Estimating Extended Supply-Use Tables in Basic Prices with Firm Heterogeneity for the United States: A Proof of Concept

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This paper presents proof-of-concept trade-in-value added (TiVA) statistics estimated from extended supply-use tables for the United States that account for firm heterogeneity. The tables used to estimate the TiVA statistics extend recently-introduced supply-use tables for the United States by disaggregating the components of supply and use by multinational and other firms. Recent research has shown both the advantages of measuring trade on a value added basis when analyzing bilateral trade flows and the dominance of multinational enterprises in U.S. trade in goods and services. Our TiVA statistics for the United States include measures based on traditional supply-use presentations as well as statistics that reflect firm-level heterogeneity for the year 2011. The comparative analysis of the two sets of statistics allows us to understand better how firms within industries engage in global value chains and if the incorporation of firm heterogeneity provides a more accurate measurement of TiVA. We find that domestic value added as a share of the value of exports is similar within large industry groups. However, there is much more variation in the value added share of exports when firm type is accounted for. Also, the additional granularity shows the share of this value added that comes directly from the producing industry varies much more across industries.

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1 Introduction

Pioneering work on measuring trade in value added (TiVA) began with efforts in academia (e.g. Global Trade Analysis Project (GTAP)), in government (e.g. United States International Trade Commission (USITC) and the World Input-Output Database (WIOD)), and in international organizations (e.g. Organisation for Economic Co-operation (OECD) and World Trade Organization). These initial efforts have raised the profile of TiVA and generated strong demand for better understanding of how global value chains work, which has motivated national statistical agencies to find ways to measure trade-in-value added (TiVA) more accurately. Research has shown that a sizeable share of trade is composed of intermediate goods that have crossed borders multiple times and that bilateral trade balances measured using (TiVA) can be very different than the trade balances using gross trade flows (Johnson and Noguera (2012)). These differences matter because they imply differences in competitiveness vis-a-vis trading partners and their implications for trade policy.[2]

As noted by Fetzer and Strassner (2015) and others, national statistical agencies have found direct measurement of TiVA to be impractical. Instead, efforts to measure TiVA more accurately have focused on better refining supply-use tables (SUTs) that can be used to measure the value added portion of trade indirectly by particular industries. Accurate measurement of TiVA for a country using this method depends on the SUTs of all major trading partners because the SUTs must be linked using bilateral trade flows. Improvements in these

[2] See Dervis, Metzer and Foda (2013) "Value-Added Trade and Its Implications for Trade Policy" http://www.brookings.edu/research/opinions/2013/04/02-implications-international-trade-policy-dervis-meltzer

tables have benefitted from international collaboration on issues such as the industry and product classifications and valuations of these tables. These efforts have also aimed to extend these tables by taking into account different dimensions of firm-level heterogeneity within industries and challenging the historical assumption of a homogenous production function for all firms within a given industry.

This paper builds on recently-published SUTs for the United States (Young, Howells, Strassner, and Wasshausen 2015). We estimate "proof of concept" extended SUTs disaggregated by firm type based on the methodology of Fetzer and Strassner (2015). These tables foreshadow more precise estimates of extended SUTs that will be the product of an ongoing long-term U.S. Bureau of Economic Analysis (BEA) - U.S. Census Bureau (Census) microdata link project. We also estimate measures of TiVA based on the input-output coefficients derived from these SUTs.

2 Literature Review

Our paper builds on research that has decomposed industry output by firm type, estimated extended input-output tables (IOTs), and estimated TiVA indicators using a single country IOT. Recent research such as Fetzer and Strassner (2015), Piacentini and Fortanier (2015), Ahmad, Araujo, Lo Turco, and Maggioni (2013), and Ma, Wang, and Zhu (2015) have found evidence of heterogeneity in value added and trade between foreign- and domestic-owned enterprises in a broad group of countries including the United States, China, and many European countries. Our paper estimates the components of output and value added for multinational enterprises (MNEs) and non-MNEs for the United States based on the methodology used in Fetzer and Strassner (2015).

We also build on the literature that uses firm characteristics and constrained optimization to estimate IOTs by type of firm. Koopman, Wang, and Wei (2012) developed a method that allows for computing IOTs that distinguish between processing and normal trade. Ma, Wang, and Zhu (2015) extend this approach by distinguishing between Chinese exports by foreign-invested enterprises and by Chinese-owned enterprises. We use this framework to refine further the U.S. use table to include valuation at basic prices and to disaggregate the U.S. SUT by firm type.

Most TiVA estimates are based on global IO tables, but it is possible to generate TiVA estimates using a single country's IO tables, under certain assumptions. Koopman, Wang, and Wei (2014) indicate that gross exports can be decomposed into domestic content and foreign content using a single country IOT if there is no trade in intermediate goods. Ma, Wang, and Zhu (2015) note that single country models are limited to estimating the domestic content of exports. The domestic content of exports may differ from the domestic value added in exports since it may include domestic content that has been re-imported. Los, Timmer, and de Vries (forthcoming) indicate that domestic value added in gross exports can be estimated from the difference in reported gross domestic product (GDP) and hypothetical GDP estimated from a single country IOT assuming the country does not export. However, they indicate that global IOTs are required to decompose domestic value added by end use including the extent to which it is absorbed abroad. The weakness of this approach is that the U.S. production structure and IOT would be different if the country did not export.

3 Data

The 2011 SUTs for the United States are the foundation on which the proof-of-concept extended SUTs were constructed. The supply-use framework comprises two tables. The supply table presents the total domestic supply of goods and services from both domestic and foreign producers that are available for use in the domestic economy. The use table shows the use of this supply by domestic industries as intermediate inputs and by final users as well as value added by industry. The main part of each table is organized with industries across the columns and commodities across the rows. The cells in the main part of the supply table indicate the amount of each commodity (row) produced and/or used by an industry (column). The remaining columns indicate the amount of each commodity that is imported and valuation adjustments such as trade margins, transportation costs, taxes, and subsidies for each commodity. The cells in the main part of the use table indicate the amount of a commodity purchased as an intermediate input for an industry's production process. The cells in the remaining columns in the table indicate how each commodity is allocated to different components of final demand. The cells in the bottom rows indicate how the components of value added in an industry are allocated.[3]

[3] Young, Howells, Strassner, and Wasshausen (2015).

The incorporation of BEA statistics on the Activities of Multinational Enterprises (AMNE) is how firm heterogeneity is introduced into the SUTs and is what distinguishes them as extended SUTs. These statistics cover the financial and operating characteristics of U.S. parent companies (domestic-owned MNEs) and U.S. affiliates that are majority-owned by foreign MNEs (foreign-owned MNEs). They are based on legally mandatory surveys conducted by the BEA and are used in a wide variety of studies, such as this one, to estimate the impact of MNEs on the domestic (U.S.) economy and on foreign host economies.

The tables presented here are part of a time series of SUTs, now covering the period 1997-2014, that were first released by the BEA in September of 2015.[4] Release of these tables marks an important milestone in BEA's long-term plan to make U.S. data on output, intermediate inputs, and value added available in a format that is well suited for preparation of TiVA statistics.

With the September 2015 release, data previously presented only in the make-use format were also presented in the more internationally recognized supply-use format.[5] Presentation in this format will facilitate future efforts to link U.S. data with SUTs from other countries, a step necessary to derive the full suite of TiVA-related statistics. In addition, the new SUTs incorporate important valuation changes that bring the tables into better alignment with international standards and enhance the suitability of the tables for use in TiVA analysis. First, taxes in the new tables are separated into taxes on products and other taxes on production and

[4] For a full discussion of the supply-use framework and the methodology followed by BEA to prepare the new tables, see Young, Howells, Strassner, and Wasshausen (2015).

[5] The new supply and use tables are supplemental products that will be produced in addition to, rather than in place of, BEA's current make and use tables.

output in the supply table, and value added in the use table is presented exclusive of taxes on products (i.e. valued at basic prices). Second, a commodity distribution of customs duties on imports is incorporated, and imports in the new tables are presented exclusive of duties (i.e. valued at c.i.f.[6]).

Certain future enhancements to the SUTs are not reflected in the estimates presented here. Currently, BEA is investigating the possibility of publishing tables on an International Standard Industrial Classification (ISIC) basis. Additionally, BEA is investigating the possibility of releasing a breakdown of the use tables valued at purchaser prices into their several component matrices. This decomposition could include separate matrices for domestically-produced inputs valued at basic prices, imported inputs at basic prices, margins, taxes on products, and subsidies on products. These additions were not available for purposes of this paper, so the tables were converted in a manner that approximates an ISIC basis and the component matrices had to be estimated. The decomposition process is outlined in greater detail in the methodology section and in appendix A.

The basic SUTs for 2011 are extended by incorporating data on firm-level heterogeneity by industry. These data are prepared on an ISIC-basis for 33 industries following the methodology used in Fetzer and Strassner (2015).[7] As is the case in Fetzer and Strassner (2015), we use 2011 IRS Statistics of Income (SOI) data to estimate value added by industry for all firms with operations in the United States and BEA AMNE data for 2011. For U.S. MNEs, we

[6] The c.i.f. valuation of imports refers to cost, insurance, and freight. This valuation includes the cost of the import at the foreign port plus the insurance, freight charges, and charges other than import duties associated with transferring the import to the domestic port.

[7] There is no BEA or IRS data for industry 34, "Private households with employed persons."

separately analyze data for domestic-owned MNEs and for foreign-owned MNEs. Because of some challenges working directly with the SOI data, we also use data from the BEA input-output accounts to estimate exports and intermediate imports. However, unlike Fetzer and Strassner (2015) we use the enterprise level SOI data on employee compensation and make adjustments to implausible values on a case-by-case basis. We also match these data on an ISIC-basis for 33 ISIC industries from the reported NAICS industries. This industry conversion is necessary so that our tables are comparable to those produced by other OECD countries.

Results by industry for domestic non-MNEs are computed as the difference between the SOI-based results for all U.S. firms less the results for directly measured domestic-owned and foreign-owned MNEs. We use the SOI data instead of the BEA SUTs because the SOI data are collected and published by industry at the enterprise level, similar to the BEA AMNE data.

The data for foreign MNEs, which are U.S. affiliates of foreign parent companies, are generally reported as published by BEA except where imports or exports are suppressed to protect the confidentiality of firms that make up most of the data in the industry and where gross operating surplus, consumption of fixed capital, and taxes were not published for an industry. In these cases, we estimate the share for each of these variables for all industries for which the data are not reported or are suppressed and then impute a value from this aggregate share.

