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MATERIAL OFFSHORING: ALTERNATE MEASURES

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Industry measures of offshoring of material inputs are often generated using the proportionality assumption applied to aggregate import data—that the import share of each commodity used in the production process for a particular industry is similar to the import share of a commodity for the total economy. This note compares estimates of offshoring for the Canadian manufacturing sector derived using this assumption to four alternatives: two measures that use direct measures of firm-based imports, and two hybrid measures that use both input and import information. These indirect measures are compared to survey estimates that directly assess import intensity in the production process in an effort to evaluate which indirect method yields more reasonable offshoring measures.

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1. Introduction

Imports of intermediate materials are an important facet of the production process in Western countries. The Organization for Economic Cooperation and Development (OECD, 2007) reports that more than half (54 percent in 2003) of world manufactured imports are intermediate goods. In Canada, intermediate-material imports accounted for 53 percent of total imports in 2002 and grew at an average rate of 5.4 percent per year between 2002 and 2006. The increasing use of imported materials has generated extensive research and debate, both academically and within the media, on the effects of offshoring on domestic employment and industrial structure.

As a result of a lack of data on imported intermediates by industry, almost all major studies on offshoring have relied on a proxy measure that uses aggregate imports of commodities and assumes an industry's import intensity of a particular

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input commodity is similar to that for the economy as a whole.[1] This is referred to as the proportionality-based measure of offshoring (Feenstra and Hanson, 1996, 1999). This assumption has two main shortcomings: it does not draw a distinction between imports that are used as intermediate goods or as final goods; and it makes no allowance for differences in import intensity across industries. Industry differences arise only from differences across industries in the composition of commodities used.

Being able to evaluate these and alternate measures of import use is important since studies of offshoring rely on such measures. The OECD and the World Trade Organization (WTO) are constructing world input–output tables to study the impact of globalization and are making use of the proportionality assumption to measure, *mutatis mutandis*, the impact of global value chains. Other studies (Hummels *et al*., 2001; Koopman *et al*., 2010; Trefler and Zhu, 2010; Daudin *et al*., 2011; Johnson and Noguera, 2012) have also either implicitly or explicitly used the proportionality assumption to examine the pattern and impact of world value-added trade.

Empirical analyses of the effects of offshoring need to consider the errors that will be generated from using imprecise data on import intensity. To date, only two studies have assessed the accuracy of the proxy measure derived from the proportionality assumption. Winkler and Milberg (2012) compared a direct measure of import–input use by German industry to the proxy measure derived from the standard proportionality assumption, and found that the proxy-based measure differed significantly from the direct measure. Feenstra and Jensen (2012) linked firms' import data with production data in an effort to use information collected in the U.S. Census of Manufactures regarding materials employed by manufacturing establishments in order to allocate imported intermediates to industries. They find a correlation of 0.68 (un-weighted) and 0.87 (value-weighted) between the offshoring shares made with and without the proportionality assumption.

This paper extends these studies to provide more extensive comparisons across alternative estimators of offshoring for Canada. Recent advances in administrative trade data in Canada that provide information on the company doing the importing permit the calculation of more direct industry-specific measures of imports. However, these measures capture the agent that engages in importation, who may be an intermediary rather than a final user of the import. They may therefore provide inaccurate measures of imports that are used in production

[1]The input–output tables in many countries provide information about the use of imported inputs at the industry level. As far as the authors are aware, these are invariably derived by using the proportionality assumption. For example, the U.S. produces an imported intermediate input matrix for its benchmark years based on the proportionality assumption. As is noted in their description file, "The imputed-import values are based on the assumption that each industry uses imports of a commodity in the same proportion as imports-to-domestic supply of the same commodity. (Domestic supply represents the total amount of a commodity available for consumption within the United States; it equals domestic output plus imports less exports.) The implication of using this assumption to calculate the estimates is that all variability of import usage across industries reflects this assumption and is not based on industry-specific information" (Bureau of Economic Analysis: http://www.bea.gov/industry/more.htm).

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of a particular industry. When using data based on the company responsible for importation, an import commodity may be assigned to a different industry than the user. This study reports on these more direct measures of industry imports using Canadian micro-data on firm imports. It further proposes a hybrid method that supplements the direct-import approach with a modified proportionality input approach, which is used to reallocate surplus imports purchased by intermediary industries to other input-using industries. Estimates from these alternative approaches are then compared to estimates derived from a survey that directly obtained imports used in the production process. The latter is used as the benchmark against which the alternative estimates of offshoring using the proportionality approach or direct-import data are assessed.

Section 2 outlines the methodology used to construct the various offshoring measures. Results are presented in Section 3. Section 4 concludes.

