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CENTRE FOR THE STUDY OF LIVING STANDARDS

Further Evidence on the Contribution of Services Outsourcing to the Decline in Manufacturing's Employment Share in Canada

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Abstract

In October 2015, the Centre for the Study of Living Standards released a report examining how outsourcing of work from the manufacturing sector to the services sector contributed to the recorded decline in Canadian manufacturing employment over the past four decades. The evidence was mixed. An examination of the input-output structure of the economy suggested that the effect of services outsourcing was very small while a decomposition of employment growth by industry and occupation suggested that the effect may have been substantial. This report revisits these results using new custom data products provided by Statistics Canada. In particular, the earlier work examined an input-output structure based on current dollar data which may have skewed the results due to large price swings, particularly in the oil and gas sector. This report uses chained dollar estimates to avoid this problem. Similarly, the employment decomposition used highly aggregated occupational data which may have overstated the contribution of outsourcing to manufacturing's declining employment share. We use more detailed occupational data from the Census / National Household Survey. We find that the results regarding the contribution of services outsourcing are fairly robust to the choice of data. Furthermore, we are able to reconcile the differing estimates of the importance of services outsourcing between the input-output and occupational decomposition methodologies by noting that much of the decline in manufacturing employment in services occupations might be expected to occur if the manufacturing sector shrank for reasons unrelated to services outsourcing. In particular, the expected share of the decline associated with service occupations in response to a negative shock to the manufacturing sector should be roughly equal to the share of service occupations in total manufacturing employment. Adjusting for this, we find that both exercises suggest the contribution of services outsourcing to the decline of manufacturing's employment share was quite small, explaining no more than 8.3 per cent.

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Executive Summary

Canada's manufacturing sector has been on the decline for half a century. From 1961 to 2012, the share of manufacturing in nominal GDP fell from 22.4 per cent to 10.7 per cent. Similarly, the manufacturing sector's share of total economy employment fell from 19.1 per cent in 1976 to 9.5 per cent as of 2014. This may be a cause for concern because the manufacturing industry provides high-quality jobs which pay above average wages to less-skilled workers.

Several explanations have been put forward as to why manufacturing employment has been on the decline. Some have suggested that rising labour productivity levels have displaced workers from the industry. Others have blamed low-cost foreign competition and profit-seeking firms for moving manufacturing activities overseas. In recent years, commentators have pointed at weakening demand for Canadian manufacturing due to slowing demand in the United States and (until recently) the high Canadian dollar.

In October 2015, the Centre for the Study of Living Standards released a report entitled "The Evolution of Manufacturing Employment in Canada: The Role of Outsourcing" (Capeluck, 2015b) which investigated the extent to which outsourcing of work which had once been performed within the manufacturing sector to firms in the services sector has contributed to the recorded decline in manufacturing's employment share. No distinction is made between the effects of domestic services outsourcing and foreign services outsourcing (offshoring). The report used a pair of methodologies recently applied by Berlingieri (2014), finding evidence that outsourcing of work to the professional and business services (PBS) and financial services (FS) industries led to a non-negligible reduction in manufacturing employment in the United States. However, the two methodologies produced divergent results as to the magnitude of the effect, with the input-output analysis suggesting it was very small (about 3.5 per cent of the decline) while the labour decomposition suggested that it could account for as much as 29 per cent.

However, Capeluck (2015b) noted several limitations to the study, some of which were related to the data used. This report re-evaluates the two major exercises using custom data products from Statistics Canada with the objective of assessing the robustness of the results.

Input-Output Analysis

The first exercise involves examining how changes to the input-output structure of the economy reduced the labour requirements of manufacturing relative to those of other sectors between 1976 and 2008.The analysis is based upon a very simple gross output growth accounting model developed by Berlingieri (2014). Holding sectoral final demand shares constant at their implied 1976 levels, the direct requirements coefficients in 1976 and 2008 are used to predict employment shares of two-digit industries in 2008 based on the observed changes to the input-output structure of the economy between 1976 and 2008.

Capeluck (2015b) found that the model could predict 76.3 per cent of the observed decline in manufacturing's employment share when all changes in the input-output (IO) structure of the economy were considered. These changes to the IO structure were driven by many factors, one of which was services outsourcing. Capeluck used current dollar data to construct the input-output tables which he suggested may have resulted in spurious predictions. In particular, the rising price of oil and gas increased the nominal direct requirements for inputs from primary industries, implying a large shift in employment towards this sector and a decline in employment elsewhere in the economy. Such a reallocation of employment was not observed in the data.

We reassess the predictions of the model using chained dollar input-output data. We find that the predicted employment share of primary industry is more reasonable, but the model is now only able to predict 46.3 per cent of the decline in manufacturing's employment share. Generally, the model does a slightly better job of predicting the 2008 employment distribution in the economy when chained dollar data are used, although in absolute terms the model's performance remains rather poor. The mean prediction error of sectoral employment shares for all industries is 2.10 percentage points when nominal data is used but falls to 1.88 percentage points when real dollar input-output estimates are used instead.

In this exercise, the PBS sector is defined to include professional, scientific, and technical services and the FS sector includes financial, business, building, and other support services. We find that the predicted impacts of the change in manufacturing input requirements from the PBS and FS sectors based on a simple counterfactual exercise of holding the direct requirements coefficients of manufacturing for inputs from the PBS and FS industries constant at their 1976 levels remain very modest when the constant dollar input-output structure is used. The model suggests that the rise in PBS requirements for manufacturing explains 0.18 percentage points of the decline in manufacturing's employment share (2.2 per cent), while the rise in FS requirements explains 0.09 percentage points (1.1 per cent). This is our key estimate of the contribution of services outsourcing to the decline in manufacturing's employment share from the input-output analysis. It is very similar to the total effect of 0.29 percentage points (3.5 per cent) which Capeluck (2015b) estimated from varying both the FS and PBS direct requirements coefficients simultaneously. These small effects are not all that surprising since PBS and FS services are relatively small components of the overall input requirements for manufacturing.

Occupational Analysis

The second exercise involves performing a simple decomposition of the change in manufacturing's employment share into contributions from movement between industries within each occupation (the within-occupation component), movement between occupations within each industry (the between-occupation component), and a cross term capturing the interaction of between- and within-occupation effects.

We define PBS occupations as those which have a greater share of their total employment in the PBS industry than the PBS industry's share of total employment in 2011. Employment in PBS industries in this exercise includes those working in NAICS codes 54 (professional, scientific, and technical services), 55 (management of companies and enterprises), and 56 (administrative and support, waste management, and remediation services). In 2011, 11.2 per cent of workers were employed in these PBS industries, so any occupation with more than 11.2 per cent of its workers employed in the PBS industry in 2011 is classified as a PBS occupation.

This definition of PBS occupations allows for a distinction between the within-, between- and cross-components of the decomposition for PBS and non-PBS industries. Using data from the Labour Force Survey between 1987 and 2014, the exercise from Capeluck (2015b) suggests that about 30 per cent of the decline in manufacturing's employment share is due to the within-occupation PBS component. The within-occupation component of the decomposition is defined as the share of workers in PBS occupations in total employment in 1987 multiplied by the change in manufacturing's share of PBS workers between 1987 and 2014. This component captures PBS outsourcing, as it reflects movements of workers away from manufacturing who continue to perform the same work in other sectors. However, the within-occupation component also includes occupational shifts unrelated to PBS outsourcing (for example, the share of manufacturing of accountants would fall if demand for agricultural products increased, raising the employment share of accountants in agriculture), so that it likely overstates the contribution of PBS outsourcing to the decline of the manufacturing sector.

Capeluck (2015b) notes that the within-occupation PBS component might be overstated due to the high level of aggregation of the Labour Force Survey data used. In particular, if movements between industries within broadly defined occupations are really movements across industry-specific sub-occupations, the within-occupation effect would be overestimated while the between-occupation effect would be underestimated. For this reason, we redo the exercise using more detailed occupational data between the 1991 Census and the 2011 National Household Survey. We find that, depending upon the level of disaggregation, the PBS within-occupation component accounts for between 25 and 38 per cent of the decline in manufacturing's employment share. Similar to Capeluck (2015b), we find that the magnitude of the effect diminishes considerably if we adopt a stricter definition of PBS occupations.

Furthermore, we note that the PBS within-occupation component likely overstates the contribution of PBS outsourcing for another reason. If all occupations in manufacturing employment decline at the same rate in response to falling demand for manufacturing output, then we should expect employment in PBS occupations to account for a large share of the decline in manufacturing employment simply because they account for a large share of total manufacturing employment (about 26 per cent in 1987). Restricting our attention to contributions exceeding those expected from a uniform decline in manufacturing employment across all occupations, we find that the PBS within-occupation component of the decomposition only explains between 0 and 8.3 per cent of the reduction in manufacturing's employment share. The results are quite sensitive to the definition of PBS occupations, with the effect becoming much smaller if a restrictive definition is chosen.

Conclusions

Our results suggest that a small portion of the decline in manufacturing's employment share in Canada is related to the outsourcing of services from the manufacturing sector. The use of alternative data sources which address concerns about the data used by Capeluck (2015b) do not seem to resolve the discrepancy between the input-output and occupational decompositions with regard to the magnitude of the effect, as the latter remains much larger.

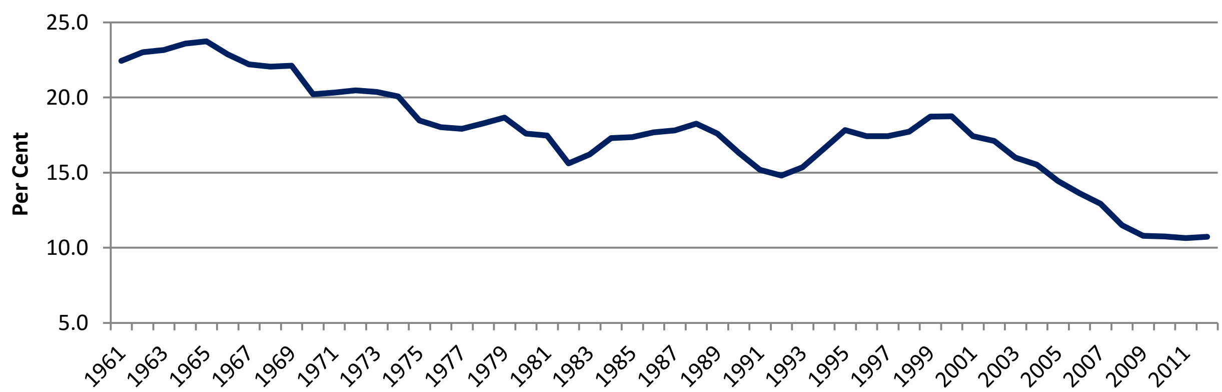
However, we are able to reconcile the results of the two exercises by noting that there would be a sizable within-occupation component associated with PBS occupations in the labour decomposition exercise even if there was no PBS outsourcing and only an external demand shock which affected all occupations in the manufacturing industry in proportion to their size. Adjusting for this, we find that both methodologies agree that the contribution of services outsourcing was small, accounting for less than 8.3 per cent of the decline in manufacturing's employment share. Intuitively, this seems like a sensible conclusion since the share of services in manufacturing's overall input requirements is rather small.

Further Evidence on the Contribution of Services Outsourcing to the Decline in Manufacturing's Employment Share in Canada[1]

I. Introduction

Canada's manufacturing sector has declined considerably over the last half century. Chart 1 illustrates that the share of manufacturing in nominal GDP has fallen from a high of 23.7 per cent in 1965 to 10.7 per cent in 2012.[2] Most of this decline in relative importance to the Canadian economy was concentrated over two periods. Manufacturing's share of nominal GDP fell throughout through the 1960s and 1970s to about 17.5 per cent by 1980. During the 1980s and 1990s the sector stabilized with its share of nominal GDP hovering around this 17.5 per cent level before the sector's share of GDP rapidly shrank from 18.7 per cent in 2000 to 10.7 per cent by 2012.

Chart 1: Manufacturing's Share of Total Economy Nominal GDP, Per Cent, Canada, 1961-2012



Source: CSLS calculations based on Statistics Canada data. CANSIM tables 379-0023 (1961-2008) and 379-0029 (2009-2012). Original chart from Capeluck (2015a), updated to include most recent data for 2009-2012.

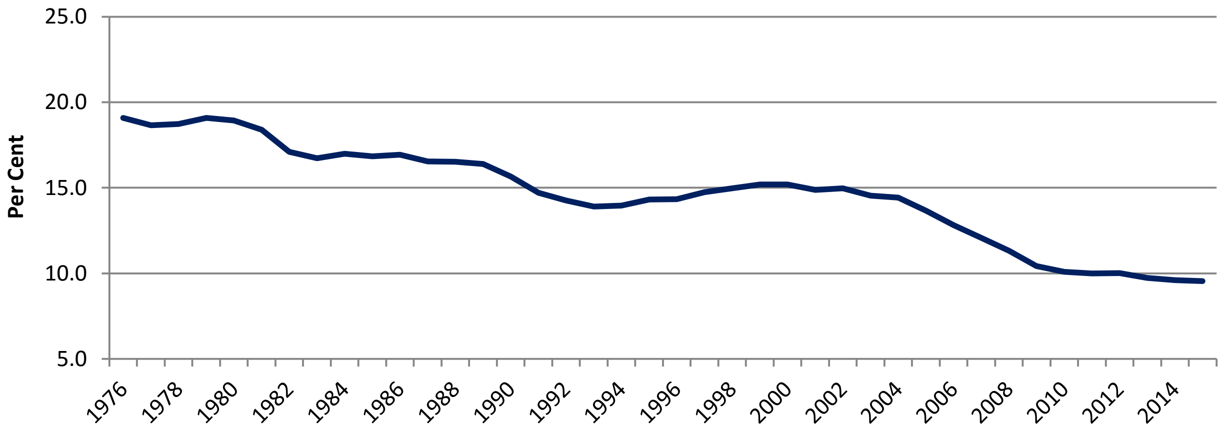
A declining share of manufacturing relative to GDP alone would not necessarily be a cause for concern. After all, the sector has grown in absolute terms, but other sectorsof the economy have simply grown faster due to market forces. The issue is that the manufacturing sector tends to be associated with high paying jobs for less skilled workers. Chart 2 shows that

[1] This paper was written by Matthew Calver and Evan Capeluck under the supervision of Andrew Sharpe. The CSLS would like to thank Innovation, Science and Economic Development Canada for their financial support and for valuable comments on an earlier draft of the paper. Please direct any questions to evancapeluck@gmail.com.

[2] In real terms, manufacturing output has been relatively stable. For example, CANSIM table 383-0021 provides estimates of real (chained 2007 dollar) output and nominal output in the Canadian business sector. In nominal terms, the share of manufacturing in business sector output fell from 28.1 per cent in 1961 to 14.5 per cent in 2012. In real terms (normalizing shares to sum to 1 due to non-additivity of the chained Fisher estimates) manufacturing's share only fell from 16.5 per cent in 1961 to 14.5 per cent in 2012. Therefore, much of the decline was in the share of nominal GDP was related to changes in relative prices rather than reductions in real output.

the employment share of the manufacturing sector fell along with its share of nominal GDP between 1976 and 2015. If this reduction in manufacturing's employment implies worse labour market prospects for the Canadian population, particularly for less skilled workers, then this trend may be a cause for alarm.

Chart 2: Manufacturing's Share of Total Employment, Per Cent, Canada, 1976-2015



Source: CSLS calculations based on Statistics Canada data. Labour Force Survey. CANSIM table 282-0008. Original chart from Capeluck (2015a), updated to include most recent data 1976-2015.

Policymakers would like to understand why the manufacturing sector is on the decline in Canada in order to determine what, if anything, can and should be done in response. Several different explanations have been put forward for these trends. These have been summarized and explored in depth by Capeluck (2015a).

Capeluck (2015a) identifies two major explanations for the falling employment share. The first is rising labour productivity relative to other sectors of the economy. For a given level of output, rising labour productivity implies that less labour is required. Capeluck finds that this explanation can account for most of the decline in manufacturing's employment share between 1961 and 2000, but it cannot account for the fall since 2000. Instead, Capeluck (2015a) suggests that a second cause is responsible for much of the decline since 2000: declining demand for manufactured goods due to slowing demand from the United States, deterioration in cost competitiveness due to the appreciation of the Canadian dollar and dismal productivity growth, and increased competition from emerging markets.

Another possibility is that the decline in manufacturing's employment share is partly the result of reallocation of tasks from within manufacturing firms to other industries.[3] In particular, Berlingieri (2014) estimates that 16 per cent of the decline in manufacturing employment observed in the United States between 1948 and 2002 was the result of outsourcing of work from manufacturing to the professional and business services (PBS) sector. For example, a

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[3] Berlingieri (2014) notes that in its starkest form, such outsourcing may be thought of as a relabeling of work in the data from one industry to another. More broadly, outsourcing may imply the reallocation of labour to other sectors in which it operates more productively or provides a substitute service.

manufacturer which once employed an accountant in-house may have switched to hiring an accounting firm. An individual continues to be employed providing accounting services for the manufacturing industry, but the individual would be classified as working in the professional and business services sector rather than manufacturing. Some of this outsourcing reflects offshoring of production and ancillary services abroad, but some of it is due to domestic outsourcing of work.

Previous research by the Centre for the Study of Living Standards adopted Berlingieri's methodology to examine the extent to which services outsourcing may be able to account for the decline of manufacturing employment in Canada (Capeluck 2015b).Two exercises were performed yielding inconclusive results. The first used a simple gross output growth accounting model to explore how changes in the input-output (IO) structure of the economy affected employment in manufacturing and services. Capeluck found that the model could explain 76.3 per cent of the fall in manufacturing's employment share between 1976 and 2008. Holding manufacturing's direct requirements from the financial services and professional and business services industries constant through time, he found that outsourcing to these sectors could only explain about 3.5 per cent of the decline in the manufacturing employment share.

The second exercise involved decomposing the change in manufacturing's employment share from 1987 to 2014 into the reallocation of workers from manufacturing to other sectors within the same occupation (the within-occupation component) and the reallocation of manufacturing workers in a given occupation to other occupations (the between-occupation component).Capeluck (2015b) found that the reallocation of workers in PBS occupations from manufacturing to PBS occupations in other industries accounted for 28.8 per cent of the decline in manufacturing's employment share.[4]

Capeluck (2015b) expresses some concerns about the results of both exercises. While the simple input-output model seems to predict most of the decline in manufacturing's employment share, the model performs poorly at predicting the employment shares of several other industries. Capeluck (2015b) suggests that the predictive power of the model for the manufacturing sector may be spurious, driven by fluctuations in the price of oil which implied a large increase in the employment share of mining and oil and gas extraction in the model which was not observed in reality. He suggests that using IO tables using constant rather than current dollar data may improve the model's performance.

Similarly, there are some concerns about the data used in the occupation-based employment decomposition. Capeluck (2015b) only had data on occupations at the 2-digit level

[4] Note that the data used does not actually allow us to see the industry in which a given worker is employed through time. The exercise only entails a comparison of the employment distribution of workers across occupations and at two points in time. When we talk about reallocation of PBS workers from manufacturing to other industries, we mean that the employment share in other industries has increased and the employment share in manufacturing has fallen. This does not necessarily imply that workers have left their jobs in manufacturing for positions in other industries.

(out of 4), resulting in very broad categories. He suggests that the large within-occupation component of the decline in manufacturing associated with PBS occupations may be misleading. If the broad occupational categories are composed of specific occupations that are each closely linked to specific industries, then the reallocation of workers between occupations within a given broad occupational category may have shown up as a reallocation of workers between industries within that broad occupational category. The result would be an overestimation of the contribution of movements within PBS occupations to the fall in manufacturing's employment share. For example, the NOC-2011 occupation code 72 is industrial, electrical and construction trades. Among other occupations, it includes both welders and plumbers. We may expect that welders tend to work in manufacturing and plumbers in construction. If we only used two digit occupation codes, we might misinterpret movement across occupations (welders to plumbers) for movement out of manufacturing into construction within the same occupation.

Given these concerns about the data used in Capeluck (2015b) and the conflicting results of the two exercises as to the importance of PBS outsourcing to the decline in manufacturing, we think it would be prudent to explore the robustness of the results. We do so using custom data products obtained from Statistics Canada which provide constant dollar input-output tables and industry-occupation employment distributions at the highest available level of disaggregation.

The remainder of the report will proceed as follows. Section 2 will provide a discussion of how inputs in manufacturing have changed through time and how the use of chained dollar (real) rather than current dollar (nominal) data can lead to different understandings of the input structure of manufacturing. Section 3 will review the methodology from Berlingieri (2014) and Capeluck (2015b) used in this report and discuss the data. Section 4 will present the results of the input-output exercise using constant dollar input-output data with a comparison to the results in Capeluck (2015b) based on current dollar data. Section 5 will present the results of the occupational decomposition exercise with detailed occupational data. Again, the results will be compared to those from Capeluck (2015b). Section 6 will conclude with a short summary of the findings.

II. Intermediate Inputs in Manufacturing

Before examining the issue of whether or not services outsourcing was a major contributor to the decline of manufacturing employment in Canada over the last several decades, it is useful to perform a high-level examination of the inputs used by Canada's manufacturing sector.

This section has two goals. The first is to familiarize the reader with general trends regarding the importance of services as inputs in manufacturing relative to other inputs. The second is to clarify why the use of chained rather than current dollar IO data may be expected to lead to different results.

Broadly speaking, output is produced using three broad classes of inputs: labour (workers), capital (machines, buildings, structural engineering, and intellectual property), and intermediate inputs. Intermediate inputs are outputs of one industry which are used as inputs in another industry. For example, the agricultural industry produces grain. Grain is produced by primary industry and used as an intermediate input in the production of flour. In turn, flour may be an intermediate input in the production of bread, and bread in the production of a sandwich by a restaurant.

In this section, we will focus on three broad categories of intermediate inputs: services, materials, and energy.[5] In particular, we are interested in the extent to which services have become more or less important as a share of gross output in manufacturing over time.

We will examine trends in the relative shares of these three types of intermediates based on both real (chained dollar) and nominal (current dollar) data. The distinction between the two is how prices are applied to each type of input through time. Current dollars simply use the prices prevalent in each year. For example, 2008 input is valued based on 2008 prices, 2009 input is valued based on 2009 prices, etc.

Current dollars are relevant if one wishes to estimate the total value of output, as the changing price structure supposedly reflects changes in how society values different types of output. The issue with current dollars for our purposes is not so much that they capture inflation, but rather that they may suggest large changes in the amount of inputs due to changing prices while the actual number of inputs has remained stable. For example, suppose an input's relative price doubles. Using current dollar data would suggest that twice as much of the input is being used even though the number of physical units of the input remains constant. For this reason it

[5] Energy input includes various fuels purchased for use as heat or power including electricity, fuel oil, coal, natural gas, and other miscellaneous fuels. Material input includes all commodity inputs exclusive of fuel (electricity, fuel oil, coal, natural gas, and other miscellaneous fuels) but inclusive of fuel-type inputs used as raw materials in a manufacturing process, such as crude petroleum used by the refining industry. Service input includes communications; finance and insurance; real estate rental; hotel services; repair services; business services, including equipment rental, engineering and technical services, and advertising; vehicle repair; medical and educational services; and purchases from government enterprises.

may misleading to use current dollar estimates to assess how the input-output structure of the economy has changed through time when interested in the physical requirements of production processes.

In order to assess changes in "real" inputs, one should control for changes in prices through time. A straightforward approach is to take the price level in some base year and apply it to the output levels in all years under consideration (a Laspeyres volume index). For example, if we chose 2008 prices, then 2007 input is valued based on 2008 prices, 2008 input is valued based on 2008 prices, 2009 input is valued based on 2008 prices, etc. This example would be called using constant 2008 dollars.[6] The problem with constant dollars is that the choice of the base year can change the results, especially if large relative price changes occur over the period under consideration. To avoid this issue, statistical offices often provide data based on chained dollars.

Chained dollars combine a set of constant dollar estimates based on a different base year for each time period under consideration. Suppose we want to compare inputs in 2007, 2008, and 2009. To construct a (Laspeyres) chained dollar series, we could calculate the values of 2007 and 2008 inputs using 2007 prices and the values of 2008 and 2009 inputs using 2008 prices. Neither pair of quantity estimates reflects changes in relative prices. The two are combined by taking the implied growth rates of "real" input between 2007 and 2008 based on 2007 prices and between 2008 and 2009 based on 2008 prices and applying them sequentially to the level of inputs in an arbitrarily chosen reference year. If we chose 2009 as the reference year, we would call this chained 2009 dollars.

The data on intermediate inputs used in this section are from *CANSIM Table 383-0022:Multifactor productivity, gross output, value-added, capital, labour and intermediate inputs at a detailed industry level, by North American Industry Classification System (NAICS)*. The chained dollar estimates are based on chained Fisher[7] quantity indexes.

Panels A, B, C, and D of Chart 3 provide current and chained (2002) dollar estimates of the shares of total intermediate inputs, energy inputs, material inputs, and service inputs respectively in gross output for the manufacturing sector from 1976 to 2008.

In real terms, the share of intermediate inputs in gross output has remained fairly stable. It was about 70 per cent in 1976 and was 69 per cent in 2008, although the share was somewhat lower between 1975 and 1995 when it hovered around 67 per cent. Current dollar data paints a very different picture. Based on current dollar estimates, the share of intermediate inputs in gross output rose considerably from 64 per cent in the 1960s to 72 per cent in 2008.

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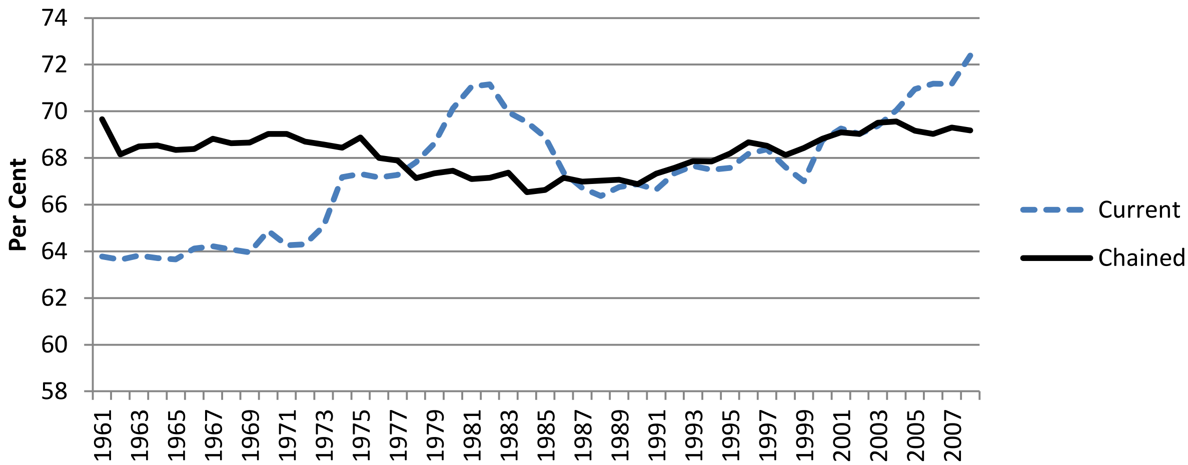
[6] The "constant" refers to the constant choice of the base year. We could also construct a "constant" dollar series based on a Paasche index framework which would use the prices observed in each year to compare the level of physical output in that year to the level observed in the base year.