The data for domestic-owned MNEs are adjusted by removing the MNEs that are majority-owned by foreign parents to put the data on an ultimate U.S.-owner basis, just as the foreign-owned MNE data are on an ultimate foreign-owner basis. Some industries had no majority foreign-owned MNEs, so their data are the same as the regularly published data. We impute data for several industries to protect the confidentiality of firms that make up a large share of data for an industry. In these cases, we typically estimate the share of each variable that needs to be imputed in the unadjusted data for all industries for which the data were not reported or are suppressed and then impute a value from this aggregate share. One exception is where we use unadjusted output shares to impute the imports and exports for industries where the original unadjusted data were suppressed. Additionally, we reduce the trade data for wholesale and retail trade for both domestic- and foreign-owned MNEs to better attribute the trade to the using industries.[8]

We also make some adjustments to the SOI data to adjust for implausible values. Most of the adjustments are made to employee compensation and to imports and exports, which in total were based on the BEA SUTs. In particular we make large changes to values for "Manufacturing not elsewhere classified and recycling." The need to make large changes to residual industry groups is typical because, by construction, these groups reflect measurement error in all of the industry groups that are shown separately. There are no MNE data for public administration and defense. We also assume that imports and exports were zero for public administration and defense. Trade in both goods and services are included in the SOI data, but only trade in goods is included in our MNE data. The BEA AMNE data include trade in services and we are planning on incorporating this information along with information from our services

[8] The adjustment is necessary because there is a wide body of evidence showing that wholesale intermediaries play an important role in connecting imported products to using industries.

surveys in the future. Therefore our tables may attribute a disproportionate share of trade in services to domestic-owned non-MNEs.

4 Methodology

We take several steps to prepare the extended SUTs and to derive TiVA estimates from both the standard and extended SUTs. As mentioned in the previous section, a decomposition of the use table at purchasers' prices into its several component matrices is not currently available. Therefore, we first estimate this decomposition using a quadratic programming constrained optimization model and data from the published BEA SUTs. We then estimate an extended SUT in which industries are broken down into different firm types. Following the approach taken by Ma, Wang, and Zhu (2015), this is also done using a quadratic programming constrained optimization model with estimates of the components of output by firm type derived from BEA and IRS data. We use the resulting extended SUTs to construct a symmetric industry-by-industry extended input-output table (IOT). Using the IOT, we calculate the Leontief inverse from which are derived our TiVA statistics.

4.1 Decomposing the purchasers' price use table and constructing extended SUTs and IOTs

The international standard is for use table transactions to be valued at purchaser prices. However, a basic price valuation is preferred for purposes of calculating TiVA statistics because it ensures more homogenous valuation across different products, more accurately reflects a country's input-output relationships, and allows separate identification of the effects of import tariffs, production taxes, and subsidies. Using a quadratic programming model with parameters from BEA's published SUTs, we decompose the purchaser price use table into separate matrices for domestically-produced inputs valued at basic prices, imported inputs valued at basic prices, margins, taxes on products, and subsidies on products. The model is detailed in Appendix A.

Following the decomposition of the purchaser price use table, we incorporate BEA and IRS data on the components of output by firm type into the basic price SUT to construct extended SUTs. We incorporate these data into the basic price SUT using an approach similar to the constrained optimization model used by Ma, Wang, and Zhu (2015) for Chinese IOTs. We estimate the share of output attributable to different types of firms: U.S.-owned MNEs, foreign-owned MNEs, and non-MNEs. We then apply these shares to output of both primary and secondary products and to taxes and margins in the supply tables to estimate the value of these variables for each type of firm. Similarly, for the use table, we estimate the share of value added attributable to each firm type from SOI and BEA data. We apply these shares to value added in the use table. We then create a symmetric IOT from the SUTs for estimation of TiVA statistics. The optimization model used for estimating extended SUTs is described in detail in appendix B.

Tables 1 and 2 show a highly aggregated example of our proof-of-concept, extended SUTs for the United States for 2011. Across the columns, the supply and use tables are arranged first by the three firm-types: domestic-owned MNEs, foreign-owned MNEs, and domestic-owned non-MNEs. The columns show an aggregation of industries of primary goods, manufacturing, services, and unclassified "special" products. In this aggregation, the primary industry includes agriculture and mining while services include utilities, construction, other private service industries and government services. The rows are arranged by firm types and commodities, which are the same as those in the columns. Note that the rows and columns of each table add up to total supply and total use of $29.5 trillion. This is composed of $2.1 trillion in exports, $15.4 trillion of domestic final demand, and $12.0 trillion of total intermediate use.[9]

Tables 3 and 4 show the values in the aggregated SUTs as a share of total output. Table 3 shows that the largest shares in the supply tables are along the main diagonal. This indicates that these highly aggregated groups of industries supply most of their output to firms in the same industry. Also note that these shares do not vary much by firm type at this level of aggregation. The table also shows that about two-thirds of imports are manufacturing commodities.

According to table 4, all three types of firms generally purchase a higher share of their output from domestic-owned non-MNEs than from MNEs. Also, table 4 indicates that manufacturing imports are a larger share of output for MNEs compared with non-MNEs, but imports of primary products are a larger share output for non-MNEs. Because trade in services is not included for MNEs as noted earlier, non-MNEs are assigned a disproportionality large share of trade in services.

[9] An excel file of the extended tables for all 33 industries will be posted on the BEA website along with the paper.

4.2 TiVA estimates

Once the extended SUTs are constructed, we derive a symmetric industry-by-industry extended IOT from the extended SUTs. First, we generate a commodity-by-commodity IOT using the industry technology assumption that each industry has its own specific method of production, irrespective of its product mix. We derive an industry-by-industry IOT using the fixed product sales structure approach from this table, in which each product has its own specific sales structure, irrespective of the industry in which it is produced.[10] Dietzenbacher, Los, Stehrer, Timmer, and de Vries (2013) note that this approach is also used to construct the world IOTs for the World Input-Output Database Project. They indicate that practitioners prefer the fixed product sales structure approach to the fixed *industry* sales structure where each industry has its own sales structure. This is because it is more plausible that products have the same sales structure than industries having the same sales structure. It also does not yield negative values in cells that were not negative in the original SUT.

TiVA estimates are most rigorously calculated using international IOTs that account for the production of all countries in the world. However, TiVA statistics can be calculated using single country IOTs. We follow the approach of Ma, Wang, and Zhu (2015) and Tang, Wang, and Wang (2014) and assume that domestic content in gross exports is the same as the value added in exports. Because part of domestic content in gross exports is re-imported goods, domestic content is an upper bound on domestic value added.

[10] Eurostat (2008).

We calculate TiVA measures using a methodology that is typically used for international IOTs. A key to calculating TiVA statistics is the Leontief inverse of the IOT. The matrix depends on both the direct input requirements from the same industry and the indirect input requirements from other industries. Domestic value added embodied in gross exports for a particular industry depends on both these direct and indirect requirements. Following Ma, Wang, and Zhu (2015) and Tang, Wang, and Wang (2014), we calculate domestic value added as the product of the vector of the domestic value added share of output for each industry, the Leontief inverse of the U.S. IOT matrix, and the value of gross exports for each industry. Likewise, the *direct* domestic value added content of gross exports is calculated as the vector of domestic value added shares of output multiplied by the value of gross exports for each industry. *Indirect* domestic content of gross exports is calculated as the difference between total and direct domestic value added.

5 Results

In this section we describe the TiVA indicators from the U.S. IOTs. These TiVA indicators help us better understand how an economy engages in global value chains. We find that the domestic value added of exports is similar across large industry groups. However, there is much more variation in the value added share of exports once firm type is considered. Also, the share of this value added that comes directly from the producing industry varies much more across industries than within industries.

Powers (2012) points out that TiVA indicators typically focus on either a decomposition of value added where goods are consumed or a decomposition of gross trade. He indicates that examining trade on a value added basis shows a different picture of bilateral trade balances than gross trade flows. However, the total trade deficit summed across all countries is identical for both TiVA and gross trade flows.

One core measure of TiVA is decomposing value added of gross exports and imports into domestic and foreign components. Other things being equal, the higher the foreign value added share of exports, the more a particular industry is integrated in global value chains. This could mean that the current level of exports depends on foreign content. It is also possible that the foreign content is substituted for potential additional domestic content.

According to the OECD TiVA database, domestic value added as a share of exports for the United States fluctuated slightly between 85 and 89 percent between 1997 and 2013. The share is stable around 89 percent during 1997 to 2002 and then gradually decreases to 85 percent in 2008. Domestic value added embodied in gross exports fluctuates between 86 and 89 percent of gross exports during 2009 to 2013. The fluctuations during this period are most likely due to the contraction of international trade following the financial crisis and the subsequent recovery during that period.[11]

Domestic value added is a relatively larger share of exports for the United States compared with other major economies. Domestic value added as a share of exports in 2011 for the United States is similar to the share of domestic value added in exports for Australia, Japan,

[11] OECD Trade in Value Added Database, Updated October 2015.

and Russia, but about 10 percentage points higher than the share for most major European countries and Canada, about 17 percentage points higher than the share for China and Mexico, and about 27 percentage points higher than the share of domestic valued in exports for Korea.[12] While this seems to suggest that the United States is relatively less integrated into global value chains than many other major economies, it has the third highest level of foreign value added content in exports in the world in 2011 at $286 billion. The only other countries with greater foreign value added content of gross exports were China at $632 billion and Germany at $365 billion.

Before estimating TiVA statistics by firm type from the extended U.S. IOT, we calculate TiVA statistics for all U.S. firms based on the 71 industry 2011 U.S. make and use tables. Domestic value added as a share of gross exports for the United States varies by industry in 2011. As seen in figure 1, industries in the service sector generally have the highest shares of domestic value added in their exports. Domestic value added as a share of exports for industries in the services sector ranges from 77 percent to 99 percent. This is not surprising given the labor intensive nature of services. One exception is the relatively more capital intensive transportation services for which domestic value added as a share of exports is about 78 percent to 86 percent. Domestic value added as a share of output is slightly smaller for the mining and extraction sector for which many inputs are geographically constrained to have a domestic location compared to the services sector. Figure 2 shows that industries in the manufacturing sector have more heterogeneity in the domestic value added as share of output,

[12] "Domestic value added share of gross exports," October 2015, OECD TiVA database.

but in most cases the share is between 81 and 87 percent. A notable exception is petroleum and coal products for which domestic value added makes up only slightly more than one half of the value of exports. In 2011, the industry most likely used more imported foreign crude oil and coal to produce refined petroleum and coal products for export.