2. Methodology

Offshoring is defined as the proportion of imported intermediate products in total intermediate inputs used in the production process. Seven different approaches are used in this study to measure the offshoring of inputs into the production process: (1) the standard proportionality approach that includes all commodities that are imported; (2) a modified proportionality approach that excludes imports that are non-intermediate commodities; (3) the simple direct-import approach, which makes use of information on imports at the industry level used in the production process derived from an Importer Register that identifies the firm doing importation; (4) a micro linked approach, which links input and import data at the firm level using information from the Import Register; (5) a more complex hybrid approach, which supplements the direct-import approach with input information derived from production surveys in order to distribute the imports of intermediary industries in excess of their inputs to other industries using proportionality assumptions; (6) a modified hybrid approach, which recognizes that some commodities imported by intermediary industries may be inappropriately classified as intermediates; and (7) direct survey-based estimates. The first six methods are all compared to the benchmark derived from the direct survey estimates in order to ascertain the biases that exist in each of the indirect methods.

Method 1: Standard Proportionality Approach (Includes Non-Intermediate Commodities)

The standard proxy measure of offshoring $\left(O_i^{Method1}\right)$ intensity for industry i is typically constructed using total imports of commodities and inputs per industry derived from input–output tables. Offshoring measures at the industry level are weighted averages of the commodity import intensity for the entire economy, where the weights applied to these intensities are taken from the importance of inputs in a particular industry as contained in the input–output tables. It is defined as follows (for abbreviation, the time subscripts are omitted):

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$$(1) \qquad O_i^{Method1} = \frac{\sum_j INP_{ij} \cdot \left(\frac{IMP_j}{CON_j} \right)}{\sum_j INP_{ij}} = \sum_j \frac{INP_{ij}}{\sum_j INP_{ij}} \cdot \left(\frac{IMP_j}{CON_j} \right),$$

where IMP_j and CON_j are total import and total domestic consumption, respectively, of commodity j, and INP_{ij} is the input of commodity j for industry i. Commodity j is defined by a classification used in the Canadian input–output tables—the IOCCX level—which contains a total of 293 commodities.[2]

Method 2: Modified Proportionality Approach (Excludes Non-Intermediate Commodities)

One limitation of Method 1 is that the aggregate import intensity for commodity $j \left(\frac{IMP_j}{CON_j} \right)$ in equation (1) that is available in standard input–output tables includes both intermediates and final goods. Each commodity j typically consists of a set of more detailed products, some of which are used as intermediates, some for investment, some for final consumption, and some for both intermediate and final demand. Offshoring is an activity that involves sourcing of intermediate inputs abroad. Final products therefore need to be removed from offshoring measures.

In order to do so, the measure in Method 1 is modified to include only intermediate imports and calculated relative to inputs of commodities used at the industry level. The new measure is written as:

$$(2) \qquad O_i^{Method2} = \frac{\sum_j INP_{ij} \cdot \left(\frac{IMP'_j}{INP_j} \right)}{\sum_j INP_{ij}} = \sum_j \frac{INP_{ij}}{\sum_j INP_{ij}} \cdot \left(\frac{IMP'_j}{INP_j} \right),$$

where IMP'_j is the total intermediate imports within commodity group j. Three steps are used to define intermediate imports. First, a commodity concordance is constructed between the 293 IOCCX commodities and the approximate 19,000 commodities classified at the 10-digit Harmonized System (HS10) in the Importer Register. Each IO commodity group j is linked to a set of corresponding HS10 imported products. Second, to identify which imported HS10 products are intermediates, the United Nations (UN) Broad Economic Categories (BEC), which groups HS6 commodities (more aggregate level than HS10, containing around 5,000 commodities) into intermediates and non-intermediates, is used. Third, total intermediate imports within commodity group j $\left(IMP'_j\right)$ are benchmarked to total imports of commodity j in the Canadian IO tables, by first estimating the proportion of intermediates in total imports within each commodity j from the Importer Register and then applying the proportion to the total

[2]The IOCCX level of commodity classification is defined at a slightly more aggregate level than the *W* level used in the input–output tables of Statistics Canada.

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import of commodity j in the input–output table. Equation (1) can also be rewritten as:

$$O_i^{Method2} = \frac{\sum_j \frac{INP_{ij}}{\sum_i INP_{ij}} \cdot IMP'_j}{\sum_j INP_{ij}}. \tag{3}$$

This formulation then distributes total intermediate imports of commodity j $\left(IMP'_j\right)$ to an industry according to its share of input use of that commodity $\left(\frac{INP_{ij}}{\sum_i INP_{ij}}\right)$.

