comparisons, we would like establishment specific prices. The collection of this type of price information is not feasible at this time. Our goal is merely to provide rough proxies for Canada-US price differences at the industry level.

(iii) Third, we could use Maddison's or Prados' PPP measures to convert US values into Canadian equivalents. If we use Maddison's PPP measure we must assume that the composition of the basket of goods making up the general price level in 1970 has been unchanged. Given the changes in technology, average incomes and consumer preferences throughout the nineteenth and twentieth centuries, it seems unlikely that this assumption holds. If we use Prados' PPP measure we must assume that his out-of-sample predictions accurately reflect changes in the composition of the basket of goods making up the general price level in Canada and the US. More generally, because these two PPP measures are proxies for a GDP deflator they are meant to control for price and currency differences among a typical basket of goods and services purchased by an average consumer in the two nations. This implies that they do not distinguish between the output prices for manufactured products and prices for all non-manufactured output goods and services, and they do not distinguish between input prices and output prices. Cross-border productivity comparisons require an adjustment for differences in both the value of the Canadian and US currencies, and for differences in input and output price levels specific to the manufacturing sectors in the two nations. A GDP deflator is unlikely to be an accurate proxy for sector specific, producer prices.

(iv) A final price and currency conversion approach – our preferred approach – involves the construction of PPP measures that are specific to the inputs and outputs associated with the manufacturing industries in our sample. To be more specific, we have calculated a rough proxy for Canadian relative to US output and intermediate input prices specific to the industries included in our sample by noting the single largest (by value) output product and raw material input for each of the 25 industries in the 1910 Canadian census of manufacturing. We then sought an 1870 nominal price for these products and raw material inputs in Canada (Ontario if possible).[14] Armed with as detailed a description as possible of the Canadian products and raw material inputs for which we had nominal

[14] Virtually all of the Canadian nominal prices came from the Dominion Bureau of Statistics, Prices and Price Indexes, 1913-1925. Virtually all of the US nominal prices came from US Statistical Abstracts (various years).

prices, we attempted to find a matching nominal price for the US (New York if possible). We then generated relative nominal price ratios for the seven industries for which we could find matching output prices, and the twelve industries for which we could find matching intermediate input prices. We constructed an arithmetic average of these ratios using industry level shares of aggregate value added as weights. Our industry specific PPP measures indicate that $1.00 spent on US manufactured products was equivalent to less than $0.77 spent on the same products in Canada, and $1.00 spent on US intermediate inputs could acquire only $0.75 in similar Canadian intermediate inputs. Our industry specific output price conversion is very similar to the figure used by Maddison as a GDP deflator for 1870, its use does imply that Prados' measure considerably overestimates Canada-US price differentials in 1870. There are no other intermediate input price ratios available for the late nineteenth century with which we can compare our intermediate input PPP measure.[15]

To convert Canadian and US nominal values for fixed capital into real values we have constructed a user cost of capital ratio for Canada and the US in 1870. Our ratio takes the form:

$$Wk_{CDA} / Wk_{US} = (Pk_{CDA} / Pk_{US}) \times (i_{CDA}^* / i_{US}^*) \qquad (3)$$

Where Wk_j = user cost of plant, equipment and machinery in country j; Pk_j = purchase price for plant, equipment and machinery in country j; and i_j^* = real interest rate in country j.[16] Our user cost of capital price ratio indicates that in 1870 $1.00 spent on US plant, machinery or equipment was equivalent to more than $1.12 spent on the same inputs in Canada. This suggests that, unlike the output produced and the intermediate inputs used by manufacturers in Canada and the US, capital inputs were more expensive in Canada in 1870. There are no other capital cost ratios available for the late nineteenth century with which we can compare our capital input specific PPP measure.

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[15] Our intermediate input price comparison is broadly consistent with the qualitative comparisons made by Mitchell (1935).

[16] The ratio of Canadian relative to US purchase prices for capital has been taken from Collins and Williamson (2001). The nominal interest rate and inflation rate for Canada have been taken from the McInnis macro-history data set. The nominal interest rate and inflation rate for the US has been taken from the NBER macro-history data set.