Another core TiVA measure is to decompose the share of domestic value added in gross exports into value added directly in the industry and indirect value added from other domestic industries. This decomposition measures the degree to which an industry participates in a domestic supply chain. Focusing on manufacturing industries in 2011, we see from figure 3 that both direct and indirect domestic value added as a share of gross exports vary much more by manufacturing industry than domestic value added as a share of gross exports.

The computer and electronic products industry has the largest share of direct domestic value added in its gross exports. This reflects the industry's high investment in R&D and its high-skilled, high-paid labor force. The food, beverage, and tobacco industry has the largest share of indirect domestic value added in its gross exports. This reflects the fact that its domestic value added content mainly comes through intermediate inputs, particularly agricultural inputs.

Next we estimate TiVA statistics by firm type from our extended IOTs. Domestic value added as share of exports does not vary much by type of firm on average, but the difference varies between different types of firms for a particular industry. Table 5 shows that domestic value added makes up 86 percent of gross exports for domestic-owned MNEs in 2011, similar to the 88 percent share for non-MNEs, and the 80 percent share for foreign-owned MNEs.

However, this share varies widely by industry, ranging from a minimum of 62 percent for coke, petroleum products, and nuclear fuel to a maximum of 98 percent for renting of machinery and equipment.

Table 6 shows that there are many instances of variability in domestic value added as a share of output across different types of firms in the same industry. Domestic value added as a share of output is smaller for foreign-owned MNEs compared with both domestic-owned MNEs and domestic non-MNEs for all but a few industries. Although there are sizable differences between domestic value added as a share of output for domestic-owned MNEs and non-MNEs for many industries, there is no clear pattern for direction of those differences. The largest differences are in agriculture and textiles.

Table 7 shows that although the average direct and indirect value added embodied in gross exports is similar across firm type, there are differences by industry. The largest differences are between MNEs and non-MNEs. For example, in the food products, beverage, and tobacco industry, direct domestic value makes up more than 72 percent of the value of gross exports while indirect domestic value makes up 69 percent of the value of gross exports for non-MNEs. This suggests that the non-MNEs are much more integrated in domestic value chains (including vertically integrated single firms) in these industries.

6 Conclusion

In this paper we construct proof-of-concept extended SUTs and TiVA estimates for the United States. We do so by disaggregating production characteristics by type of firm and applying them to recently-introduced SUTs for the United States by the BEA (Young, Howells III, Strassner and Wasshausen 2015). The project requires some modeling of basic price valuations in order to translate BEA's official use tables into domestic and import use, and to refine the valuation of intermediate inputs and final demand from purchaser price valuation to basic prices. This refinement to basic prices can be important for better understanding the economic activity based on the theory of the firm. Basic price valuation removes taxation and trade policy distortion from the estimates.

The results from this work build on a body of evidence found in other studies about the importance of reflecting firm-level heterogeneity in traditional SUTs to understand global value chains better through TiVA analysis. Our results indicate that heterogeneity by firm-type and by ownership does matter particularly for industries such as agriculture, textiles, and construction. Our analysis also reveals that it is a useful exercise to estimate TiVA from a single country SUT and IOT. For example, the single-model approach does indeed allow for distinctions to be made about how engaged domestic industries are in both global and domestic value chains, even if there are some limitations in interpreting the indirect value added estimates. For example, direct and indirect value added estimates reveal that the degree to which firms are integrated in domestic production chains varies widely by industry.

Looking ahead, there are a suite of projects that remain on the agenda for the BEA and for the USITC. These include collaborations with the OECD and with the Asia-Pacific Economic Cooperation (APEC) where work continues to develop the framework for extended SUTs and to develop APEC region SUTs and IOTs and associated TiVA estimates. The aim of this work is to incorporate the APEC database into the OECD database sometime around 2018. Additionally, the BEA and the USITC are collaborating with Statistics Canada and the Instituto Nacional de Estadistíca y Geografía to develop North America Regional SUTs and TiVA statistics with a goal to complete the regional SUT and TiVA statistics in 2018 and extended tables and TiVA measures around 2020.

Lastly, much work remains at the BEA to improve the economic infrastructure to support global value chain efforts. This work includes enhancing the international comparability of BEA's SUTs and expanding the detail BEA publishes by type of service and by country. In addition, a critical element is to produce official extended SUTs after completing a five-year microdata linking project with the Census Bureau. This project will link BEA's AMNE and trade in services data with data from Census Bureau economic censuses and establishment surveys and data on trade in goods. The output of this linking project will identify firm-level heterogeneity tabulations that, ideally, will be made available for use on a recurring basis to construct official statistics.

Bibliography

Ahmad, N., Araujo, S., Lo Turco, A., & Maggioni, D. (2013). Using trade microdata to improve trade in value added measures: proof of concept using Turkish data. Mattoo, A., Wang, Z. and Wei, S. (Eds.), *Trade in Valued Added: Developing New Measures of Cross-Border Trade* (pp. 187-219.) Washington, DC: The World Bank.

Barefoot, K. & Koncz-Bruner, J. (2012). A profile of U.S. exporters and importers of services. *Survey of Current Business,* 92(6), 66-87.

Bernard, A. B., Jensen, J. B., & Schott, P.K. (2009). Importers, exporters, and multinationals. In Dunne, T., Jensen J. B., and Roberts, M. J. (Eds.), *Producer dynamics: new evidence from micro data* (pp. 513-551). Cambridge, MA: NBER, University of Chicago Press.

Curcuru, S. E. & Thomas, C. P. (2015). The return on U.S. direct investment at home and abroad. In Hulten, C. R. and Reinsdorf, M. B. (Eds.), *Measuring wealth and financial intermediation and their links to the real economy* (pp. 205- 230). Cambridge, MA: NBER, University of Chicago Press.

Dietzenbacher ,E., Los, B., Stehrer, R., Timmer, M.P., and de Vries, G.J. (2013). The Construction of World Input-Output Tables in the WIOD Project. *Economic Systems Research*, 25, 71-98.

Fetzer, J.J. & Strassner, E.H. (2015). Identifying Heterogeneity in the Production Components of Globally Engaged Business Enterprises in the United States, BEA Working Paper WP2015-13.

Johnson, Robert C. & Noguera, Guillermo (2012). Accounting for intermediates: production sharing and trade in value added. *Journal of International Economics*, 86(2), 224-236.

Koopman, Wang, and Wei (2012). Tracing value-added and double counting in gross exports. *American Economic Review*, 104(2), 459-494.

Los, B., Timmer, M.P. & de Vries, G.J. (Forthcoming). Tracing value-added and double counting in gross exports: comment. *American Economic Review*.

Ma, H., Wang, Z., & Zhu, K. (2015). Domestic content in China's exports and its distribution by firm ownership. *Journal of Comparative Economics*, 43(1), 3-18.

Piacentini, M. & Fortanier, F. (2015). Firm heterogeneity and trade in value added. *OECD Working Paper*.

Samuels, J. D., Howells III, T. F., Russell, M., & Strassner, E. H. (2015). Import allocations across industries, import prices across countries, and estimates of industry growth and productivity. Houseman, S. N., & Mandel, M., (Eds.), *Measuring globalization: better trade statistics for better policy* (pp. 251-289.). Kalamazoo, MI: W.E. Upjohn Institute for Employment Research.

Tang, H., Wang, F., & Wang Z. (2014). The Domestic Segment of Global Supply Chains in China Under State Capitalism. *World Bank Policy Research Paper* 6960.

Young, J. A., Howells III, T. F., Strassner, E.H., & Wasshausen, D.B. (2015). BEA Briefing: Supply-Use Tables for the United States. *Survey of Current Business* 95:(9) , 1-8.

Table 1 Extended supply table at basic prices for United States, 2011 in millions of current US dollars

		(Industries) Domestic-owned MNE			Foreign-owned MNE			Domestic-owned non-MNE			Imports	Commodity Supply
		Primary	Manuf	Services	Primary	Manuf	Services	Primary	Manuf	Services		
(Commodities) Domestic MNE	Primary	102,770	177	186								103,134
	Manufacturing	5,590	2,193,731	6,859								2,206,180
	Services	3,015	106,170	3,320,068								3,429,252
	Special products	0	1,446	119								1,564
Foreign MNE	Primary				55,927	180	104					56,211
	Manufacturing				3,246	936,219	3,000					942,465
	Services				1,731	34,961	1,033,608					1,070,300
	Special products				0	767	25					793
Non-MNE	Primary							774,138	324	5,205		779,667
	Manufacturing							22,072	2,430,895	29,104		2,482,071
	Services							13,880	148,278	15,810,718		15,972,877
	Special products							0	2,455	8,408		10,863
Imports	Primary										413,425	413,425
	Manufacturing										1,649,390	1,649,390
	Services										200,292	200,292
	Special products										220,749	220,749
	Total industry output	111,376	2,301,523	3,327,231	60,904	972,127	1,036,737	810,090	2,581,952	15,853,436	2,483,856	29,539,233

Table 2 Extended Use table at basic prices for United States, 2011 in millions of current US dollars

		(Industries)											
		Domestic-owned MNE			Foreign-owned MNE			Domestic-owned non-MNE			Domestic Final Demand	Exports	Total Use
(Commodities)		Primary	Manuf	Services	Primary	Manuf	Services	Primary	Manuf	Services			
Domestic MNE	Primary	513	21,207	1,222	275	8,450	703	6,761	26,324	8,839	22,675	6,165	103,134
	Manufacturing	638	203,359	30,877	256	95,236	11,033	18,904	146,094	263,017	1,081,469	355,297	2,206,180
	Services	2,603	97,343	404,804	1,306	40,544	136,712	43,721	116,771	1,050,261	1,398,120	137,066	3,429,252
	Special products	-85	141	-1,221	-46	279	-578	-993	266	-4,815	2,361	6,256	1,564
Foreign MNE	Primary	283	10,977	701	158	4,518	406	3,228	14,168	5,005	12,246	4,521	56,211
	Manufacturing	322	97,745	10,717	149	54,033	4,143	8,113	74,221	118,416	379,590	195,016	942,465
	Services	844	35,336	105,008	431	14,475	36,888	14,978	40,774	303,854	430,306	87,406	1,070,300
	Special products	-43	72	-618	-23	141	-292	-503	134	-2,439	1,194	3,169	793
Non-MNE	Primary	2,867	182,555	5,275	1,115	60,550	2,992	80,534	177,544	41,032	151,888	73,316	779,667
	Manufacturing	982	217,581	53,128	402	106,008	19,048	26,531	255,685	465,087	945,656	391,964	2,482,071
	Services	6,910	306,178	790,022	3,507	126,834	295,079	111,956	347,572	3,127,681	10,235,327	621,812	15,972,877
	Special products	-448	2,898	7,107	-243	2,088	384	-5,211	4,053	-3,436	-188,861	192,531	10,863
Imports	Primary	2,440	90,287	4,974	907	34,097	2,050	22,404	221,800	23,958	10,507		413,425
	Manufacturing	9,803	190,217	100,796	6,484	165,206	80,839	12,154	140,758	127,268	815,864		1,649,390
	Services	388	3,085	7,194	95	830	2,472	6,753	30,150	135,338	13,988		200,292
	Special products	119	505	1,060	50	253	531	2,572	15,751	65,571	134,339		220,749
	Total Intermediates	28,135	1,459,485	1,521,046	14,822	713,542	592,410	351,903	1,612,066	5,724,637			12,018,046
	Value added	83,240	842,038	1,806,185	46,082	258,586	444,327	458,187	969,886	10,128,800			
	Total industry output	111,376	2,301,523	3,327,231	60,904	972,127	1,036,737	810,090	2,581,952	15,853,436	15,446,669	2,074,518	29,539,233