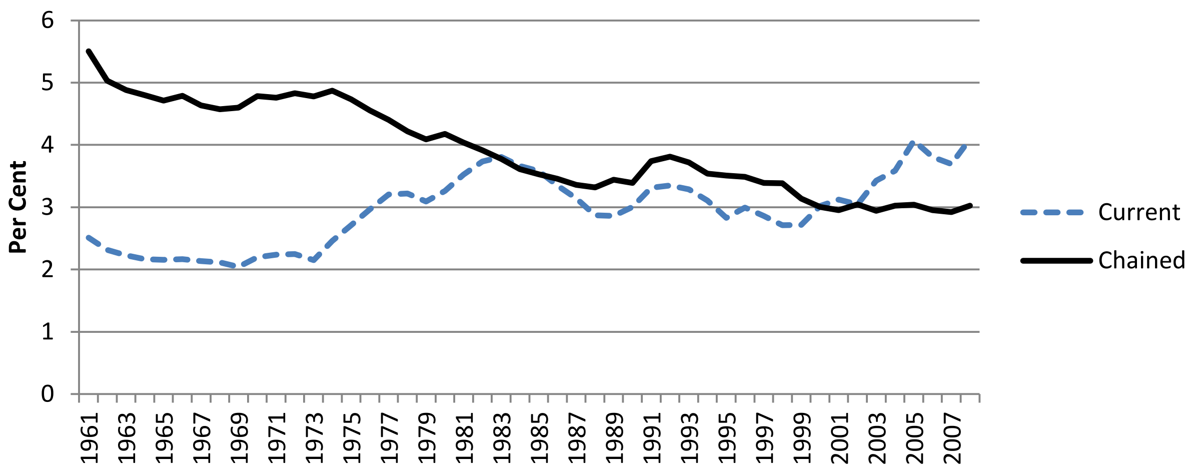
[7] A Fisher index uses the geometric average of the quantities calculated based on prices in each of the two years under comparison (a Laspeyres index uses the base year prices while a Paasche index uses the current prices).

Chart 3: Share of Gross Output in Manufacturing in Canada, by Type of Intermediate Input, Per Cent, 1961-2008

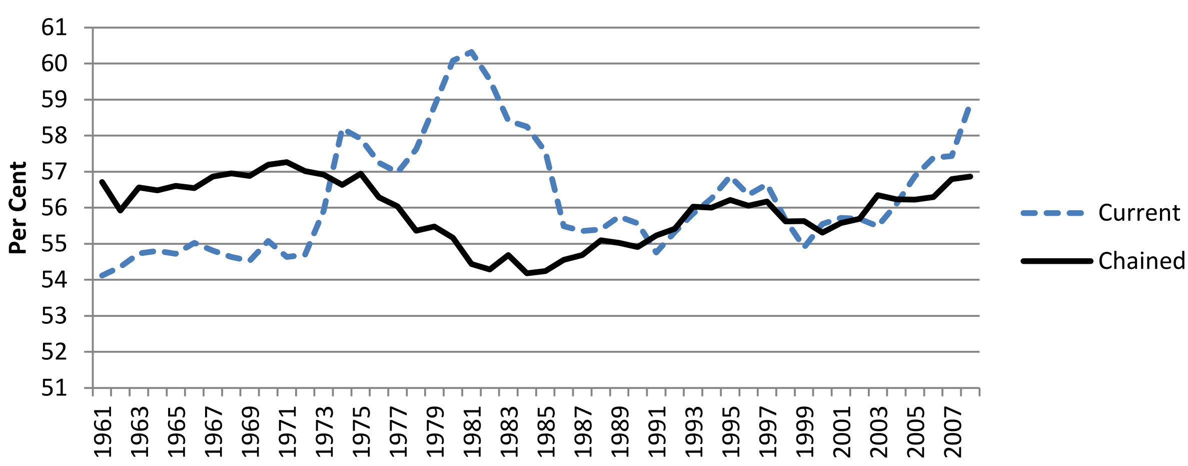
Panel A: All Intermediate Inputs



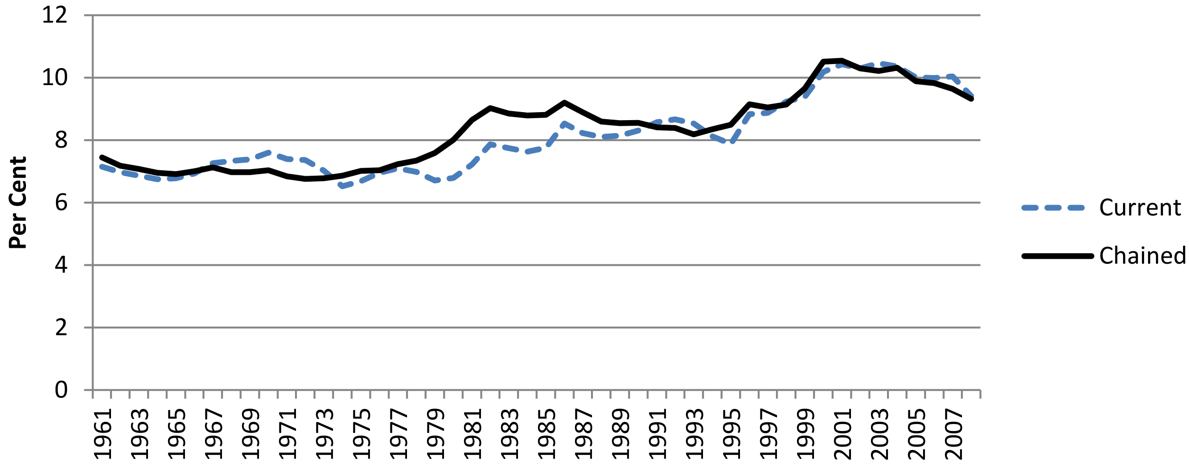
Panel B: Energy Inputs



Panel C: Material Inputs



Panel D: Services Inputs



Source: CSLS Calculations using data from CANSIM Table 383-0022. Chained dollars. Reference year is 2002.

Notice that the share of intermediates was much higher in the 1970s and in recent years when oil and gas prices spiked. Indeed, one can see from panel B that the nominal share of energy inputs, which was 4 per cent as of 2008, increased during the 1970s and again in recent years. However, the long-term trend in real terms has been a decline in the share of energy inputs from 5.5 per cent in 1976 to 3 per cent in 2008. This reflects adoption of more energy efficient practices and machinery in response to rising energy prices.

Panel C reveals that there were also very large increases in the share of material inputs in current dollars when oil prices were high. As Capeluck (2015b) pointed out, metal ores and concentrates, mineral fuels, and non-metallic minerals is a category of materials which accounted for a sizable share of gross output in manufacturing because oil refineries are classified as manufacturing. These inputs likely explain much of the large fluctuations in the current dollar share of material inputs in gross output. Notice that while the share of material inputs remains at a very similar level (about 57 per cent) in 1976 and 2008, it fell off in the 1970s when prices for these inputs were relatively high. Besides the direct link between the price and demand for inputs, this reduced share of material inputs may also be related to exchange rate fluctuations.

The share of services in gross output rose from about 7 per cent in 1976 to around 10 per cent as of 2008. To the extent that services produced within the manufacturing sector are quantified as labour inputs while those outside the sector are classified as services, this may suggest services outsourcing.

The key observation to take away from Chart 3 is that the evolution of the manufacturing industry’s demand for inputs between 1976 and 2008 appears somewhat different depending on whether inputs are measured in real or nominal terms. In particular, the use of energy and material inputs appears to have increased considerably based on current dollars, while the relative importance of material inputs remained stable and that of energy inputs declined when inputs are measured in real terms.

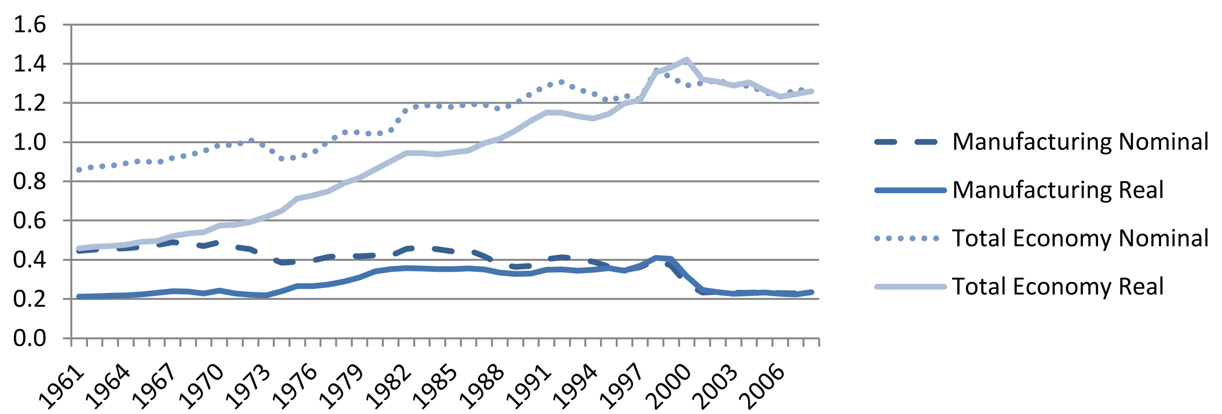
It is also important to observe that the rise in services as manufacturing inputs occurred regardless of whether real or nominal data is used. The similar performance of these series suggests that if we only explore the impact of changes in the requirements for services, holding everything else constant, then the results will probably look very similar whether we use current or constant dollar data.

The relatively small share of services in total intermediate input use and in gross output suggests that outsourcing of services will only be able to explain a small amount of the overall decline in manufacturing employment.[8]

As service intermediates are the focus of this report, it is worth exploring the growth in manufacturing's service requirements in further detail. We do so using more detailed data on the input-output structure of the Canadian economy in nominal terms from CANSIM and equivalent chained dollar estimates provided by Statistics Canada.[9]

We will consider four classes of intermediate inputs between 1961 and 2008 at the summary (S) level of commodity aggregation. In each case, we will compare the requirements for the input relative to gross output.[10] We will also consider trends in service requirements in the total economy. If outsourcing of a service requirement was a major driver of the decline in manufacturing's employment share, we may expect to observe a large increase in manufacturing's requirements for that service as an input.[11]

Chart 4: Communications Service Inputs Relative to Gross Output, Manufacturing and Total Economy, Per Cent, 1961-2008



Source: CSLS calculations based on Statistics Canada Input-Output data, special order. Reference year is 2008.

[8] To the extent that services are more labour intensive than materials or energy, the impact on the industry providing services may be larger than the share of services in manufacturing's intermediate inputs suggests

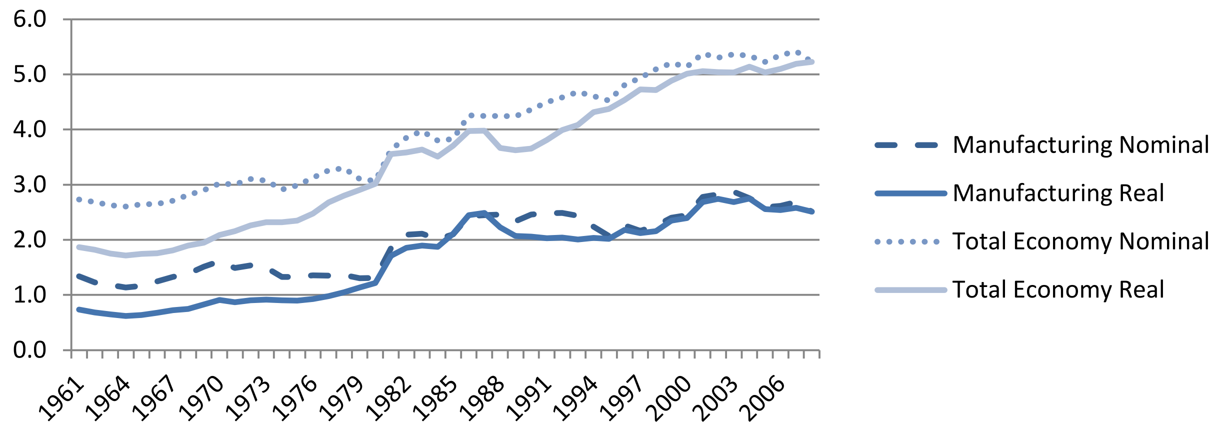
[9] Further details on this data are provided in section III.A.iv of this report.

[10] In the case of chained estimates, this is not exactly a percentage of gross output because chained dollar estimates are not exactly additive so that the total chained dollar value of all inputs is not equal to the sum of the chained dollar values of each input.

[11] Previously, we would expect that these services would have appeared as labour requirements within the boundary of manufacturing firms, although there may also have been some provision of services from one manufacturing firm to another which would have been quantified as manufacturing production and use of the service.

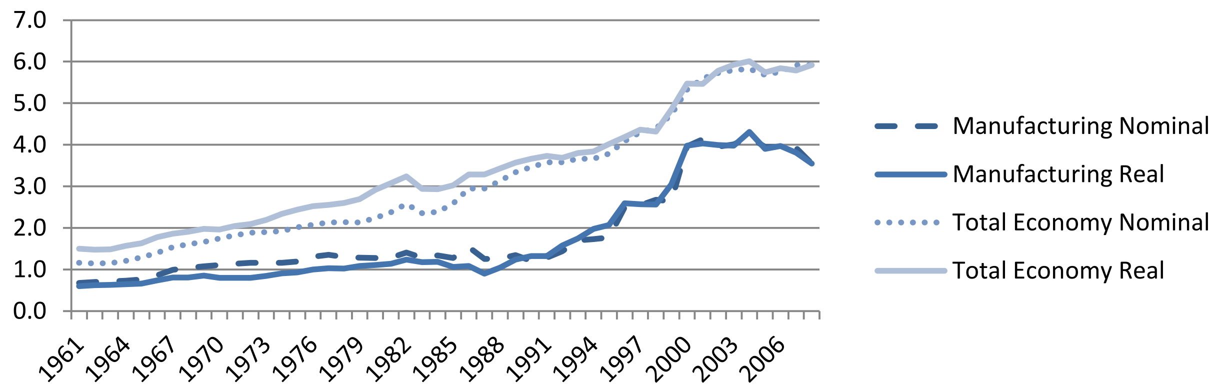
The first type of service intermediate input which we will consider is communications services (Chart 4). Communication service inputs have become increasingly important for the total economy, rising from about 0.5 per cent of gross output in real terms in 1961 to over 1.2 per cent in 2008. Interestingly, the real communications service requirements of the manufacturing sector remain of about 0.2 per cent of gross output in 2008 are about the same as those observed in 1961 while in nominal terms the requirements of manufacturing for communication services have fallen from over 0.4 per cent to about 0.2 per cent. It does not seem likely that communications services outsourcing by the manufacturing industry has increased over this period based on these descriptive trends.

Chart 5: Finance, Insurance, and Real Estate Service Inputs Relative to Gross Output, Manufacturing and Total Economy, Per Cent, 1961-2008



Source: CSLS calculations based on Statistics Canada Input-Output data, special order. Reference year is 2008.

Chart 6: Professional, Scientific, Technical, Computer, Administrative, Support, and Related Service Inputs Relative to Gross Output, Manufacturing and Total Economy, Per Cent, 1961-2008



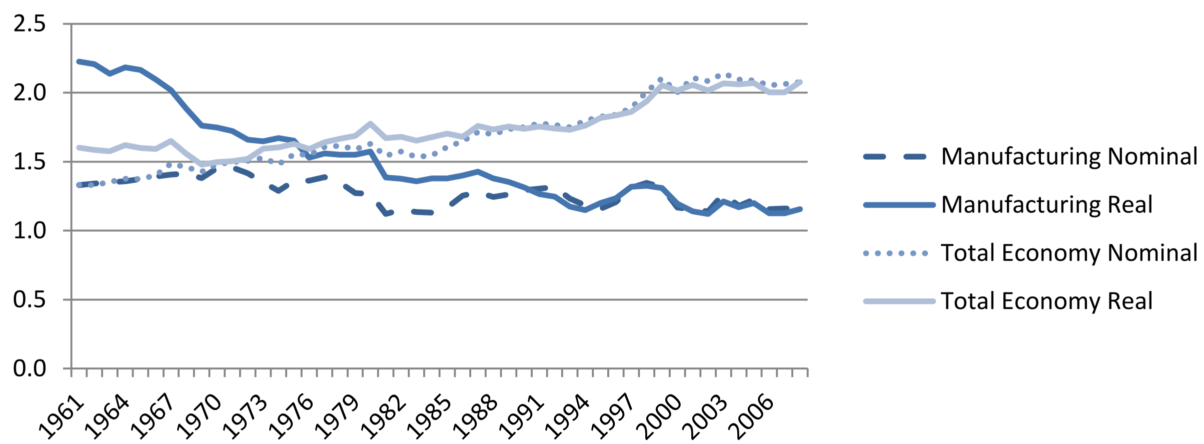
Source: CSLS calculations based on Statistics Canada Input-Output data, special order. Reference year is 2008.

In contrast, Chart 5 and Chart 6 reveal that manufacturing's requirements for finance, insurance, and real estate service intermediate inputs and professional, scientific, technical, computer, administrative, support, and related service inputs increased considerably both in nominal and real terms. In the case of finance, insurance, and real estate services, manufacturing's real requirements rose from about 0.8 per cent of gross output in 1961 to about 2.5 per cent in 2008. Similarly, its requirements for professional, scientific, and technical service inputs increased dramatically from about 0.6 per cent of gross output in 1961 to about 3.5 per cent in 2008, with most of the increase concentrated between 1990 and 2000. This latter set of services includes most of the services which we consider when discussing "professional and business services".

While the large increase in manufacturing requirements for technical and financial services between 1961 and 2008 is consistent with a story of manufacturing outsourcing of professional and business services, it is worth noting that the intensity with which these services were being used relative to the total economy increased even more than in the manufacturing sector. Outsourcing of services may not have been unique to manufacturing. Moreover, manufacturing's employment share likely fell in part due to increased demand for services in the economy relative to the demand for manufacturing. It is also worth noting that the total economy has used financial and technical services more intensively than manufacturing throughout the entire 1961 to 2008 period.

Finally, we consider miscellaneous service inputs which include additional services which do not fall within the three manufacturing relevant categories we have considered. In real terms, manufacturing requirements for miscellaneous services have declined from about 2.2 per cent of gross output in 1961 to 1.2 per cent of gross output in 2008 (Chart 7), so outsourcing of these services was unlikely to have been a major source of the decline in manufacturing employment. Over the same period, these miscellaneous services became increasingly more important to the total economy.

Chart 7: Miscellaneous Service Inputs Relative to Gross Output, Manufacturing and Total Economy, Per Cent, 1961-2008



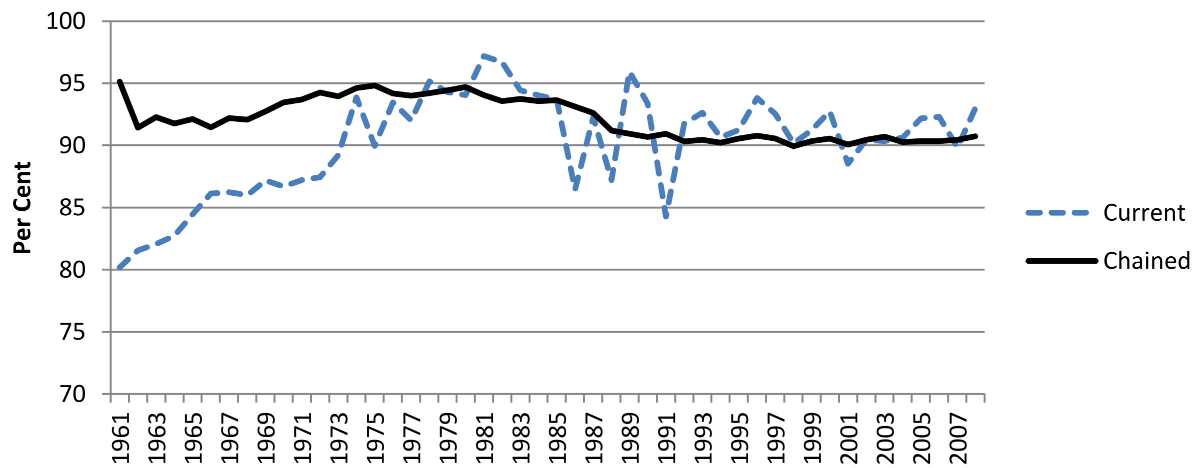
Source: CSLS calculations based on Statistics Canada Input-Output data, special order. Reference year is 2008.

Capeluck (2015b) was particularly concerned that the use of constant dollar data may have led to the model having predictive power regarding the share of employment in manufacturing for spurious reasons. In particular, manufacturing (along with most other sectors) would seem to have a significantly greater requirement for inputs from the oil and gas sector because of rising energy prices, pushing the predicted employment share of primary industry up and employment shares of all other industries down.

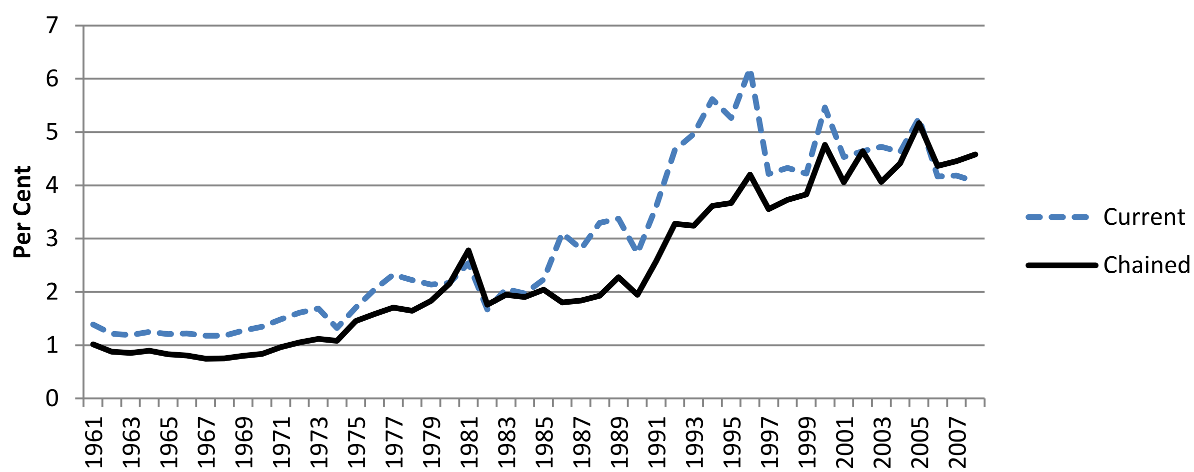
Chart 8 is analogous to Chart 3 but focuses on the petroleum and coal products manufacturing subsector, as this is the manufacturing subsector which will use the most inputs from the oil and gas industry. It demonstrates how different the trends are for the share of material inputs in gross output according to current dollar data and chained dollar data (Panel C).[12] In particular, the share of material inputs is rising over much of the 1961-2008 period in the current dollar data while it is on a downward trajectory in the chained dollar data. These differences appear to be related to rising crude oil prices in the 1970s and 2000s.

Chart 8: Share of Gross Output in Petroleum and Coal Products Manufacturing in Canada, by Type of Intermediate Input, Per Cent, 1961-2008

Panel A: All Intermediate Inputs

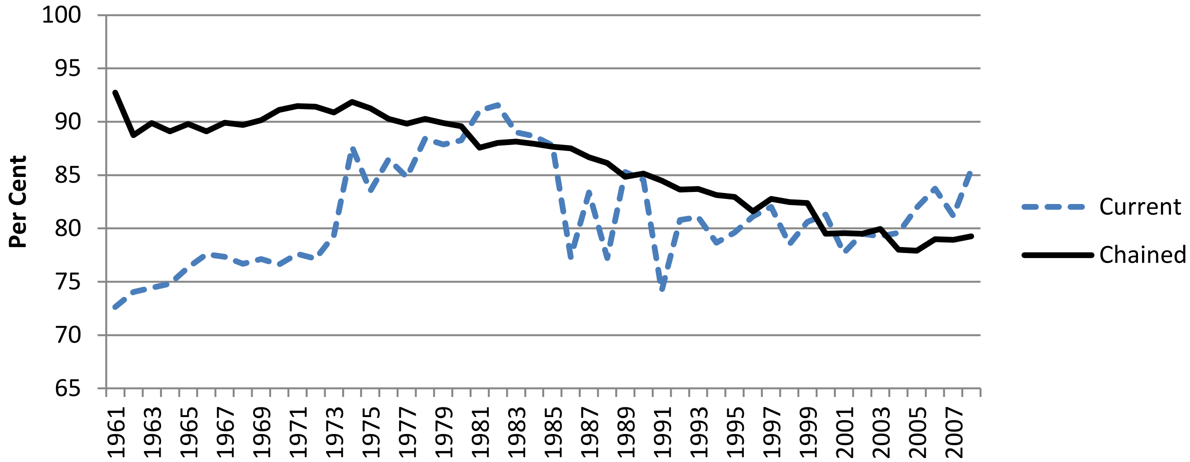


Panel B: Energy Inputs

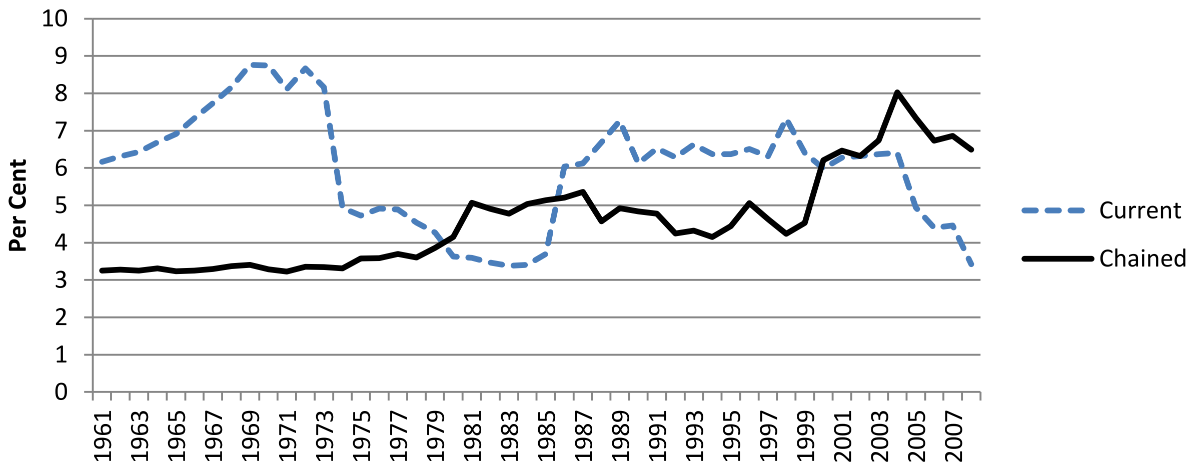


[12] Material inputs includes crude petroleum used by the refining industry, which is located in the petroleum and coal products manufacturing subsector.

Panel C: Material Inputs



Panel D: Services Inputs



Source: CSLS Calculations using data from CANSIM Table 383-0022. Chained dollars. Reference year is 2002.

Intermediate inputs represent an extremely large share of gross output in this sector. In real terms, they account for 90 per cent of inputs as of 2000, although they had accounted for nearly 94 per cent in the 1970s. The nominal share of intermediates has increased considerably from only 80 per cent in 1976 to as high as 97 per cent in 1981. The nominal share was about 93 per cent as of 2008.