4.5 Input Elasticities

Theoretically the weights in equation (2) are intended to be input elasticities with respect to output. If production occurs in an economic environment characterized by perfect competition and constant returns to scale, then the input elasticities can be measured as income or cost shares (depending on our choice of output measure). Productivity studies have employed a wide variety of techniques for the calculation and/or estimation of the weights in equation (2).

Bozza (2000) describes in detail the calculation of three sets of income shares and four sets of cost shares that can be used to construct Canadian relative to US TFP ratios using manuscript census data. If we use value added as the output measure, then we can calculate one set of income shares based on the assumption that fixed capital has been poorly enumerated, and should therefore be a residual factor when calculating input weights. In this case, labour's income share is defined to be the total wage bill divided by value added for each establishment, and the capital income share is the difference between one and labour's share. We can calculate a second set of income shares that rely on the assumption that payments to labour were poorly enumerated, and labour should therefore be the residual factor. In this case, capital's income share is defined to be 30% of the value of fixed capital employed by each establishment (15% for net user cost and 15% for depreciation) divided by value added, and labour's share is the difference between one and capital's income share.[17] A third set of income shares may be employed if we are not confident that intermediate input costs, and hence value added figures, have been enumerated accurately. This third set of income shares uses reconstructed, rather than reported, value added. More specifically, we can calculate labour's income share to be the total wage bill divided by the sum of the total wage bill and 30% of the value of fixed capital employed, capital's income share will then be 30% of the value of fixed capital employed divided by the sum of the total wage bill and 30% of the value of fixed capital employed.

[17] Because the Canadian industries had substantially higher capital productivity relative to the US industries, the results are somewhat sensitive to the construction of the capital cost share. Assuming greater user cost or depreciation figures improves the relative T.F.P. performance of the Canadian industries.

If we use gross output as our output measure, then we can calculate four sets of cost shares. Similar to the income share calculations, the first three sets of cost shares assume that capital, labour or intermediate inputs were enumerator poorly, and therefore each may be treated as a residual factor. For the fourth set of cost shares total cost is reconstructed from the sum of the total wage bill, 30% of the value of fixed capital employed and the cost of intermediate inputs.

In an effort to avoid the need to calculate income or cost shares based on some arbitrary assumptions about the quality of the enumeration of various values in the census of manufactures, Sokoloff (1984), Baldwin and Gorecki (1986) and Atack (1985) econometrically estimated industry and country specific production functions, and used the resultant parameter estimates to derive input elasticities. The reliance on econometric estimation, of course, requires sufficient data for the estimation of all relevant parameters, and increasing quantities of data facilitate the identification of statistically significant results. For our illustrative example we have derived input elasticities for Cobb-Douglas production functions and translog production functions for all 25 Canadian and US industries. Because Cobb-Douglas production technologies are special cases within the more general family of translog production technologies, we maintain technological consistency when we use either set of input elasticity estimates in the Tornqvist index described by equation (2). To maintain the constant returns to scale assumption implicit in our use of income and cost shares, we restricted our production function estimates to be homogeneous of degree one in output. Income and cost shares are theoretically equivalent to the input elasticities we have econometrically estimated if Canadian and US producers operated in an environment of perfect competition and constant returns to scale. The absence of perfect competition and constant returns to scale does not invalidate the use of the income shares, cost shares, or input elasticity estimates, it simply implies that any deviations from these conditions will be reflected in the TFP ratios.

For our illustrative example we have calculated three sets of income shares and estimated two sets of input elasticities using value added as an output measure. We have also calculated four sets of cost shares and estimated two sets of input elasticities using gross output as an output measure. Aside from issues associated with data requirements and statistical significance among the econometrically estimated input elasticities, it is not clear which set of weights is the most desirable. It is, however, clear that the choice among the sets of weights does have an impact on our assessment of relative TFP performance. Because Canadian capital productivity was relatively high in 1870/71, the weights that favour capital tend to generate more optimistic performance assessments, from a Canadian perspective. These include the income and cost shares that treat capital as the residual factor, and the Cobb-Douglas input elasticity estimates. Because Canadian labour productivity was relatively low, the weights that favour labour tend to generate more pessimistic performance assessments, from a Canadian perspective. These include the income and cost shares that treat labour as the residual factor, and the translog input elasticity estimates. In table 5 we report three sets of Canadian weights that can be used in equation (2), all of which assume gross output is the output measure – reconstructed cost shares, estimated input elasticities derived from Cobb-Douglas production functions, and estimated input elasticities derived from translog production functions. In general, all three sets of weights are quite similar – exceptions include blacksmith shops, brick and tile producers, cabinet makers, carpentry shops, furriers, printing shop, sawmills, and shingle makers. We can also conclude that regardless of which set of weights we consider intermediate inputs' shares tend to be by far the largest, and labour tends to account for larger shares than capital.