Table 3 Extended supply table at basic prices for United States, 2011, share of total output

(Commodities)		Domestic-owned MNE			Foreign-owned MNE (Industries)			Domestic-owned non-MNE			Imports	Commodity Supply
		Primary	Manuf	Services	Primary	Manuf	Services	Primary	Manuf	Services		
Domestic MNE	Primary	92	0	0								0
	Manufacturing	5	95	0								7
	Services	3	5	100								12
	Special products	0	0	0								0
Foreign MNE	Primary				92	0	0					0
	Manufacturing				5	96	0					3
	Services				3	4	100					4
	Special products				0	0	0					0
Non-MNE	Primary							96	0	0		3
	Manufacturing							3	94	0		8
	Services							2	6	100		54
	Special products							0	0	0		0
Imports	Primary										17	1
	Manufacturing										66	6
	Services										8	1
	Special products										9	1
	Total industry output	100	100	100	100	100	100	100	100	100	100	100

Table 4 Extended use table at basic prices for United States, 2011, share of total output

(Commodities)		(Industries) Domestic-owned MNE			Foreign-owned MNE			Domestic-owned non-MNE			Domestic Final Demand	Exports	Total Use
		Primary	Manuf	Services	Primary	Manuf	Services	Primary	Manuf	Services			
Domestic MNE	Primary	0	1	0	0	1	0	1	1	0	0	0	0
	Manufacturing	1	9	1	0	10	1	2	6	2	7	17	7
	Services	2	4	12	2	4	13	5	5	7	9	7	12
	Special products	0	0	0	0	0	0	0	0	0	0	0	0
Foreign MNE	Primary	0	0	0	0	0	0	0	1	0	0	0	0
	Manufacturing	0	4	0	0	6	0	1	3	1	2	9	3
	Services	1	2	3	1	1	4	2	2	2	3	4	4
	Special products	0	0	0	0	0	0	0	0	0	0	0	0
Non-MNE	Primary	3	8	0	2	6	0	10	7	0	1	4	3
	Manufacturing	1	9	2	1	11	2	3	10	3	6	19	8
	Services	6	13	24	6	13	28	14	13	20	66	30	54
	Special products	0	0	0	0	0	0	-1	0	0	-1	9	0
Imports	Primary	2	4	0	1	4	0	3	9	0	0		1
	Manufacturing	9	8	3	11	17	8	2	5	1	5		6
	Services	0	0	0	0	0	0	1	1	1	0		1
	Special products	0	0	0	0	0	0	0	1	0	1		1
	Total Intermediates	25	63	46	24	73	57	43	62	36			41
	Value added	75	37	54	76	27	43	57	38	64			
	Total industry output	100	100	100	100	100	100	100	100	100	100	100	100

Table 5 Domestic value added as a share of exports, by type of firm, by industry, 2011

ISIC	Description	Domestic MNE	Foreign MNE	Non-MNE
I01	Agriculture, hunting, forestry, and fishing	64	40	91
I02	Mining and quarrying	93	91	94
I03	Food products, beverages, and tobacco	92	89	86
I04	Textiles, textile products, leather, and footwear	76	58	90
I05	Wood and products of wood and cork	83	75	89
I06	Pulp, paper, paper products, printing, and publishing	91	78	93
I07	Coke refined petroleum products and nuclear fuel	62	57	47
I08	Chemicals and chemical products	90	87	92
I09	Rubber and plastics products	85	83	83
I10	Other non-metallic mineral products	85	90	86
I11	Basic metals	83	78	70
I12	Fabricated metal products except machinery and equip.	81	77	85
I13	Machinery and equipment n.e.c	83	77	81
I14	Computer electronic and optical products	93	82	91
I15	Electrical machinery and apparatus n.e.c	82	72	81
I16	Motor vehicles trailers and semi-trailers	81	76	73
I17	Other transport equipment	84	74	84
I18	Manufacturing n.e.c; recycling	92	83	80
I19	Electricity, gas, and water supply	93	88	93
I20	Construction	88	68	90
I21	Wholesale and retail trade; repairs	96	94	96
I22	Hotels and restaurants	93	89	94
I23	Transport and storage	91	83	81
I24	Post and telecommunications	93	87	91
I25	Finance and insurance	96	96	92
I26	Real estate activities	94	94	98
I27	Renting of machinery and equipment	97	88	95
I28	Computer and related activities	95	87	95
I29	Other business activities (incl. R&D)	95	90	96
I30	Public admin. and defence; compulsory social security			94
I31	Education	93	83	96
I32	Health and social work	88	69	96
I33	Other community, social, and personal services	91	78	95
	All Industries	**86**	**80**	**88**
	Minimum	**62**	**40**	**47**
	Maximum	**97**	**96**	**98**

Note: The darker blue a cell is, the greater its value is from the "grand median" of all values in the table of 88. The darker red a cell is, the lesser its value is compared with 88.

Table 6 Differences in domestic value added as a share of exports, by type of firm, by industry, 2011

ISIC	Description	Foreign MNE minus Domestic MNE	Foreign MNE minus Non-MNE	Domestic MNE minus Non-MNE
I01	Agriculture, hunting, forestry, and fishing	-24	-51	-27
I02	Mining and quarrying	-1	-2	-1
I03	Food products, beverages, and tobacco	-2	4	6
I04	Textiles, textile products, leather, and footwear	-18	-32	-14
I05	Wood and products of wood and cork	-8	-13	-6
I06	Pulp, paper, paper products, printing, and publishing	-14	-15	-2
I07	Coke refined petroleum products and nuclear fuel	-5	10	15
I08	Chemicals and chemical products	-3	-5	-2
I09	Rubber and plastics products	-3	0	3
I10	Other non-metallic mineral products	5	4	-1
I11	Basic metals	-4	8	13
I12	Fabricated metal products except machinery and equip.	-4	-8	-3
I13	Machinery and equipment n.e.c	-5	-4	2
I14	Computer electronic and optical products	-11	-9	2
I15	Electrical machinery and apparatus n.e.c	-9	-8	1
I16	Motor vehicles trailers and semi-trailers	-5	3	8
I17	Other transport equipment	-11	-11	0
I18	Manufacturing n.e.c; recycling	-9	3	12
I19	Electricity, gas, and water supply	-5	-5	0
I20	Construction	-20	-22	-2
I21	Wholesale and retail trade; repairs	-3	-3	0
I22	Hotels and restaurants	-4	-5	-1
I23	Transport and storage	-8	2	10
I24	Post and telecommunications	-6	-4	2
I25	Finance and insurance	0	3	4
I26	Real estate activities	1	-4	-5
I27	Renting of machinery and equipment	-8	-7	1
I28	Computer and related activities	-8	-8	0
I29	Other business activities (incl. R&D)	-5	-5	-1
I30	Public admin. and defence; compulsory social security			
I31	Education	-10	-13	-3
I32	Health and social work	-19	-27	-9
I33	Other community, social, and personal services	-12	-17	-4

Note: Blue cells indicate negative values and yellow cells indicate positive values.

Table 7 Direct and indirect domestic value added as a share of gross output, by type of firm, by industry, 2011

ISIC	Description	Direct			Indirect		
		Dom. MNE	For. MNE	Non-MNE	Dom. MNE	For. MNE	Non-MNE
I01	Agriculture, hunting, forestry, and fishing	15	19	54	49	21	37
I02	Mining and quarrying	30	36	17	62	56	77
I03	Food products, beverages, and tobacco	78	72	16	13	17	69
I04	Textiles, textile products, leather, and footwear	51	33	69	25	25	20
I05	Wood and products of wood and cork	21	35	36	63	40	53
I06	Pulp, paper, paper products, printing, and publishing	42	40	68	50	37	25
I07	Coke refined petroleum products and nuclear fuel	46	48	21	16	9	26
I08	Chemicals and chemical products	61	58	48	29	29	44
I09	Rubber and plastics products	28	42	53	57	40	30
I10	Other non-metallic mineral products	51	36	53	34	54	33
I11	Basic metals	28	24	23	54	54	47
I12	Fabricated metal products except machinery and equipment	34	35	35	48	42	50
I13	Machinery and equipment n.e.c	74	67	73	9	11	8
I14	Computer electronic and optical products	80	76	70	13	7	21
I15	Electrical machinery and apparatus n.e.c	74	66	52	8	6	29
I16	Motor vehicles trailers and semi-trailers	42	59	70	39	17	3
I17	Other transport equipment	59	67	84	25	7	1
I18	Manufacturing n.e.c; recycling	88	81	78	4	2	2
I19	Electricity, gas, and water supply	18	6	2	74	82	91
I20	Construction	32	5	0	56	63	90
I21	Wholesale and retail trade; repairs	42	54	16	55	39	80
I22	Hotels and restaurants	14	6	16	79	83	78
I23	Transport and storage	1	3	58	91	80	23
I24	Post and telecommunications	27	25	41	66	63	50
I25	Finance and insurance	1	0	71	95	95	22
I26	Real estate activities	0	0	7	93	94	91
I27	Renting of machinery and equipment	6	3	70	91	85	25
I28	Computer and related activities	58	14	44	37	73	52
I29	Other business activities (incl. R&D)	4	3	16	91	87	80
I30	Public admin. and defence; compulsory social security	0	0	85	0	0	9
I31	Education	37	20	51	56	62	45
I32	Health and social work	27	63	52	60	7	45
I33	Other community, social, and personal services	26	29	59	64	50	36
	All Industries	47	47	49	39	33	39

Note: The darker blue a cell is, the greater its value is from the "grand median" of all values in the table of 38. The darker red a cell is, the lesser its value compared with 38.