Method 3: Direct-Import Measures from Administrative Import Files

A potential limitation of the standard proportionality approach comes from the assumption used that the import intensity of particular commodities is constant across industries. Method 3 addresses this deficiency by using data on firm imports that are derived from the Canadian Importer Register. The firm identifier that all importers provide to the customs authorities is assigned to an industry code by the Business Register.[3]

Since the Importer Register may not be complete and therefore totals using this technique may not correspond identically to total commodity imports that are listed in the input–output system, the direct measure of industry intermediate imports from the Importer Register is adjusted so that, for each commodity j, the total intermediate imports across all industries equal the benchmark total of intermediate imports $\left(IMP'_j\right)$ in the input–output system derived under Method 2. This more direct measure of offshoring $\left(O_i^{Method3}\right)$ intensity is defined as:

$$O_i^{Method3} = \frac{\sum_j IMP'_{ij}}{\sum_j INP_{ij}} = \frac{\sum_j \frac{IMP_{ij}}{\sum_i IMP_{ij}} \cdot IMP'_j}{\sum_j INP_{ij}}, \tag{4}$$

where IMP'_{ij} is the adjusted direct measure of industry i's total intermediate imports of commodity j, and IMP_{ij} is the total intermediate imports of commodity j for industry i calculated directly from the Importer Register.

Method 4: Linked Import–Input Measures

The fourth method generates direct measures by using firm import data directly linked to individual data derived from the Annual Survey of Manufacturers (ASM). This approach does not use the North American Industry Classification System (NAICS) industry code contained in the Import Registry as is done in

[3]Ideally, the industry code will pertain to a narrowly defined entity that produces in only one industry (e.g., establishment rather than a broadly defined entity (parent enterprise of many firms) so as to precisely identify the industry of use of the imports).

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Method 3, which relies for its accuracy on a process of industry identification associated with linking of a firm into the Business Register. Rather, it links the importing firm identifier in the Importer Register to the firm identifier in the ASM file to obtain an industry classification that exists in the ASM (see Appendix). The latter may be more precise than the link to the Business Register in terms of industry identification. The linked dataset also has the advantage that it contains firm-level information on the value of total material costs derived from the ASM and on the value of total intermediate imports from the Importer Register. Together, the two types of information can be used to calculate an offshoring ratio for each firm in the ASM.

The linked firms are typically large enterprises in the manufacturing sector. Over the 2002–06 period, around 52 percent of firms in the ASM are linked to the Importer Register. These firms account for an average of 76 percent of total manufacturing shipments. For the purposes of this study, it was assumed that unlinked ASM firms are not importers. An industry *i*'s offshoring intensity is defined as:

$$O_i^{Method4} = \frac{\sum_{f \in i} IMP_{f,j}}{\sum_{f \in i} TMAT_{f,j}}, \tag{5}$$

where $TMAT_{f,j}$ is total material costs and $IMP_{f,j}$ is total intermediate imports of commodity j for firm f, taken from the ASM and the Importer Register, respectively. This direct measure using linked production and import micro-data is conceptually similar to the measure employed in Method 3, but different in terms of the method used to assign industry identifiers.

Method 5: Hybrid Measures Combining the Proportionality-Input and the Direct-Import Approach

Using import data creates a problem if the firm that reports imports does not use the product in production and is in a separate industry from the actual user. This can happen if the importer serves as an intermediary (such as the wholesale and retail industries, or the holding companies and head offices that are classified under the Finance and Insurance, Real Estate and Rental and Leasing, Management of Companies and Enterprises industries). To address this issue, the simple approach to import measurement contained in Method 3 is modified by assuming that the surplus of imports in excess of inputs used in an industry, as are reported by the input–output tables, are consumed in other industries—in proportion to the intermediate inputs used elsewhere. In effect, this variant combines the information available on the industry of the firm doing the importing and supplements it with the direct proportionality assumption for imports that are purchased by intermediaries for imports that are in excess of their intermediate consumption.

Method 6: Modified Hybrid Measure

Even though non-intermediate products were excluded in Methods 2, 3, 4, and 5 under the UN BEC classification system, the classification of some

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commodities between intermediate and non-intermediate may be imprecise for some commodities. Engines, for example, are classified as intermediate goods under the UN BEC system. This is most likely to be true if they are imported and utilized by Transportation Equipment industries. However, they become investment goods if utilized by other industries (e.g., for hoists in mining) and become final consumption goods if used by consumers. Other similar products include Fabricated Metal Products, Machinery, Motor Vehicles, Other Transportation Equipment and Parts, Electrical, Electronic, and Communication Products, Mineral Fuels, and Hosiery, Clothing, and Accessories.