Insert Table 5

4.6 The Impact on TFP Assessment

For our illustrative example we have generated Canadian relative to US TFP ratios for 25 manufacturing industries using manuscript census data from 1870/71, drawn from a carefully and consistently constructed sample of 13,126 Canadian manufacturing establishments and 8,461 US manufacturing establishments. We could have generated TFP ratios using a wide range of methodological approaches, but in an effort to focus on the impact that common variable definitions have on productivity assessment, we have confined ourselves to the Tornqvist index number approach – described by equation (2).

Although there are many ways to adjust for the number of months an establishment was in operation, and for the gender and age of an establishment's employees, we have calculated TFP ratios using only two definitions for labour. Our first definition makes no adjustments whatsoever and simply sums all reported employees, regardless of gender, age, or months in operation. Our second definition measures male equivalent months in operation by weighting female and child workers by their approximate relative wages and then multiplying the male equivalent number of employees by the number of months in operation.

To measure the Canadian and US establishments' capital inputs we could use reported horse power, but the reduction in the number of establishments in our sample with complete information, particularly for Canada, would be severe. Therefore, in our illustrative example we have only defined capital as the value of fixed capital multiplied by the number of months in operation.

For an output measure we have used both gross value of production and value added. The choice between the output measures is perhaps the most controversial because there are very good reasons for using either definition depending on exactly what question, issue or debate one wishes to address.

Price and currency conversion is another problematic issue for cross-border productivity assessment because the approach one chooses to adopt has a substantial impact on the qualitative and quantitative results, and for any dates earlier than the 1960s there are very few empirically robust cross-border price and currency comparisons available. For our illustrative example we have used all of the available options for 1870/71 Canada – US price and currency comparisons. More specifically, we have calculated Canadian relative to US TFP with no price or currency conversion, with only an official exchange rate conversion, with Maddison's and Prados' general PPP measures, and with the Inwood-Keay output price, intermediate input price and user cost of capital conversion measures described in sub-section 4.4.

Finally, for the weights used in equation (2) we have used two sets of econometrically estimated input elasticities and three sets of income shares when we are using value added as our output measure. When we use gross value of production as our output measure we have used two sets of econometrically estimated input elasticities and four sets of cost shares.

Insert Figure 1

To summarize – for our illustrative example we have generated TFP ratios at the mean of the data for 25 matching Canadian and US manufacturing industries using two labour definitions, one capital definition, two output measures, nine input weighting schemes, and five price and conversions techniques. In total, therefore, we have generated 110 relative TFP ratios for each industry. Along the horizontal axis in figure 1 we have listed the 25 industries included in our illustrative example starting with the industry with the lowest median TFP ratio – cut stone producers – and finishing with the industry with the highest median TFP ratio – wool mills. In figure 1 we have also illustrated the maximum relative TFP ratio for each industry and the minimum relative TFP ratio for each industry.

There are a number of observations we can make based on the results illustrated in figure 1. If we consider only the minimum ratios for each industry in our illustrative example, then all 25 Canadian industries appear considerably less efficient than their US counterparts in 1870/71. The mean minimum TFP ratio across the 25 industries is only 0.62, and only three of the Canadian industries' TFP performances are within 15% of the matching US industries' TFP performances – harness makers, wool mills and tanneries. The minimum relative TFP ratios, therefore, clearly indicate that Canadian producers were dramatically less efficient than their US counterparts. However, if we consider the maximum relative TFP ratios for each industry in our illustrative example, then we would be compelled to reach a very different qualitative conclusion. 23 of the 25 industries' maximum TFP ratios are greater than one, and the mean maximum TFP ratio across all of the industries is 1.54. Only five of the industries have maximum relative TFP ratios with a 15% or smaller differential – cheese factories, watch makers, carpentry shops, flour and grist mills, and printing shops. The story one can tell with the maximum relative TFP ratios, therefore, is in stark contrast to the pessimism associated with the minimum relative TFP ratios.