Figure 1 Domestic value added as a share of gross exports by industry, 2011

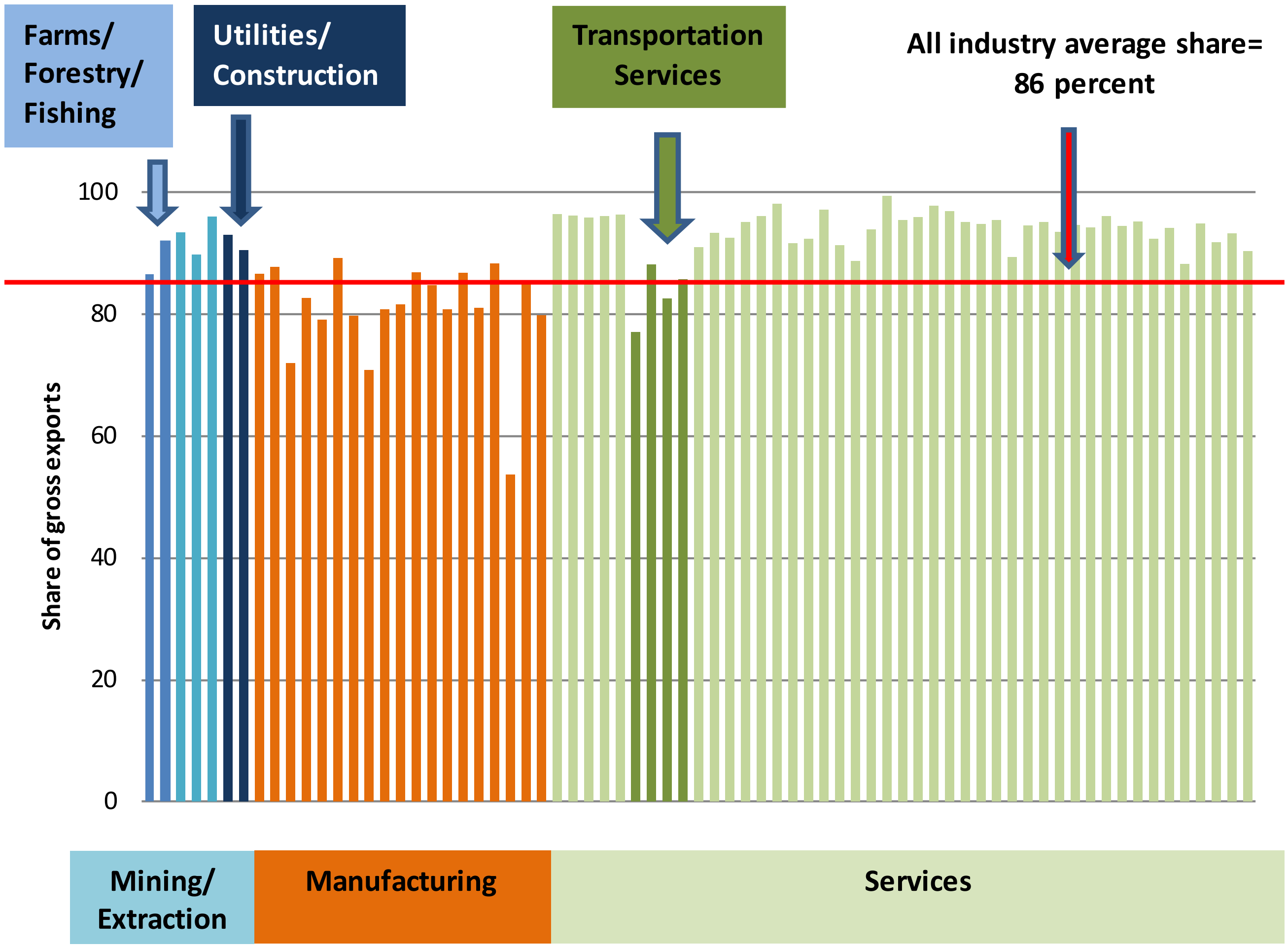


Figure 2 Domestic value added as a share of gross exports by manufacturing industry, 2011

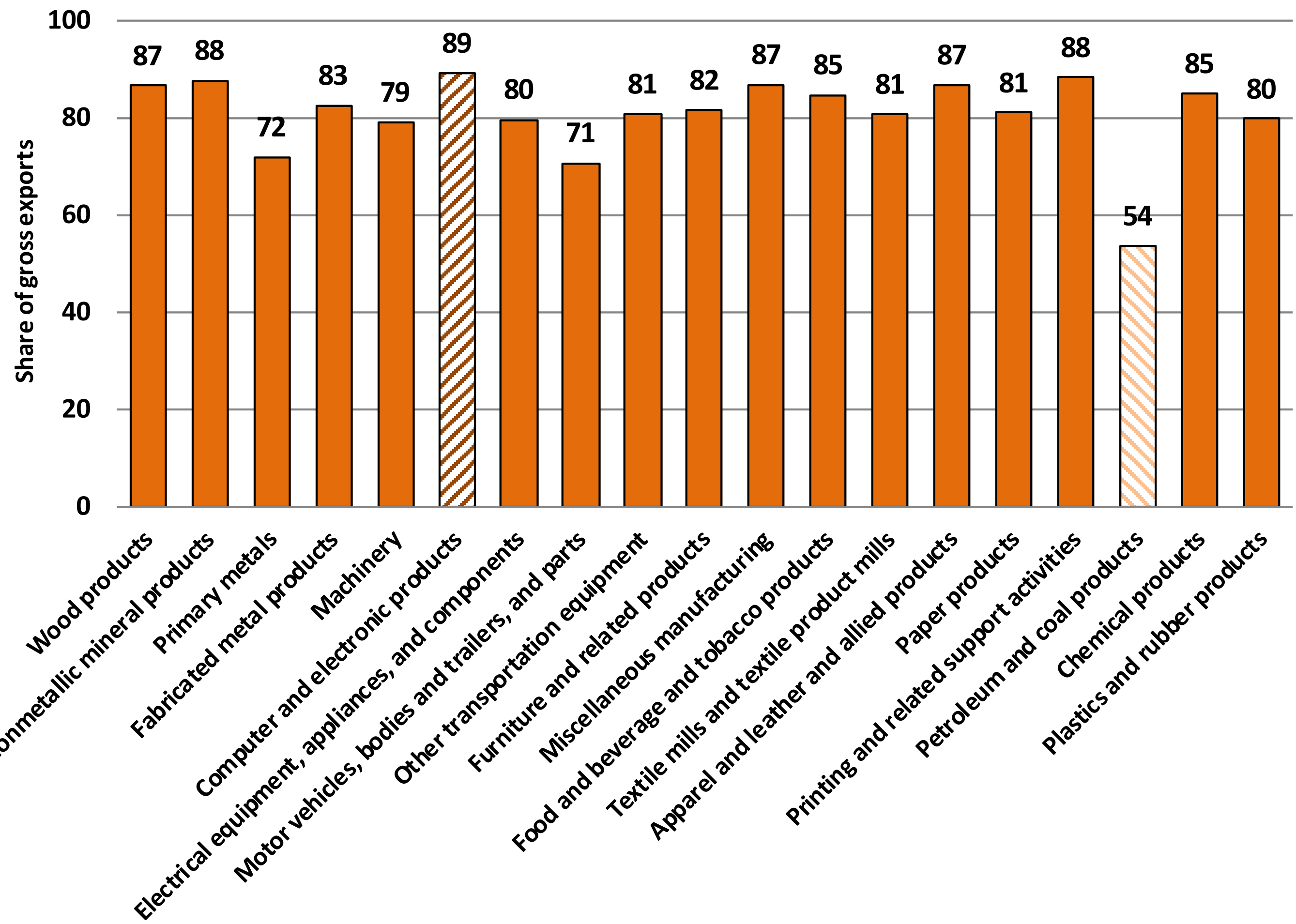
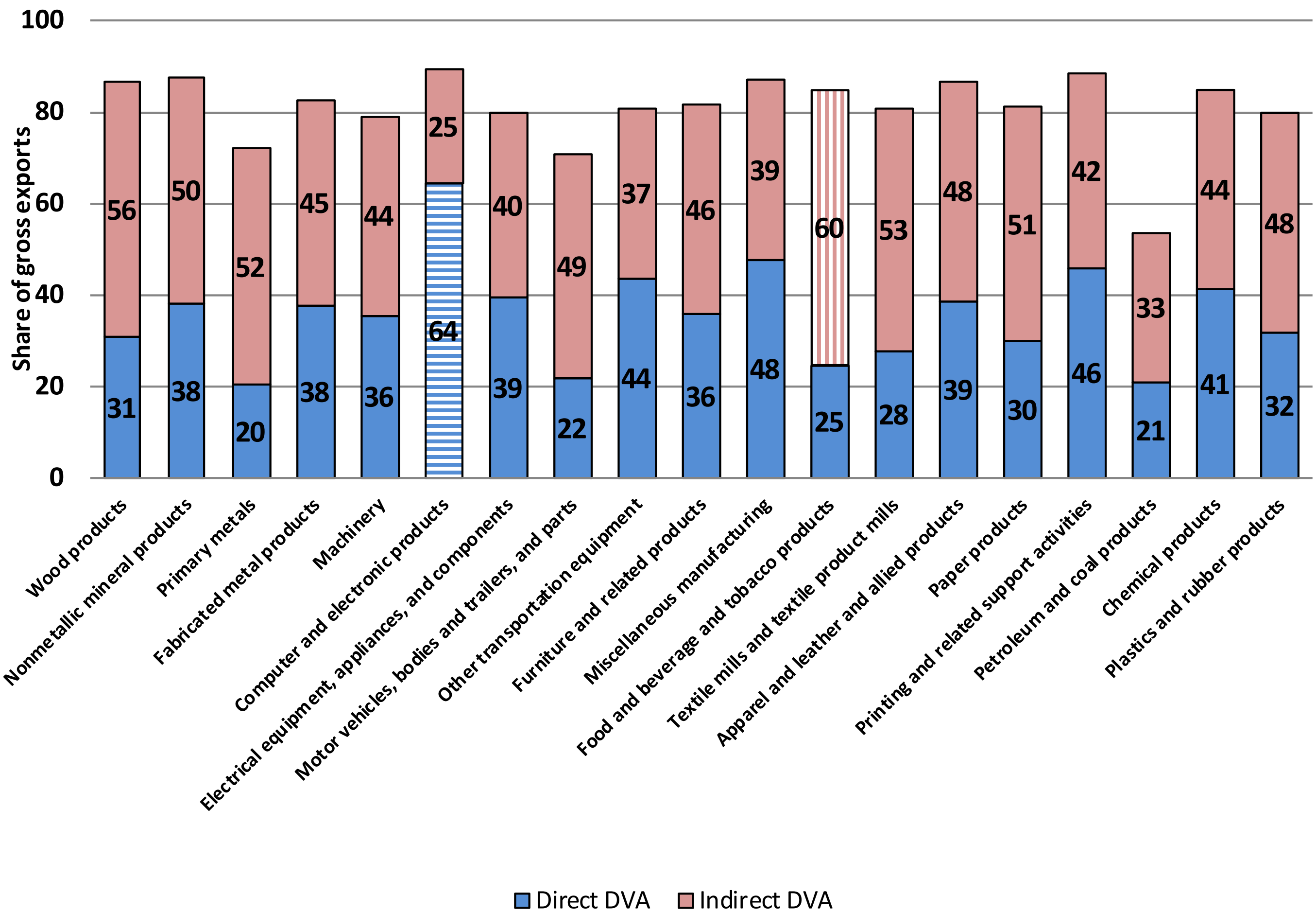