Both in real and nominal terms, the petroleum and coal products manufacturing subsector has become considerably more energy intensive. The share of energy inputs in gross output rose from around one per cent in 1976 to between 4 and 5 per cent in the 2000s. This may be related to compositional changes within the sector.

Table 1: Intermediate Inputs as a Share of Gross Output, Manufacturing Subsectors, Current Dollars, 1961 and 2008

	All Intermediates		Energy		Materials		Services	
	1961	2008	1961	2008	1961	2008	1961	2008
Manufacturing	63.8	72.4	2.5	4.1	54.1	58.9	7.2	9.4
Food manufacturing	76.6	72.1	1.5	1.9	68.9	61.1	6.2	9.1
Beverage and tobacco product manufacturing	55.3	50.7	1.1	1.7	40.5	30.2	13.7	18.7
Textile and textile product mills	66.7	59.6	1.5	3.0	59.5	46.7	5.7	9.8
Clothing manufacturing	60.8	52.8	0.4	1.1	52.9	42.7	7.5	9.1
Leather and allied product manufacturing	58.9	57.8	0.9	2.1	51.9	43.8	6.2	11.9
Wood product manufacturing	62.7	67.2	1.9	3.3	55.4	55.7	5.5	8.1
Paper manufacturing	56.4	68.4	5.5	9.8	45.9	48.1	5.0	10.5
Printing and related support activities	49.6	49.1	0.9	1.5	38.0	35.1	10.8	12.5
Petroleum and coal products manufacturing	80.2	93.0	1.4	4.1	72.6	85.5	6.2	3.4
Chemical manufacturing	59.1	75.2	3.9	14.9	43.1	47.6	12.0	12.7
Plastics and rubber products manufacturing	59.7	66.0	1.5	2.7	50.1	52.8	8.1	10.4
Non-metallic mineral product manufacturing	54.0	57.2	7.1	7.9	36.9	37.2	10.0	12.2
Primary metal manufacturing	68.1	76.7	6.6	6.7	57.8	64.3	3.7	5.7
Fabricated metal product manufacturing	57.1	59.7	1.3	2.0	50.0	49.7	5.8	8.0
Machinery manufacturing	52.8	60.1	1.2	1.3	43.7	50.4	7.9	8.5
Computer and electronic product manufacturing	49.0	61.5	0.5	0.7	38.6	41.7	9.8	19.2
Electrical equipment, appliance and component manufacturing	58.3	66.9	1.0	1.2	49.1	52.2	8.1	13.5
Transportation equipment manufacturing	64.4	79.3	1.0	0.7	56.5	67.0	6.9	11.6
Furniture and related product manufacturing	55.9	56.2	1.1	1.7	48.0	44.9	6.9	9.6
Miscellaneous manufacturing	55.3	57.3	1.0	1.3	44.1	45.4	10.3	10.5

Source: CSLS Calculations using data from CANSIM Table 383-0022.

In real terms, the subsector's use of material inputs has fallen from a stable 90 per cent of gross output throughout the 1960s and 1970s to slightly under 80 per cent of gross output in 2008. The nominal share of material inputs has been volatile, rising from 73 per cent in 1976 to a high of around 92 per cent in 1981, back down as low as 75 per cent in 1991, and then rebounding to above 85 per cent by 2008.

Table 1 and Table 2 summarize how the shares of energy, materials, and services intermediates have changed between 1961 and 2008 in manufacturing subsectors using both current and chained dollar estimates. A few trends are worth noting. First, while the shares of energy, material, and service inputs in gross output rose in the economy in nominal terms between 1961 and 2008, in real terms the share of materials remained stable and the share of energy decreased. Only the share of services increased. The overall share of intermediates remained fairly stable in real terms but rose considerably in current dollars.

Table 2: Intermediate Inputs as a Share of Gross Output, Manufacturing Subsectors, Chained 2002 Dollars, 1961 and 2008

	All Intermediates		Energy		Materials		Services	
	1961	2008	1961	2008	1961	2008	1961	2008
Manufacturing	69.7	69.2	5.5	3.0	56.7	56.9	7.4	9.3
Food manufacturing	73.0	73.6	3.4	1.4	63.5	63.5	6.5	8.6
Beverage and tobacco product manufacturing	50.1	55.0	2.3	1.3	33.2	35.7	14.9	18.5
Textile and textile product mills	61.9	61.2	5.8	2.3	48.6	50.2	9.9	8.7
Clothing manufacturing	53.9	54.3	1.2	0.8	43.2	45.2	9.7	8.3
Leather and allied product manufacturing	62.3	58.8	2.2	1.6	53.6	45.9	6.6	10.9
Wood product manufacturing	66.1	60.2	4.1	2.2	56.5	51.5	5.6	6.5
Paper manufacturing	62.6	65.0	14.7	8.5	44.4	47.0	4.9	9.4
Printing and related support activities	36.1	48.4	1.4	1.1	26.2	35.9	8.6	11.5
Petroleum and coal products manufacturing	95.1	90.7	1.0	4.6	92.7	79.3	3.2	6.5
Chemical manufacturing	75.1	68.4	10.3	9.8	49.3	44.6	15.2	13.9
Plastics and rubber products manufacturing	66.1	62.5	4.5	2.2	50.4	50.8	12.2	9.6
Non-metallic mineral product manufacturing	58.3	57.2	17.5	5.9	32.3	39.2	12.0	12.2
Primary metal manufacturing	74.4	74.0	12.9	7.7	56.1	59.2	4.8	7.1
Fabricated metal product manufacturing	58.0	57.9	3.6	1.7	49.6	47.9	5.6	8.3
Machinery manufacturing	56.5	59.4	2.6	0.9	46.8	50.9	7.3	7.7
Computer and electronic product manufacturing	62.2	69.2	4.8	0.5	37.7	53.4	37.9	15.4
Electrical equipment, appliance and component manufacturing	68.4	66.9	3.0	1.0	55.5	52.8	10.3	13.2
Transportation equipment manufacturing	75.8	74.0	2.5	0.4	67.5	65.3	6.6	8.7
Furniture and related product manufacturing	54.5	60.4	2.5	1.3	45.0	50.1	7.3	9.0
Miscellaneous manufacturing	68.9	57.2	2.5	1.0	55.5	45.6	10.0	10.6

Source: CSLS Calculations using data from CANSIM Table 383-0022.

The rising nominal share and declining real share of energy inputs in gross output is true for virtually every manufacturing subsector.[13]

The growth in service intermediates is also true for most manufacturing subsectors regardless of whether real or nominal data is used, although there are several exceptions, particularly when the chained dollar data is used.[14] These exceptions include textile and textile product mills, clothing manufacturing, chemical manufacturing, plastics and rubber products manufacturing, and computer and electronic product manufacturing.

Changes in the relative importance of material inputs vary considerably across industries.

[13] The only exceptions are that the nominal share of energy inputs falls for transportation equipment manufacturing and the real share of energy inputs rises for petroleum and coal products manufacturing.

[14] The only exception based on nominal data is petroleum and coal products manufacturing, which is likely driven by the large increases in the nominal shares of energy and material inputs.

III. Methodology and Data

This section will provide a brief overview of the methodology and data used in the report. For the most part, the methodology is almost exactly the same as that of Capeluck (2015b) which was based on Berlingieri (2014). Interested readers are encouraged to refer to Berlingieri (2014) for the most extensive discussion of the methodology.

The section is divided into two parts. The first describes the input-output model and how it is used to assess the impact of PBS outsourcing on manufacturing's employment share. The second focuses on the occupational decomposition. In both parts, special attention is given to describing how the data used in this study differs from that used in Capeluck (2015b).

A. Input-Output Structure and Manufacturing Outsourcing

i. The Model

We evaluate the effects of changes to the input-output (IO) structure of the economy using a simple gross output growth accounting model. There are J sectors in the economy. The production function for the good produced by sector j takes on a Cobb-Douglas form:

$$Y_j = A_j L_j^{\beta_j} \left[\prod_{k=1}^{J} M_{kj}^{\gamma_{kj}} \right]^{1-\beta_j}$$

where Y_j represents gross output in sector j, L_j is the amount of labour used by the sector, A_j represents the productivity level in sector j, β_j is the share of value added in the gross output of the sector, M_{jk} is the amount of intermediate inputs from sector k used in the production of sector j, and γ_{jk} is the share of intermediates from sector k in the total intermediate input use of sector j. There is no capital in the model, which eliminates the need to worry about dynamic decisions.

Taking wages, w, and prices, P_j, as given, firms in each sector choose inputs M_{jk} and L_j in order to minimize costs while producing a level of output of at least Y_j. Solving this problem, the conditional factor demands are:

$$L_j = \beta_j \frac{P_j Y_j}{w}$$

$$M_{kj} = \gamma_{kj}(1 - \beta_j) \frac{P_j Y_j}{P_k}$$

These first order conditions have a standard Cobb-Douglas interpretation: expenditures on each input are proportional to the share of that input in the sector's gross output.

Households are simply assumed to inelastically provide labour at the prevailing wage rate. The market clearing condition is also very simple. Goods from each sector must be either consumed (C_j) or used as intermediate inputs in production:

$$Y_j = C_j + \sum_{k=1}^{J} M_{jk}$$

Combining the goods market clearing condition and the conditional input demands, Berlingieri (2014) shows that the share of labour allocated to each sector, l_j, can be expressed as:

$$l_j = \frac{\beta_j P_j Y_j}{wL} = \beta_j X_j + \beta_j \sum_{k=1}^{J} \gamma_{jk}(1-\beta_k)\frac{P_k Y_k}{wL}$$

where $X_j = \frac{P_j C_j}{wL}$ is the consumption expenditure share of sector j. The labour share of each sector is equal to labour's share of sector j's consumption expenditure share plus labour's share of sector j's share of intermediates in sector k's consumption expenditure share. That is, it reflects the extent to which the sector contributes directly to the final consumption of good j and indirectly to final consumption of all goods via production of intermediate inputs.

Since there are J sectors, we have J equations representing equilibrium labour shares. These can be expressed using linear algebra at a give time t as:

$$\boldsymbol{l}_t = \boldsymbol{\beta}_t \Omega_t^{-1} \mathbf{X}_t$$

where

$$\boldsymbol{l}_t = \begin{pmatrix} l_1 \\ \vdots \\ l_J \end{pmatrix} \boldsymbol{\beta}_t = \begin{pmatrix} \beta_1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \beta_J \end{pmatrix} \mathbf{X}_t = \begin{pmatrix} X_1 \\ \vdots \\ X_J \end{pmatrix} \Omega_t = \begin{pmatrix} 1-\gamma_{11}(1-\beta_1) & \cdots & -\gamma_{1J}\left(1-\beta_J\right) \\ \vdots & \ddots & \vdots \\ -\gamma_{J1}(1-\beta_1) & \cdots & 1-\gamma_{JJ}\left(1-\beta_J\right) \end{pmatrix}$$

Berlingieri (2014) notes that the matrix Ω_t is equal to a $J \times J$ identity matrix minus an industry-by-industry direct requirements matrix. This is convenient because this matrix is easy to construct using IO data.

Given a final uses vector at time t, $\mathbf{X}_t$, the model predicts labour shares based on the IO structure of the economy given by Ω_t and $\boldsymbol{\beta}_t$. It is important to note that the theoretical model implies that the current dollar direct requirements are the right data to use in the analysis; the parameters inside the Ω_t and $\boldsymbol{\beta}_t$ matrices are just expenditure shares. In this respect, the results based on real input requirements are harder to interpret. However, the results do address the fact that labour shares are more closely related to real requirements than nominal requirements.

ii. Counterfactual Exercises

To evaluate the predicted impact of changes in the IO structure of the economy on the sectoral allocation of labour through time, we hold $\mathbf{X}_t$ fixed and allow only Ω_t and $\boldsymbol{\beta}_t$ to vary. In practice, this requires calibrating the model to obtain the implied final demand structure in the base year by calculating $\boldsymbol{X}_t = \Omega_t \boldsymbol{\beta}_t^{-1} \mathbf{l}_t$. In our case, the base year will be 1976. By combining the 1976 final demand vector with the IO structure in 2008, we are able to use the model to estimate how changes in the IO structure of the economy will have changed the distribution of labour across industries.

We can compare this predicted baseline based on the true evolution of the IO structure to a series of counterfactual IO structures to learn about how the changing IO structure likely contributed to changes manufacturing's share of labour.

We generate four counterfactual distributions of labour in 2008 based on four different IO structures and compare these to the baseline.

The first counterfactual (1) involves holding the coefficients for all intermediate inputs in manufacturing in the direct requirements table constant at their 1976 levels while allowing the rest of the coefficients for intermediate inputs in the direct requirements table to take on the values observed in 2008. This explores the question of what would have happened to employment if there had been no change in the industry sources of intermediate inputs demanded by the manufacturing sector between 1976 and 2008.

The second counterfactual (2a) involves holding only the coefficient representing professional and business services (PBS)[15]intermediates used in manufacturing production constant at its 1976 level while allowing all other coefficients to take on their 2008 values. This scenario is meant to capture what would have occurred if there had been no additional PBS outsourcing (represented by an increase in the PBS coefficient over time).[16]

Similarly, counterfactual (2b) involves changing the coefficient for the finance, insurance, real estate and rental and leasing (FS) industry instead of the PBS coefficient.[17]

The third counterfactual (3) is to change the coefficient representing manufacturing's requirements for inputs from the mining, oil, and gas industry. This exercise was used by Capeluck (2015b) to illustrate how changes in manufacturing's nominal requirements for primary inputs, which were linked to the rising price of oil, were predicted to change

[15] In this exercise, we define PBS industries to match those in Capeluck (2015b). PBS industries correspond to NAICS code 54, professional, scientific and technical services.

[16] Note that we are unable to distinguish whether the effects of outsourcing are due to domestic outsourcing or offshoring as both imported and domestically produced intermediate inputs are included in our input-output data.

[17] In this exercise, we define FS industries to match those in Capeluck (2015b). FS industries correspond to NAICS codes 52, 53, 55, and 56 for employment which include finance, insurance, real estate, and leasing and business, building, and other support services. The FS industries for the IO data include IOIC codes 5A, finance, insurance, real estate and rental and leasing and 56, administrative and support, waste management, and remediation services.

manufacturing's employment share. A change in a nominal direct requirements coefficient can reflect both price changes and quantity changes while a change in the corresponding real coefficient will be due to only changes in physical quantities. We repeat this exercise, hypothesizing that the effect estimated by Capeluck (2015b) was driven by changes in prices and that it will not be observed when we use real data.

Table 3:Summary of the Counterfactual Exercises

	Description
(1) All Coefficients	This exercise estimates the contribution of all types of outsourcing to the decline in the manufacturing employment share by fixing the direct requirements coefficients for all intermediates in manufacturing at their 1976 level.
(2a) PBS Coefficient	This exercise estimates the contribution of PBS outsourcing to the decline in the manufacturing employment share by fixing the direct requirements coefficient for intermediates purchased from the PBS industry in manufacturing at its 1976 level.
(2b) FS Coefficient	This exercise estimates the contribution of financial services (FS) outsourcing to the decline in the manufacturing employment share by fixing the direct requirements coefficient for intermediates purchased from finance, insurance, real estate and rental and leasing in manufacturing at its 1976 level.
(3) Mining Coefficient	This exercise estimates the contribution of 'outsourcing' of mining products to the decline in the manufacturing employment share by fixing the direct requirements coefficient for intermediates purchased from mining and oil and gas extraction in manufacturing at its 1976 level.

Note that there are some difficulties with the interpretation of these counterfactual exercises. In particular, counterfactuals (2a) and (2b) assume that any change between the PBS or FS coefficients for inputs into manufacturing were the result of PBS outsourcing. However, there may have been other factors influencing these coefficients. Changes in the composition of manufacturing outputs may have increased demand for inputs from the PBS and FS industries, although we expect the effect would be fairly minor in practice. Changes in the production processes may also have changed input requirements. It is possible that manufacturing simply requires more PBS / FS inputs relative to gross output than it had in the past. Improvements in the productivity of certain intermediate inputs may have also generally reduced the direct requirements coefficients through time. For example, increased energy efficiency means that fewer energy inputs are needed per unit of output. To the extent that the productivity of service inputs has increased, the observed increase in the PBS / FS coefficients may understate the extent of manufacturing outsourcing.

iii. Allowing Demand to Vary Through Time

Berlingieri (2014) and Capeluck (2015b) also consider an extension in which they allow the relative shares of final demand across industries to vary through time in order to demonstrate the robustness of the predicted effects of manufacturing when the rather unrealistic assumption of a constant final demand structure is relaxed.

To do this, they use a simple model of consumer demand based upon a constant elasticity of substitution (CES) utility function:

$$U_j = \left(\sum_{j=1}^{J} \psi_j C_j^{\frac{\epsilon-1}{\epsilon}} \right)^{\frac{\epsilon}{1-\epsilon}}$$

Where preferences over consumption of good j are governed by parameters ψ_j and a constant elasticity of substitution ϵ. Following Berlingieri (2014) and Capeluck (2015b), we will assume that $\epsilon = 0.5$ as there is no consensus in the literature on the appropriate value.

Maximizing utility subject to a standard consumer budget constraint yields:

$$C_j = \frac{\psi_j^{\epsilon} P_j^{-\epsilon} wL}{P^{1-\epsilon}}$$

where P is an aggregate price index. The consumption expenditure on good j is given by:

$$X_j = \frac{P_j C_j}{wL} = \psi_j^{\epsilon} \left(\frac{P_j}{P} \right)^{1-\epsilon}$$

Defining x_j to be the ratio of the consumption expenditure on the good produced by industry j to the consumption expenditure of the good produced by the manufacturing sector, Berlingieri (2014) shows that the "logarithmic growth rate" of x_j, denoted by $\hat{x}_{jt}$, can be expressed as a simple function of the logarithmic growth rate of the price of the good relative to that of the manufactured good:

$$\hat{x}_{jt} = ln(x_{jt}) - ln(x_{jt-1}) = (1-\epsilon)(\hat{P}_{jt} - \hat{P}_{mt})$$

As before, we calibrate sectoral final use shares X_j in the base year (1976). The final use ratios in the base year are then simple to calculate. Using data on gross output price indexes, the equation above allows for the estimation of final demand for the output of each sector in each future period relative to manufacturing. Given relative final demand shares and that the absolute final demand shares sum to 100 per cent, it is straightforward to calculate the predicted final use shares in each period.

iv. Data

The data on employment by industry and gross price indexes used in this report are exactly the same as those used in Capeluck (2015b).

The employment data come from the Labour Force Survey. The estimates are consistently defined through time based on the NAICS, and are readily available at the two-digit level for the 1976-2014 period from CANSIM Table 282-0008.

The gross output price indexes are implicit gross output deflators calculated by dividing an index of nominal gross output by an index of real gross output. The underlying real and nominal estimates of gross output are from CANSIM Table 383-0032.

The "new" data used in this report are constant dollar input-output data over the 1961-2008 period which were provided by Statistics Canada upon request. Capeluck (2015b) suggested that the poor predictive power of the IO model for changes in employment shares in many industries may have been the result of large increases in oil prices skewing the current dollar direct requirements table so as to suggest that there would be a large increase in employment in the oil and gas sector. The hope is that data on the "real" direct requirements of industries may lead to more reasonable estimate.

The constant dollar IO data were provided in two tables, one for the 1961-1997 period and a second for the 1997-2008 period. Data were reported for several margins (retail, wholesale, gas, etc.). We use the estimates of producer prices.

The 1961-1997 data contain information on commodities classified by IOCC codes at the S-level of aggregation (59 categories) and IOIC industry classification codes at the two-digit level.

The 1997-2008 data contain information on commodities classified by IOCC codes at the link level of aggregation (469 categories) and IOIC industry classification codes at the four-digit level.[18]

In order to construct consistent series through time, we aggregate the 1997-2008 data to the S-level of aggregation and two-digit IOIC industries. The mapping of IOCC codes from the link level to the S-level was performed using a hierarchy posted by Statistics Canada (Statistics Canada, 2007). We then map the IOIC industries over the entire 1961-2008 period to match the LFS NAICS industry aggregations outlined in the appendix of Capeluck (2015b).

The constant dollar estimates of inputs and outputs were produced based on Laspeyres index number methods.[19] Over the 1961-1997 period, the Laspeyres estimates were each based on the prices in the previous year. Over the 1997-2008 period, the Laspeyres constant dollar estimates were based on three different reference years: 1997 for 1997-2002; 2002 for 2002-2007; and 2007 for 2007-2008. In both cases, additivity should hold, as the estimates were not chained.

[18]http://www23.statcan.gc.ca/imdb-bmdi/document/1401_D11_T9_V1-eng.pdf

[19] Under a Laspeyres constant dollar framework, the prices in the base year of the series are used to compare quantities through time. Constructing a Laspeyres chained dollar series entails sequentially linking multiple Laspeyres constant dollar estimates which use different base years to some reference year based on the growth rates in each series.

We linked the four series together by using 2008 as the reference year and then extending backwards to 1961. That is, the year-over-year growth rates from each series were applied consecutively beginning in 2008 and working backwards.

There are few errors / inconsistencies in the data which we noted when constructing the chained dollar estimates. In particular, a few series seem to imply that the chained dollar output of a single industry greatly exceeded that of all industries. For example, our raw calculations from the data suggest that the total output of metal ores and concentrates by primary industry was 51 times greater than total output of metal ores and concentrates by all industries. This led to nonsensical results when constructing the direct requirements tables. To avoid these sorts of problems, we have treated any extreme year-over-year quantity changes in the data exceeding a factor of 5 times as simply being constant (no growth).[20] One may be concerned that this adjustment may eliminate some of the most important shifts in the input-structure through time. In practice, we do not think that this should be a major concern, as this adjustment changes a very small number of estimates.[21]

These input-output tables were used to construct industry-by-industry direct requirements tables in the same manner as Capeluck (2015b). Details of this procedure are provided in the appendix.

B. Decomposition of Employment Share Growth by Occupation

i. The Decomposition

The second major exercise of this report involves performing a simple decomposition of how movements within and across occupations contributed to the fall in manufacturing's employment share.

Rather than looking at the input-output structure of the economy, another approach is to examine how the distribution of work related to PBS industries has varied across occupations over time. Unfortunately, the nature of the work being performed within any given industry is difficult to observe in practice. Instead, we consider the occupation of workers as a proxy for the type of work being performed, assuming that all individuals in the same occupation are performing similar tasks.

[20] We acknowledge that a strong case could be made that some average rate of growth may be a better assumption, but it is not obvious which average should be used (total economy in that year, average for the industry and commodity historically, etc.). We do not expect that the decision to assume no growth will have a significant effect on our results as this adjustment is rarely applied.

[21] For outputs, this constraint binds 46 times out of 17,107 observations, For inputs, it binds 30 times compared to 26,863 observations.

Berlingieri (2014) notes that the change in the share of manufacturing employment in total employment over a period of time, Δl_{man}, can be broken down as follows:

$$\Delta l_{man} = \underbrace{\sum_{o} \Delta w_{man}^{o} l_{1}^{o}}_{Within} + \underbrace{\sum_{o} w_{man,1}^{o} \Delta l^{o}}_{Between} + \underbrace{\sum_{o} \Delta w_{man}^{o} \Delta l^{o}}_{Cross}$$

where w_{man}^{o} is the share of workers employed in the manufacturing industry for a given occupation o, l^{o} is the share of a given occupation o in total employment, and the subscript 1 indicates the share of workers at the beginning of the period.

The decomposition consists of three components:

- The **within-occupation component** captures shifts of workers into or out of the manufacturing sector within a given occupation. For example, if cleaners leave the manufacturing sector but continue to work as custodians in the transportation and warehousing sector, this will be captured primarily by the within-occupation component.

- The **between-occupation component** captures shifts of workers into or out of the occupations employed in the manufacturing sector. For example, if cleaners in the manufacturing sector start to work as mechanics in the manufacturing sector, this will be captured primarily by the between-occupation component.

- The **cross component** captures the interaction between movement of workers within and between industries. For example, the effect of a decline in employment in a given occupation on manufacturing employment will be lower if workers in that occupation were simultaneously leaving manufacturing.

If PBS outsourcing contributed to the decline in manufacturing's employment share, we would expect that the within-occupation component of the decline in manufacturing's employment share associated with PBS related occupations would be sizable. If the decline is related to falling demand in the total economy for the occupations employed in manufacturing, then most of the change should occur within the between-occupation components. Note that while a large within-PBS-occupation component is expected if PBS outsourcing occurred, it is possible to observe one even in the absence of PBS outsourcing. We generally think that PBS outsourcing requires that the work is still ultimately being performed for the manufacturing industry. If workers are leaving the manufacturing sector as it declines and finding similar work in the same occupation but providing services to non-manufacturing industries, this will also show up in the PBS within-occupation component.

The major technical difficulty is how to define PBS occupations. Berlingieri (2014) defines PBS occupations based on the share of workers in each occupation which are employed in the PBS industry (the importance of the PBS industry to the occupation). If the share of workers in an occupation was above an arbitrary threshold in a chosen baseline year, then it is considered a PBS occupation. Berlingieri finds that his results are generally robust to the choice of threshold, manual classification, and alternatively defining PBS occupations based on the share of the occupation in the total employment of the PBS industry (the importance of the occupation to the PBS industry).

Capeluck (2015b) defines PBS occupations as those for which the PBS industry's share of workers in the occupation exceeded the PBS industry's share of workers in total employment in 1987.[22] We adopt the same definition, but use 2011 as our point of comparison. This implies a threshold of 11.2 per cent. Any occupation with more than 11.2 per cent of its workers employed in the PBS industry in 2011 is considered to be a PBS occupation.[23] For robustness, we experiment with several higher thresholds based on requirements that the PBS industry's share of employment in the occupation exceed the PBS industry's share in total employment by at least 0.5, 1, and 2 standard deviations of the PBS share in occupations at the finest level of detail (thresholds of 19.7, 28.2, and 45.3 per cent respectively). We also present some descriptive statistics based upon a similar definition of manufacturing occupations.

ii. Data

The data requirements for this occupational decomposition exercise are straightforward. All that is required is the employment distribution across industries and occupations in two years. Capeluck (2015b) used data from the Labour Force Survey from 1987 to 2014 on employment in 2-digit NAICS categories and 2-digit NOC-S occupations. This data was acquired from statistics Canada by special order.

Capeluck (2015b) suggests these data may overstate the within-occupation components of the decomposition if shifts between detailed occupations which are highly industry specific appear as shifts within industries when the broad occupational categories are being used. We will explore what happens when finer grained occupational data are used. We originally intended to acquire more detailed Labour Force Survey data from Statistics Canada, but were told that this was not possible. Instead, we have acquired a custom tabulation of the industry-occupation employment distribution from the 1991 Census. A similar table for the 2011 National Household

[22] Our definition of PBS industries used in this exercise is slightly different from that in the previous input-output exercise (but consistent with the definition used by Capeluck (2015b)). Employment in PBS industries in this exercise includes those working in NAICS codes 54 (professional, scientific, and technical services), 55 (management of companies and enterprises), and 56 (administrative and support, waste management, and remediation services).

[23] This definition may lead to a bias towards identifying occupations which are disproportionately required in small firms because PBS firms tend to be quite a bit smaller than manufacturing firms. In particular, if there are some occupations which most firms require in similar quantity relative to size, then industries with smaller firms may require a greater share of workers in these occupations than of all workers. In practice, we do not think that this should be a major cause for concern as the types of occupations which we think may have this property, such as lawyers or accountants, tend to be services.