Not surprisingly, the minimum relative TFP ratios illustrated in figure 1 consistently rely on unadjusted labour figures, they use no output or input price and currency conversion, and the input weighting schemes tend to favour labour and minimize the importance of capital – for example, they use cost shares that consider labour the residual factor. On the other hand, the maximum relative TFP ratios illustrated in figure 1 consistently use labour figures adjusted for cross-border differences in female and child employment and months in operation, Prados' PPP measures and input weights that favour capital over labour. As we have discussed in the sections above, there are fairly compelling theoretical and empirical reasons for using caution when we employ some of the input definitions that contribute to the generation of both the maximum and the minimum TFP ratios.

The median relative TFP ratios illustrated in figure 1 are not necessarily constructed with the most desirable combination of variable definitions, but they do provide a more muted and ultimately a more satisfactory basis for comparison. Nine of the 25 industries have median relative TFP ratios greater than one, indicating superior Canadian productivity performance. The average median relative TFP ratio across all 25 industries is 0.93, and 11 of the 25 industries have median TFP ratios with a 15% or smaller differential. The median TFP ratios, therefore, tell yet another story about Canadian relative to US productivity performance in 1870/71. In particular, the median TFP ratios indicate that for most manufacturing industries, and on average, there was very little productivity difference between producers on either side of the international border in 1870/71.

The final observation we can make based on the results illustrated in figure 1 is that for all of the industries there is considerable quantitative variation over the 110 relative TFP ratios. For 23 of the 25 industries our qualitative assessment of Canadian manufacturing productivity performance switches from pessimism to optimism depending on our choice among the variable definitions we have employed. For some of the industries the difference between the maximum and minimum relative TFP ratios was dramatic – lime kilns and wool mills, for example, increase their TFP ratios by more than a factor of 3.5 when we move from the minimum to the maximum ratio.

In table 6 we report the maximum, minimum and median relative TFP ratios for each industry illustrated in figure 1. We also report the coefficient of variation[18] for each industry to emphasize the quantitative variation across the ratios. As we have already mentioned, lime kilns and wool mills have particularly high coefficients of variation, while printing shops, cabinet makers and bakeries have particularly low coefficients of variation. The industries with little difference between their maximum

[18] For each industry the coefficient of variation is equal to the standard deviation across all 110 TFP ratios divided by the mean TFP ratio.

and minimum TFP ratios tend to have similar relative labour, capital and intermediate input productivity ratios. The Canadian industries with larger differences between their maximum and minimum TFP ratios tend to have very low labour productivity and very high capital productivity, relative to their US counterparts. Substantial differences in partial factor productivity ratios exacerbate differences in the input weighting schemes used to calculate relative TFP. For example, because Canadian wool mills have very high relative capital productivity and very low relative labour productivity, any change in the input weighting scheme that favours capital will result in a dramatic improvement in their relative TFP performance.

Insert Table 6

In table 6 we have also reported our 'preferred' TFP ratio. This ratio is preferred because it has been constructed using the variable definitions that address most of our concerns regarding accuracy and consistency across establishments, industries and the international border. Of course, the desirable features of the variable definitions that were used in our preferred ratio are dependent on the question, issue or debate we wish to address with the results. In our illustrative example we are primarily interested in assessing the technical efficiency of Canadian manufacturing establishments relative to US manufacturing establishments in 1870/71. Therefore, for our preferred TFP ratio we have used male equivalent months in operation, the value of fixed capital, the gross value of production, reconstructed cost shares[19], and the Inwood-Keay output and input price and currency conversions. Similar to the median relative TFP ratios reported in table 6, our preferred TFP ratio generates muted results in our illustrative example. The average across all 25 industries for our preferred ratio is 0.928, nine of the 25 Canadian industries appear to have been more efficient than their US counterparts, and 16 of the 25 Canadian industries' TFP performance was within 15% of their US counterparts' performance. If we rely on our preferred TFP ratios, for most of the industries in our illustrative example there does not appear to have been any substantial productivity differential between the Canadian and US producers in 1870/71.