Figure 3 Direct and indirect domestic value added (DVA) as a share of gross exports by manufacturing industry, 2011



Appendix A: Refining the use table valued at basic prices

To develop separate matrices for domestically-produced inputs valued at basic prices, imported inputs at basic prices, margins, taxes on products, and subsidies on products, we solve a quadratic programming model with parameters from BEA's published SUTs. Before introducing the estimation model, let us review the major data reported in the BEA Supply-Use IO tables. At the product and sector level (73 groups of products and 71 industries), we know the following values from the supply table:

$x0_{cjt}$ = Output of product group c by industry j at year t, basic prices, 73 by 71 matrix;

$m0_{ct}$ = Imports from the world of product group *c* at year t, cif prices, 73 by 1 vector;

$TSb0_{ct}$ = Total supply of product c at year t, basic prices;

$Tmg0_{ct}$ = Total trade margins by product c at year t, 73 by 1 vector;

$Ttrs0_{ct}$ = Total transport margins by product c at year t, 73 by 1 vector;

$Ttxc0_{ct}^{itx}$ = Total tax by product c at year t, (import duty, Tax and Subsidies) 73 by 3 matrix

$TSp0_{ct}$ = Total supply of product c at year t, purchaser prices, 71 by 1 vector;

We also know following values from the use tables:

$zp0_{cit}$ = Product c used by industry i at year t, purchaser prices, 73 by 71 matrix

$vb0_{it}$ = total value added of industry i at basic prices at year t, 1 by 71 vector

$TXIb0_{it}$ = Total output of industry i at year t, basic prices, 1 by 71 vector

$Ttxi0_{it}^{itx}$ = Total tax/duty or subsidy by industry i at year t, (tax and import duties, subsidies 2 by 71 matrix)

$yp0_{cht}$ = Product c used by final user h at year t, purchaser prices

$e0_{ct}$ = Exports to the world of product group *c* at year t, fob prices

$TUp0_{ct}$ = Total use of product group c at year t, purchaser prices;

From the import use tables we know these values:

$zmb0_{cit}$ = Imported product c used by industry i at year t, basic prices

$ymb0_{cht}$ = Imported product c used by final user h at year t, basic prices

These data will be used as parameters (right hand constant) to construct the linear constraints and the initial value of variables in the estimation model.

Model specification:

The notation used to specify the programming model is as follows:

Index:

I ={ 01…71}; C ={ 01…73}; H = { F01,F02,IVT ,GOV, EXP}

NMG ={ 1…26,36,38…73}; MGC ={ 27…35,37};ITX={TAX,DUTY,SUB}

Variables (Unknowns: basic-price-based intermediate transactions and final demand transactions) **:**

zb_{cit} = Product c used by industry i at year t, basic prices

yb_{cht} = Product c used by final user h at year t, basic prices

zdb_{cit} = Domestic made product c used by industry i at year t, basic prices

ydb_{cht} = Domestic made product c used by final user h at year t, basic prices

The following variables constitute the valuation matrix. Each margin has the same dimension as the corresponding use table:

mgi_{cit}^{mgc} = Trade and transport margins for intermediate input of Product c used by industry i at year t (10 by 73 by 71 array);

mgy_{cit}^{mgc} = Trade and transport margins for final use of Product c used by final user h at year t (10 by 73 by 5 array)

$ntxi_{cit}^{itx}$ = tax for intermediate input of Product c used by industry i at year t (3 by 73 by 71 array);

$ntxy_{cht}^{itx}$ = tax for final use of Product c used by final user h at year t (3 by 73 by 71 array);

The estimation model is based on the economic and statistical relationship between elements in the use table valued at basic prices and elements in the use table valued at purchaser prices. These are used to construct several linear equations as constraints and to compute the initial values of variables that are used to formulate an optimization problem to minimize the deviation of the solution values from the initial values of these variables.

Constraints:

The relationship between cells of the use table based on basic prices and the use table based on purchaser prices is:

For non-margin products: C = NMG

$$zb_{cit} + \sum_{mgc=1}^{10} mgi_{cit}^{mgc} + \sum_{itx=1}^{3} neti_{cit}^{itx} = zp0_{cit} \quad \text{(A.1)}$$

$$yb_{cht} + \sum_{mgc=1}^{10} mgy_{cht}^{mgc} + \sum_{itx=1}^{3} ntxy_{cht}^{itx} = yp0_{cht} \quad \text{(A.2)}$$

For margin products: C=MGC

$$zb_{cit} - \sum_{nmg}^{73} mgi_{cit}^{mgc} + \sum_{itx=1}^{3} neti_{cit}^{itx} = zp0_{cit} \quad \text{(A.3)}$$

$$yb_{cht} - \sum_{nmg}^{73} mgy_{cht}^{mgc} + \sum_{itx=1}^{3} ntxy_{cht}^{itx} = yp0_{cht} \quad \text{(A.4)}$$

The split between domestic and import use at basic prices is assumed to be:

$$zd_{cit} + zm0_{cit} = zb_{cit} \quad \text{(A.5)}$$

$$yd_{cht} + ym0_{cht} = yb_{cht} \quad \text{(A.6)}$$

Basic balance condition

Supply and use balance for each product groups at purchaser prices:

For non-margin products: C=NMG

$$\sum_{i=1}^{71}(zb_{cit} + \sum_{mgc=1}^{10} mgi_{cit}^{mgc} + \sum_{itx=1}^{3} neti_{cit}^{itx}) + \sum_{h=1}^{5}(yb_{cht} + \sum_{mgc=1}^{10} mgy_{cht}^{mgc} + \sum_{itx=1}^{3} ntxy_{cht}^{itx}) = TSp0_{ct} \quad \text{(A.7)}$$

For margin products: C=MGC

$$\sum_{i=1}^{71}(zb_{cit} - \sum_{nmg}^{73} mgi_{cit}^{mgc} + \sum_{itx=1}^{3} neti_{cit}^{itx}) + \sum_{h=1}^{5}(yb_{cht} - \sum_{nmg}^{73} mgy_{cht}^{mgc} + \sum_{itx=1}^{3} ntxy_{cht}^{itx}) = TSp0_{ct} \quad \text{(A.8)}$$

Supply and use balance for each product group at basic prices:

$$\sum_{i=1}^{71} zb_{cit} + neti_{cit}^{tax} + neti_{cit}^{sub} + \sum_{h=1}^{5} yb_{cht} = \sum_{i=1}^{71} x0_{cit} + m0_{ct} = TSb0_{ct} \quad \text{for all c} \tag{A.9}$$

Input cost and total output balance for each industry at basic prices:

$$\sum_{c=1}^{73} (zd_{cit} + zm0_{cit}) + neti_{cit}^{tax} + neti_{cit}^{sub} + \sum_{l=1}^{3} vb0_{ift} = \sum_{c=1}^{73} x0_{ict} = TXIb0_{it} \quad \text{for all i} \tag{A.10}$$

Balance condition for total domestic product output and use at basic prices:

$$\sum_{i=1}^{71} zd_{cit} + \sum_{h=1}^{6} yd_{cht} + neti_{cit}^{tax} + neti_{cit}^{sub} = \sum_{i=1}^{71} x0_{ict} \quad \text{for all c} \tag{A.11}$$

Balance condition for total import supply and use at basic prices:

$$\sum_{i=1}^{71} zm_{cit} + \sum_{h=1}^{7} ym_{cht} = m0_{ct} \quad \text{for all c} \tag{A.12}$$

Transportation cost, trade margins and net tax constraints

Trade and transport margin supply and use balance:

For MGC={27…31}

$$\sum_{c=nmg}^{73} \sum_{i=1}^{71} (mgi_{cit}^{mgc} + mgy_{cht}^{mgc}) = -Tmg0_{ct} \tag{A.13}$$

For MGC ={32…35,37}

$$\sum_{c=nmg}^{73} \sum_{i=1}^{71} (mgi_{cit}^{mgc} + mgy_{cht}^{mgc}) = -Ttrs0_{ct} \tag{A.14}$$

Domestic trade and transportation cost constraints for non-margin products:
For C=NMG and MGC={27…31}

$$\sum_{mgc} \sum_{i=1}^{71} mgi_{cit}^{mgc} + \sum_{mgc} \sum_{h=1}^{5} mgy_{cht}^{mgc} = Tmg0_{ct} \tag{A.15}$$

For C=NMG and MGC={32…35,37}

$$\sum_{mgc} \sum_{i=1}^{71} mgi_{cit}^{mgc} + \sum_{mgc} \sum_{h=1}^{5} mgy_{cht}^{mgc} = Ttrs0_{ct} \tag{A.16}$$

Tax constraints for each product group:

$$\sum_{i=1}^{71} ntxi_{cit}^{itx} + \sum_{h=1}^{5} ntxy_{cht}^{itx} = Ttxc0_{ct}^{itx} \quad \text{for all c} \tag{A.17}$$

Tax and duty constraints for each industry:

$$\sum_{c=1}^{73} ntxi_{cit}^{itx} = Ttxi0_{it}^{itx} \qquad \text{for all i} \qquad (A.18)$$

Aggregate expenditure components constraints:

$$\sum_{c=1}^{73} \left(\sum_{h}^{4} yb_{cht} + \sum_{nmg}^{73} \sum_{mgc=1}^{10} mgy_{cht}^{mgc} + \sum_{itx=1}^{3} ntxy_{cht}^{itx}\right) = GDPE_{ht} \quad \text{for all h except EXP} \qquad (A.19)$$