Survey is publically available online.[24] The large sample size of the census allows for the highest level of disaggregation (4-digit) of the occupation codes. However, the industry and occupation classification schemes differ between the 1991 Census and the 2011 NHS. Our 1991 Census data uses1980 SIC codes and 1980 SOC codes. The 2011 NHS data is based upon 2007 NAICS codes and 2011 NOC codes. These categories are not readily comparable.

We attempt to map the 1991 data into the 2011 classifications using concordance tables available online from Statistics Canada.[25]

The concordance between the 1980 SIC and 2007 NAICS industries turns out to be very simple if we are only concerned with identifying the manufacturing sector and "everything else". With a handful of exceptions, the 1980 SIC sector E, Manufacturing Industries, corresponds to NAICS sectors 31, 32, and 33, Manufacturing. The notable exceptions are codes E283 and E284 which we remove from E to obtain an estimate of employment for each occupation in the manufacturing sector.

Despite this seemingly clean concordance, a couple major concerns remain. The SIC and NAICS took very different approaches to the classification of head offices and ancillary units. Ancillary units exclusively produce services in support of other units within the same company or enterprise. NAICS classifies ancillary units according to the NAICS code related to the activity of the ancillary unit while the SIC classified ancillary units according to the activity of the enterprise or company they served. Under the SIC, administrative head offices were classified as performing the same activity as the enterprise or company, but the NAICS places head offices into a separate category, management of companies and enterprises (NAICS code 55). Since ancillary units and head offices[26]would have been classified under manufacturing under the SIC and not under NAICS, our data will overstate the extent of PBS outsourcing to the extent that ancillary units and head offices employ workers with PBS occupations.

The mapping of 1980 SOC codes into 2011 NOC codes is much more complicated. This issue is discussed in Appendix C.

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[24]*99-012-X2011060, Occupation - National Occupational Classification (NOC) 2011 (691), Industry - North American Industry Classification System (NAICS) 2007 (122), Age Groups (5) and Sex (3) for the Employed Labour Force Aged 15 Years and Over, in Private Households of Canada, Provinces, Territories, Census Metropolitan Areas and Census Agglomerations, 2011 National Household Survey (NHS).*

[25] http://www.statcan.gc.ca/eng/concepts/concordances-classifications

[26] In practice, we expect that the impact of reclassifying head offices was fairly limited, as NAICS code 55 (management of companies and enterprises) only represented 0.1 per cent of employment in 2011 according to data from the NHS.

IV. Input-Output Structure and Manufacturing Employment

This section of the report presents the results of the input-output based exercises using chained 2008 dollars to construct the direct requirements tables. First, we present the direct and total requirements tables and compare how they changed between 1976 and 2008. Next we reproduce the core exercises of Capeluck (2015b), assessing the predictive power of the model and the impact of changes in the IO structure on manufacturing's employment share. For robustness, we explore how the results change using the extended model which allows the relative final demands of the outputs of each industry to vary through time. We conclude the section by highlighting the main conclusions of the analysis.

A. Direct and Total Requirements Tables

Table 4 and Table 6 present the industry by industry total requirements tables in 1976 and 2008 in 2008 chained dollars. Each coefficient of the total requirements table shows the number of dollars of gross output from the industry at the beginning of the row required for the industry at the top of the column to satisfy one dollar of final demand for its output. A higher coefficient indicates that the row industry is relatively important to the production of the column industry. These total requirements tables are important because they provide information as to how labour must be allocated across industries in order to satisfy the final demand of the economy. They are used directly in the calculation of labour shares in our input-output model, where Ω_t^{-1} is the total requirements matrix.

The total requirements coefficients include both direct and indirect requirements. Direct requirements, presented in Table 5 and Table 7, represent the inputs the industry requires for final production of one unit of final demand. In particular, each column of the direct requirements table includes the number of dollars of input from each industry required as final inputs to create a single dollar of output in the industry at the top of the column. The direct requirements table is used to calculate the total requirements table.

Indirect requirements capture the total value of all the output required to produce the inputs used in the final production (Horowitz and Planting, 2009).

Notice that the diagonal elements of the total requirements tables tend to be above 1 because it usually takes at least one dollar of output from an industry to provide one dollar of final demand. This reflects "double counting" of the value generated by each industry along which is similar to that which occurs when we consider gross output rather than value added. The off-diagonal elements are always less than 1 (Horowitz and Planting, 2009).

The sums of the rows and columns of the total requirements table are called the forward and backward linkages respectively (Horowitz and Planting, 2009). The forward linkage provides an indication of the extent to which all industries in the economy rely on inputs from the industry in that row. The forward linkage of manufacturing was 4.34 in 1976 which is higher than that for all other industries. This indicates that, on average, industries rely more on output from manufacturing to satisfy final demand than on output from any other industry. Berlingieri (2014) and Capeluck (2015b) make reference to the influence vector, which is simply the forward linkage divided by the number of industries. The influence vector has a simple interpretation. The sector's influence vector of 0.39 (4.34 / 11) means that the average industry requires 0.39 dollars of output from the manufacturing sector to satisfy one dollar of final demand.

The backward linkage provides an indication of the extent to which final demand for an industry impacts final demand for output from all industries. For example, manufacturing's backward linkage in 1976 was 2.63, which means that the manufacturing industry requires 2.63 dollars of output for each dollar of final demand. Note that manufacturing also had the highest backward linkage.

The total and direct requirements tables provide much interesting information on how the structure of the economy has changed over time. In conjunction with final demand, the total requirements table indicates the amount of output required from each sector, which is indicative of the amount of labour required (given labour productivity). We focus our attention on the manufacturing industry.

Many of the coefficients in the 2008 total requirements table are lower than those in the 1976 table, reflecting improvements in the productivity of intermediate inputs between 1976 and 2008. The forward linkage of manufacturing has fallen considerably from 4.34 in 1976 to 3.41 in 2008. This is a much greater reduction than that observed in other industries suggesting that, on average, manufacturing is simply not as important compared to other industries in satisfying final demand as it once was.[27] Notice that for the majority of industries, the forward linkages were actually higher in 2008 than in 1976.

Most industries had notable reductions in their total manufacturing requirements. The exceptions were utilities (0.10 to 0.11), professional, scientific, and technical services (0.04 to 0.06) and other tertiary industries (0.11 to 0.12). The largest declines relative to 1976 manufacturing requirements were in primary industries (0.36 to 0.15, or 58 per cent), trade (0.15 to 0.09, or 40 per cent), and information, culture, and recreation (0.26 to 0.12, or 54 per cent).

Manufacturing's backward linkage also fell between the two periods, although only by 12 per cent which was quite a bit less than the decline in the forward linkage (79 per cent), indicating that fewer dollars' worth of output from all industries were required to produce a dollar of final demand for manufacturing's output. Besides itself, the industry which manufacturing relied on the most to meet final demand was primary industries. Manufacturing's requirements from primary industries fell from 0.51 to 0.35 dollars of output per dollar of final demand between 1976 and 2008.

[27] This likely also reflects greater productivity improvements in manufacturing relative to those in other sectors.

Table 4: Total Requirements Table, Chained 2008 Dollars, 1976

	Primary industries	Utilities	Construction	Manufacturing	Trade	Transportation and warehousing	Information, Culture and Recreation	Financial, business, building, and other support services	Professional, scientific and technical services	Accommodation and food services	Other tertiary industries	Forward Linkage
Primary industries	1.30	0.06	0.22	**0.51**	0.05	0.13	0.08	0.02	0.01	0.13	0.04	2.55
Utilities	0.03	1.00	0.02	**0.04**	0.03	0.02	0.03	0.02	0.01	0.03	0.02	1.24
Construction	0.05	0.04	1.02	**0.03**	0.02	0.05	0.09	0.05	0.01	0.01	0.03	1.40
Manufacturing	**0.36**	**0.10**	**0.61**	**1.83**	**0.15**	**0.41**	**0.26**	**0.06**	**0.04**	**0.39**	**0.11**	**4.34**
Trade	0.03	0.01	0.07	**0.06**	1.02	0.04	0.05	0.01	0.01	0.05	0.02	1.37
Transportation and warehousing	0.02	0.01	0.02	**0.03**	0.03	1.10	0.03	0.01	0.01	0.01	0.02	1.28
Information, Culture and Recreation	0.01	0.00	0.02	**0.02**	0.02	0.02	1.06	0.01	0.02	0.01	0.01	1.21
Financial, business, building, and other support services	0.05	0.02	0.06	**0.05**	0.10	0.06	0.13	1.09	0.06	0.05	0.03	1.68
Professional, scientific and technical services	0.02	0.01	0.07	**0.03**	0.02	0.02	0.10	0.04	1.08	0.02	0.03	1.43
Accommodation and food services	0.00	0.00	0.00	**0.00**	0.00	0.01	0.00	0.00	0.00	1.03	0.00	1.05
Other tertiary industries	0.02	0.01	0.03	**0.03**	0.02	0.04	0.06	0.02	0.02	0.02	1.07	1.33
Backward Linkage	1.91	1.26	2.13	**2.63**	1.46	1.92	1.89	1.33	1.26	1.74	1.37	

Source: CSLS calculations based on Statistics Canada Input-Output data. Special order

Table 5: Direct Requirements Table, Chained 2008 Dollars, 1976

	Primary industries	Utilities	Construction	**Manufacturing**	Trade	Transportation and warehousing	Information, Culture and Recreation\	Financial, business, building, and other support services	Professional, scientific and technical services	Accommodation and food services	Other tertiary industries
Primary industries	0.17	0.03	0.04	**0.23**	0.00	0.01	0.00	0.00	0.00	0.01	0.00
Utilities	0.02	0.00	0.00	**0.02**	0.02	0.01	0.02	0.01	0.00	0.01	0.02
Construction	0.03	0.04	0.00	**0.01**	0.01	0.04	0.08	0.04	0.00	0.00	0.02
Manufacturing	**0.15**	**0.04**	**0.32**	**0.40**	**0.07**	**0.18**	**0.09**	**0.01**	**0.01**	**0.20**	**0.04**
Trade	0.02	0.00	0.05	**0.02**	0.02	0.02	0.03	0.00	0.01	0.04	0.01
Transportation and warehousing	0.01	0.00	0.01	**0.01**	0.02	0.08	0.02	0.00	0.01	0.01	0.01
Information, Culture and Recreation\	0.00	0.00	0.01	**0.01**	0.02	0.02	0.05	0.01	0.01	0.01	0.01
Financial, business, building, and other support services	0.02	0.01	0.03	**0.01**	0.08	0.03	0.09	0.08	0.05	0.03	0.02
Professional, scientific and technical services	0.01	0.00	0.05	**0.01**	0.01	0.01	0.07	0.03	0.07	0.01	0.02
Accommodation and food services	0.00	0.00	0.00	**0.00**	0.00	0.01	0.00	0.00	0.00	0.02	0.00
Other tertiary industries	0.01	0.00	0.01	**0.01**	0.01	0.03	0.05	0.01	0.01	0.01	0.06

Source: CSLS calculations based on Statistics Canada Input-Output data. Special order

Table 6: Total Requirements Table, Chained 2008 Dollars, 2008

	Primary industries	Utilities	Construction	Manufacturing	Trade	Transportation and warehousing	Information, Culture and Recreation	Financial, business, building, and other support services	Professional, scientific and technical services	Accommodation and food services	Other tertiary industries	Forward Linkage
Primary industries	1.16	0.16	0.18	**0.35**	0.03	0.09	0.03	0.02	0.02	0.10	0.04	2.19
Utilities	0.01	1.01	0.01	**0.03**	0.02	0.02	0.01	0.01	0.01	0.02	0.02	1.16
Construction	0.01	0.04	1.01	**0.01**	0.01	0.03	0.01	0.04	0.01	0.01	0.02	1.20
Manufacturing	**0.15**	**0.11**	**0.49**	**1.61**	**0.09**	**0.29**	**0.12**	**0.05**	**0.06**	**0.32**	**0.12**	**3.41**
Trade	0.03	0.02	0.09	**0.07**	1.03	0.05	0.05	0.02	0.03	0.07	0.04	1.50
Transportation and warehousing	0.01	0.01	0.02	**0.02**	0.03	1.18	0.03	0.01	0.02	0.01	0.02	1.36
Information, Culture and Recreation	0.02	0.02	0.03	**0.03**	0.05	0.04	1.09	0.04	0.05	0.03	0.03	1.43
Financial, business, building, and other support services	0.08	0.06	0.11	**0.11**	0.17	0.13	0.15	1.17	0.14	0.16	0.09	2.36
Professional, scientific and technical services	0.04	0.04	0.08	**0.06**	0.07	0.04	0.07	0.05	1.12	0.04	0.05	1.66
Accommodation and food services	0.00	0.00	0.00	**0.00**	0.00	0.01	0.00	0.00	0.00	1.02	0.00	1.05
Other tertiary industries	0.02	0.05	0.04	**0.03**	0.03	0.06	0.05	0.03	0.04	0.03	1.15	1.52
Backward Linkage	1.54	1.51	2.05	**2.32**	1.52	1.93	1.62	1.45	1.50	1.82	1.58	

Source: CSLS calculations based on Statistics Canada Input-Output data. Special order

Table 7, Direct Requirements Table, Chained 2008 Dollars, 2008

	Primary industries	Utilities	Construction	**Manufacturing**	Trade	Transportation and warehousing	Information, Culture and Recreation\	Financial, business, building, and other support services	Professional, scientific and technical services	Accommodation and food services	Other tertiary industries
Primary industries	0.11	0.11	0.06	**0.19**	0.01	0.02	0.00	0.01	0.00	0.02	0.01
Utilities	0.01	0.00	0.00	**0.01**	0.01	0.01	0.01	0.01	0.00	0.01	0.01
Construction	0.01	0.03	0.00	**0.00**	0.00	0.02	0.00	0.03	0.00	0.00	0.02
Manufacturing	**0.08**	**0.04**	**0.29**	**0.35**	**0.04**	**0.13**	**0.05**	**0.01**	**0.02**	**0.19**	**0.05**
Trade	0.02	0.01	0.07	**0.04**	0.02	0.03	0.04	0.01	0.02	0.05	0.02
Transportation and warehousing	0.01	0.00	0.00	**0.01**	0.02	0.15	0.02	0.01	0.01	0.00	0.01
Information, Culture and Recreation\	0.01	0.01	0.02	**0.01**	0.03	0.02	0.07	0.02	0.04	0.01	0.02
Financial, business, building, and other support services	0.04	0.03	0.04	**0.04**	0.12	0.06	0.10	0.13	0.10	0.11	0.05
Professional, scientific and technical services	0.02	0.02	0.04	**0.02**	0.05	0.02	0.05	0.03	0.10	0.02	0.03
Accommodation and food services	0.00	0.00	0.00	**0.00**	0.00	0.01	0.00	0.00	0.00	0.02	0.00
Other tertiary industries	0.01	0.04	0.02	**0.01**	0.02	0.03	0.03	0.02	0.02	0.02	0.12

Source: CSLS calculations based on Statistics Canada Input-Output data. Special order

Most other industries were relatively minor contributors to manufacturing output (compared to primary industry) and saw their contributions fall slightly through time. However, manufacturing's requirements from the financial, business, building, and other support services (FS) and professional, scientific, and technical services (PBS) industries roughly doubled from 0.05 and 0.03 respectively in 1976 to 0.11 and 0.06 in 2008. Over the same period, manufacturing's requirements from the manufacturing industry fell from 1.83 to 1.61. Our central premise is that the rise of manufacturing's requirements from FS and PBS represented outsourcing from manufacturing (part of the decline in the manufacturing coefficient) and led to a reduction in manufacturing's employment share.

B. Performance of the Model

Before exploring the results of our counterfactual exercises, we assess the ability of the input-output model to predict the observed changes in employment shares at the 2-digit NAICS level. Capeluck (2015b) had found that while the model made a reasonably good prediction of the decline in manufacturing's employment share (a prediction of 6.3 percentage points compared to an actual fall of 8.3 percentage points[28]), it was quite inaccurate for other industries. Table 8, taken from Capeluck (2015b) shows the model's predictions and how they compare to reality.

Capeluck (2015b) pointed out that in some industries the prediction errors are quite large. The most striking case is primary industries, where the employment share fell by 3.8 percentage points but the model predicted that it would rise by 2.4 percentage points. The concern is that the large increase in the price of oil and gas (and therefore, the current dollar output of the oil and gas sector) between 1976 and 2008 overstated the required labour implied by the current dollar IO tables and the model. Since all the employment shares are related, this would lead to errors in all sectors, including manufacturing.

It would be useful to have a summary measure of the model's predictions so that we can compare overall predictive power across models. We have added the column on the far right of Table 8 showing the absolute prediction errors to the original table. The mean absolute error reported at the bottom of this column offers a simple summary measure of the model's performance. In this case, the average prediction error across industries is 2.1 percentage points. If the model does not fit the data well, this may raise concerns about how much we should trust the counterfactual exercises based upon the model.[29]

[28] An observant reader may notice that the actual manufacturing employment shares in this table are slightly higher than those in Chart 2 and the executive summary. This is because employment in farming and public administration has been deducted from employment in all industries for consistency with the IOIC codes underlying the IO data (see Appendix Table 1 of Capeluck, 2015b).

[29] As a point of reference, if we had simply predicted that the employment shares in 2008 would be identical to that observed in 1976, the mean absolute prediction error would have been about 2.5 percentage points. So the model does seem to have at least some predictive power compared to this benchmark.

Table 8: Predicted versus Actual Changes in the Sectoral Employment Shares, Current Dollar Model, Baseline Case, 1976-2008

IOIC Codes	Actual			Predicted			Ratio			
	1976	2008	Δ76-08	1976	2008	Δ76-08	1976	2008	Δ76-08	Prediction Error
	A	B	C=B-A	D	E	F=D-E	D/A*100	E/B*100	F/C*100	Abs(F-C)
Primary industries [1A, 1B, 1C, 1D, 21]	7.9	4.1	-3.8	7.9	10.3	2.4	100.0	248.1	-62.8	6.12
Secondary industries	29.1	20.7	-8.4	29.1	21.8	-7.3	100.0	105.4	86.7	1.12
Utilities [22]	1.2	0.9	-0.3	1.2	1.6	0.4	100.0	172.7	-153.4	0.68
Construction [23]	7.5	7.6	0.1	7.5	6.1	-1.4	100.0	80.0	-1082.3	1.52
Manufacturing [3A]	20.4	12.1	-8.3	20.4	14.1	-6.3	100.0	116.2	76.3	1.97
Tertiary industries	63.0	75.2	12.2	63.0	67.9	5.0	100.0	90.4	40.6	7.25
Trade [41, 4A]	17.3	16.6	-0.7	17.3	16.0	-1.3	100.0	96.3	194.2	0.62
Transportation and warehousing [4B]	6.2	5.3	-0.9	6.2	5.5	-0.7	100.0	104.3	75.7	0.22
Information, culture and recreation [51, 71]	3.8	4.7	0.9	3.8	4.4	0.6	100.0	94.3	69.7	0.26
Financial, business, building and other support services [5A, 56]	7.6	10.9	3.3	7.6	13.4	5.9	100.0	123.4	176.4	2.54
Professional, scientific and technical services [54]	2.8	7.4	4.6	2.8	5.5	2.7	100.0	74.9	59.8	1.84
Accommodation and food services [72]	4.5	6.7	2.2	4.5	3.5	-1.1	100.0	52.0	-49.6	3.21
Other tertiary industries [61, 62, 81, NP, GS]	20.8	23.7	2.8	20.8	19.6	-1.2	100.0	82.8	-43.7	4.08
Mean absolute error (Unweighted)										2.10

Source: Capeluck (2015b). Prediction errors have been calculated by the author.

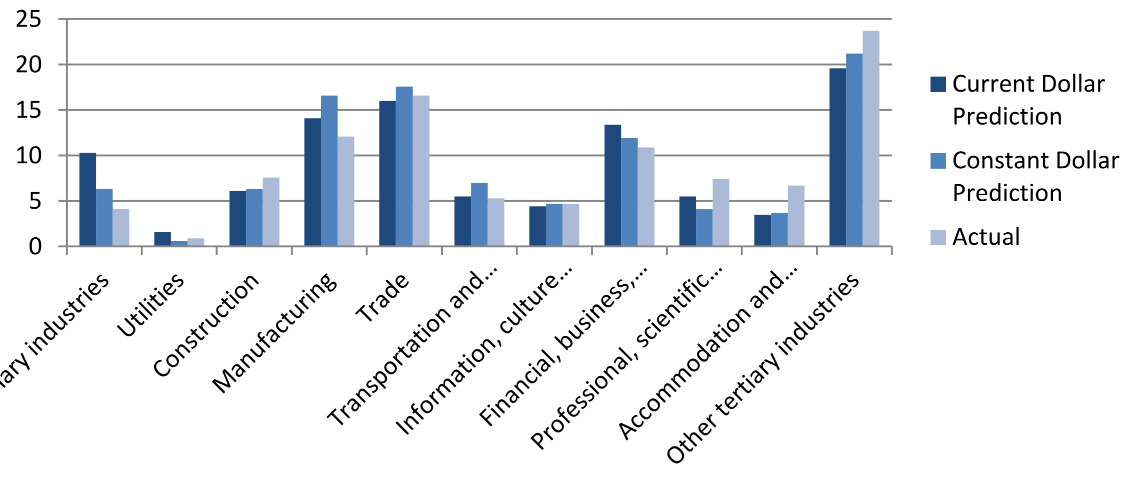
Table 9 presents the model's predictions using our chained dollar IO structure. The predicted employment distributions are quite different (Chart 9). The model does a much better job predicting the employment share of primary industries when chained dollar IO tables are used. The sign of the change in the share between years is now correct, although the predicted decline is still 2.1 percentage points too small. However, the chained dollar model performs worse for several sectors as well. The predictive power for manufacturing has fallen, with a new prediction of 16.6 per cent of employment which is 4.46 percentage points less than the actual decline and 2.49 percentage points less than the decline predicted by the current dollar model. The model also has a large prediction error of 3.22 percentage points for the PBS industry. This poor performance in our industries of interest may be a cause for concern, although we must keep in mind that the model is assuming a fixed final demand structure through time which is probably erroneous. Additionally, the model is not explicitly accounting for productivity improvements except to the extent that they manifest in the input-output structure. On average, the model performs slightly better than it had using current dollars, with a mean absolute error of 1.9 percentage points.

Table 9: Predicted versus Actual Changes in the Sectoral Employment Shares, Constant Dollar Model, Baseline Case, 1976-2008

IOIC Codes	Actual			Predicted			Ratio			Prediction Error
	1976	2008	Δ76-08	1976	2008	Δ76-08	1976	2008	Δ76-08	
	A	B	C=B-A	D	E	F=D-E	D/A*100	E/B*100	F/C*100	Abs(F-C)
Primary industries [1A, 1B, 1C, 1D, 21]	7.9	4.1	-3.8	7.9	6.3	-1.6	100.0	151.5	43.4	2.13
Secondary industries	29.1	20.7	-8.4	29.1	23.5	-5.6	100.0	113.6	66.6	2.82
Utilities [22]	1.2	0.9	-0.3	1.2	0.6	-0.6	100.0	64.6	223.5	0.33
Construction [23]	7.5	7.6	0.1	7.5	6.3	-1.2	100.0	82.8	-914.6	1.31
Manufacturing [3A]	20.4	12.1	-8.3	20.4	16.6	-3.8	100.0	136.7	46.3	4.46
Tertiary industries	63.0	75.2	12.2	63.0	70.2	7.2	100.0	93.4	59.4	4.95
Trade [41, 4A]	17.3	16.6	-0.7	17.3	17.6	0.3	100.0	105.9	-51.2	0.98
Transportation and warehousing [4B]	6.2	5.3	-0.9	6.2	7.0	0.8	100.0	133.0	-85.6	1.73
Information, culture and recreation [51, 71]	3.8	4.7	0.9	3.8	4.7	0.9	100.0	100.2	101.0	0.01
Financial, business, building, and other support services [5A, 56]	7.6	10.9	3.3	7.6	11.9	4.4	100.0	109.4	130.7	1.02
Professional, scientific and technical services [54]	2.8	7.4	4.6	2.8	4.1	1.4	100.0	56.2	29.7	3.22
Accommodation and food services [72]	4.5	6.7	2.1	4.5	3.7	-0.9	100.0	55.1	-39.9	3.00
Other tertiary industries [61, 62, 81, NP, GS]	20.8	23.7	2.8	20.8	21.2	0.4	100.0	89.5	12.9	2.48
Mean absolute error (Unweighted)										1.88

Source: CSLS calculations based on Statistics Canada data.

Chart 9: Comparison of Predicted and Actual Employment Distributions



Source: Table 8 and Table 9

C. Counterfactual Exercises

The current and constant dollar models make very different predictions about how the employment shares of the manufacturing and PBS industries would have evolved through time. Will this translate into different results regarding the effect of PBS outsourcing?

For comparison, the results from Capeluck (2015b) using current dollar IO tables are presented in Table 10, and the parallel results based on chained 2008 dollars are in Table 11.

First, consider the top row of the two tables which shows the predicted change under the "baseline case". This refers to the change in the employment share of manufacturing predicted by the model. The current dollar model predicted that manufacturing's employment share would fall by 6.3 per cent, which is 76.3 per cent of the actual decline. As we noted above, the chained dollar model is considerably less successful at predicting the decline in manufacturing's employment share. It only predicts a fall of 3.84 percentage points, about 46.3 per cent of the true reduction.

The second row (1) shows the predicted change if the direct requirements of the manufacturing industry had remained at their 1976 levels in 2008. In this case, the current dollar model predicts a predicted change of only -4.58 percentage points. To assess the impact of the changing requirements structure of manufacturing, we compare this scenario to that predicted under the baseline. In this case the predicted change is 1.75 percentage points smaller than under the baseline which suggests that the changing requirements for manufacturing can explain 21.1 per cent of the fall in manufacturing employment.

Table 10: Effect of Simulations on the Predicted Manufacturing Employment Share, Current Dollar Model, 1976-2008

Counterfactual Exercise	Predicted Change (Percentage Points)	Difference w.r.t. Baseline (Percentage Points)	Share of Actual Change (Per Cent)
	A	B = -6.33 - A	C = B / 8.30
Baseline Case	-6.33	..	76.3
1: All Coefficients Representing Requirements of Manufacturing for Intermediates	-4.58	-1.75	21.1
2: PBS/FS Coefficient	-6.05	-0.29	3.5
3: Primary Coefficient	-6.06	-0.28	3.3

Note: The predicted change and the difference with respect to the baseline case are expressed in percentage points of total employment. The ratio to data is the prediction of the simulation expressed as percentage share of the actual change in the data. The baseline prediction is based on changing all coefficients in the 1976 direct requirements table to their 2008 levels. Counterfactuals 1, 2, and 3 are identical to the baseline except that the stated coefficients are held fixed at their 1976 levels.
Source: CSLS calculations from Capeluck (2015b) based on Statistics Canada data.

When we use the chained dollar IO structure instead, we find that the predicted change under counterfactual one shrinks to only 2.84 per cent. This is one per cent less than the baseline and only represents 12.0 per cent of the actual change. Changes in the direct requirements of manufacturing only seem to have had a limited impact on the sector's employment share, noticeably less than when the current dollar estimates were used.