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[19] Our choice of input weights is somewhat arbitrary because none of the available schemes is obviously superior to the others on theoretical or empirical grounds. In both Canada and the US the reconstructed cost shares are near the average amongst the sets of weights available, implying that the TFP ratios using these weights are not substantially biasing our conclusions.

5. Summary and Conclusions

When we use manuscript census data to assess TFP performance there are a number of issues associated with consistency and accuracy that must be addressed. These issues are exacerbated if we are interested in cross-border productivity comparisons. However, with careful data preparation, exclusions, reconstitutions, aggregation and filtration most of our more serious concerns about data quality can be overcome. To compare TFP performance at a point in time (or across time) the Tornqvist index number approach is not only one of the most common techniques employed, it is flexible, theoretically robust and empirically tractable. We conclude, therefore, that when one wishes to compare economic performance across international borders there are issues of concern regarding data preparation and methodological choice, but these issues can be acknowledged and addressed. However, having carefully prepared the appropriate data and selected a methodological approach, there remain a number of issues associated with variable definitions that pose problems for relative efficiency measurement. Defining key variables used to calculate relative TFP ratios is important because there are a number of common input, output, input weighting and price conversion measures that can have both a quantitative and qualitative impact on our assessment of productivity performance.

To investigate the sensitivity of TFP assessment to various common variable definitions we have used an illustrative example in which we calculated 110 relative TFP ratios for 25 Canadian and matching US manufacturing industries using data drawn from the manuscripts of the 1870 US and 1871 Canadian census of manufacturing. We find that the most pessimistic assessment of Canadian performance suggests dramatic inefficiencies relative to US manufacturers among virtually all of the industries considered in our example, while the most optimistic assessment paints a very different picture of Canadian performance. Among all the industries in our example there is substantial variation between the most pessimistic and most optimistic relative TFP ratios. Our preferred set of variable definitions generates fairly muted relative TFP ratios that coincide closely with the median relative TFP ratios we have generated for each industry. In particular, our preferred TFP ratio indicates that for most of the industries, and on average, there was only a small TFP differential in favour of US producers in 1870/71.

We have considered the cross-border productivity comparison in the context of two countries at a particular historical moment and using specific sources, but much of our methodology and many of the issues are relevant to other historical comparisons. Our illustrative example suggests that both quantitative and qualitative assessments of TFP performance depend on the combination of variable definitions employed. This in turn implies that those interested in productivity performance should be aware of the sensitivity of published results and they should demand meticulous data preparation, theoretically robust methodological choice, and defensible variable definitions.

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7. Appendix: Tables and Figures

Table 1: Twenty-Five Largest Canadian Industries Using Three Industry Selection Criteria