GDP from the production side:

$$\sum_{i=1}^{71} \sum_{f=1}^{3} vb_{ift} + \sum_{c=1}^{73} \sum_{itx=1}^{3} ntxi_{cit}^{itx}) = GDP_t \qquad (A.20)$$

GDP from the expenditure side:

$$\sum_{h=1}^{5} GDPE_{ht} + \sum_{c=1}^{73} (e0_{ct} - m0_{ct})] = GDP_t \qquad (A.21)$$

The objective function:

$$\text{Min S} = \frac{1}{2}\left\{ \sum_{c=1}^{73}\sum_{i=1}^{71} \frac{(zd_{cit} - zd0_{cit})^2}{zd0_{cit}} + \sum_{c=1}^{73}\sum_{i=1}^{71} \frac{(zm_{cit} - zm0_{cit})^2}{zm_{cit}} + \sum_{c=1}^{71}\sum_{h=1}^{6} \frac{(yd_{cht} - yd0_{cht})^2}{yd0_{cht}} \right.$$

$$+ \sum_{c=1}^{73}\sum_{h=1}^{6} \frac{(ym_{cht} - ym0_{cht})^2}{ym0_{cht}} + \sum_{mgc=1}^{10}\sum_{i=1}^{71}\sum_{c=1}^{73} \frac{(mgi_{cit}^{mgc} - mgi0_{cit}^{mgc})^2}{mgi0_{cit}^{mgc}} + \sum_{mgc=1}^{10}\sum_{c=1}^{73}\sum_{h=1}^{6} \frac{(mgy_{cht}^{mgc} - mgy0_{cht}^{mgc})^2}{mgy0_{cht}^{mgc}}$$

$$\left. + \sum_{c=1}^{73}\sum_{h=1}^{6}\sum_{itx=1}^{3} \frac{(ntxy_{cht}^{itx} - ntxy0_{cht}^{itx})^2}{ntxy0_{cht}^{itx}} + \sum_{i=1}^{71}\sum_{c=1}^{73}\sum_{itx=1}^{3} \frac{(ntxi_{cit}^{itx} - ntxi0_{cit}^{itx})^2}{ntxi0_{cit}^{itx}} \right\}$$

To obtain a solution the problem, we minimize the objective function subject to constraints (A.1) to (A.21).

Initial values for all unknowns in the constrained optimization problem are based on various proportionality assumptions and other BEA data. Notice that the initial values obtained usually do not satisfy the linear constraints.

Variable initiation:

$\tau_{ct}^{itx} = \dfrac{Ttxc_{ct}^{itx}}{TSb_{ct}}$ (tax rate computed from supply table)

$ntxi0_{cit}^{itx}$ = τ_{ct}^{itx} z_pr_{cit} net tax rate multiplied by industry cells at producer prices from the traditional use table;

$ntxy0_{cht}^{itx}$ = $\tau_{ct}^{itx} y\_pr_{cht}$ net tax rate multiplied by final demand by categories at producer prices from the traditional use tables

$zmb0_{cit}$ = industry cells from the import use table before redefinition

$ymb0_{cht}$ = final demand by categories from the import use table before redefinition

$$zdb0_{cit} = z\_pr_{cit} - zmb0_{cit} - \sum_{itx=1}^{3} ntxi0_{cit}$$

$$ydb0_{cht} = y\_pr_{cit} - ymb0_{cit} - \sum_{itx=1}^{3} ntxy0_{cht}$$

$$zb0_{cit} = z\_pr_{cit} - \sum_{itx=1}^{3} ntxi0_{cit}$$

$$yb0_{cht} = y\_pr_{cit} - \sum_{itx=1}^{3} ntxy0_{cht}$$

Using the 2007 margin table, we compute a transportation cost rate and apply it to 1997 and 2011

$mrt_{cit} = \dfrac{mgi_{cit}}{zp_{cit}}$, t=2007

$mgi0_{cit}$ = $mrt_{cit} zp_{cit}$

$mgy0_{cht}$ = total trade margin in PCE and PQE bridge table

Trade margin products

42	Wholesale trade	C27
441	Motor vehicle and parts dealers	C28
445	Food and beverage stores	C29
452	General merchandise stores	C30
4A0	Other retail	C31

Transportation margin products

81	Air transportation	C32
82	Rail transportation	C33
83	Water transportation	C34
	Truck transportation	C35

84		
86	Pipeline transportation	C37

Appendix B: Estimating extended supply and use tables at basic prices

Statistical agencies in most countries do not currently disaggregate standard supply and use tables (SUTs) into extended SUTs by firm type. Thus, we develop a method to construct those subaccounts based on the original SUT. The SUTs already include data on industry-level output, value added, imports, exports, and aggregate inter-industry transactions. To estimate the extended SUT with firm type sub-accounts, we need to complement the official statistics with aggregated micro-level data.

Data required:

Supply and use tables in both basic and purchaser prices, the import use table at cif prices, aggregated micro data gross output, value added, exports and imports, by firm type

The notation used to specify the estimation model is as follows:

Index:

F={MNE_D,MNE_F,OTH}

I ={ 01…33}; C ={ 01…35}; H = { HC,GCF,IVT,GOV, EXP}

NMG ={0 1…,20,22,24…35}; MGC ={ 21,23};ITX={TAX,DUTY,SUB}

Parameters known from standard supply and use tables

$TXCb0_{ct}$ = Total output of product group c at year t, basic prices

$TXIb0_{it}$ = Total output of industry i at year t, basic prices

$zp0_{cit}$ = Product c used by industry i at year t, purchaser prices

$zdb0_{cit}$ = Domestic product c used by industry i at year t, basic prices

$zmb0_{cit}$ = Imported product c used by industry i at year t, basic prices

$yd0_{ct}$ = Domestic product c used by domestic final user at year t, basic prices

$ym0_{ct}$ = Imported product c used by domestic final user at year t, basic prices

$\sup 0_{cjt}$ = Output of product group c by industry j at year t, basic prices

$vb0_{it}$ = Total value added of industry i at basic prices at year t,

$yp0_{cht}$ = Product c used by final user h at year t, purchaser prices

$ex0_{ct}$ = Exports to the world of product group *c* at year t, fob prices

$mx0_{ct}$ = Imports from the world of product group *c* at year t, cif prices

$Ttxi0_{it}^{itx}$ = Total tax by industries at year t,

$Ttxc0_{ct}^{itx}$ = Total tax by products at year t,

$Tmg0_{ct}$ = Total trade margins by Product at year t

$Ttrs0_{ct}$ = Total transport margins by Product at year t

$GDPE0_{ht}$ = Gross domestic product (GDP) by major expenditure category

$GDP0_{t}$ = Gross domestic product (GDP)

Variables will be estimated by the model:

zd_{cit}^{fsf} = Domestic made product c used by industry i *between firm type fs (supplying firm) and f (using firm)* at year t, basic prices

yd_{ct}^{f} = Domestic made product c by firm f used by domestic final user at year t, basic prices

zm_{cit}^{f} = Imported product c used by firm f in industry i at year t, basic prices

x_{cit}^{f} = Output of product group c by firm type f of industry i at year t, basic prices

v_{it}^{f} = Total value added of firm type f in industry i at basic prices at year t,

e_{ct}^{f} = Exports to the world of product group *c by firm type f* at year t, fob prices

$mgi_{cit}^{mgc,fsf}$ = Trade and transport margins for intermediate input of Product c used by industry i at year t *between firm type fs (supplying firm) and f (using firm)*

$mgy_{ct}^{mgc,f}$ = Trade and transport margins for final use of product c used by domestic final user and exporter at year t of firm type f

$txi_{cit}^{itx,fsf}$ = Tax for intermediate input of product c used by industry i at year t *between firm type fs (supplying firm) and f (using firm)*

$txy_{ct}^{itx,f}$ = Tax for final use of product c used by domestic final user and exporter at year t of firm type f

Variable initiation:

$$Xsh_i^f = \frac{go_{it}^f}{\sum_{f=1}^{3} go_{it}^f}$$ where go_{it}^f is gross output by firm type f from micro data

$$Vsh_i^f = \frac{V_{it}^f}{\sum_{f=1}^{3} V_{it}^f}$$ where v_{it}^f is value added in industry i by firm type f from micro data

$$Msh_c^f = \frac{m_{ct}^f}{\sum_{f=1}^{3} m_{ct}^f}$$ where m_{ct}^f is imports of product c by firm type f from micro data

$$Esh_c^f = \frac{e_{ct}^f}{\sum_{f=1}^{3} e_{ct}^f}$$ where e_{ct}^f is exports of product c by firm type f from micro data

$$e0_{ct}^f = Esh_c^f \times ex0_{ct}$$
$$v0_{ct}^f = Vsh_c^f \times Vb0_{ct}$$
$$x0_{cit}^f = Xsh_i^f \times \sup 0_{cit}$$

$$Int_{it}^f = \sum_{c=1}^{35} x0_{ict}^f - v0_{it}^f$$ where v_{it}^f is value added by firm type f from micro data

$$Intsh_{it}^f = \frac{Int_{it}^f}{\sum_{f=1}^{3} Int_{it}^f}$$
$$zd0_{cjt}^{f1f2} = xsh_i^{f1} \times Intsh_j^{f2} \times zdb0_{cjt}$$
$$zm0_{cjt}^f = msh_c^f \times Intsh_j^f \times zmb0_{cjt}$$
$$yd0_{ct}^f = \sum_{i=1}^{33} x_{cit}^f - \sum_{f2=1}^{3} \sum_{i}^{33} zd0_{cit}^{ff2} - e0_{ct}^f$$

Model specification:

Constraints: (to simplify the estimation model we aggregate the five categories of final demand into domestic final demand and exports)

Basic balance condition

Supply and use balance for each product groups at purchaser prices

For non-margin products: C=NMG all f

$$\sum_{i=1}^{33}\left\{\sum_{fs=1}^{3}\sum_{f=1}^{3} zd_{cit}^{fsf} + \sum_{f=1}^{3} zm_{cit}^{f} + \sum_{mgc=1}^{2}\sum_{fs=1}^{3}\sum_{f=1}^{3} mgi_{cit}^{mgc,fsf} + \sum_{fs=1}^{3}\sum_{f=1}^{3}\sum_{itx=1}^{3} txi_{cit}^{itx,fsf}\right\}$$
$$+\sum_{f=1}^{3}(yd_{ct}^{f} + e_{ct}^{f}) + ym0_{ct}) + \sum_{f=1}^{3}\sum_{mgc=1}^{2} mgy_{ct}^{mgc,f} + \sum_{f=1}^{3}\sum_{itx=1}^{3} txy_{ct}^{itx,f} = TSp0_{ct} \quad \text{(B.1)}$$