To rectify this problem, this study modifies Method 5 and assumes that the above-mentioned commodities imported by wholesale and retail industries are not used as intermediates in the production process. As a result, any surplus of these commodities in the wholesale and retail industries are not reallocated to other industries as intermediate inputs.

Method 7: Survey Measures

The previous measures all employ indirect methods. To provide a source of triangulation, this study makes use of data from Statistics Canada's *2005 Survey of Innovation* that provides direct measures by asking manufacturing plants for the percentage of total expenditures on raw materials and components that are imported from different geographical locations (Canada, United States, Mexico, Europe, Asia Pacific, and all other countries) for the year 2004. This measure provides the most direct measure of import intensity and will be used as the focal point for evaluation of the other indirect measures.

3. Comparison of Offshoring Measures

Aggregate estimates derived by using the different measures of offshoring for the Canadian business sector between 2002 and 2006 are reported in Table 1. The overall estimates produced using Methods 1 and 2 are quite similar. The effect of including non-intermediate goods in the standard proportionality approach is quite small for the entire business sector. By construction, the proportion of imported intermediates for the business sector as a whole is the same under Methods 2, 3, and 5 (Table 1). Method 6 yields a lower estimate of offshoring because certain commodities imported by the wholesale and retail trade as non-intermediate products are excluded. All of the estimates are quite stable over time.

More notable differences among alternate measures occur at the industry level (Table 2). Method 2 adopts the traditional proportionality assumption, which distributes total intermediate imports to industries according to the input use of particular commodities (equation (3)), while Method 3 distributes total intermediate imports to industries according to the value of imports (equation (4)). The two methods yield very different industry estimates. Method 3 produces several unreasonable industry estimates, where import proportions of intermediate inputs exceed unity (such as Utilities; Wholesale; Professional, Scientific, and Technical Services; Finance and Insurance, Real Estate and Rental and Leasing,

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TABLE 1

Proportion of Imported Intermediates, Canadian Business Sector

Year	Proportionality Input Approach		Direct-Import Approach		Hybrid of Proportionality Input and Direct-Import Approach	
	Method 1 (including non-intermediate goods)	Method 2 (excluding non-intermediate goods)	Method 3 (micro import data linked to input–output input data)	Method 4 (micro import data linked to micro manufacturing data from the Annual Survey of Manufacturers)	Method 5 (uses proportionality to distribute all excess imports to all industries)	Method 6 (same as Method 5, but excludes certain excess imports from wholesale and retail; see notes)
2002	0.38	0.34	0.34	–	0.34	0.30
2003	0.35	0.32	0.32	–	0.32	0.28
2004	0.35	0.33	0.33	–	0.33	0.28
2005	0.35	0.33	0.33	–	0.33	0.28
2006	0.35	0.33	0.33	–	0.33	0.28
Average over all years	0.35	0.33	0.33	–	0.33	0.29

Notes: The assumption is that certain commodities imported by wholesale and retail industries are not used as intermediaries. Such commodities include Mineral Fuels, and Hosiery, Clothing, and Accessories, which are most likely to be used as consumption goods, and Fabricated Metal Products, Machinery, Motor Vehicles, Other Transportation Equipment and Parts, and Electrical, Electronic, and Communication Products, which are most likely to be used as investment goods.

Source: Canadian input–output tables, Import Register, and Annual Survey of Manufacturers.