Gross Output Threshold				Value Added Threshold				Establishment Threshold			
Industry	N	PQ (M$)	VA (M$)	Industry	N	PQ (M$)	VA (M$)	Industry	N	PQ (M$)	VA (M$)
Flour	418	12.22	1.34	Foundry	365	7.74	4.16	B-Smith	2136	1.91	1.23
Foundry	365	7.74	4.16	Sawmill	1015	7.06	2.52	Woolmill	1745	3.54	1.15
Sawmill	1015	7.06	2.52	Shoe	1510	4.10	1.91	Shoe	1510	4.10	1.91
Clothing	899	4.86	1.74	Carriage	1391	2.82	1.82	Carriage	1391	2.82	1.82
Shoe	1510	4.10	1.91	Clothing	899	4.86	1.74	Sawmill	1015	7.06	2.52
Woolmill	1745	3.54	1.15	Distillery	9	2.22	1.45	Clothing	899	4.86	1.74
Carriage	1391	2.82	1.82	Flour	418	12.23	1.34	Harness	527	1.26	0.64
Baking	327	2.68	0.65	B-Smith	2136	1.91	1.23	Cooper	487	0.87	0.47
Meat	77	2.65	0.43	Woolmill	1745	3.54	1.15	Cabinet	447	2.10	1.11
Tannery	356	2.60	0.86	Cabinet	447	2.10	1.11	Flour	418	12.23	1.34
Oil	32	2.28	0.99	Oil	32	2.28	0.99	Shingle	398	1.96	0.90
Distillery	9	2.22	1.45	Shingle	398	1.96	0.90	*Lime*	385	0.18	0.11
Cabinet	447	2.10	1.11	Printing	132	1.62	0.88	Fish	368	1.11	0.52
Shingle	398	1.96	0.90	Tannery	356	2.60	0.86	Foundry	365	7.74	4.16
B-Smith	2136	1.91	1.23	Brewery	93	1.47	0.80	Tannery	356	2.60	0.86
Printing	132	1.62	0.88	Baking	327	2.68	0.65	Baking	327	2.68	0.65
Brewery	93	1.47	0.80	Harness	527	1.26	0.64	*Potash*	264	0.34	0.16
Harness	527	1.27	0.64	SewMch	10	0.91	0.56	Cheese	237	1.25	0.20
Cheese	237	1.25	0.20	Fish	368	1.11	0.52	Tile	223	0.46	0.32
Fish	368	1.11	0.52	Cooper	487	0.87	0.47	*Carpty*	177	0.22	0.14
SewMch	10	0.91	0.56	Meat	77	2.65	0.43	Printing	132	1.62	0.88
Cooper	487	0.87	0.47	Door	109	0.77	0.41	*Pump*	129	0.15	0.11
Door	109	0.77	0.41	Brick	223	0.46	0.32	Door	109	0.77	0.41
Candle	27	0.48	0.07	*MusInst*	22	0.41	0.26	Brewery	93	1.47	0.80
Brick	223	0.46	0.32	Cheese	237	1.25	0.20	*Photo*	78	0.12	0.08
Total	**13338**	**70.97**	**27.13**	**Total**	**13333**	**70.90**	**27.32**	**Total**	**14216**	**63.44**	**24.24**

Note: The industries are listed in descending order for each threshold.
Note: Industries in *italics* are only included under the given industry selection criteria.
Note: Because we have matched Canadian and US industries using an establishment threshold, in our example only industries with 50 or more establishments in both nations are included.

Table 2: Canadian Relative to US Gross Output and Value Added

Industry	PQ Cda / PQ US	VA Cda / VA US
Baking	1.657	1.014
Blacksmith	0.353	0.416
Bootshoe	1.164	0.940
Brewery	1.457	1.468
Bricktile	0.599	0.556
Cabinet	1.089	0.840
Carpentry	0.408	0.488
Carriage	0.791	0.771
Cheese	0.396	0.321
Clothing	0.809	0.602
Cooperage	0.231	0.304
Flour	1.075	0.670
Foundry	0.726	0.860
Furrier	0.160	0.145
Harness	1.165	1.143
Lime	0.117	0.147
Photo	0.876	0.830
Printing	1.434	1.194
Sashdoor	0.507	0.588
Sawmill	0.692	0.544
Shingle	0.471	0.491
Stone	0.638	0.404
Tannery	0.420	0.575
Watch	1.695	1.594
Woolmill	0.092	0.077
Mean	**0.761**	**0.679**

Note: Industries are listed in alphabetical order.
Note: The US gross output figures have been adjusted for price and currency differentials using the Inwood-Keay PPP measure. See Section 4.4.
Note: the US value added figures have been adjusted for price and currency differentials using Maddison's more general 1870 PPP for cross border GDP deflation.
Note: Industries in *italics* have more optimistic Canadian gross output figures.

Table 3: Canadian Relative to US Months in Operation, Canadian and US Female Employees per Male Employee, and Canadian and US Child Employees per Male Employee