For margin products: C=MGC, all f

$$\sum_{i=1}^{33}\left\{\sum_{fs=1}^{3}\sum_{f=1}^{3} zd_{cit}^{fsf} + \sum_{f=1}^{3} zm_{cit}^{f} - \sum_{nmg=1}^{35}\sum_{fs=1}^{3}\sum_{f=1}^{3} mgi_{cit}^{mgc,fsf} + \sum_{fs=1}^{3}\sum_{f=1}^{3}\sum_{itx=1}^{3} txi_{cit}^{itx,fsf}\right\}$$
$$+\sum_{f=1}^{3}(yd_{ct}^{f} + e_{ct}^{f} + ym_{ct}^{f}) - \sum_{f=1}^{3}\sum_{mgc=1}^{2} mgy_{ct}^{mgc,f} + \sum_{f=1}^{3}\sum_{itx=1}^{3} txy_{ct}^{itx,f} = TSp0_{ct} \quad \text{(B.2)}$$

Input cost and total output balance for each industry at basic prices, for all i and f

$$\sum_{c=1}^{35}\sum_{f=1}^{3}(zd_{cit}^{fsf} + zm_{cit}^{f}) + \sum_{c=1}^{35}\sum_{s=1}^{3} txi_{cit}^{tax,fsf} + \sum_{c=1}^{35}\sum_{s=1}^{3} txi_{cit}^{sub,fsf} + v_{it}^{f} = \sum_{c=1}^{35} x_{ict}^{f} \quad \text{(B.3)}$$

Balance condition for total domestic product output and use at basic prices, for all c and all f

$$\sum_{i=1}^{33}\sum_{fs=1}^{3} zd_{cit}^{fsf} + yd_{ct}^{f} + e_{ct}^{f} + \sum_{nmg}^{35}\sum_{i=1}^{33} txi_{cit}^{"tax"} + \sum_{nmg}^{35} txi_{cit}^{"sub"} = \sum_{i=1}^{33} x_{ict}^{f} \quad \text{(B.4)}$$

Balance condition for total import supply and use at basic prices for all c:

$$\sum_{i=1}^{33}\sum_{f=1}^{3} zm_{cit}^{f} + ym0_{ct} = mx0_{ct} \quad \text{(B.5)}$$

Transportation cost, trade margins and net tax constraints

Trade and transport margin supply and use balance

For MGC={21}

$$\sum_{c=nmg}^{35}\sum_{i=1}^{33}\sum_{f=1}^{3}(\sum_{fs=1}^{3} mgi_{cit}^{mgc,fsf} + mgy_{ct}^{mgc,f}) = -Tmg0_{ct} \quad \text{(B.6)}$$

For MGC ={23}

$$\sum_{c=nmg}^{35}\sum_{i=1}^{33}\sum_{f=1}^{3}(\sum_{fs=1}^{3} mgi_{cit}^{mgc,fsf} + mgy_{ct}^{mgc,f}) = -Ttrs0_{ct} \quad \text{(B.7)}$$

Domestic trade and transportation cost constraints for non-margin products

For C=NMG and MGC={21}

$$\sum_{mgc}\sum_{i=1}^{33}\sum_{fs=1}^{3}\sum_{f}^{3} mgi_{cit}^{mgc,fsf} + \sum_{mgc}\sum_{f=1}^{3} mgy_{ct}^{mgc,f} = Tmg0_{ct} \qquad \text{(B.8)}$$

For C=NMG and MGC={23}

$$\sum_{mgc}\sum_{i=1}^{33} mgi_{cit}^{mgc} + \sum_{mgc} mgy_{ct}^{mgc} = Ttrs0_{ct} \qquad \text{(B.9)}$$

Tax constraints for each product group, for all c

$$\sum_{i=1}^{33}\sum_{fs=1}^{3}\sum_{f=1}^{3} txi_{cit}^{itx,fsf} + \sum_{f=1}^{3} txy_{ct}^{itx,f} = Ttxc0_{ct}^{itx} \qquad \text{(B.10)}$$

Tax and duty constraints for each industry for all i

$$\sum_{fs=1}^{3}\sum_{f=1}^{3}\sum_{c=1}^{35} txi_{cit}^{itx,fsf} = Ttxi0_{it}^{itx} \qquad \text{(B.11)}$$

GDP constraints:

$$\sum_{c=1}^{35}\left(\sum_{f=1}^{3}(yd_{ct}^{f} + e_{ct}^{f}) - m0_{ct}\right) + \sum_{nmg}^{35}\sum_{f=1}^{3}\sum_{mgc=1}^{2} mgy_{ct}^{mgc,f} + \sum_{f=1}^{3}\sum_{itx=1}^{3} txy_{ct}^{itx,f}) = GDP_{t} \qquad \text{(B.12)}$$

Adding up constraints:

Relationship between use table cells based on basic prices and purchaser prices:

For non-margin products: C = NMG

$$\sum_{fs=1}^{3}\sum_{f=1}^{3} zd_{cit}^{fsf} + \sum_{f=1}^{3} zm_{cit}^{f} + \sum_{fs=1}^{3}\sum_{f=1}^{3}\sum_{mgc=1}^{2} mgi_{cit}^{mgc,fsf} + \sum_{fs=1}^{3}\sum_{f=1}^{3}\sum_{itx=1}^{3} txi_{cit}^{ix,fsf} = zp0_{cit} \qquad \text{(B.13)}$$

$$\sum_{f=1}^{3}(yd_{ct}^{f} + e_{ct}^{f}) + ym0_{ct} + \sum_{mgc=1}^{2}\sum_{f=1}^{3} mgy_{ct}^{mgc,f} + \sum_{f=1}^{3}\sum_{itx=1}^{3} txy_{ct}^{itx,f} = \sum_{h=1}^{5} yp0_{cht} \qquad \text{(B.14)}$$

For margin products: C=MGC

$$\sum_{fs=1}^{3}\sum_{f=1}^{3} zd_{cit}^{fsf} + \sum_{f2=1}^{3} zm_{cit}^{f} - \sum_{fs=1}^{3}\sum_{f=1}^{3}\sum_{mgc=1}^{2} mgi_{cit}^{mgc,fsf} + \sum_{fs=1}^{3}\sum_{f=1}^{3}\sum_{itx=1}^{3} txi_{cit}^{ix,fsf} = zp0_{cit} \qquad \text{(B.15)}$$

$$\sum_{f=1}^{3}(yd_{ct}^{f} + e_{ct}^{f}) + ym_{ct} - \sum_{mgc=1}^{2}\sum_{f=1}^{3} mgy_{ct}^{mgc,f} + \sum_{f=1}^{3}\sum_{itx=1}^{3} txy_{ct}^{itx,f} = \sum_{h=1}^{5} yp0_{cht} \qquad \text{(B.16)}$$

$$\sum_{f=1}^{3} x_{cit}^{f} = \sup 0_{cjt} \qquad \text{(B.17)}$$

Or $\sum_{i=1}^{33}\sum_{f=1}^{3} x_{cit}^{f} = TXPb0_{ct}$ and $\sum_{c=1}^{35}\sum_{f=1}^{3} x_{cit}^{f} = TXIb0_{ct}$

$\sum_{f=1}^{3} e_{ct}^{f} = ex0_{ct}$; for all c (B.18)

$\sum_{f=1}^{3} v_{it}^{f} = vb0_{it}$ for all i (B.19)

The objective function:

$$\begin{aligned}
\text{Min S} = \frac{1}{2}\Bigg\{ & \sum_{c=1}^{35}\sum_{i=1}^{33}\sum_{f=1}^{3}\sum_{ft=1}^{3}\frac{(zd_{cit}^{fft}-zd0_{cit}^{fft})^2}{zd0_{cit}^{fft}} + \sum_{c=1}^{35}\sum_{i=1}^{33}\sum_{f=1}^{3}\frac{(zm_{cit}^{f}-zm0_{cit}^{f})^2}{zm0_{cit}^{f}} + \sum_{c=1}^{35}\sum_{f=1}^{3}\frac{(yd_{ct}^{f}-yd0_{ct}^{f})^2}{yd0_{ct}^{f}} \\
& + \sum_{i=1}^{33}\sum_{f=1}^{3}\frac{(v_{it}^{f}-v0_{it}^{f})^2}{v0_{it}^{f}} + \sum_{c=1}^{35}\sum_{f=1}^{3}\frac{(e_{ct}^{f}-e0_{it}^{f})^2}{e0_{ct}^{f}} + \sum_{mgc=1}^{2}\sum_{i=1}^{33}\sum_{c=1}^{35}\sum_{fs=1}^{3}\sum_{f=1}^{3}\frac{(mgi_{cit}^{mgc,fsf}-mgi0_{cit}^{mgc,fsf})^2}{mgi0_{cit}^{mgc,fsf}} \qquad \text{(B.20)} \\
& + \sum_{mgc=1}^{2}\sum_{c=1}^{35}\sum_{f=1}^{3}\frac{(mgy_{ct}^{mgc,f}-mgy0_{ct}^{mgc,f})^2}{mgy0_{ct}^{mgc,f}} + \sum_{i=1}^{33}\sum_{c=1}^{35}\sum_{itx=1}^{3}\sum_{fs=1}^{3}\sum_{f=1}^{3}\frac{(txi_{cit}^{itx,fsf}-txi0_{cit}^{itx,fsf})^2}{txi0_{cit}^{itx,fsf}} \\
& + \sum_{c=1}^{35}\sum_{itx=1}^{3}\sum_{f=1}^{3}\frac{(txy_{ct}^{itx,f}-txy0_{ct}^{itx,f})^2}{txy0_{ct}^{itx,f}} \Bigg\}
\end{aligned}$$

Scheme of Extended Use Table

		Intermediate use			Final use	Exports	Domestic or Imported supply
		MNE_D	MNE_F	OTH			
Domestic Intermediate use	MNE_D	Z^{DtoD}	Z^{DtoF}	Z^{DtoO}	Y^{D}	E^{D}	X^{D}
	MNE_F	Z^{FtoD}	Z^{FtoF}	Z^{FtoO}	Y^{F}	E^{F}	X^{F}
	OTH	Z^{OtoD}	Z^{OtoF}	Z^{OtoO}	Y^{O}	E^{O}	X^{O}
Imports		Z^{MtoD}	Z^{MtoF}	Z^{MtoO}	Y^{M}		M
Value added		V^{D}	V^{F}	V^{O}			
Gross Input		$(X^{D})^{T}$	$(X^{F})^{T}$	$(X^{O})^{T}$			