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TABLE 2

PROPORTION OF IMPORTED INTERMEDIATES, CANADIAN BUSINESS SECTOR BY INDUSTRY, 2004

Industry Name (NAICS)	Proportionality Input Approach		Direct-Import Approach		Hybrid of Proportionality Input and Direct-Import Approach	
	Method 1 (including non-intermediate goods)	Method 2 (excluding non-intermediate goods)	Method 3 (micro import data linked to input–output input data)	Method 4 (micro import data linked to micro manufacturing data from the Annual Survey of Manufacturers)	Method 5 (uses proportionality to distribute all excess imports to all industries)	Method 6 (same as Method 5, but excludes certain excess imports from wholesale and retail; see notes)
Total business sector	0.35	0.33	0.33	–	0.33	0.28
Agriculture, forestry, fishing, and hunting (11)	0.16	0.16	0.03	–	0.11	0.10
Mining, quarrying, and oil and gas extraction (21)	0.32	0.29	0.13	–	0.23	0.15
Utilities (22)	0.34	0.28	1.15	–	0.44	0.42
Construction (23)	0.25	0.23	0.02	–	0.18	0.13
Manufacturing (3A)	0.41	0.40	0.25	0.25	0.41	0.35
Wholesale (41)	0.15	0.13	5.38	–	0.35	0.35
Transportation (48)	0.24	0.17	0.09	–	0.13	0.11
Warehousing (49)	0.13	0.10	0.93	–	0.13	0.12
Retail trade (4A)	0.12	0.09	0.96	–	0.11	0.10
Information and cultural industries (51)	0.47	0.74	0.09	–	0.75	0.64
Professional, scientific, and technical services (54)	0.25	0.23	1.53	–	0.31	0.31
Administrative and support, waste management, and remediation services (56)	0.16	0.13	0.61	–	0.16	0.14
Finance and insurance, real estates and rental and leasing, management of companies and enterprises (5A)	0.07	0.06	2.62	–	0.02	0.02
Educational services (61)	0.05	0.04	4.89	–	0.01	0.00
Health care and social assistance (62)	0.42	0.16	0.04	–	0.13	0.13
Arts, entertainment and recreation (71)	0.17	0.06	0.04	–	0.05	0.05
Accommodation and food services (72)	0.14	0.05	0.19	–	0.03	0.03
Other services (except public administration) (81)	0.19	0.13	0.41	–	0.18	0.17

Notes: The assumption is that certain commodities imported by wholesale and retail industries are not used as intermediaries. Such commodities include Mineral Fuels, and Hosiery, Clothing, and Accessories, which are most likely to be used as consumption goods, and Fabricated Metal Products, Machinery, Motor Vehicles, Other Transportation Equipment and Parts, and Electrical, Electronic, and Communication Products, which are most likely to be used as investment goods.

Source: Canadian input–output tables, Import Register, and Annual Survey of Manufacturers.

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Management of Companies and Enterprises; and educational services[4]). This occurs because Method 3 assumes an industry reporting an import is also the industry using the import in the production process. This assumption will not be true if firms in some industries such as wholesales serve as intermediaries for imports that are then sold to firms in other industries that make use of these imports in the production process.

To correct for the intermediary problem, the hybrid approaches (Method 5 and Method 6) use both the industry direct-import information as well as the input information on commodities used in the production process to distribute surplus imports in intermediary industries to input-use industries. By assuming that the surplus of imports in excess of inputs in an industry is consumed in other industries in proportion to their intermediate inputs used, the hybrid methods partially correct for the import-reporting and import-using problems inherent in Method 3. The hybrid methods yield offshoring measures that lie between the proportionality input approach (Method 2) and the direct-import approach (Method 3). Measures from Method 6 are slightly lower than those under Method 5 since it is assumed in the former case that certain commodities imported by intermediaries, such as wholesale and retail firms, are not used as intermediate inputs and therefore that any surplus imports in the two industries are not redistributed.

The first six formulae used in this study to measure import utilization in the production process all employ indirect methods, and produce estimates at the industry level that differ from one another. The differences across these alternate techniques are sufficiently large that the possibility that there are errors in the estimation of any one arbitrarily chosen technique cannot be ignored. To provide a source of triangulation, this study makes use of data from Statistics Canada's 2005 Survey of Innovation. The survey provides direct measures for manufacturing industries by asking plants in the manufacturing sector for the percentage of total expenditures on raw materials and components that are imported from different geographical locations. The point estimates will have confidence intervals that arise both from non-sampling error (the question may not be correctly answered by respondents) and from sampling error (not all firms were asked the question and not all answered it). Nevertheless, these estimates provide a base point that will be used here to assess the direction and size of the errors that may be associated with each of the indirect methods.

The six alternative measures of offshoring are compared to those derived from the Survey of Innovation for NAICS three-digit Canadian manufacturing industries in Table 3. The confidence interval surrounding the survey's point estimates are also provided. Three observations are noteworthy.

[4]Under the UN BEC classification of intermediate commodities, Wholesale, Retail, and FIRE (head offices are classified under FIRE) industries import around 22, 3, and 12 percent of total intermediate materials, respectively. Mineral Fuels, Fabricated Metal Products, Machinery, Motor Vehicles, Other Transportation Equipment and Parts, and Electrical, Electronic, and Communication Products are among the major imported items, accounting for around 50 percent of total imports in the Wholesale and FIRE industries. Mineral Fuels account for 69 percent of total intermediate imports in the retail industry. In the Utilities industry, 92 percent of imports are Mineral Fuels. The total material imports in the Warehousing and Education sectors are small, accounting for less than 0.5 percent of total material imports.