Table 11: Effect of Simulations on the Predicted Manufacturing Employment Share, Chained Dollar Model, 1976-2008

Counterfactual Exercise	Predicted Change (Percentage Points)	Difference w.r.t. Baseline (Percentage Points)	Share of Actual Change (Per Cent)
	A	B = -3.84 - A	C = B / 8.30
Baseline Case	-3.84	..	46.3
1: All Coefficients Representing Requirements of Manufacturing for Intermediates	-2.84	-1.00	12.0
2a: PBS Coefficient	-3.66	-0.18	2.2
2b: FS Coefficient	-3.75	-0.09	1.1
3: Primary Coefficient	-4.10	0.26	-3.1

Note: The predicted change and the difference with respect to the baseline case are expressed in percentage points of total employment. The ratio to data is the prediction of the simulation expressed as percentage share of the actual change in the data. The baseline prediction is based on changing all coefficients in the 1976 direct requirements table to their 2008 levels. Counterfactuals 1, 2a, 2b, and 3 are identical to the baseline except that the stated coefficients are held fixed at their 1976 levels.
Source: CSLS calculations based on Statistics Canada data.

Since the overall change in the structure of the direct requirements of manufacturing has only a minor effect, it is not surprising that we find that changes in specific coefficients also do not have much of an impact. Capeluck (2015b) varied both the PBS and FS direct requirements coefficients simultaneously over the 1976-2008 time period, finding that they could explain 0.29 percentage points of the fall in the manufacturing employment share or 3.5 per cent. Using the chained dollar IO data, we find that the rising PBS coefficient can explain 0.18percentage points (2.2 per cent) and the FS coefficient 0.09 percentage points (1.1 per cent). These estimates remain quite small, although they are larger than those in Capeluck (2015b). The results seem to confirm the general finding from Capeluck (2015b) that the effect of services outsourcing was quite small, although not entirely negligible.

Last, we consider the impact of changing the manufacturing requirements for intermediate inputs from primary industry. Capeluck (2015b) had found that 3.3 per cent of the reduction in manufacturing's employment share could be accounted for by the rising requirements for mineral fuels processed by manufacturing using current dollar input-output data. However, this may have been skewed by the rising price of mineral fuels. We find that this was likely the case. In real terms, the contribution of primary industries to manufacturing final demand fell considerably. The chained dollar model suggests that the primary coefficient may have increased the employment share of manufacturing by 0.26 percentage points, -3.1 per cent of the decline.

D. Time Varying Composition of Final Demand by Industry

Following Berlingieri (2014) and Capeluck (2015b), we will briefly consider how the results of the exercise change when we allow for final demand to vary through time.

Using current dollar IO data, Capeluck (2015b) concluded that accounting for changes in the structure of final demand marginally improved the ability of the model to explain manufacturing's declining employment share. The absolute prediction error shrank from 1.97 percentage points to 1.72 percentage points (Table 12). However, Capeluck notes that the predictive power of the model is worse for seven out of the eleven industries, so it is not clear that the approach to estimating how final demand changed through time improves the performance of the model. When we consider the sizes of the errors by looking at the mean absolute error, we find that the model with time varying demand is quite a bit less reliable. The mean absolute error is 2.50 per cent, 0.40 per cent higher than in the vanilla model. This is about as bad as simply predicting that the employment shares remained at their 1976 levels.

If we use chained dollar IO data instead, the time-varying demand variant of the model does not perform much better (Table 13). It has a mean absolute error of which is only 0.01 lower than that of the model based on constant dollar data and 0.61 percentage points worse than the model without time varying demand. While the prediction for manufacturing is somewhat better (the error is only 3.11 percentage points instead of 4.46 percentage points), the generally poor performance of the model raises concerns about whether it will provide a better understanding of how services outsourcing has contributed to manufacturing's decline.

Nonetheless, we will briefly examine the robustness of the results to this alternative approach to final demand.

Table 12: Predicted versus Actual Changes in the Sectoral Employment Shares, Current Dollar Model with Time Varying Final Demand, Baseline Case, 1976-2008

IOIC Codes	Actual			Predicted			Ratio			Prediction Error
	1976	2008	Δ76-08	1976	2008	Δ76-08	1976	2008	Δ76-08	
	A	B	C=B-A	D	E	F=D-E	D/A*100	E/B*100	F/C*100	Abs(F-C)
Primary industries [1A, 1B, 1C, 1D, 21]	7.90	4.13	-3.76	7.90	11.72	3.83	100	283.6	-101.8	7.59
Secondary industries	29.14	20.7	-8.44	29.14	22.54	-6.60	100	108.9	78.2	1.84
Utilities [22]	1.21	0.94	-0.27	1.21	2.63	1.42	100	280.6	-529.8	1.69
Construction [23]	7.49	7.62	0.13	7.49	6.05	-1.44	100	79.4	-1,116.80	1.57
Manufacturing [3A]	20.44	12.14	-8.3	20.44	13.86	-6.58	100	114.1	79.3	1.72
Tertiary industries	62.97	75.17	12.2	62.97	65.73	2.77	100	87.5	22.7	9.43
Trade [41, 4A]	17.26	16.61	-0.65	17.26	14.83	-2.43	100	89.3	373	1.78
Transportation and warehousing [4B]	6.19	5.25	-0.93	6.19	5.14	-1.05	100	97.8	112.4	0.12
Information, culture and recreation [51, 71]	3.81	4.69	0.88	3.81	3.66	-0.15	100	78.1	-16.5	1.03
Financial, business, building, and other support services [5A, 56]	7.55	10.88	3.33	7.55	13.64	6.09	100	125.3	182.8	2.76
Professional, scientific and technical services [54]	2.78	7.36	4.58	2.78	5.60	2.82	100	76.1	61.6	1.76
Accommodation and food services [72]	4.54	6.69	2.15	4.54	3.74	-0.80	100	55.9	-37.3	2.95
Other tertiary industries [61, 62, 81, NP, GS]	20.84	23.68	2.84	20.84	19.13	-1.72	100	80.8	-60.4	4.56
Mean absolute error (Unweighted)										2.50

Source: Capeluck (2015b). Prediction errors have been calculated by the author.

Table 13: Predicted versus Actual Changes in the Sectoral Employment Shares, Constant Dollar Mode with Time Varying Final Demand, Baseline Case, 1976-2008

IOIC Codes	Actual			Predicted			Ratio			
	1976	2008	Δ76-08	1976	2008	Δ76-08	1976	2008	Δ76-08	Prediction Error
	A	B	C=B-A	D	E	F=D-E	D/A*100	E/B*100	F/C*100	Abs(F-C)
Primary industries [1A, 1B, 1C, 1D, 21]	7.9	4.1	-3.8	7.9	10.0	2.1	100.0	241.5	-55.5	5.85
Secondary industries	29.1	20.7	-8.4	29.1	25.5	-3.7	100.0	123.0	43.7	4.75
Utilities [22]	1.2	0.9	-0.3	1.2	3.7	2.5	100.0	390.7	-913.5	2.72
Construction [23]	7.5	7.6	0.1	7.5	6.5	-0.9	100.0	85.9	-734.9	1.08
Manufacturing [3A]	20.4	12.1	-8.3	20.4	15.2	-5.2	100.0	125.6	62.6	3.11
Tertiary industries	63.0	75.2	12.2	63.0	64.6	1.6	100.0	85.9	13.1	10.60
Trade [41, 4A]	17.3	16.6	-0.7	17.3	14.1	-3.2	100.0	84.7	490.0	2.54
Transportation and warehousing [4B]	6.2	5.3	-0.9	6.2	6.0	-0.1	100.0	115.1	14.8	0.79
Information, culture and recreation [51, 71]	3.8	4.7	0.9	3.8	2.4	-1.4	100.0	52.1	-154.1	2.25
Financial, business, building, and other support services [5A, 56]	7.6	10.9	3.3	7.6	12.1	4.6	100.0	111.5	137.5	1.25
Professional, scientific and technical services [54]	2.8	7.4	4.6	2.8	4.6	1.8	100.0	62.3	39.5	2.77
Accommodation and food services [72]	4.5	6.7	2.1	4.5	4.6	0.1	100.0	69.1	3.7	2.07
Other tertiary industries [61, 62, 81, NP, GS]	20.8	23.7	2.8	20.8	20.7	-0.2	100.0	87.3	-6.3	3.02
Mean absolute error (Unweighted)										2.49

Source: CSLS calculations based on Statistics Canada data.

Table 14: Effect of Simulations on the Predicted Manufacturing Employment Share, Current Dollar Model, 1976-2008

Counterfactual Exercise	Predicted Change (Percentage Points)	Difference w.r.t. Baseline (Percentage Points)	Share of Actual Change (Per Cent)
	A	B = -6.58 - A	C = B / 8.30
Baseline Case	-6.58	..	79.3
1: All Coefficients Representing Requirements of Manufacturing for Intermediates	-4.87	-1.71	20.9
2: PBS/FS Coefficient	-6.53	-0.05	0.6
3: Primary Coefficient	-6.32	-0.26	3.1

Note: The predicted change and the difference with respect to the baseline case are expressed in percentage points of total employment. The ratio to data is the prediction of the simulation expressed as percentage share of the actual change in the data. The baseline prediction is based on changing all coefficients in the 1976 direct requirements table to their 2008 levels. Counterfactuals 1, 2, and 3 are identical to the baseline except that the stated coefficients are held fixed at their 1976 levels.
Source: CSLS calculations from Capeluck (2015b) based on Statistics Canada data.

Table 15: Effect of Simulations on the Predicted Manufacturing Employment Share, Chained Dollar Model, 1976-2008

Counterfactual Exercise	Predicted Change (Percentage Points)	Difference w.r.t. Baseline (Percentage Points)	Share of Actual Change (Per Cent)
	A	B = -5.20 - A	C = B / 8.30
Baseline Case	-5.20	..	62.6
1: All Coefficients Representing Requirements of Manufacturing for Intermediates	-4.24	-0.95	11.5
2a : PBS Coefficient	-5.04	-0.15	1.8
2b : FS Coefficient	-5.12	-0.08	0.9
3: Primary Coefficient	-5.41	0.21	-2.5

Note: The predicted change and the difference with respect to the baseline case are expressed in percentage points of total employment. The ratio to data is the prediction of the simulation expressed as percentage share of the actual change in the data. The baseline prediction is based on changing all coefficients in the 1976 direct requirements table to their 2008 levels. Counterfactuals 1, 2a, 2b, and 3 are identical to the baseline except that the stated coefficients are held fixed at their 1976 levels.
Source: CSLS calculations based on Statistics Canada data.

Table 14 and Table 15 present the results of the counterfactual exercises. While the chained dollar model is now able to explain 62.6 per cent of the drop in manufacturing's employment share compared to 46.3 per cent in the model with constant demand, the remainder of the results are reasonably robust. The total impact of changes in all requirements for manufacturing was about 11.5 per cent using chained dollars and significantly lower than the estimate of 20.9 per cent from Capeluck (2015b). The PBS and FS coefficients had fairly small impacts of 1.8 and 0.9 per cent of the total change respectively, although this is a bit larger than their combined effect of 0.6 per cent of the change estimated by Capeluck (2015b). Consistent with Table 11, changes to the coefficient from primary industries were found to have made a positive contribution of 2.5 per cent to manufacturing's employment share.

E. Conclusions from the Input-Output Analysis

Our findings are generally in line with those from Capeluck (2015b) despite the change from current to chained data for constructing the direct requirements tables.

The basic model with chained dollar data performs modestly better at predicting the overall distribution of employment in the economy than that with current dollars from Capeluck (2015b).

We find that using the real rather than nominal IO structure of the economy provides a much better estimate of the change in the employment share of primary industry between 1976 and 2008. However, it is not able to explain as much of the decline in manufacturing's employment share, accounting for only 46 per cent.

The finding that increased PBS and FS outsourcing by manufacturing likely only had a small effect on the fall in manufacturing employment relative to the total decline holds whether current or chained IO data is used.

The findings regarding the effects of PBS and FS outsourcing remain robust under the extended model which allows final demand to vary. However, this extension is quite a bit worse at predicting the employment distribution of the economy than the model with a constant demand structure.

Regardless of the model's poor performance at predicting the evolution of Canada's employment distribution across industries between 1976 and 2008, there is reason to think that the consistent result of relatively small contributions from PBS and FS outsourcing whether real or nominal IO data is correct. Simply examining the IO tables, one sees that PBS and FS intermediate inputs are simply not all that large compared to the total intermediate use of manufacturing, let alone the overall economy. In 2008, the PBS and FS coefficients represented only 8 per cent of manufacturing's direct requirements for intermediate inputs. Moreover, the change in the PBS coefficient between 1976 and 2008 only amounted to1.7 per cent of manufacturing's 2008 direct requirements for intermediate inputs and the change in the FS coefficient was only 3.1 per cent. Given the relatively small magnitudes of the changes we are considering in comparison to the total needs of the manufacturing sector, it is not surprising that only changing these two direct requirements coefficients would be found to have a small effect on the employment share of manufacturing.

V. Analysis of Occupation and Employment by Industry

Instead of examining how changes to the input-output structure may have changed labour requirements for manufacturing, another approach to exploring how service outsourcing contributed to the decline of manufacturing employment is to examine how the allocation of employment across industries and occupations has changed with time.

The premise is quite simple. If PBS outsourcing by manufacturing has taken place, we would expect to observe employment shifting away from "PBS occupations" in the manufacturing sector to similar jobs (that is, jobs in the same service occupations) in non-manufacturing sectors. We can decompose the change in manufacturing's employment share through time into such a "within-PBS-occupation component" as well as components due to changes in the industry of employment of workers within non-PBS occupations, movements from occupations which are concentrated in manufacturing into other occupations which are not (between-occupation components), and interactions of these within and between occupational changes.

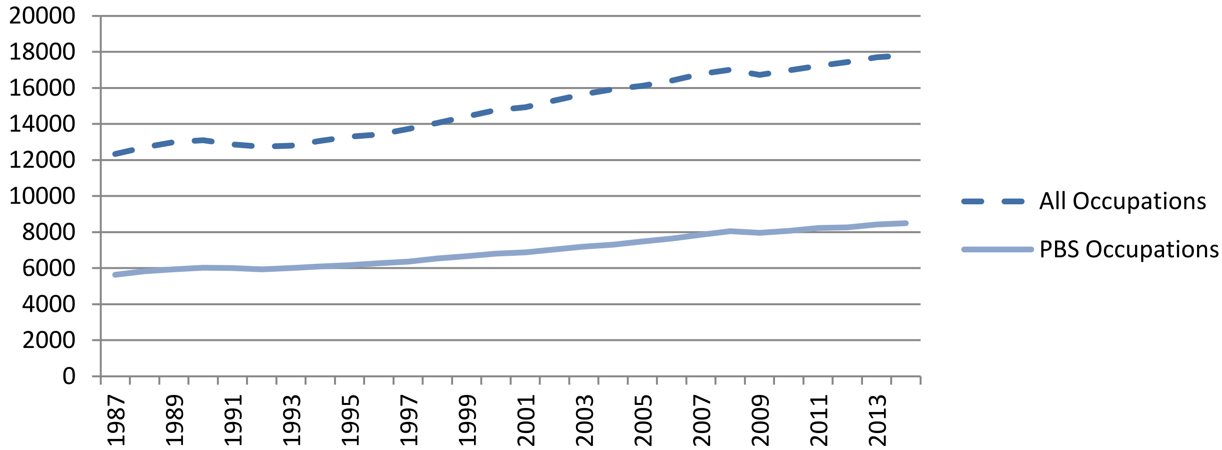
This approach is somewhat imprecise because it must assume that working in the same occupation is equivalent to doing the same work. It is also important to note that even observing 100 clerks leave manufacturing to work in the PBS industry does not necessarily imply that any outsourcing has occurred – it is possible that all of the clerks might be providing PBS services to those in non-manufacturing industries. Our data does not even allow us to observe the gross flows between industries, so we are not able to identify movements of the same workers from manufacturing to PBS industries. Such data would allow us to make stronger claims regarding the occurrence of PBS outsourcing and could be obtained from the Labour Force Survey, at least in principle. Our data only identifies how the shares in total employment of each occupation in each industry have changed through time, but not the underlying flows. Nonetheless, our data on the overall occupation-industry employment distribution through time can provide some suggestive evidence that PBS outsourcing may have occurred, particularly given that we know that the share of service inputs in manufacturing gross output has increased through time.

The decomposition exercise requires identification of occupations associated with the PBS industry. For comparability, we adopt a very similar definition to that of Capeluck (2015b): PBS occupations are defined as occupations for which the PBS industry's share of the total employment in the occupation was larger than the PBS industry's share of total employment in 2011. This means that an occupation is classified as PBS if more than 11.2 per cent of its workers were employed in the PBS industry in 2011. We also define manufacturing occupations in a similar manner. Note that manufacturing and PBS occupations are not mutually exclusive groups as an occupation can fall into both categories.

A. Trends in PBS Occupations

First, we will review a few trends noted in Capeluck (2015b), based upon data from the Labour Force Survey using 2-digit NOC-S occupations and our definition of PBS occupations. In absolute terms, employment in PBS occupations has been rising in Canada since 1987(Chart 10). The pace of growth has been fairly similar to that of all occupations.

Chart 10: Employment, PBS Occupations and All Occupations, Total Economy, Thousands of Workers, Canada, 1987-2014

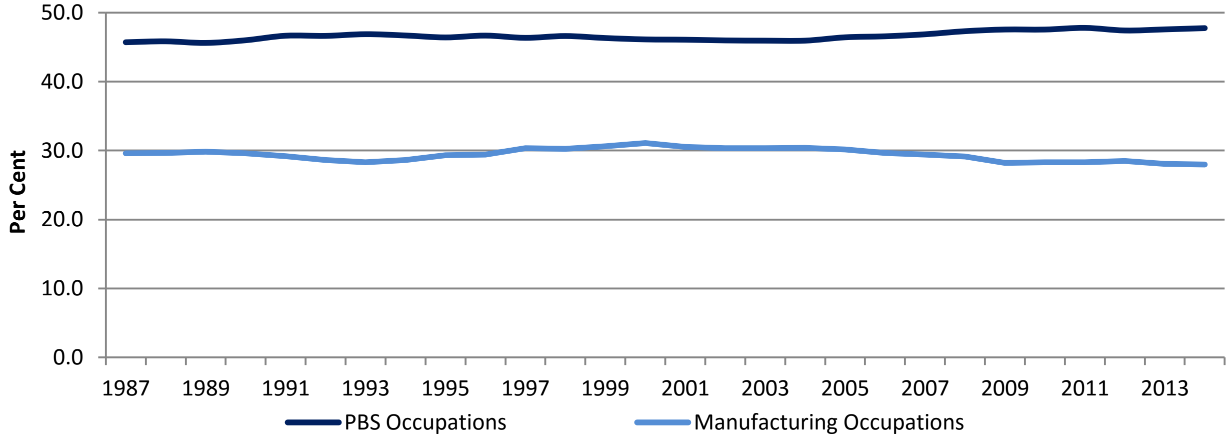


Source: CSLS calculations based on Statistics Canada data. Labour Force Survey. Special order.

The share of PBS workers in total employment has risen from slightly above 45 per cent in 1987 to about 48 per cent in 2014 (Chart 11). Over the same period, the share of manufacturing occupations in total employment fell from nearly 30 per cent in 1987 to slightly below 28 per cent in 2014. This suggests that there has been some reduction in the importance of occupations associated with manufacturing[30] in Canada and an increase in occupations associated with the PBS industry, but the change is much smaller than the shifts observed in the employment shares of the PBS and manufacturing industries.

[30] Note that our broad definition implies that not all "manufacturing occupations" are necessarily occupations directly involved in production. Service occupations which are overrepresented in the manufacturing industry relative to its size are also included. The share of production manufacturing occupations in total economy employment will be much lower.

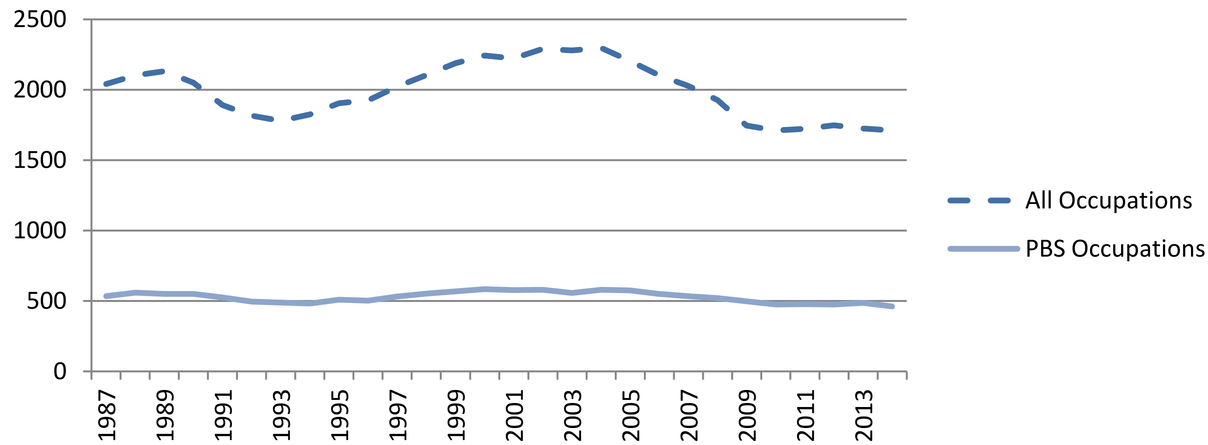
Chart 11: Employment in PBS and Manufacturing Occupations as a Share of Total Employment, Per Cent, 1987-2014



Source: CSLS calculations based on Statistics Canada data. Labour Force Survey. Special order.

Within the manufacturing sector, total employment in 2014 was considerably lower than it had been in 1987 in absolute terms (1.7 million workers compared to 2.0 million). One can see in Chart 12 that manufacturing employment fluctuated widely. It rose throughout most of the 1990s but has collapsed since 2004. Manufacturing employment in PBS occupations has generally followed the same trends but appears to have been relatively stable. Employment in PBS occupations within the sector has fallen from 534 thousand workers in 1987 to 461 thousand workers in 2014.

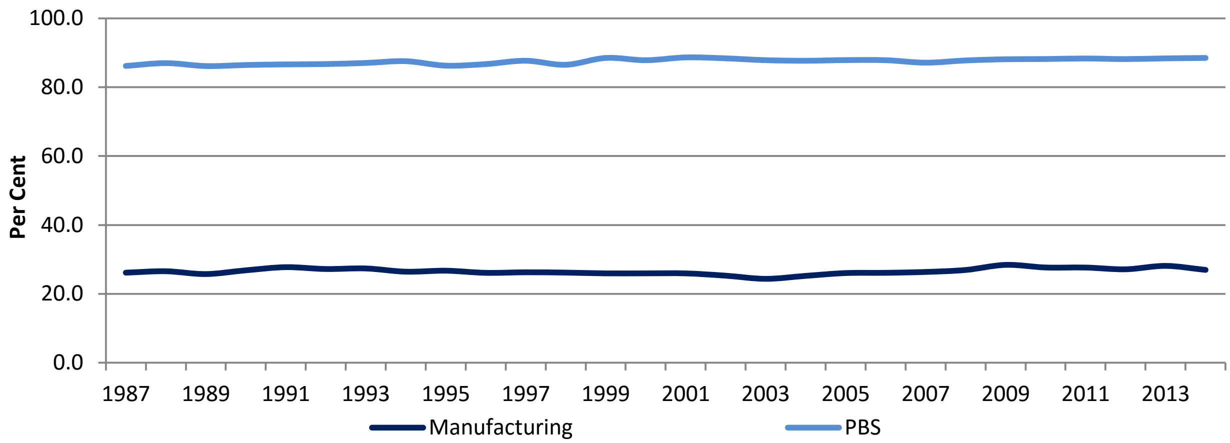
Chart 12: Employment, PBS Occupations and All Occupations, Manufacturing Industry, Thousands of Workers, Canada, 1987-2014



Source: CSLS calculations based on Statistics Canada data. Labour Force Survey. Special order.

Chart 13shows workers in PBS occupations as a percentage of total employment in the manufacturing and PBS industries over the period. As we might hope, most (nearly 90 per cent) of the workers in the PBS industry work in PBS occupations. This share has risen through time. PBS workers are considerably less important in manufacturing, where they account for about 27 per cent of employment, slightly more than in 1987. One may have expected the share of PBS workers in manufacturing to have fallen through time if PBS outsourcing occurred. However, this observation is not necessarily inconsistent with an outsourcing story, because it could be that PBS occupations have become more important to manufacturing so that the share rose even with greater outsourcing. For example, since 2003 there has been a notable increase in the share of employment in PBS occupations in total manufacturing employment. This may reflect reductions in the number of production staff required due to weak demand while the number of administrative staff remained relatively stable. Similarly, if there were significantly greater improvements in the productivity of production workers in the manufacturing industry than there were in the productivity of workers employed in PBS occupations in the manufacturing industry, then the share of PBS occupations in the industry's employment would have been expected to increase.

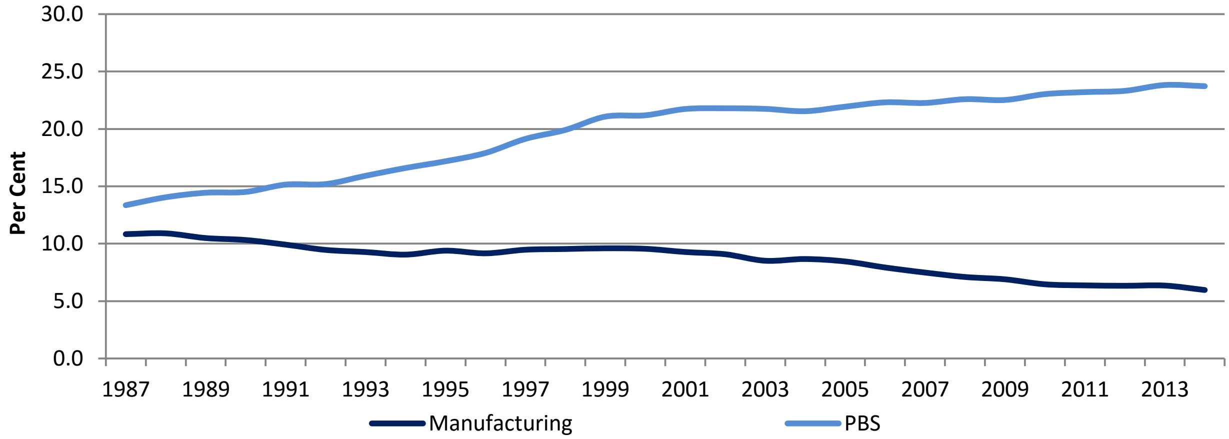
Chart 13: Workers in PBS Occupations as a Share of Total Employment in the Manufacturing and PBS Industries, Per Cent, 1987-2014



Source: CSLS calculations based on Statistics Canada data. Labour Force Survey. Special order

Finally, Chart 14 shows the shares of the manufacturing and PBS industries in the total employment of workers in PBS occupations from 1987 to 2014. There has been a significant increase in the PBS industry's share of workers in PBS occupations from about 14 per cent in 1987 to about 24 per cent in 2014. Over the same period, the manufacturing industry's share of PBS workers fell by nearly 5 percentage points from slightly more than 10 per cent to slightly more than 5 per cent. This is consistent with a hypothesis of PBS outsourcing from manufacturing. However, we would also expect to observe a decline in the manufacturing industry's share of employment in PBS occupations if manufacturing employment in PBS occupations fell proportionally to total manufacturing employment as the sector declined for reasons other than PBS outsourcing. Indeed, the decline in manufacturing's share of PBS employment by 45 per cent over the period was similar to the decline in manufacturing's share of total employment by 42 per cent.