	Months Cda / Months US	Female / Male Cda	Female / Male US	Child / Male Cda	Child / Male US
Baking	1.042	0.125	0.117	0.171	0.054
Blacksmith	0.981	0.001	0.002	0.037	0.004
Bootshoe	0.985	0.138	0.030	0.079	0.013
Brewery	1.093	0.006	0	0.016	0.013
Bricktile	0.961	0.013	0.003	0.154	0.030
Cabinet	0.998	0.055	0.056	0.054	0.032
Carpentry	0.983	0	0.007	0.025	0.009
Carriage	1.006	0.003	0.003	0.032	0.007
Cheese	0.950	0.581	0.490	0.164	0.015
Clothing	1.059	2.459	1.465	0.265	0.196
Cooperage	1.028	0	0.009	0.043	0.075
Flour	1.100	0.007	0.020	0.035	0.015
Foundry	1.049	0.006	0.003	0.061	0.035
Furrier	1.199	0.006	0.405	0.083	0.012
Harness	1.015	0.007	0.021	0.063	0.005
Lime	0.471	0.001	0	0.056	0.012
Photo	1.009	0.138	0.127	0.155	0.029
Printing	1.043	0.116	0.118	0.232	0.248
Sashdoor	0.949	0.004	0	0.110	0.062
Sawmill	0.970	0.004	0.006	0.038	0.022
Shingle	1.033	0.006	0.020	0.209	0.127
Stone	1.152	0.003	0.001	0.027	0.014
Tannery	1.026	0.020	0.048	0.064	0.019
Watch	1.026	0.016	0.053	0.156	0.040
Woolmill	0.627	1.168	0.936	0.330	0.231
Mean	**0.990**	**0.195**	**0.158**	**0.106**	**0.053**

Note: Industries listed in alphabetical order.
Note: Industries in *italics* were in operation fewer months of the year, employed more women per male employee and employed more children per male employee.

Table 4: Mean Values of Fixed Capital and Horsepower Reported by Canadian Industries

	Mean Value of Fixed Capital (C$)	Mean Horsepower	% Establishments Reporting Horsepower
Baking	1316.405	7	2.128
Blacksmith	275.95	5.421	0.762
Bootshoe	597.729	3	0.324
Brewery	9527.609	30.059	71.579
Bricktile	770.563	41.556	70.543
Cabinet	2723.483	40.714	34.515
Carpentry	312.802	7.021	12.414
Carriage	791.035	25.32	6.126
Cheese	1240.718	6.5	4.673
Clothing	1237.138	0	0
Cooperage	423.793	6.382	4.531
Flour	6802.298	260.456	98.480
Foundry	8989.174	61.395	96.447
Furrier	1019.407	0	0
Harness	621.45	2	0.315
Lime	121.027	1	0.184
Photo	987.714	0	0
Printing	6157.121	20.9	13.089
Sashdoor	2323.843	40.587	68.387
Sawmill	4285.739	483.198	99.439
Shingle	2266.699	69.583	70.699
Stone	1085.833	1.6	5.208
Tannery	2382.179	50.585	54.300
Watch	1138.039	0	0
Woolmill	962.527	58.91	99.482
Mean	**2334.411**	**48.928**	**32.545**

Note: Industries listed in alphabetical order.

Table 5: Canadian Weights – Reconstructed Cost Shares, Cobb-Douglas Estimates, Translog Estimates