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TABLE 3

Proportion of Imported Intermediates, Canadian Manufacturing, 2004

Industry Name (NAICS code)	Estimates from Survey of Innovation 2005		Proportionality-Input Approach		Direct-Import Approach		Hybrid Approach	
	Mean	Confidence Interval	Method 1 (including non-intermediate goods)	Method 2 (excluding non-intermediate goods)	Method 3 (micro import data linked to input–output input data)	Method 4 (micro import data linked to micro manufacturing data from the Annual Survey of Manufacturers)	Method 5 (uses proportionality to distribute all excess imports to all industries)	Method 6 (same as Method 5, but exclude certain excess imports from wholesale and retail)
Manufacturing	0.29	[0.28, 0.29]	0.41	0.40	0.25	0.25	0.41	0.35
Non-durables sector	0.32	[0.30, 0.33]	0.31	0.27	0.15	0.17	0.27	0.23
Food, beverage, and tobacco products (311–312)	0.16	[0.14, 0.18]	0.15	0.10	0.05	0.05	0.09	0.09
Textile mills and textile product mills (313–314)	0.53	[0.49, 0.58]	0.58	0.54	0.39	0.49	0.60	0.52
Clothing, leather, and allied products (315–316)	0.44	[0.40, 0.47]	0.57	0.73	0.27	0.14	0.67	0.49
Paper (322)	0.32	[0.28, 0.35]	0.20	0.19	0.12	0.12	0.19	0.19
Printing and related support activities (323)	0.26	[0.22, 0.29]	0.33	0.32	0.11	0.08	0.24	0.24
Petroleum and coal products (324)	0.24	[0.17, 0.31]	0.42	0.41	0.16	0.15	0.42	0.28
Chemical (325)	0.40	[0.36, 0.43]	0.31	0.26	0.20	0.34	0.29	0.28
Plastic and rubber products (326)	0.43	[0.40, 0.46]	0.54	0.43	0.30	0.29	0.42	0.41
Durables sector	0.27	[0.26, 0.28]	0.50	0.50	0.34	0.32	0.52	0.46
Wood products (321)	0.11	[0.09, 0.13]	0.12	0.11	0.08	0.07	0.12	0.12
Non-metallic mineral products (327)	0.23	[0.18, 0.27]	0.22	0.24	0.17	0.18	0.24	0.23
Primary metal (331)	0.30	[0.26, 0.35]	0.40	0.41	0.19	0.41	0.39	0.37
Fabricated metal products (332)	0.24	[0.22, 0.26]	0.36	0.34	0.29	0.26	0.38	0.29
Machinery (333)	0.32	[0.29, 0.35]	0.51	0.46	0.17	0.24	0.44	0.32
Computer and electronic products (334)	0.53	[0.50, 0.57]	0.82	0.82	0.32	0.16	0.81	0.59
Electrical equipment, appliances, and components (335)	0.42	[0.37, 0.47]	0.53	0.48	0.24	0.28	0.51	0.41
Transportation equipment (336)	0.41	[0.37, 0.45]	0.60	0.63	0.51	0.52	0.67	0.61
Furniture and related product (337)	0.18	[0.15, 0.20]	0.37	0.31	0.14	0.08	0.29	0.24
Miscellaneous (339)	0.31	[0.27, 0.34]	0.69	0.63	0.40	0.27	0.77	0.74

Source: Canadian input–output tables, Import Register, Annual Survey of Manufacturers, and 2005 Survey of Innovation.

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First, for the non-durables sector as a whole, offshoring estimates using the proportionality assumption contained in Methods 1 and 2 (0.31 and 0.27, respectively) are quite close to the survey point estimates of 0.32. The similarity between the direct survey measure and the proportionality estimates extends to the individual industries contained within the non-durables sector. Around 25 percent of non-durable industries have proportionality estimates that lie within the survey confidence intervals. Methods 3 and 4, which directly use the import information, yield much smaller values (0.15 and 0.17, respectively). The lower estimates using the direct import data would occur if the non-durables sector uses more intermediate imports than it directly purchases from abroad, and if it relies on intermediate purchases of imports from other industries such as wholesale and retail trade. When corrections for this phenomenon are applied in the hybrid techniques (Methods 5 and 6), the import intensity for non-durables as a whole improves. Moreover, the number of individual industries using Method 6 that fall within the confidence intervals derived from the survey (50 percent of non-durables industries) is twice as many as those using the proportionality assumption (Methods 1 and 2). Thus, where a substantial proportion of imports of an industry are sourced from other domestic intermediaries, the proportionality assumption provides reasonable estimates at the aggregate sector level, but methods using imports that are directly sourced by firms need to be modified to take into account the degree to which imported inputs are derived through intermediates. Since the proportionality Method 1 is more straightforward to calculate than the hybrid approach that directly measures imports (Method 6), the proportionality approach might be considered adequate at the aggregate sector level. But, at the more detailed industry level, hybrid Method 6 that is based on the intermediary-adjusted import data outperforms Method 1, which depends on the proportionality assumption in that 50 percent of the individual industries of the non-durables sector in Method 6 as opposed to 25 percent of the individual industries in Method 1 fall within the survey confidence intervals.