Chart 14: Manufacturing and PBS Industry Employment of Workers in PBS Occupations as a Share of Total Employment of Workers in PBS Occupations, Per Cent, 1987-2014



Source: CSLS calculations based on Statistics Canada data. Labour Force Survey. Special order.

B. Occupational Decomposition of Manufacturing's Declining Employment Share

Capeluck (2015b) presented decompositions of growth in the employment share of the PBS industry by PBS and non-PBS occupations, growth in the employment share of the financial services industry by FS and non-FS occupations, and the fall in the employment share of the manufacturing industry by manufacturing and non-manufacturing occupations. However, the report did not present the details of a decomposition of manufacturing's falling employment share by PBS and non-PBS occupations (although the results of such an exercise were noted in the text). We will focus on this last decomposition, as it most clearly addresses the objectives of this report.

Table 16presents the decomposition based on the data from Capeluck (2014b) except that PBS industries are defined based on the industry-occupation employment distribution of 2011 instead of 1987. The results indicate that, of a 7.03 percentage point decline in manufacturing's employment share between 1987 and 2014 from 16.6 per cent to 9.6 per cent, 1.78percentage points are associated with PBS occupations. Secretaries, specialist managers, clerical occupations, and sales and service occupations were the most important PBS contributors. The "within-occupation component" is responsible for the entire decline related to PBS occupations (-2.04percentage points) suggesting that a significant amount of the decline (29per cent) was due to PBS workers shifting into other industries. This within-occupation component may be related to PBS outsourcing. The increase in the share of PBS workers in the total economy made a positive contribution (the between-occupation effect) to manufacturing's employment share.

Table 16: Decomposition of Decline in the Employment Share of Manufacturing, Percentage Points, 1987-2014

NOC-S Occupation	Per Cent of Manufacturing Employment	Within	Between	Cross	Total
PBS Occupations	26.24	-2.04	0.38	-0.11	-1.78
Specialist Managers	2.87	-0.26	0.00	0.00	-0.26
Professional Occupations in Business and Finance	1.16	-0.11	0.11	-0.06	-0.06
Finance and Insurance Administrative Occupations	0.57	-0.05	0.00	0.00	-0.05
Secretaries	2.35	-0.30	-0.30	0.23	-0.37
Administrative and Regulatory Occupations	1.31	-0.09	0.13	-0.05	-0.01
Clerical Occupations	7.24	-0.38	-0.22	0.07	-0.53
Professional Occupations in Natural and Applied Sciences	1.16	-0.24	0.40	-0.19	-0.03
Technical Occupations Related to Natural and Applied Sciences	3.28	-0.18	0.15	-0.05	-0.07
Judges, Lawyers, Psychologists, Social Workers, Ministers of Religion, and Policy and Program Officers	0.17	-0.01	0.03	-0.01	0.00
Paralegals, Social Services Workers and Occupations in Education and Religion, N.E.C.	0.00	0.00	0.00	0.00	0.00
Professional Occupations in Art and Culture	0.21	-0.01	0.01	0.00	-0.01
Technical Occupations in Art, Culture, Recreation and Sport	0.66	-0.06	0.06	-0.04	-0.04
Occupations in Protective Services	0.26	-0.03	0.00	0.00	-0.03
Occupations in Travel and Accommodation Including Attendants in Recreation and Sport	0.00	0.00	0.00	0.00	0.00
Sales & Service Occupations N.E.C.	2.31	-0.24	0.02	-0.01	-0.24
Heavy Equipment and Crane Operators Including Drillers	0.81	-0.08	-0.01	0.01	-0.09
Occupations Unique to Agriculture Excluding Labourers	0.00	0.00	0.00	0.00	0.00
Primary Production Labourers	0.00	0.00	0.00	0.00	0.00
Non-PBS Occupations	73.76	-2.03	-3.43	0.20	-5.26
Total	100.00	-4.07	-3.05	0.09	-7.03

Note: All figures are expressed in terms of percentage points of total employment. The grand total is the decrease in the manufacturing industry's share of total employment from 1987 to 2014. All the PBS occupations are listed.
Source: CSLS calculations based on Statistics Canada data. Labour Force Survey. Special order.

Notice that the majority of the decline, 5.26 percentage points, was associated with non-PBS occupations. The between-occupation component of -3.43 percentage points was somewhat larger than the within-occupation component of -2.03 percentage points for non-PBS occupations, although both were greater than the overall effect of PBS occupations.

These results suggest that more than one quarter of the decline in manufacturing's employment share since 1987 was the result of manufacturing's share of total employment within PBS occupations declining.[31] Unfortunately, we do not know exactly what sort of work this segment of the population was doing in the manufacturing sector in 1987 compared to outside the sector in 2014, but only that its workers were employed in the same 2-digit occupation. The decomposition does not quantify the extent to which manufacturing's declining share of an occupation's employment coincides with a rising share of the PBS industry in that occupation's employment. It also does not provide any information as to how manufacturing's share of the output produced by those working in PBS occupations has changed through time.

When assessing the potential relationship between the PBS within sector component and PBS outsourcing, we should keep in mind that we might expect to attribute a sizable share of the decline to PBS occupations simply because they account for a sizable share (about 26 per cent in 1987) of employment in the manufacturing sector. In particular, if the manufacturing sector had declined for purely exogenous reasons, say a negative shock to demand, and if this decline occurred uniformly across all occupations in manufacturing, then we would expect 26 per cent of the decline to be in PBS occupations, potentially with a sizable within occupation component. For this reason, we should consider the estimated within-sector contribution above and beyond that expected from such a negative shock when using this decomposition to search for evidence supporting a hypothesis of services outsourcing as a source of the decline.

Table 17 provides a counterfactual decomposition which would have been observed if employment growth had been uniform across all industries and occupations since 1987 except that manufacturing employment declined by a constant rate across all occupations such that the decline in manufacturing's employment share was in line with that observed between 1987 and 2014. Under such a scenario, the decline in the employment share associated with each occupation is proportional to that occupation's share in manufacturing employment. The specific assumption about what happens to employment in all non-manufacturing sectors allows for this to be decomposed into within, between, and cross-occupation terms. Notice that the predicted

[31] It is not necessarily accurate to describe this as indicating that employees in PBS occupations in the manufacturing sector in 1987 left the industry and continued to work in the same PBS occupations in the non-manufacturing sector in 2014, although the absolute fall in the number of the manufacturing industry's employees in PBS occupations from 534 thousand in 1987 to 461 thousand in 2014 suggests that this is at least part of the story, It is more accurate to say that an increasing share of PBS workers have been working outside the manufacturing sector. Keep in mind that a decline in manufacturing's share of workers in PBS occupations may be observed if employment in these occupations in non-manufacturing was rising for reasons completely unrelated to manufacturing. For example, if the oil and gas industry was growing and required more security guards (occupations in protective services, a PBS occupation), this would raise the PBS within-occupation component of the manufacturing employment share decomposition even if there was no change in the number of security guards employed in the manufacturing industry.

within-PBS occupation component under this counterfactual scenario would also have been very large, about -1.86 percentage points.[32]

Table 17: Expected Decomposition of Decline in the Employment Share of Manufacturing from Proportional Decline, Percentage Points, 1987-2014

NOC-S Occupation	Within	Between	Cross	Total
PBS Occupations	-1.86	0.04	-0.02	-1.84
Specialist Managers	-0.19	-0.02	0.01	-0.20
Professional Occupations in Business and Finance	-0.08	0.01	0.00	-0.08
Finance and Insurance Administrative Occupations	-0.04	0.00	0.00	-0.04
Secretaries	-0.17	0.01	-0.01	-0.16
Administrative and Regulatory Occupations	-0.09	0.00	0.00	-0.09
Clerical Occupations	-0.52	0.03	-0.01	-0.51
Professional Occupations in Natural and Applied Sciences	-0.21	-0.01	0.00	-0.21
Technical Occupations Related to Natural and Applied Sciences	-0.22	-0.01	0.01	-0.23
Judges, Lawyers, Psychologists, Social Workers, Ministers of Religion, and Policy and Program Officers	-0.01	0.00	0.00	-0.01
Paralegals, Social Services Workers and Occupations in Education and Religion, N.E.C.	0.00	0.00	0.00	0.00
Professional Occupations in Art and Culture	-0.02	0.00	0.00	-0.01
Technical Occupations in Art, Culture, Recreation and Sport	-0.05	0.00	0.00	-0.05
Occupations in Protective Services	-0.02	0.00	0.00	-0.02
Occupations in Travel and Accommodation Including Attendants in Recreation and Sport	0.00	0.00	0.00	0.00
Sales & Service Occupations N.E.C.	-0.17	0.02	-0.01	-0.16
Heavy Equipment and Crane Operators Including Drillers	-0.06	0.00	0.00	-0.06
Occupations Unique to Agriculture Excluding Labourers	0.00	0.00	0.00	0.00
Primary Production Labourers	0.00	0.00	0.00	0.00
Non-PBS Occupations	-2.53	-2.92	0.28	-5.17
Total	-4.39	-2.87	0.26	-7.00

Note: All figures are expressed in terms of percentage points of total employment. The grand total is the decrease in the manufacturing industry's share of total employment from 1987 to 2014. All the PBS occupations are listed.
Source: CSLS calculations based on Statistics Canada data. Labour Force Survey. Special order.

[32] Notice that under this scenario, most of the between-occupation effects would have been very small. Intuitively, reducing manufacturing employment in each occupation will lower the share of manufacturing within each occupation quite a bit, but it will only have a sizable impact on the share of the occupation in total employment in a small set of occupations which are highly concentrated in manufacturing. Under this counterfactual, the only occupations for which the between occupation component exceeds 0.10 percentage points in magnitude are Machinists, Metal Forming, Shaping and Erecting Occupations (-0.22 percentage points); Supervisors in Manufacturing (-0.27 percentage points); Machine Operators in Manufacturing (-1.28 percentage points); Assemblers in Manufacturing (-0.58 percentage points); and Labourers in Processing, Manufacturing and Utilities (-0.49 percentage points).

Table 18: Decomposition of Decline in the Employment Share of Manufacturing in Excess of Expected Proportional Change, Percentage Points, 1987-2014

NOC-S Occupation	Within	Between	Cross	Total
PBS Occupations	-0.18	0.33	-0.09	0.07
Specialist Managers	-0.06	0.01	-0.01	-0.06
Professional Occupations in Business and Finance	-0.02	0.11	-0.06	0.02
Finance and Insurance Administrative Occupations	-0.01	0.00	0.00	-0.01
Secretaries	-0.13	-0.32	0.24	-0.21
Administrative and Regulatory Occupations	0.01	0.13	-0.05	0.08
Clerical Occupations	0.14	-0.24	0.08	-0.02
Professional Occupations in Natural and Applied Sciences	-0.03	0.41	-0.19	0.19
Technical Occupations Related to Natural and Applied Sciences	0.04	0.17	-0.06	0.16
Judges, Lawyers, Psychologists, Social Workers, Ministers of Religion, and Policy and Program Officers	0.00	0.02	-0.01	0.01
Paralegals, Social Services Workers and Occupations in Education and Religion, N.E.C.	0.00	0.00	0.00	0.00
Professional Occupations in Art and Culture	0.00	0.01	0.00	0.01
Technical Occupations in Art, Culture, Recreation and Sport	-0.02	0.06	-0.04	0.01
Occupations in Protective Services	-0.01	-0.01	0.00	-0.01
Occupations in Travel and Accommodation Including Attendants in Recreation and Sport	0.00	0.00	0.00	0.00
Sales & Service Occupations N.E.C.	-0.07	-0.01	0.00	-0.07
Heavy Equipment and Crane Operators Including Drillers	-0.03	-0.01	0.01	-0.03
Occupations Unique to Agriculture Excluding Labourers	0.00	0.00	0.00	0.00
Primary Production Labourers	0.00	0.00	0.00	0.00
Non-PBS Occupations	0.50	-0.52	-0.08	-0.09
Total	0.32	-0.18	-0.17	-0.02

Note: All figures are expressed in terms of percentage points of total employment minus the rates expected from a uniform decline in the manufacturing employment levels observed in 1991 holding employment in all other industries fixed.. The grand total is the decrease in the manufacturing industry's share of total employment from 1987 to 2014. All the PBS occupations are listed.
Source: CSLS calculations based on Statistics Canada data. Labour Force Survey. Special order.

The difference between the actual PBS within-occupation component of -2.04 percentage points and that of -1.86 percentage points which we would expect from a proportional decrease in all occupations driven by some external decline in manufacturing provides some idea of the disproportional loss in employment associated with movements across industries within PBS occupations (Table 18). The disproportional impact is -0.18 percentage points, or about 2.6 per cent of the total decline. While this effect can still not be definitively tied to PBS outsourcing, the scale is much closer to the estimates from our input-output exercise. Controlling for the size of employment in PBS occupations relative to total employment in the manufacturing industry seems to reconcile the divergent results of the input-output and labour decomposition exercises regarding the magnitude of the effect of PBS outsourcing. When we consider that a major driver of the decline in manufacturing employment was reduced demand for the sector's output and that this likely impacted all occupations within manufacturing in a similar way, the decomposition only suggests a very small effect which may be related to PBS outsourcing.

Capeluck (2015b) expressed some concern that the within-occupation component, which would capture PBS outsourcing, may be overstated because this LFS data only allows for a very broad classification of occupations and may misclassify movements across industries in similar occupations as movements within the same occupation. We now examine the robustness of the results using data from the 1991 Census and 2011 National Household Survey at the finest available level of occupational disaggregation.

As noted in the methodology section, these occupational data should be considered lower quality than that from the LFS used above because the data for 1991 was based upon 1980 SIC and 1980 SOC classifications while the data for 2011 was based on 2007 NAICS and 2011 NOC codes. While we have endeavoured to make the data as comparable as possible using Statistics Canada's publically available concordance tables, the comparison remains imperfect. Comparisons through time are particularly problematic at the finest levels of disaggregation, which is what we are interested in. For this reason, we will consider a series of decompositions based on four different levels of disaggregation and two different assumptions regarding how 1980 SOC codes map to 2011 NOC codes in cases of ambiguity. We will see that the general result of a sizable PBS within-occupation component which is smaller than the non-PBS contribution tends to be fairly robust, although the precise magnitude of the contributions varies somewhat.

Table 19presents the results using all four possible levels of disaggregation based on upon an equal weighting scheme to map the 1980 SOC codes into 2011 NOC codes. According to these data, the employment share of manufacturing fell by 4.66 percentage points between 1991 and 2011. Under all four levels of disaggregation, PBS occupations made a significant contribution to the decline in manufacturing employment mostly through the within-occupation effect. The PBS within-occupation component ranged from 25 per cent of the decline at the one-digit level to 38 per cent at the 3-digit level. At the two-digit level, this channel explains about 31 per cent of the decline which is very similar to the result using the LFS data.

Unlike the results using the Labour Force Survey data, the PBS between-occupation term based on census data is now negative and tends to be quite small in magnitude.

Most of the decline is associated with non-PBS occupations, with the between occupation component appearing to be more important. The decline associated with movements across industries within occupations is mostly in PBS occupations under the 2, 3, and 4 digit levels of disaggregation. The non-PBS occupation cross term is also non-negligible at most levels of disaggregation.

Table 19: Decomposition of Decline in the Employment Share of Manufacturing by Level of Occupational Aggregation, 1991-2011

		Within	Between	Cross	Total
1-Digit	PBS Occupation	-1.17	-0.07	0.09	-1.16
	Non-PBS Occupations	-1.23	-1.77	-0.50	-3.50
	Total	-2.40	-1.84	-0.41	-4.66
2-Digit	PBS Occupation	-1.48	-0.19	0.05	-1.62
	Non-PBS Occupations	-0.87	-1.69	-0.48	-3.04
	Total	-2.35	-1.88	-0.43	-4.66
3-Digit	PBS Occupation	-1.76	-0.29	0.32	-1.73
	Non-PBS Occupations	-0.54	-1.71	-0.67	-2.92
	Total	-2.30	-2.00	-0.35	-4.66
4-Digit	PBS Occupation	-1.51	-0.16	0.18	-1.49
	Non-PBS Occupations	-1.18	-1.85	-0.13	-3.17
	Total	-2.70	-2.01	0.05	-4.66

Note: All figures are expressed in terms of percentage points of total employment. The grand total is the decrease in the manufacturing industry's share of total employment from 1991 to 2011.Occupational data converted to 2011 NOC codes based on an "equal" weighting scheme (see Appendix C).
Source: CSLS calculations based on Statistics Canada data. 1991 Census, special order, and publically available National Household Survey data.

Table 20: Expected Decomposition of Decline in the Employment Share of Manufacturing in from Proportional Decline by Level of Occupational Aggregation, 1991-2011

		Within	Between	Cross	Total
1-Digit	PBS Occupation	-1.14	0.03	-0.01	-1.13
	Non-PBS Occupations	-2.81	-0.87	0.15	-3.53
	Total	-3.95	-0.85	0.14	-4.66
2-Digit	PBS Occupation	-1.40	0.05	-0.02	-1.37
	Non-PBS Occupations	-2.50	-0.96	0.17	-3.28
	Total	-3.90	-0.91	0.15	-4.66
3-Digit	PBS Occupation	-1.38	-0.04	0.01	-1.41
	Non-PBS Occupations	-2.32	-1.12	0.19	-3.25
	Total	-3.70	-1.16	0.20	-4.66
4-Digit	PBS Occupation	-1.19	-0.13	0.03	-1.29
	Non-PBS Occupations	-2.25	-1.28	0.17	-3.36
	Total	-3.44	-1.41	0.20	-4.66

Note: All figures are expressed in terms of percentage points of total employment. The grand total is the decrease in the manufacturing industry's share of total employment from 1991 to 2011.Occupational data converted to 2011 NOC codes based on an "equal" weighting scheme (see Appendix C).
Source: CSLS calculations based on Statistics Canada data. 1991 Census, special order, and publically available National Household Survey data.

Notice that the results do not suggest that the PBS within-occupation component is overstated at the two-digit level of disaggregation as Capeluck (2015b) had suggested they might be. In fact, we find that it increases as we move from the 1-digit (-1.17 percentage points) to the 2-digit (-1.48 percentage points) and 3-digit (-1.76 percentage points) levels of aggregation, although it does decline to -1.51 percentage points at the 3-digit level of disaggregation.

As we noted above, we should adjust for the relative importance of the occupation to manufacturing when searching for evidence of PBS outsourcing, otherwise we may mistake a proportional decline due to external shocks to the sector for PBS outsourcing. Table 20 presents the counterfactual decomposition based on a uniform decline in manufacturing employment while all other sectors remained at their 1991 levels (analogous to Table 17).

Table 21 presents the results net of the effects expected under the counterfactual. First, notice that the all four levels of disaggregation suggest that the decline is disproportionately related to PBS occupations. There is quite a bit of variation regarding the magnitude of the PBS within-occupation component, although it is consistently negative and fairly small, ranging from -0.03 percentage points at the 1-digit level of disaggregation (0.6 per cent of the total decline) to -0.39 percentage points (8.4 per cent of the decline).

Table 21: Decomposition of Decline in the Employment Share of Manufacturing in Excess of Expected Proportional Change by Level of Occupational Aggregation, 1991-2011

		Within	Between	Cross	Total
1-Digit	PBS Occupation	-0.03	-0.10	0.10	-0.03
	Non-PBS Occupations	1.58	-0.89	-0.66	0.03
	Total	1.55	-0.99	-0.56	0.00
2-Digit	PBS Occupation	-0.07	-0.24	0.07	-0.24
	Non-PBS Occupations	1.62	-0.73	-0.65	0.24
	Total	1.55	-0.97	-0.58	0.00
3-Digit	PBS Occupation	-0.39	-0.26	0.31	-0.33
	Non-PBS Occupations	1.78	-0.59	-0.87	0.33
	Total	1.40	-0.84	-0.55	0.00
4-Digit	PBS Occupation	-0.32	-0.03	0.15	-0.20
	Non-PBS Occupations	1.07	-0.57	-0.30	0.20
	Total	0.75	-0.60	-0.15	0.00

Note: All figures are expressed in terms of percentage points of total employment minus the rates expected from a uniform decline in the manufacturing employment levels observed in 1991 holding employment in all other industries fixed.Occupational data converted to 2011 NOC codes based on an “equal” weighting scheme (see Appendix C).

Source: CSLS calculations based on Statistics Canada data. 1991 Census, special order, and publically available National Household Survey data.

The full decomposition at the 3-digit level is presented in Appendix B. [33]

C. Robustness

Table 22presents the same decompositions as Table 21 (adjusted for proportionality) using an alternative weighting scheme based on the relative sizes of the NOC categories to assign weights.[34] We find that the main finding of a small PBS occupation within-occupation component remains with the contribution disproportional to the occupation's share of manufacturing employment ranging from ranging from 0 to 4.3 per cent of the decline in manufacturing's employment depending on the level of aggregation. Generally, the relative importances of the within- and between-occupation contributions of PBS and non-PBS occupations (adjusted for proportionality) are fairly similar regardless of the choice of weighting.

Table 22: Decomposition of Decline in the Employment Share of Manufacturing Exceeding Expected Proportional Change by Level of Occupational Aggregation, Alternative Weighting, 1991-2011

		Within	Between	Cross	Total
1-Digit	PBS Occupation	0.00	-0.12	0.09	-0.03
	Non-PBS Occupations	1.42	-0.97	-0.42	0.03
	Total	1.41	-1.09	-0.33	0.00
2-Digit	PBS Occupation	-0.10	-0.39	0.24	-0.24
	Non-PBS Occupations	1.50	-0.72	-0.54	0.24
	Total	1.41	-1.11	-0.30	0.00
3-Digit	PBS Occupation	-0.20	-0.32	0.20	-0.33
	Non-PBS Occupations	1.82	-0.93	-0.57	0.33
	Total	1.62	-1.25	-0.37	0.00
4-Digit	PBS Occupation	-0.01	-0.05	-0.14	-0.20
	Non-PBS Occupations	1.08	-0.81	-0.07	0.20
	Total	1.07	-0.86	-0.22	0.00

Note: All figures are expressed in terms of percentage points of total employment. The grand total is the decrease in the manufacturing industry's share of total employment from 1991 to 2011.
Source: CSLS calculations based on Statistics Canada data. 1991 Census, special order, and publically available National Household Survey data.

We also consider the robustness of the results to the definition of PBS occupations. The threshold which we have adopted is quite loose, only requiring that the PBS industry be more

[33]The "PBS occupations" which made the largest total contributions to manufacturing's falling employment share were: Legislators and senior management, -0.12 percentage points; Managers in financial and business services, -0.23 percentage points; Office administrative assistants - general, legal and medical -0.17 percentage points; Court reporters, transcriptionists, records management technicians and statistical officers, -0.15 percentage points; Library, correspondence and other clerks, -0.11 percentage points; Creative designers and craftspersons, -0.18 percentage points; Cleaners, -0.10 percentage points; and Public works and other labourers not elsewhere classified, -0.35 percentage points.

[34] The raw decomposition is presented in Appendix Table 3

important to an occupation (in terms of employment share) than it is to total employment in all occupations. Using data on the employment shares of the PBS industry in all four-digit NOC occupations in 2011, we calculate a series of stricter thresholds requiring that the share of an occupation's employment in the PBS industry be 0.5, 1, or 2 standard deviations above the weighted mean (i.e., all occupations). The results of this exercise at the three digit level which are comparable to Table 21 are presented in Table 23.

Table 23: Decomposition of Decline in the Employment Share of Manufacturing Exceeding Expected Proportional Change, Alternative Definitions of PBS Occupation, 1991-2011

Standard Deviations		Within	Between	Cross	Total
	PBS Occupation	-0.39	-0.26	0.31	-0.33
0	Non-PBS Occupations	1.78	-0.59	-0.87	0.33
	Total	1.40	-0.84	-0.55	0.00
	PBS Occupation	-0.08	0.13	-0.06	-0.01
0.5	Non-PBS Occupations	1.47	-0.98	-0.49	0.01
	Total	1.40	-0.84	-0.55	0.00
	PBS Occupation	-0.04	0.14	-0.11	-0.01
1	Non-PBS Occupations	1.43	-0.99	-0.44	0.01
	Total	1.40	-0.84	-0.55	0.00
	PBS Occupation	0.01	0.03	0.00	0.04
2	Non-PBS Occupations	1.38	-0.87	-0.55	-0.04
	Total	1.40	-0.84	-0.55	0.00

Note: All figures are expressed in terms of percentage points of total employment. The grand total is the decrease in the manufacturing industry's share of total employment from 1991 to 2011.An occupation is considered to be PBS if the share of the occupation's workers employed in the PBS industry exceeds the share PBS industry's share of total employment by at least the given number of standard deviations. Standard deviations are calculated based upon the PBS industry's employment share in all four-digit NOC occupations (weighted by occupational shares in total employment). The 0, 0.5, 1, and 2 standard deviation thresholds are 11.2 per cent, 19.7 per cent, 28.2 per cent, and 45.3 per cent respectively. The decompositions underlying this table have been performed at the 3-digit NOC level based on an "equal" weighting scheme for the 1980 SOC concordances.
Source: CSLS calculations based on Statistics Canada data. 1991 Census, special order, and publically available National Household Survey data.

Similar to Capeluck (2015b), we find that under stricter definitions of what constitutes a PBS occupation, the importance of PBS occupations in explaining manufacturing's employment share dwindles.[35] The PBS within-occupation component explains 8.4 per cent (-0.39 percentage points) under the baseline definition, 1.7 per cent under the 0.5 standard deviation definition, 0.9 per cent under the 1 standard deviation definition, and -0.2 per cent under the strictest definition. To some degree, this may simply suggest that the occupations which are most tightly linked to the PBS industry were not employed by the manufacturing sector in-house in 1991.

[35] Although not presented here, we have also used an alternative definition based on the relative importance of an occupation to the PBS industry and found results which were qualitatively similar.

Given that the results vary so much depending on the selected narrowness of the definition of a PBS occupation, it is worth seriously considering which definition is most appropriate. We do so by constructing a list of all the 3-digit NOC PBS occupations under the loosest definition and examining how this list changes under stricter definitions (Table 24).Choosing an appropriate threshold is inherently difficult especially given that many of the occupations are fairly broad and debatably should be associated with the PBS industry. If too wide, then occupations which will be captured which have very little to do with PBS (legislators and senior management for example). But if the requirement is too restrictive we may exclude occupations which very clearly perform PBS services (e.g. auditors, accountants, and investment professionals are excluded if the requirement is 1 or 2 standard deviations above the mean).

To make this a bit more quantitative, we (somewhat arbitrarily) classify the occupations based on whether or not they intuitively seem like they would entail the provision of PBS services.[36] We then examine which of the four classification schemes most accurately matches our subjective assessment.

Table 24 presents the 43 occupations which are classified as PBS occupations based upon our baseline definition (0 standard deviations above the mean). The highlighted occupations are those which we subjectively suggest should be classified as PBS occupations. We suggest that 34 of the 43 occupations are reasonable even under the loosest definition. As the threshold becomes stricter, it is not surprising that many of the occupations are no longer classified as PBS. The strictest requirement of two standard deviations above the mean removes all occupations except for civil, mechanical, electrical, and chemical engineers; architects, urban planners, and land surveyors; technical occupations in architecture, drafting, surveying, geomatics and meteorology, Judges, lawyers and Quebec notaries; and Security guards and related security service occupations. This seems too strict.