	Reconstructed Cost Shares			Cobb-Douglas Estimates			Translog Estimates		
	SL	SK	SM	SL	SK	SM	SL	SK	SM
Baking	0.175	0.063	0.762	0.174	0.060	0.766	0.142	0.055	0.803
Blacksmith	0.493	0.115	0.391	0.393	0.047	0.560	0.393	0.048	0.560
Bootshoe	0.401	0.075	0.524	0.344	0.061	0.594	0.318	0.060	0.622
Brewery	0.193	0.238	0.569	0.229	0.026	0.745	0.235	0.020	0.745
Bricktile	0.498	0.137	0.365	0.261	0.055	0.684	0.252	0.054	0.693
Cabinet	0.507	0.171	0.322	0.353	0.101	0.546	0.346	0.097	0.557
Carpentry	0.527	0.141	0.332	0.333	0.066	0.601	0.339	0.049	0.612
Carriage	0.491	0.144	0.365	0.422	0.101	0.477	0.421	0.109	0.470
Cheese	0.107	0.108	0.785	0.093	0.097	0.810	0.062	0.033	0.905
Clothing	0.275	0.071	0.654	0.253	0.071	0.676	0.219	0.072	0.709
Cooperage	0.547	0.094	0.358	0.401	0.047	0.552	0.405	0.050	0.545
Flour	0.048	0.112	0.840	0.080	0.061	0.859	0.038	0.047	0.915
Foundry	0.411	0.173	0.416	0.388	0.042	0.571	0.393	0.051	0.557
Furrier	0.317	0.125	0.558	0.222	0.066	0.712	0.210	0.071	0.719
Harness	0.342	0.091	0.567	0.308	0.074	0.619	0.291	0.072	0.637
Lime	0.452	0.099	0.449	0.214	0.031	0.755	0.219	0.024	0.758
Photo	0.460	0.177	0.364	0.207	0.079	0.714	0.219	0.119	0.662
Printing	0.400	0.236	0.364	0.287	0.068	0.645	0.298	0.057	0.644
Sashdoor	0.457	0.165	0.378	0.386	0.065	0.549	0.401	0.082	0.517
Sawmill	0.218	0.236	0.546	0.166	0.047	0.787	0.168	0.047	0.786
Shingle	0.342	0.185	0.473	0.283	0.007	0.710	0.277	0.015	0.708
Stone	0.342	0.080	0.578	0.300	0.056	0.644	0.282	0.050	0.668
Tannery	0.233	0.141	0.625	0.153	0.033	0.814	0.155	0.040	0.805
Watch	0.518	0.137	0.344	0.378	0.101	0.521	0.373	0.139	0.488
Woolmill	0.240	0.057	0.703	0.223	0.040	0.736	0.196	0.051	0.753
Mean	**0.360**	**0.135**	**0.505**	**0.274**	**0.060**	**0.666**	**0.266**	**0.060**	**0.674**

Note: Industries listed in alphabetical order.
Note: Cobb-Douglas and translog input elasticities have been estimated using labour figures adjusted for gender, age and months in operation, and value of fixed capital figures adjusted for months in operation. The estimated input elasticities have been constrained to sum to one.
Note: Complete econometric results are available from the authors.

Table 6: Canadian Relative to US TFP Ratios

	Max TFP Ratio	Min TFP Ratio	Median TFP Ratio	Preferred TFP Ratio	Coefficient of Variation
Baking	1.499	0.684	1.004	1.006	0.162
Blacksmith	1.393	0.608	0.833	0.833	0.188
Bootshoe	1.567	0.677	0.976	0.950	0.194
Brewery	1.613	0.650	0.976	0.964	0.206
Bricktile	1.329	0.593	0.847	0.812	0.195
Cabinet	1.428	0.702	0.984	0.981	0.164
Carpentry	1.075	0.479	0.727	0.866	0.195
Carriage	1.419	0.573	0.822	0.682	0.221
Cheese	0.962	0.342	0.703	0.773	0.266
Clothing	1.428	0.502	0.829	0.870	0.214
Cooperage	1.353	0.498	0.800	0.864	0.208
Flour	1.108	0.393	0.816	0.893	0.265
Foundry	1.729	0.732	1.065	1.086	0.204
Furrier	1.642	0.713	1.026	0.993	0.170
Harness	2.042	0.892	1.208	1.072	0.200
Lime	2.725	0.543	1.014	1.032	0.379
Photo	1.713	0.806	1.047	1.007	0.195
Printing	1.110	0.594	0.837	0.852	0.154
Sashdoor	1.780	0.843	1.188	1.224	0.177
Sawmill	1.227	0.508	0.798	0.820	0.192
Shingle	1.655	0.604	0.957	0.999	0.247
Stone	0.731	0.321	0.449	0.378	0.218
Tannery	1.860	0.848	1.121	1.072	0.186
Watch	1.130	0.550	0.725	0.647	0.182
Woolmill	3.055	0.862	1.534	1.534	0.308
Mean	**1.543**	**0.621**	**0.931**	**0.928**	**0.212**

Note: Industries listed in alphabetical order.
Note: Maximum, minimum and median TFP ratios are illustrated in figure 1.
Note: Preferred TFP ratio uses gross output, adjusted labour, reconstructed cost shares, and Inwood-Keay input and output price and currency conversion.
Note: Coefficient of variation = $(\sigma_x \bullet N) / (\Sigma X)$.

Figure 1: Canadian / US TFP