Second, for the durables sector as a whole, offshoring estimates using the proportionality assumption under Methods 1 and 2 (0.50) are higher than the survey point estimates of 0.27. This is also the case for most of the industries contained within the durables sector (80 percent of the individual durable industries). The proportionality approach assumes the industry-specific import share of each input is the same as the economy-wide import intensity of the input. The proportionality approach will yield an over-estimation of the amount of imports being used in a particular industry if the import intensity of an industry is less than the economy-wide intensity. The fact that the proportionality assumption yields higher estimates in the durables sector for Canada than is appropriate suggests that the import intensity outside of the durables manufacturing sector (e.g., mining, oil and gas, and other resource sectors) is higher than in the durables manufacturing sector. In comparison to the proportionality methods, Methods 3 and 4, which directly use the import information, yield aggregate estimates (0.34 and 0.32, respectively) that are closer to the survey estimates. The superior relative accuracy of the method using direct imports for the durable as opposed to the non-durables sector would arise if the durables sector directly imported a relatively larger proportion of its intermediate inputs used in production without going

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through intermediaries than did the non-durables sector—possibly because intermediate goods in this sector are more firm-specific and require greater control over the import stream. Moving to the hybrid version of the direct-import technique improves the estimates further. For individual industries, hybrid Method 6 outperforms proportionality Methods 1 and 2 in that 40 percent versus 20 percent of individual durables industries fall within the confidence intervals of the survey.

Third, the hybrid estimates as a whole for Methods 5 and 6 are higher than for Methods 3 and 4 and closer to the survey point estimates than those under the simple direct-import approach (Method 3) since surplus imports from other industries are reallocated to input-using industries. In particular, Method 6, which recognizes that some commodities imported by intermediary industries may not be used as inputs into the production process, yields estimates within the survey confidence intervals for 44 percent of 18 NAICS three-digit manufacturing industries. This occurs in less than 22 percent of industries under either the standard proportionality input approach or the direct-import approach.

The observation that Method 6 yields the best estimates is reinforced by non-parametric tests, which are used to examine whether estimates from the six methods are in general significantly different from survey estimates. The null hypothesis is that there are no significant differences in mean values of the individual industries covered in Table 3 using a t-test and in median values under the sign and signed-rank tests. Table 4 shows that for industry estimates in the manufacturing sector as a whole, the null is rejected for all methods except Method 6 under the t-test and signed-rank test. Method 6 yields industry estimates that are on the whole not significantly different from survey estimates. Estimates from the proportionality approach are not significantly different from survey estimates for industries in the non-durables sector, while estimates from the direct-import approach are not significantly different from survey estimates for industries in the durables sector. On the basis of these tests, the use of data derived directly from imports by firm, once adjusted for imports that are derived indirectly by firms that act as intermediaries in the import process, yields estimates across the industry spectrum that are superior to those produced by the proportionality method that is widely used to examine the impact of offshoring.

4. Conclusion

In the absence of precise data on the exact imports that each industry uses, the proportionality assumption has been widely adopted in order to construct a proxy measure of offshoring. This paper suggests that it yields inaccurate results in many manufacturing industries and that superior measures are available from data on direct firm imports—but that even here, adjustments are required.

The paper first proposes an alternative proxy measure that makes use of the proportionality assumption but focuses only on intermediate goods. It finds that the difference between the standard proxy measure (which includes non-intermediate final goods) and the alternative proxy measure (which excludes

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TABLE 4

Tests for the Differences between Alternate Measures and Survey Estimates, Canadian Manufacturing, 2004

	Proportionality-Input Approach against Survey Estimates		Direct-Import Approach against Survey Estimates		Hybrid Approach against Survey Estimates	
	Method 1 (including non-intermediate goods)	Method 2 (excluding non-intermediate goods)	Method 3 (micro import data linked to input–output input data)	Method 4 (micro import data linked to micro manufacturing data from the Annual Survey of Manufacturers)	Method 5 (uses proportionality to distribute all excess imports to all industries)	Method 6 (same as Nethod 5, but exclude certain excess imports from wholesale and retail)
				Test Probability		
Probability value for the Student's t-test for mean differences						
Manufacturing	0.00*	0.01*	0.00*	0.00*	0.01*	0.27
Non-durables sector	0.31	0.62	0.00*	0.00*	0.69	0.19
Durables sector	0.00*	0.00*	0.06	0.11	0.01*	0.11
Probability value for the sign test for median differences						
Manufacturing	0.03*	0.01*	0.01*	0.01*	0.10	0.48
Non-durables sector	0.73	0.73	0.01*	0.01*	0.73	0.29
Durables sector	0.02*	0.00*	0.11	0.11	0.00*	0.02*
Probability value for the signed rank test for median differences						
Manufacturing	0.00*	0.01*	0.00*	0.00*	0.02*	0.44
Non-durables sector	0.38	0.74	0.01*	0.01*	1.00	0.25
Durables sector	0.00*	0.00*	0.08	0.06	0.00*	0.01*