Which classification rule do we think is best? We judge this by considering the percentage of classifications which match our subjective classification. The baseline definition matches our subjective classification 79 per cent of the time. This is better than all of the stricter definitions. If a threshold of 0.5 standard deviations above the mean is used, the classifications match 70 per cent of the time. At 1.0 standard deviations, the agreement falls to 67 per cent. And at 2.0 standard deviations, the classification agrees with our assessment for only 33 per cent of occupations. This exercise suggests that the loosest classification is the appropriate one if we wish to match our subjective notions of which occupations are associated with PBS activities.[37]

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[36] This was done in consultation with the NAICS definitions of the PBS industries (NAICS codes 54, professional, scientific, and technical services, 55, management of companies and enterprise, and 56, administrative and support, waste management, and remediation services)

[37] We have not explored the issue of whether the definition is too strict, although the results suggest that this may be a possibility.

Table 24: List of PBS Occupations by Number of Standard Deviations above the Mean Share of the PBS Industry in an Occupation's Employment

	PBS Industry's Share of Total Employment in the Occupation (Per Cent)	Standard Deviations			
Occupation		0	0.5	1	2
001 Legislators and senior management	18.1	1	0	0	0
011 Administrative services managers	14.6	1	0	0	0
012 Managers in financial and business services	13.2	1	0	0	0
021 Managers in engineering, architecture, science and information systems	34.1	1	1	1	0
065 Managers in customer and personal services, n.e.c.	24.3	1	1	0	0
111 Auditors, accountants and investment professionals	27.8	1	1	0	0
112 Human resources and business service professionals	32.6	1	1	1	0
122 Administrative and regulatory occupations	12.7	1	0	0	0
124 Office administrative assistants - general, legal and medical	19.6	1	0	0	0
125 Court reporters, transcriptionists, records management technicians and	21.4	1	1	0	0
131 Finance, insurance and related business administrative occupations	25.1	1	1	0	0
141 General office workers	11.8	1	0	0	0
142 Office equipment operators	14.8	1	0	0	0
143 Financial, insurance and related administrative support workers	17.8	1	0	0	0
145 Library, correspondence and other clerks	12.0	1	0	0	0
211 Physical science professionals	33.8	1	1	1	0
212 Life science professionals	29.8	1	1	1	0
213 Civil, mechanical, electrical and chemical engineers	45.3	1	1	1	1
214 Other engineers	32.2	1	1	1	0
215 Architects, urban planners and land surveyors	65.0	1	1	1	1
216 Mathematicians, statisticians and actuaries	29.1	1	1	1	0
217 Computer and information systems professionals	44.7	1	1	1	0
221 Technical occupations in physical sciences	27.8	1	1	0	0
222 Technical occupations in life sciences	25.2	1	1	0	0
223 Technical occupations in civil, mechanical and industrial engineering	24.5	1	1	0	0
224 Technical occupations in electronics and electrical engineering	17.1	1	0	0	0
225 Technical occupations in architecture, drafting, surveying, geomatics and meteorology	52.1	1	1	1	1
226 Other technical inspectors and regulatory officers	23.9	1	1	0	0
228 Technical occupations in computer and information systems	29.8	1	1	1	0
411 Judges, lawyers and Quebec notaries	72.0	1	1	1	1
416 Policy and program researchers, consultants and officers	20.1	1	1	0	0
512 Writing, translating and related communications professionals	28.6	1	1	1	0
522 Photographers, graphic arts technicians and technical and co-ordinating occupations in motion pictures, broadcasting and the performing arts	28.7	1	1	1	0
524 Creative designers and craftspersons	45.1	1	1	1	0
631 Service supervisors	16.3	1	0	0	0
652 Occupations in travel and accommodation	31.9	1	1	1	0
654 Security guards and related security service occupations	62.3	1	1	1	1
655 Customer and information services representatives	16.5	1	0	0	0
673 Cleaners	33.0	1	1	1	0
738 Printing press operators and other trades and related occupations, n.e.c.	12.7	1	0	0	0
762 Public works and other labourers, n.e.c.	14.5	1	0	0	0
825 Contractors and supervisors, agriculture, horticulture and related	39.4	1	1	1	0
861 Harvesting, landscaping and natural resources labourers	44.9	1	1	1	0

Note: A "1" indicates that the occupation is classified as a PBS occupation under the given threshold while a "0" indicates that it is not. The highlighted occupations are the ones which we have deemed to be associated with the PBS industry. The 0, 0.5, 1, and 2 standard deviation thresholds are 11.2 per cent, 19.7 per cent, 28.2 per cent, and 45.3 per cent respectively.
Source: CSLS calculations based on publically available National Household Survey data.

Overall, our findings are in line with those of Capeluck (2015b). While the decomposition based on the more disaggregated LFS data should be viewed as the most trustworthy, the results fairly consistently suggest that a significant part of the decline in manufacturing's employment share can be traced to movements of workers away from the manufacturing sector within PBS occupations. This contribution is greater than what one would expect if the entire decline in manufacturing’s employment share had been the result of an external shock to manufacturing demand which affected employment in all manufacturing occupations in proportion to their size. While this is not direct evidence of PBS outsourcing, as this may reflect workers moving to similar but different jobs unrelated to manufacturing, it is consistent with an outsourcing hypothesis.

VI. Conclusion

We have examined one potential explanation for the decline in manufacturing's employment share in Canada since 1976: outsourcing of services from the manufacturing industry to the professional and business services (PBS) and financial services (FS) sectors. Our analysis was based upon previous work performed by Capeluck (2015b) which had found mixed evidence using an input-output modeling approach and a simple occupational decomposition which were both developed by Berlingieri (2014).

Our work has attempted to address two data limitations facing Capeluck (2015b). First, Capeluck (2015b) relied upon a current dollar IO structure of the economy, which may have been misleading because it captures rising prices, most notably those in the oil and gas sector. Second, the relatively high level of occupational aggregation in Capeluck (2015b) may have misclassified movements between occupations as movements across industries within PBS occupations. We have redone the main exercises of Capeluck (2015b) using chained dollar IO data and detailed industry-occupation data.

Generally speaking, we have found that most of the results from Capeluck (2015b) are robust to our alternative choice of data. In particular, we find that:

- The predictive power of the baseline IO model for the change in manufacturing's employment share from 1976-2008 is weaker using the chained dollar IO structure (explains 46.3 per cent) than using the current dollar IO structure (76.3 per cent). This is likely related in part to the current dollar model grossly overestimating growth in the employment share of primary industry because rising natural resource prices greatly increased nominal output;

- The chained dollar IO data allows the model to perform modestly better than the current dollar IO data at predicting the overall employment distribution of the economy based on the mean absolute errors of their employment predictions for 2008. However, the errors remain sizable (1.9 percentage points on average);

- PBS outsourcing, estimated by the rising direct requirements of the manufacturing industry for intermediate inputs produced by the PBS industry, accounts for 2.2 per cent of the fall in manufacturing's employment share between 1976 and 2008. FS outsourcing accounts for 1.1 per cent;

- In line with Capeluck (2015b)'s expectations, the negative effect on manufacturing's employment share of changes in manufacturing's intermediate input requirements from primary inputs vanishes when we use constant dollar data and the predicted share of employment in primary industries is considerably lower. This is much closer to what has been observed in reality;

- Extending the model to allow for the structure of final demand to vary through time does not seem to improve its performance at predicting the changes in the employment distribution across industries, but the core results regarding the effects of outsourcing on manufacturing employment remain the same;

- A sizable component of the decline in manufacturing's employment share between 1987 and 2011, in the realm of 25 to 38 per cent, was associated with reallocation of employment in PBS occupations from manufacturing to other industries within the same occupation. This result is robust to the level of occupational disaggregation and the method chosen to convert 1980 SOC codes to 2011 NOC codes. However, the contribution becomes much smaller if a stricter definition of PBS occupations is used.

- Adjusting for the fact that each occupation would be expected to account for a share of the decline proportional to its share in manufacturing employment even if the decline was unrelated to outsourcing, we estimate that the contribution potentially related to PBS outsourcing was between 0 and 8 per cent.

These findings rule out a few concerns which Capeluck (2015b) had about his results. By adjusting for the fact that PBS occupations should be expected to have an impact on manufacturing's employment share roughly proportional to their contribution to manufacturing employment, we are able to reconcile the seemingly contradictory evidence regarding the importance of services outsourcing provided by the input-output and labour decomposition exercises. It is important to keep in mind that the two analyses are preformed are over two very different time periods due to data availability (1976-2008 and 1987-2011), so it is possible that services outsourcing may have been somewhat more important in the latter period and we should not entirely discount estimates as high as 8 per cent for reasons of consistency. Given methodological issues, neither of the two findings should be viewed as definitive.

The IO exercise is based upon a model which is not all that effective at predicting the employment structure of the economy. Even if the model is making accurate predictions about how the PBS and FS manufacturing requirement coefficients impacted the change in employment between 1976 and 2008, the change in the coefficients may reflect other factors besides outsourcing. In particular, many of the coefficients in the total requirements table fell over time, reflecting improvements in productivity – fewer intermediates were necessary to produce a unit of output in manufacturing in 2008 than in 1976. Our counterfactual exercise of lowering the 2008 manufacturing requirements coefficients for the PBS and FS industries may understate the extent of outsourcing if productivity improvements had lowered these coefficients compared to their 1976 values. For this reason, we may want to view the IO exercise as providing an estimate which is biased downwards.

The occupational decomposition exercise may provide an upper bound estimate of the effects of PBS outsourcing. This is because movement of workers out of the manufacturing industry within PBS occupations does not necessarily imply services outsourcing. Services outsourcing would require that these individuals continue to provide services to the manufacturing sector. However, they may simply have found similar work (same occupation) serving non-manufacturing sectors and may no longer be needed in manufacturing. The within occupation effect is not even restricted to occupational movements into the PBS industry – it includes movements into all non-manufacturing sectors. Furthermore, we find that tightening the requirements as to what constitutes a PBS occupation significantly reduces the within PBS occupation contribution. Restricting the definition to 0.5, 1, and 2 standard deviations above the mean reduces the estimated contribution of PBS outsourcing to 2 per cent, 1 per cent, and 0 per cent respectively.

Overall the evidence suggests that PBS outsourcing has made a contribution to the decline of Canada's manufacturing sector, but it was not a major driver. Rising labour productivity and falling demand were the major culprits (Capeluck, 2015a).The true impact of manufacturing outsourcing likely lies somewhere between the core estimates of our two exercises.

To the extent that the decline in manufacturing has been the result of domestic outsourcing, this is not necessarily a cause for concern as the same work is still being done in Canada, perhaps even more efficiently (presumably manufacturers chose to outsource for a reason). If, on the other hand, it represents offshoring, this may also be a welcome development if the work is being completed more efficiently abroad, Canadian manufacturers are increasing their cost-competitiveness, and domestic labour is being reallocated to more productive uses. It is the loss of high paying domestic jobs which are not offset by gains from trade which we should be concerned about.

We will close with a few quick suggestions for future work related to understanding how services outsourcing has contributed to the employment share of manufacturing.

Given the poor performance of Berlingieri's (2014) simple IO model at predicting employment shares, we may need to consider ways to improve upon the analysis or other approaches altogether. One potential problem is not so much an issue with the model as an issue with the data. We have been using total requirements tables, which includes both domestic and international inputs, to try to predict the domestic distribution of employment. It may be more sensible to use total domestic requirements tables, as requirements for foreign inputs likely do not change employment needs in Canada.

It may not even be necessary to use Berlingieri's (2014) gross output growth accounting model at all. A simpler approach may be to simply construct domestic employment requirements tables for Canada in the years 1976 and 2008 as described in Horowitz and Planting (2009) and use these, along with information as to how labour productivity has changed through time in each industry to assess how changes in industrial structure have impacted manufacturing employment.

The occupational decomposition exercise is relatively clean and has managed to produce fairly consistent results. Given the problems associated with comparing 1980 SOC and 2011 NOC occupation codes, our work could be improved if could find a data source with consistent coding at a high level of disaggregation.

There may be some scope to experiment further with occupational definitions in order to obtain a better understanding of how much of the within PBS occupation contribution represents outsourcing. One possibility may be to construct a set of "manufacturing-PBS" occupations – those which are important in both the manufacturing and PBS industries. It may also be possible to extend the decomposition to only consider declines in manufacturing's share of PBS occupations to the extent that they correspond to a rising share for PBS industries of the same PBS occupation. Acquiring data on gross flows of workers across industries and occupations, perhaps from the Labour Force Survey, may be a very effective way to link declines in manufacturing's share of PBS occupations to the PBS industry.

References

Berlingieri, G. (2014) "Outsourcing and the Rise in Services," LSE Centre for Economic Performance Discussion Paper No. 1199.

Capeluck, Evan (2015a) "Explanations of the Decline in Manufacturing Employment in Canada," CSLS Research Report 2015-17.

Capeluck, Evan (2015b) "The Evolution of Manufacturing Employment in Canada: The Role of Outsourcing," CSLS Research Report 2015-18.

Statistics Canada (2007) "Hierarchical Structure of the Input-Output Commodity Classification,"http://www23.statcan.gc.ca/imdb-bmdi/document/1401_D11_T9_V1-eng.pdf.

Statistics Canada (2010) "The Input-Output Structure of the Canadian Economy," http://www.statcan.gc.ca/pub/15-201-x/15-201-x2010001-eng.pdf.

Horowitz, K.J. and M.A. Planting (2009) "Concepts and Methods of the Input-Output Accounts," Bureau of Economic Analysis. Retrieved from: http://www.bea.gov/papers/pdf/IOmanual_092906.pdf.

Appendix A: Deriving Industry-by-Industry Total Requirements[38]

A. Input-Output Requirements Tables

There are four requirements tables in the input-output (I-O) accounts. The first table – a direct requirements table – shows the relationship between commodity inputs and gross output. The remaining tables – total requirements tables – show the relationship between gross output and final uses expenditure (Horowitz and Planting, 2009: 12-7). More detailed is provided below.

- The **direct requirements** table shows the amount of the commodity at the top of the column that is needed to produce a dollar of the gross output in the industry at the beginning of the row. In other words, it shows the share of each commodity input in total gross output in a given industry.

- The **commodity-by-commodity total requirements** table shows the amount of gross output of the commodity at the beginning of each row that is required per dollar of final uses expenditure on the commodity at the top of the column.

- The **industry-by-commodity total requirements** table shows the amount of gross output in the industry at the beginning of the row that is required per dollar of final uses expenditure on the commodity at the top of the column.

- The **industry-by-industry total requirements** table shows the amount of gross output in the industry at the beginning of the row that is required per dollar of final uses expenditure in the industry at the top of the column.

In order to perform the analyses in Berlingieri (2014), we have to derive industry-by-industry total requirements tables, as only industry-by-commodity input, output and final demand tables are publicly available in Canada. To do this, we derive industry-by-industry total requirements tables from industry-by-commodity input and output tables using the procedure outlined in Horowitz and Planting (2009) and United Nations (1999). In particular, we employ the industry-technology assumption despite its drawbacks, as it makes the derivation of the

[38] This appendix is taken from Capeluck (2015b), as the procedure for constructing the industry-by-industry requirements table is exactly the same whether current or nominal data is used. Ultimately, most of the information originates from an Input-Output Handbook produced by researchers at the U.S. Bureau of Economic Analysis (Horowitz and Planting, 2009). For an overview of the Canadian input-output accounts, the interested reader may consult Statistics Canada (2010).

industry-by-industry total requirements table straightforward and it allows for the number of commodities to differ from the number of industries in the input and output tables.

B. Deriving the Requirements Tables from the Input and Output Tables

I will now discuss the procedure used to derive industry-by-industry total requirements tables from industry-by-commodity input and output tables.[39] The procedure will be based on the following notations and definitions:

q:	A $c \times 1$ matrix that shows the total gross output of each commodity where c is the number of commodities.
g:	A $j \times 1$ matrix that shows the total gross output of each industry where j is the number of industries.
U:	The intermediate portion of the input (or the "use") matrix in which each column shows the total amount of each commodity that is used by a given industry. This is a $c \times j$ commodity-by-industry matrix.
V:	The output (or the "make") matrix in which each column shows the gross output in each industry of a given commodity. This is a $j \times c$ industry-by-commodity matrix.
^:	When this symbol is placed over a vector, it signifies a square ($n \times n$) matrix in which the entries of the vector appear on the main diagonal and there are zeros everywhere else.
I:	An identity matrix.

There are four steps in the derivation of industry-by-industry total requirements tables from industry-by-commodity input and output tables. The first step is the calculation of a commodity-by-industry direct requirements table (*B*) as follows:

$$B = U\hat{g}^{-1} \tag{1}$$

where *B* is a $c \times j$ commodity-by-industry matrix in which each column shows how much of each commodity is required per dollar of gross output in a given industry.

The second step is to calculate an industry-by-commodity market shares or transformation matrix (*D*) using the following equation:

$$D = V\hat{q}^{-1}$$

[39] This section is based on the notation and definitions in the Appendix to Chapter 12 in Horowitz and Planting (2009). For more information on the derivation of requirements tables, see Horowitz and Planting (2009) and United Nations (1999).

(2)

where D is a $j \times c$industry-by-commodity matrix in which each column shows the share of the total gross output of a given commodity that is produced in each industry. According to the BEA (2009:12-22), the use of the market shares matrix to generate the total requirements table involves the assumption that "each commodity is produced by the various industries in fixed proportions," known as the industry-technology assumption.

The third step is the conversion of the commodity-by-industry direct requirements table (*B*) into a $j \times j$ industry-by-industry direct requirements matrix (*DB*) by multiplying the transformation matrix (*D*) by the commodity-by-industry direct requirements matrix (*B*).

The final step is to derive a $j \times j$ industry-by-industry total requirements matrix (Ω_t^{-1}) from the industry-by-industry direct requirements matrix (*DB*). In particular, the industry-by-industry direct requirements matrix (*DB*) is subtracted from the identity matrix (I) and then the inverse of this difference is taken, as represented by:

$$\Omega_t^{-1} = (I - DB)^{-1} \tag{3}$$

where Ω_t^{-1} is the industry-by-industry total requirements matrix, also known as the Leontief inverse matrix, which shows the amount of gross output required in each industry per dollar final uses expenditure in a given industry.[40]

C. Technology Assumptions

A symmetric I-O matrix – that is, matrix *A* in the Leontief model – is required for I-O analysis, as only a symmetric matrix can be inverted to obtain the Leontief inverse matrix. However, many national statistical offices only publish rectangular I-O tables – that is, industry-by-commodity tables. For instance, the number of commodities is greater than the number of industries in the Canadian I-O tables. In these cases, a symmetric I-O table must be derived.

There are two main procedures for deriving a symmetric I-O matrix from rectangular input (the intermediates portion of "use") tables and output (or "make") tables. Although these approaches are quite similar, they are based on very different assumptions about the input

[40] The term Leontief inverse matrix comes from the Leontief model in which a industry gross output is equal to the Leontief inverse matrix, a measure of inter-industry linkages through the use of intermediate inputs, multiplied by a industry final demand or value added as follows:

$$x = (1 - A)^{-1}y \tag{4}$$

where y is a vector of industry final demand or value added, x is a vector of industry gross output, and $(1 - A)^{-1}$is the Leontief inverse matrix.

structure of the economy – namely, the industry-technology assumption and the commodity-technology assumption.

Under the industry-technology assumption, “inputs are consumed in the same proportions by every product produced by a given industry, which means that principal and secondary products are all produced using the same technology, i.e. the same input structure” (United Nations, 1999:86). This means, for example, that the inputs used by the agricultural industry to produce wheat are assumed to be same as the inputs used to produce all products in the agricultural industry. In other words, the input structure of an industry acts as a proxy for the input structure of all of the commodities produced by that industry.

According to the United Nations (1999), there are two principal advantages of the industry-technology approach: 1) this approach always generates symmetric I-O tables with positive entries; 2) this approach allows for the use of rectangular input-output to generate symmetric I-O tables.[41] However, this assumption breaks “the fundamental economic rule that products with different prices at a given moment must reflect different costs or different technology” (United Nations, 1999:86).

Under the commodity-technology assumption, “the input structure of the technology that produces a given product is the same no matter where it is produced” (United Nations, 1999:87). This means, for example, that the inputs used by the agricultural industry to produce wheat are assumed to be same as the inputs used in the wheat industry. In other words, the input structure of a given commodity is assumed to be the same in all industries. While this assumption is reasonable than the industry-technology assumption, it frequently generates *negative* symmetric I-O tables and it only works if the input and output tables are square (*i.e.*, the number of industries must equal the number of commodities).[42] As a result, further adjustments are required to produce usable Leontief matrix under this assumption.

In this report, the industry-technology assumption is used to derive symmetric industry-by-industry total requirements tables from the Canadian I-O tables. A detailed description of the two approaches as well as a discussion of their respective advantages and disadvantages is available in United Nations (1999).

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[41] The matrix *A* in the Leontief model is always positive because the matrix *B* and the matrix *D* are both always positive, and the matrix *B* and the matrix *D* can both be rectangular and the matrix *A* will still be symmetric.

[42] In order to use this approach, it is necessary to either have square I-O tables or to aggregate commodities and/or industries such that the number of commodities equals the number of industries.

Appendix B: Detailed Decomposition Results

Appendix Table 1: Decomposition of Decline in the Employment Share of Manufacturing by 3-Digit NOC Occupation, 1991-2011

3-Digit NOC 2011 Occupation Code	Within	Between	Cross	Total Contribution
001 Legislators and senior management	**-0.11**	**-0.02**	**0.01**	**-0.12**
011 Administrative services managers	**-0.01**	**0.01**	**0.00**	**0.00**
012 Managers in financial and business services	**-0.19**	**-0.15**	**0.10**	**-0.23**
013 Managers in communication (except broadcasting)	0.00	0.00	0.00	0.00
021 Managers in engineering, architecture, science and information systems	**-0.02**	**0.02**	**0.00**	**0.00**
031 Managers in health care	0.00	0.00	0.00	0.00
041 Managers in public administration	0.00	0.00	0.00	0.00
042 Managers in education and social and community services	0.00	0.00	0.00	0.00
043 Managers in public protection services	0.00	0.00	0.00	0.00
051 Managers in art, culture, recreation and sport	-0.04	-0.03	0.03	-0.04
060 Corporate sales managers	0.06	-0.04	-0.03	-0.01
062 Retail and wholesale trade managers	0.00	0.13	-0.08	0.04
063 Managers in food service and accommodation	-0.01	0.01	0.00	0.00
065 Managers in customer and personal services, n.e.c.	**-0.02**	**-0.01**	**0.01**	**-0.02**
071 Managers in construction and facility operation and maintenance	-0.01	0.04	-0.02	0.01
073 Managers in transportation	-0.01	0.01	0.00	0.00
081 Managers in natural resources production and fishing	-0.14	-0.13	0.11	-0.16
082 Managers in agriculture, horticulture and aquaculture	0.00	0.00	0.00	0.00
091 Managers in manufacturing and utilities	0.10	0.04	0.02	0.16
111 Auditors, accountants and investment professionals	**-0.03**	**0.08**	**-0.04**	**0.01**
112 Human resources and business service professionals	**-0.02**	**0.06**	**-0.03**	**0.01**
121 Administrative services supervisors	-0.02	-0.05	0.01	-0.06
122 Administrative and regulatory occupations	**-0.03**	**0.20**	**-0.08**	**0.09**
124 Office administrative assistants - general, legal and medical	**-0.13**	**-0.08**	**0.04**	**-0.17**
125 Court reporters, transcriptionists, records management technicians and statistical officers	**-0.09**	**-0.14**	**0.08**	**-0.15**
131 Finance, insurance and related business administrative occupations	**-0.03**	**-0.01**	**0.00**	**-0.04**
141 General office workers	**-0.08**	**0.02**	**-0.01**	**-0.06**
142 Office equipment operators	**-0.02**	**-0.01**	**0.00**	**-0.03**
143 Financial, insurance and related administrative support workers	**-0.03**	**-0.04**	**0.01**	**-0.06**
145 Library, correspondence and other clerks	**-0.09**	**-0.07**	**0.05**	**-0.11**
151 Mail and message distribution occupations	-0.01	0.00	0.00	-0.01
152 Supply chain logistics, tracking and scheduling co-ordination occupations	-0.02	-0.09	0.00	-0.10
211 Physical science professionals	**-0.01**	**-0.01**	**0.00**	**-0.02**
212 Life science professionals	**0.00**	**0.00**	**0.00**	**0.00**
213 Civil, mechanical, electrical and chemical engineers	**-0.03**	**0.05**	**-0.01**	**0.01**
214 Other engineers	**-0.02**	**0.02**	**0.00**	**0.00**
215 Architects, urban planners and land surveyors	**0.00**	**0.00**	**0.00**	**0.00**
216 Mathematicians, statisticians and actuaries	**0.00**	**0.00**	**0.00**	**0.00**
217 Computer and information systems professionals	**-0.05**	**0.15**	**-0.08**	**0.02**
221 Technical occupations in physical sciences	**0.00**	**-0.01**	**0.00**	**-0.01**
222 Technical occupations in life sciences	**-0.01**	**-0.01**	**0.00**	**-0.02**
223 Technical occupations in civil, mechanical and industrial engineering	**0.00**	**0.06**	**0.00**	**0.06**