Note: *The null hypothesis of no differences between alternative methods and survey estimates is statistically rejected at the 5% level or better.
Source: Canadian input–output tables, Import Register, Annual Survey of Manufacturers, and 2005 Survey of Innovation.

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non-intermediate final goods) still using the standard proportionality framework is small.

The paper then calculates offshoring measures that make use of firms' direct imports taken from the Canadian Importer Register. It finds large industry differences between the proportionality approach and the direct-import approach that uses import data at the firm level: the former uses industries' input patterns to allocate total intermediate imports, while the latter uses industries' import patterns to allocate total intermediate imports. The former may generate inaccurate results if import intensity of each commodity varies across industries. The latter will be imperfect if the use of intermediaries to import commodities varies by industry. The latter is shown to exist since the paper finds that material imports in the Wholesale, Retail, and FIRE (Fire, Insurance, Real Estate, and Renting and Leasing) (head offices) industries are well above their input use. These industries serve as intermediaries, purchasing imports and reselling them to firms in other industries. Their importance is sizable, accounting for 22, 3, and 12 percent of total material imports, respectively.

Comparisons of the estimates derived from the proportionality as opposed to the direct-import approach are made to a direct measure derived from Statistics Canada's 2005 Survey of Innovation, where Canadian manufacturing firms report their estimated percentage of intermediate import use. These comparisons show that neither the proportionality approach nor a simple direct-import approach closely match the survey results across all industries. The proportionality approach generates an estimate of offshoring for non-durables industries that roughly corresponds to the survey estimate, but yields an overestimate for durables industries. By contrast, the simple direct-import approach generates a close estimate to the survey for durables industries, but yields an underestimate for non-durables industries.

Hybrid measures that modify the measure of direct imports obtained from the Importer Register by taking into account intermediary importers improve the estimates yielded by the simple direct-import approach, in the sense that measures, both at the aggregate and individual industry level, move closer to the survey estimates. In particular, the hybrid method which takes into account that some commodities imported by intermediaries may not be used as intermediates in production, yields estimates that are more accurate proxies than all other alternatives for many of the individual manufacturing industries, and for the manufacturing sector as a whole.

References

Daudin, G., C. Rifflart, and D. Schweisguth, "Who Produces for Whom in the World Economy?" *Canadian Journal of Economics*, 44, 1403–37, 2011.

Feenstra, R. C. and G. H. Hanson, "Globalization, Outsourcing, and Wage Inequality," *American Economic Review*, 86, 240–5, 1996.

———, "The Impact of Outsourcing and High-Technology Capital on Wages: Estimates for the United States, 1979–1990," *Quarterly Journal of Economics*, 114, 907–40, 1999.

Feenstra, R. C. and J. B. Jensen, "Evaluating Estimates of Materials Offshoring from U.S. Manufacturing," *Economic Letters*, 117, 170–3, 2012.

Hummels, D., J. Ishii, and K. Yi, "The Nature and Growth of Vertical Specialization in World Trade," *Journal of International Economics*, 54, 75–96, 2001.

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Johnson, R. and G. Noguera, "Accounting for Intermediates: Production Sharing and Trade in Value-Added," *Journal of International Economics*, 86, 224–36, 2012.
Koopman, R., W. Powers, Z. Wang, and S. J. Wei, "Give Credit Where Credit is Due: Tracing Value Added in Global Production Chains," National Bureau of Economic Research Working Paper 16426, 2010.
OECD (Organization for Economic Cooperation and Development), *Moving up the (Global) Value Chain*, OECD, Paris, 2007.
Trefler, D. and S. C. Zhu, "The Structure of Factor Content Predictions," *Journal of International Economics*, 82, 195–207, 2010.
Winkler, D. and W. Milberg, "Bias in the 'Proportionality Assumption' Used in the Measurement of Offshoring," *World Economics*, 13(4), 39–60, 2012.

Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Appendix: Data linkage of the Annual Survey of Manufactures and the Importer Register

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