224 Technical occupations in electronics and electrical engineering	**-0.02**	**0.03**	**-0.01**	**0.01**
225 Technical occupations in architecture, drafting, surveying, geomatics and meteorology	**-0.02**	**-0.02**	**0.00**	**-0.03**
226 Other technical inspectors and regulatory officers	**-0.02**	**0.00**	**0.00**	**-0.02**
227 Transportation officers and controllers	-0.01	0.00	0.00	-0.01
228 Technical occupations in computer and information systems	**-0.04**	**-0.01**	**0.00**	**-0.05**
301 Professional occupations in nursing	0.00	0.00	0.00	0.00
311 Physicians, dentists and veterinarians	0.00	0.00	0.00	0.00
312 Optometrists, chiropractors and other health diagnosing and treating professionals	-0.01	-0.01	0.01	-0.01
313 Pharmacists, dietitians and nutritionists	0.00	0.00	0.00	0.00
314 Therapy and assessment professionals	0.00	0.00	0.00	0.00
321 Medical technologists and technicians (except dental health)	-0.03	0.01	-0.01	-0.02
322 Technical occupations in dental health care	-0.01	0.00	0.00	-0.01
323 Other technical occupations in health care	-0.03	0.01	0.00	-0.03
341 Assisting occupations in support of health services	0.00	0.01	0.00	0.00
401 University professors and post-secondary assistants	0.00	0.00	0.00	0.00
402 College and other vocational instructors	0.00	0.00	0.00	0.00
403 Secondary and elementary school teachers and educational counsellors	0.00	0.00	0.00	0.00
411 Judges, lawyers and Quebec notaries	**0.00**	**0.00**	**0.00**	**0.00**
415 Social and community service professionals	-0.01	0.00	0.00	-0.01
416 Policy and program researchers, consultants and officers	**-0.04**	**0.03**	**-0.02**	**-0.03**
421 Paraprofessional occupations in legal, social, community and education services	0.00	0.00	0.00	0.00
431 Occupations in front-line public protection services	-0.05	0.00	0.00	-0.05
441 Home care providers and educational support occupations	0.00	0.00	0.00	0.00
442 Legal and public protection support occupations	-0.01	-0.01	0.01	-0.01
511 Librarians, archivists, conservators and curators	0.00	0.00	0.00	0.00
512 Writing, translating and related communications professionals	**-0.01**	**0.01**	**-0.01**	**0.00**
513 Creative and performing artists	0.00	0.00	0.00	0.00
521 Technical occupations in libraries, public archives, museums and art galleries	0.00	0.00	0.00	0.00
522 Photographers, graphic arts technicians and technical and co-ordinating occupations in motion pictures, broadcasting and the performing arts	**-0.03**	**-0.03**	**0.01**	**-0.05**
523 Announcers and other performers, n.e.c.	-0.02	-0.02	0.02	-0.02
524 Creative designers and craftspersons	**-0.06**	**-0.15**	**0.03**	**-0.18**
525 Athletes, coaches, referees and related occupations	0.00	0.00	0.00	0.00
621 Retail sales supervisors	0.00	0.02	-0.01	0.00
622 Technical sales specialists in wholesale trade and retail and wholesale buyers	-0.08	-0.06	0.02	-0.11
623 Insurance, real estate and financial sales occupations	-0.03	0.01	-0.01	-0.03
631 Service supervisors	**-0.01**	**-0.01**	**0.00**	**-0.01**
632 Chefs and cooks	-0.03	0.01	0.00	-0.03
633 Butchers and bakers	-0.08	0.07	-0.05	-0.05
634 Specialized occupations in personal and customer services	-0.24	-0.01	0.01	-0.25
641 Sales and account representatives - wholesale trade (non-technical)	0.10	-0.15	-0.07	-0.12
642 Retail salespersons	-0.03	0.19	-0.11	0.05
651 Occupations in food and beverage service	-0.01	0.00	0.00	-0.01
652 Occupations in travel and accommodation	**0.00**	**0.00**	**0.00**	**0.00**
653 Tourism and amusement services occupations	0.00	0.00	0.00	0.00
654 Security guards and related security service occupations	**-0.05**	**0.00**	**0.00**	**-0.05**

655 Customer and information services representatives	**0.03**	**0.00**	**0.00**	**0.03**
656 Other occupations in personal service	0.00	0.00	0.00	0.00
661 Cashiers	0.00	0.01	0.00	0.00
662 Other sales support and related occupations	-0.14	-0.08	0.07	-0.16
671 Food counter attendants, kitchen helpers and related support occupations	0.00	0.00	0.00	0.00
672 Support occupations in accommodation, travel and amusement services	-0.03	-0.01	0.01	-0.03
673 Cleaners	**-0.12**	**0.04**	**-0.02**	**-0.10**
674 Other service support and related occupations, n.e.c.	-0.02	-0.03	0.02	-0.04
720 Contractors and supervisors, industrial, electrical and construction trades and related workers	-0.01	-0.03	0.00	-0.04
723 Machining, metal forming, shaping and erecting trades	-0.05	0.21	-0.02	0.13
724 Electrical trades and electrical power line and telecommunications workers	-0.03	0.02	-0.01	-0.02
725 Plumbers, pipefitters and gas fitters	-0.02	0.03	-0.02	-0.01
727 Carpenters and cabinetmakers	-0.02	0.15	-0.06	0.06
728 Masonry and plastering trades	0.00	0.00	0.00	0.00
729 Other construction trades	-0.02	-0.01	0.00	-0.03
730 Contractors and supervisors, maintenance trades and heavy equipment and transport operators	-0.04	-0.06	0.02	-0.07
731 Machinery and transportation equipment mechanics (except motor vehicle)	-0.02	0.03	0.00	0.01
732 Automotive service technicians	-0.06	0.04	-0.03	-0.05
733 Other mechanics and related repairers	0.00	-0.06	0.00	-0.06
736 Train crew operating occupations	0.00	0.00	0.00	0.00
737 Crane operators, drillers and blasters	0.03	-0.01	-0.01	0.00
738 Printing press operators and other trades and related occupations, n.e.c.	**0.01**	**-0.02**	**0.00**	**-0.02**
744 Other installers, repairers and servicers	-0.03	-0.03	0.01	-0.05
745 Longshore workers and material handlers	-0.01	0.23	-0.04	0.18
751 Motor vehicle and transit drivers	-0.06	0.11	-0.05	0.00
752 Heavy equipment operators	-0.08	-0.04	0.02	-0.10
753 Other transport equipment operators and related maintenance workers	-0.04	-0.04	0.03	-0.05
761 Trades helpers and labourers	-0.17	-0.12	0.08	-0.21
762 Public works and other labourers, n.e.c.	**-0.32**	**-0.29**	**0.26**	**-0.35**
821 Supervisors, logging and forestry	0.00	0.00	0.00	0.00
822 Contractors and supervisors, mining, oil and gas	-0.02	-0.01	0.01	-0.02
823 Underground miners, oil and gas drillers and related occupations	-0.01	0.01	-0.01	-0.01
824 Logging machinery operators	-0.01	-0.01	0.00	-0.01
825 Contractors and supervisors, agriculture, horticulture and related operations and services	**0.01**	**0.00**	**-0.01**	**0.00**
826 Fishing vessel masters and fishermen/women	-0.01	0.00	0.00	0.00
841 Mine service workers and operators in oil and gas drilling	-0.04	-0.03	0.02	-0.04
842 Logging and forestry workers	-0.01	-0.02	0.01	-0.02
843 Agriculture and horticulture workers	0.01	0.00	0.00	0.00
844 Other workers in fishing and trapping and hunting occupations	-0.01	-0.01	0.01	-0.01
861 Harvesting, landscaping and natural resources labourers	**-0.05**	**0.01**	**0.00**	**-0.05**
921 Supervisors, processing and manufacturing occupations	-0.02	-0.01	0.00	-0.03
922 Supervisors, assembly and fabrication	0.03	-0.03	-0.01	0.00
923 Central control and process operators in processing and manufacturing	-0.02	0.00	0.00	-0.02
924 Utilities equipment operators and controllers	0.00	0.02	0.00	0.02
941 Machine operators and related workers in mineral and metal products processing and manufacturing	0.12	-0.32	-0.07	-0.27

942 Machine operators and related workers in chemical, plastic and rubber processing	0.07	-0.06	-0.02	-0.01
943 Machine operators and related workers in pulp and paper production and wood processing and manufacturing	0.07	-0.23	-0.04	-0.20
944 Machine operators and related workers in textile, fabric, fur and leather products processing and manufacturing	0.03	-0.24	-0.02	-0.22
946 Machine operators and related workers in food, beverage and associated products processing	0.17	-0.22	-0.09	-0.14
947 Printing equipment operators and related occupations	0.00	-0.05	0.00	-0.04
952 Mechanical, electrical and electronics assemblers	0.04	-0.01	0.00	0.02
953 Other assembly and related occupations	0.08	-0.06	-0.01	0.00
961 Labourers in processing, manufacturing and utilities	0.54	-0.72	-0.30	-0.48
PBS Total	**-1.76**	**-0.29**	**0.32**	**-1.73**
Non-PBS Total	-0.54	-1.71	-0.67	-2.92
Total	-2.30	-2.00	-0.35	-4.66

Note: All figures are expressed in terms of percentage points of total employment. The grand total is the decrease in the manufacturing industry’s share of total employment from 1991 to 2011. All the 3-digit occupations are listed. The PBS occupations, expressed in bold, are defined as those for which the PBS industry represented a greater share of employment for that occupation than it did for all employment in the total economy in 2011. This table is based on an “equal” weighting for mapping the 1980 SOC codes into 2011 NOC codes.

Source: CSLS calculations based on Statistics Canada data. 1991 Census, special order, and publicly available National Household Survey data.

Appendix Table 2:Decomposition of Decline in the Employment Share of Manufacturing by 3-Digit NOC Occupation, 1991-2011

3-Digit NOC 2011 Occupation Code	Within	Between	Cross	Total Contribution
001 Legislators and senior management	**-0.03**	**-0.02**	**0.01**	**-0.03**
011 Administrative services managers	**0.03**	**0.01**	**0.00**	**0.04**
012 Managers in financial and business services	**-0.10**	**-0.15**	**0.10**	**-0.14**
013 Managers in communication (except broadcasting)	0.00	0.00	0.00	0.00
021 Managers in engineering, architecture, science and information systems	**0.00**	**0.02**	**0.00**	**0.02**
031 Managers in health care	0.00	0.00	0.00	0.00
041 Managers in public administration	0.00	0.00	0.00	0.00
042 Managers in education and social and community services	0.00	0.00	0.00	0.00
043 Managers in public protection services	0.00	0.00	0.00	0.00
051 Managers in art, culture, recreation and sport	-0.03	-0.03	0.03	-0.03
060 Corporate sales managers	0.10	-0.05	-0.03	0.02
062 Retail and wholesale trade managers	0.00	0.13	-0.08	0.05
063 Managers in food service and accommodation	0.00	0.01	0.00	0.00
065 Managers in customer and personal services, n.e.c.	**-0.01**	**-0.02**	**0.01**	**-0.01**
071 Managers in construction and facility operation and maintenance	0.00	0.04	-0.02	0.02
073 Managers in transportation	0.00	0.01	0.00	0.00
081 Managers in natural resources production and fishing	-0.10	-0.11	0.11	-0.11
082 Managers in agriculture, horticulture and aquaculture	0.00	0.00	0.00	0.00
091 Managers in manufacturing and utilities	0.14	0.06	0.02	0.22
111 Auditors, accountants and investment professionals	**-0.01**	**0.08**	**-0.04**	**0.04**
112 Human resources and business service professionals	**-0.01**	**0.06**	**-0.03**	**0.03**
121 Administrative services supervisors	0.02	-0.05	0.01	-0.02
122 Administrative and regulatory occupations	**0.00**	**0.20**	**-0.08**	**0.12**
124 Office administrative assistants - general, legal and medical	**-0.04**	**-0.09**	**0.04**	**-0.08**
125 Court reporters, transcriptionists, records management technicians and statistical officers	**-0.04**	**-0.14**	**0.08**	**-0.10**
131 Finance, insurance and related business administrative occupations	**0.00**	**-0.01**	**0.00**	**-0.01**
141 General office workers	**-0.01**	**0.02**	**-0.01**	**0.00**
142 Office equipment operators	**-0.01**	**-0.01**	**0.00**	**-0.01**
143 Financial, insurance and related administrative support workers	**0.03**	**-0.04**	**0.01**	**-0.01**
145 Library, correspondence and other clerks	**-0.05**	**-0.07**	**0.05**	**-0.07**
151 Mail and message distribution occupations	0.00	0.00	0.00	-0.01
152 Supply chain logistics, tracking and scheduling co-ordination occupations	0.11	-0.08	0.00	0.03
211 Physical science professionals	**0.01**	**-0.01**	**0.00**	**0.00**
212 Life science professionals	**0.01**	**0.00**	**0.00**	**0.01**
213 Civil, mechanical, electrical and chemical engineers	**0.03**	**0.05**	**-0.01**	**0.07**
214 Other engineers	**0.02**	**0.03**	**0.00**	**0.04**
215 Architects, urban planners and land surveyors	**0.00**	**0.00**	**0.00**	**0.00**
216 Mathematicians, statisticians and actuaries	**0.00**	**0.00**	**0.00**	**0.00**
217 Computer and information systems professionals	**-0.02**	**0.15**	**-0.08**	**0.05**
221 Technical occupations in physical sciences	**0.02**	**0.00**	**0.00**	**0.02**
222 Technical occupations in life sciences	**0.00**	**-0.01**	**0.00**	**-0.01**
223 Technical occupations in civil, mechanical and industrial engineering	**0.02**	**0.07**	**0.00**	**0.09**

224 Technical occupations in electronics and electrical engineering	**0.01**	**0.04**	**-0.01**	**0.04**
225 Technical occupations in architecture, drafting, surveying, geomatics and meteorology	**0.02**	**-0.02**	**0.00**	**0.00**
226 Other technical inspectors and regulatory officers	**-0.01**	**0.00**	**0.00**	**-0.01**
227 Transportation officers and controllers	0.00	0.00	0.00	-0.01
228 Technical occupations in computer and information systems	**-0.01**	**-0.01**	**0.00**	**-0.01**
301 Professional occupations in nursing	0.00	0.00	0.00	0.00
311 Physicians, dentists and veterinarians	0.00	0.00	0.00	0.00
312 Optometrists, chiropractors and other health diagnosing and treating professionals	0.00	-0.01	0.01	0.00
313 Pharmacists, dietitians and nutritionists	0.00	0.00	0.00	0.00
314 Therapy and assessment professionals	0.00	0.00	0.00	0.00
321 Medical technologists and technicians (except dental health)	-0.01	0.01	-0.01	-0.01
322 Technical occupations in dental health care	0.00	0.00	0.00	0.00
323 Other technical occupations in health care	-0.02	0.00	0.00	-0.02
341 Assisting occupations in support of health services	0.00	0.01	0.00	0.01
401 University professors and post-secondary assistants	0.00	0.00	0.00	0.00
402 College and other vocational instructors	0.00	0.00	0.00	0.00
403 Secondary and elementary school teachers and educational counsellors	0.00	0.00	0.00	0.00
411 Judges, lawyers and Quebec notaries	**0.00**	**0.00**	**0.00**	**0.00**
415 Social and community service professionals	0.00	0.00	0.00	0.00
416 Policy and program researchers, consultants and officers	**-0.02**	**0.03**	**-0.02**	**-0.01**
421 Paraprofessional occupations in legal, social, community and education services	0.00	0.00	0.00	0.00
431 Occupations in front-line public protection services	-0.03	0.00	0.00	-0.03
441 Home care providers and educational support occupations	0.00	0.00	0.00	0.00
442 Legal and public protection support occupations	-0.01	-0.01	0.01	-0.01
511 Librarians, archivists, conservators and curators	0.00	0.00	0.00	0.00
512 Writing, translating and related communications professionals	**0.00**	**0.01**	**-0.01**	**0.00**
513 Creative and performing artists	0.00	0.00	0.00	0.00
521 Technical occupations in libraries, public archives, museums and art galleries	0.01	0.00	0.00	0.00
522 Photographers, graphic arts technicians and technical and co-ordinating occupations in motion pictures, broadcasting and the performing arts	**-0.01**	**-0.03**	**0.01**	**-0.02**
523 Announcers and other performers, n.e.c.	-0.02	-0.02	0.02	-0.02
524 Creative designers and craftspersons	**0.03**	**-0.15**	**0.03**	**-0.09**
525 Athletes, coaches, referees and related occupations	0.00	0.00	0.00	0.00
621 Retail sales supervisors	0.00	0.02	-0.01	0.00
622 Technical sales specialists in wholesale trade and retail and wholesale buyers	-0.02	-0.05	0.02	-0.05
623 Insurance, real estate and financial sales occupations	-0.02	0.01	-0.01	-0.02
631 Service supervisors	**0.00**	**-0.01**	**0.00**	**0.00**
632 Chefs and cooks	-0.01	0.00	0.00	-0.01
633 Butchers and bakers	-0.05	0.09	-0.05	-0.01
634 Specialized occupations in personal and customer services	-0.17	0.02	0.00	-0.15
641 Sales and account representatives - wholesale trade (non-technical)	0.18	-0.16	-0.07	-0.04
642 Retail salespersons	-0.01	0.19	-0.11	0.06
651 Occupations in food and beverage service	0.00	0.00	0.00	0.00
652 Occupations in travel and accommodation	**0.00**	**0.00**	**0.00**	**0.00**
653 Tourism and amusement services occupations	0.00	0.00	0.00	0.00
654 Security guards and related security service occupations	**-0.03**	**0.00**	**0.00**	**-0.03**

655 Customer and information services representatives	**0.05**	**0.00**	**0.00**	**0.04**
656 Other occupations in personal service	0.00	0.00	0.00	0.00
661 Cashiers	0.00	0.01	0.00	0.01
662 Other sales support and related occupations	-0.08	-0.09	0.07	-0.10
671 Food counter attendants, kitchen helpers and related support occupations	0.01	0.00	0.00	0.01
672 Support occupations in accommodation, travel and amusement services	-0.02	-0.01	0.01	-0.02
673 Cleaners	**-0.05**	**0.04**	**-0.02**	**-0.03**
674 Other service support and related occupations, n.e.c.	-0.01	-0.03	0.02	-0.02
720 Contractors and supervisors, industrial, electrical and construction trades and related workers	0.02	-0.03	0.00	0.00
723 Machining, metal forming, shaping and erecting trades	0.04	0.30	-0.04	0.30
724 Electrical trades and electrical power line and telecommunications workers	0.00	0.02	-0.01	0.02
725 Plumbers, pipefitters and gas fitters	-0.01	0.03	-0.02	0.00
727 Carpenters and cabinetmakers	-0.01	0.15	-0.06	0.08
728 Masonry and plastering trades	0.01	0.00	0.00	0.01
729 Other construction trades	-0.01	-0.01	0.00	-0.01
730 Contractors and supervisors, maintenance trades and heavy equipment and transport operators	0.00	-0.06	0.02	-0.04
731 Machinery and transportation equipment mechanics (except motor vehicle)	0.06	0.05	-0.01	0.10
732 Automotive service technicians	-0.03	0.04	-0.03	-0.02
733 Other mechanics and related repairers	0.03	-0.06	0.00	-0.03
736 Train crew operating occupations	0.00	0.00	0.00	0.00
737 Crane operators, drillers and blasters	0.03	-0.01	-0.01	0.01
738 Printing press operators and other trades and related occupations, n.e.c.	**0.03**	**-0.01**	**0.00**	**0.02**
744 Other installers, repairers and servicers	0.00	-0.03	0.01	-0.02
745 Longshore workers and material handlers	0.01	0.23	-0.04	0.20
751 Motor vehicle and transit drivers	-0.01	0.11	-0.05	0.05
752 Heavy equipment operators	-0.04	-0.04	0.02	-0.05
753 Other transport equipment operators and related maintenance workers	-0.02	-0.04	0.03	-0.03
761 Trades helpers and labourers	-0.08	-0.11	0.08	-0.12
762 Public works and other labourers, n.e.c.	**-0.21**	**-0.26**	**0.25**	**-0.23**
821 Supervisors, logging and forestry	0.00	0.00	0.00	0.00
822 Contractors and supervisors, mining, oil and gas	-0.01	-0.01	0.01	-0.01
823 Underground miners, oil and gas drillers and related occupations	-0.01	0.01	-0.01	0.00
824 Logging machinery operators	-0.01	-0.01	0.00	-0.01
825 Contractors and supervisors, agriculture, horticulture and related operations and services	**0.01**	**0.00**	**0.00**	**0.00**
826 Fishing vessel masters and fishermen/women	0.00	0.00	0.00	0.00
841 Mine service workers and operators in oil and gas drilling	-0.03	-0.03	0.02	-0.03
842 Logging and forestry workers	0.00	-0.02	0.01	-0.01
843 Agriculture and horticulture workers	0.01	0.00	0.00	0.01
844 Other workers in fishing and trapping and hunting occupations	-0.01	-0.01	0.01	-0.01
861 Harvesting, landscaping and natural resources labourers	**-0.03**	**0.00**	**0.00**	**-0.03**
921 Supervisors, processing and manufacturing occupations	0.01	0.04	-0.01	0.05
922 Supervisors, assembly and fabrication	0.05	-0.01	-0.01	0.03
923 Central control and process operators in processing and manufacturing	0.00	0.02	0.00	0.01
924 Utilities equipment operators and controllers	0.01	0.02	0.00	0.03
941 Machine operators and related workers in mineral and metal products	0.21	-0.20	-0.09	-0.09

processing and manufacturing				
942 Machine operators and related workers in chemical, plastic and rubber processing	0.10	-0.02	-0.03	0.05
943 Machine operators and related workers in pulp and paper production and wood processing and manufacturing	0.12	-0.14	-0.05	-0.08
944 Machine operators and related workers in textile, fabric, fur and leather products processing and manufacturing	0.09	-0.15	-0.03	-0.10
946 Machine operators and related workers in food, beverage and associated products processing	0.24	-0.14	-0.10	0.00
947 Printing equipment operators and related occupations	0.03	-0.02	-0.01	0.01
952 Mechanical, electrical and electronics assemblers	0.09	0.13	-0.01	0.20
953 Other assembly and related occupations	0.14	0.01	-0.03	0.13
961 Labourers in processing, manufacturing and utilities	0.83	-0.53	-0.34	-0.04
PBS Total	-0.39	-0.26	0.31	-0.33
Non-PBS Total	1.78	-0.59	-0.87	0.33
Total	1.40	-0.84	-0.55	0.00

Note: All figures are expressed in terms of percentage points of total employment. The grand total is the decrease in the manufacturing industry's share of total employment from 1991 to 2011. All the 3-digit occupations are listed. The PBS occupations, expressed in bold, are defined as those for which the PBS industry represented a greater share of employment for that occupation than it did for all employment in the total economy in 2011. This table is based on an "equal" weighting for mapping the 1980 SOC codes into 2011 NOC codes.

Source: CSLS calculations based on Statistics Canada data. 1991 Census, special order, and publicly available National Household Survey data.

Appendix Table 3: Decomposition of Decline in the Employment Share of Manufacturing, Alternative Weighting of SOC Codes, 1991-2011

		Within	Between	Cross	Total
1-Digit	PBS Occupation	-1.19	0.23	-0.06	-1.01
	Non-PBS Occupations	-1.64	-1.80	-0.21	-3.64
	Total	-2.82	-1.57	-0.27	-4.66
2-Digit	PBS Occupation	-1.55	0.18	-0.06	-1.43
	Non-PBS Occupations	-1.38	-1.61	-0.24	-3.23
	Total	-2.92	-1.44	-0.30	-4.66
3-Digit	PBS Occupation	-1.55	0.19	-0.01	-1.37
	Non-PBS Occupations	-1.20	-1.62	-0.47	-3.29
	Total	-2.75	-1.43	-0.48	-4.66
4-Digit	PBS Occupation	-1.33	-0.41	-0.04	-1.78
	Non-PBS Occupations	-1.53	-1.23	-0.12	-2.88
	Total	-2.86	-1.64	-0.16	-4.66

Note: All figures are expressed in terms of percentage points of total employment. The grand total is the decrease in the manufacturing industry's share of total employment from 1991 to 2011.

Source: CSLS calculations based on Statistics Canada data. 1991 Census, special order, and publically available National Household Survey data.

Appendix Table 4:Decomposition of Decline in the Employment Share of Manufacturing, Robustness of PBS Occupation Definition, 1991-2011

Standard Deviations		Within	Between	Cross	Total
0	PBS Occupation	-1.76	-0.29	0.32	-1.73
	Non-PBS Occupations	-0.54	-1.71	-0.67	-2.92
	Total	-2.30	-2.00	-0.35	-4.66
0.5	PBS Occupation	-0.76	0.12	-0.06	-0.71
	Non-PBS Occupations	-1.54	-2.12	-0.29	-3.95
	Total	-2.30	-2.00	-0.35	-4.66
1	PBS Occupation	-0.51	0.13	-0.11	-0.49
	Non-PBS Occupations	-1.79	-2.13	-0.24	-4.17
	Total	-2.30	-2.00	-0.35	-4.66
2	PBS Occupation	-0.10	0.02	0.00	-0.07
	Non-PBS Occupations	-2.21	-2.02	-0.35	-4.58
	Total	-2.30	-2.00	-0.35	-4.66

Note: All figures are expressed in terms of percentage points of total employment. The grand total is the decrease in the manufacturing industry's share of total employment from 1991 to 2011.An occupation is considered to be PBS if the share of the occupation's workers employed in the PBS industry exceeds the share PBS industry's share of total employment by at least the given number of standard deviations. Standard deviations are calculated based upon the PBS industry's employment share in all four-digit NOC occupations (weighted by occupational shares in total employment). The 0, 0.5, 1, and 2 standard deviation thresholds are 11.2 per cent, 19.7 per cent, 28.2 per cent, and 45.3 per cent respectively. The decompositions underlying this table have been performed at the 3-digit NOC level based on an "equal" weighting scheme for the 1980 SOC concordances.

Source: CSLS calculations based on Statistics Canada data. 1991 Census, special order, and publically available National Household Survey data.

Appendix C: Mapping 1980 SOC Codes to 2011 NOC Codes

There were significant changes in the classification structure between the 1980 SOC and 1991 SOC. The differences between the 1991 SOC and 2001 NOC-S, 2001 SOC and 2006 NOC-S, and 2006 NOC-S and 2011 NOC relatively minor in comparison. For each 4-digit 1980 SOC code, concordance tables from Statistics Canada indicate which 4-digit 1991 SOC codes it maps into. However, there is no indication of how the employment of a single 1980 SOC code should be distributed among multiple 1991 SOC codes when the mapping is not one-to-one.

Formally, the problem is that for each of I 1980 SOC occupations, we need to map employment in occupation i, $E_i^{SOC\ 1980}$, into employment in the J 1991 SOC occupations. This amounts to choosing weights w_{ij} such that:

$$E_j^{SOC\ 1991} = \sum_{i=1}^{I} w_{ij}\, E_i^{SOC\ 1980} \qquad \forall\, j \in (1, \dots, J),$$

and

$$\sum_{j=1}^{J} w_{ij} = 1, \qquad 1 \geq w_{ij} \geq 0, \qquad \forall\, i \in (1, \dots, I),$$

This means that employment in the 1991 SOC codes is determined by weighted averages of the 1980 SOC codes and that all employment is allocated to a 1991 SOC code.

The simplest approach to choosing weights is to equally distribute employment among all the 1991 SOC codes corresponding to the 1980 SOC codes. We refer to this as "equal weighting."

For robustness, we also implement a more complicated "alternative weighting" scheme. This distributes employment among the 1991 SOC codes based upon their relative shares of total employment in the 2006 Census.

For clarity, consider a simple example. We know that occupation X has 10 workers under SOC 1980 and that it corresponds to two occupations, Y and Z, under the SOC 1991. We also know that in the 2006, 15 workers were employed in Y and 35 in Z. Under equal weighting, we would assign 5 workers from X to Y and 5 from X to Z. Under the alternative weighting, we note that Z represented 70 per cent of the total employment between Y and Z in the 2006 Census, so we assign 3 workers from X to Y and 7 from X to Z. Both of these weighting schemes are clearly flawed in that they likely do not represent the true concordances, but this is the best that we can do with the data available. Generally, the choice of weighting makes a greater difference at finer levels of disaggregation.

The weighting procedure is repeated to map 1991 SOC codes to 2001 NOC-S codes, and 2006 NOC-S codes to 2011 NOC codes. Fortunately, the 2001 NOC-S and 2006 NOC-S codes are extremely similar so that this is not necessary.

At higher levels of disaggregation, the choice of weights becomes less relevant as many of the distinctions between categories disappear. For this reason, we explore the robustness of the results to all four possible levels of disaggregation and closely compare the results at the two-digit level to see if they are consistent with those using the consistently defined data from Capeluck (2015b).

Another challenge with the occupation-employment data from 1991 is that each three digit occupation code and two digit industry contains a number of individuals who were “assigned” to that industry or occupation based on socio-economic characteristics because they did not state an occupation or industry. We allocate those in the assigned category to the more detailed occupational and industry subcategories in proportion to the relative size of the subcategories.