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Abstract

Traditional theories of firm boundaries predict trade between vertically related units of the same firm. Using novel data that combine a comprehensive mapping of U.S. multinationals' production networks with their customs filings, we uncover a strong positive relationship between input-output linkages and trade between parents and their affiliates. We also find that intrafirm trade is prevalent, particularly between geographically proximate units: three-quarters of affiliates in North America trade with their U.S. parent. These results overturn prior findings based on survey data on intrafirm trade. Administrative intrafirm records enable correcting measurement errors in survey data, reconciling traditional theories with empirical evidence.

JEL Codes: F14, F23, D23, L20.

Keywords: Multinational enterprises, intrafirm trade, input-output linkages.

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1 Introduction

Multinational enterprises (MNEs) have played a central role in the emergence of global value chains in recent decades. They have fragmented various stages of their production processes across affiliates in different countries, which has resulted in intrafirm trade flows in both intermediate and final goods (Antràs and Chor, 2021). For example, multinational automakers that own subsidiaries in North America engage in cross-border flows of components and assembled vehicles (e.g., Head, Mayer and Melitz, 2024; Head, Mayer, Melitz and Yang, 2025). The importance of trade within multinational production networks is reflected in its share of aggregate trade flows: intra-MNE transactions account for about half of U.S. total goods imports and about a third of U.S. total goods exports (Figure 1). These shares have remained remarkably stable over the last three decades, underscoring multinationals' long-established international production networks.

Figure 1. U.S. Related Party Imports and Exports, 1992-2023

Notes: This figure plots related party imports (exports) as a share of total U.S. imports (exports), using the U.S. Census Bureau Related Party Trade Database (U.S. Census Bureau, 2025d).

We study trade flows within multinationals, using newly linked data that combines the complete mapping of U.S. multinational production networks with customs records on the universe of U.S. merchandise trade transactions. We provide empirical support for traditional theories of firm boundaries, which have been applied to study multinational ownership structures (e.g., Helpman, 1984; Antràs, 2003; Antràs and Yeaple, 2014).[1] These theories build on

[1]Since Coase (1937)'s seminal work, a large literature highlights different drivers of vertical integration, including reducing transaction and adaptation costs (Williamson, 1971, 1975), mitigating opportunism (Klein et al., 1978), enhancing multi-tasking incentives (Holmström and Milgrom, 1991), aligning control with incentives (Grossman and Hart, 1986; Hart and Moore, 1990), and improving coordination (Hart and Holmström, 2010; Legros and Newman, 2013). A parallel literature studies relational contracts within and across firm boundaries (e.g., Macchiavello and Morjaria, 2015, 2021).

the premise that firms utilize inputs produced within their boundaries, implying the presence of positive trade flows between downstream and upstream units of the same firm.

Contrary to this prediction, influential studies based on survey data on intrafirm trade find little evidence of trade in physical inputs between vertically related units of the same firm. Notably for the United States, Atalay, Hortaçsu and Syverson (2014) (henceforth AHS) use the U.S. Department of Transportation's Commodity Flow Survey to study trade between different establishments of U.S. firms; Ramondo, Rappoport and Ruhl (2016) (henceforth RRR) use the U.S. Bureau of Economic Analysis's (BEA) direct investment surveys to study trade within U.S. multinationals. Two puzzling findings emerge from these studies. First, while input-output (IO) linkages are key determinants of firms' integration choices, they do not predict whether and how much different units of the same firm trade with each other. Second, intrafirm trade is sparse: almost one-half of upstream U.S. establishments do not report making shipments inside their firms, and the median foreign affiliate ships nothing to the rest of the corporation.

These findings have prompted calls for theories of firm boundaries featuring transfers of intangible inputs (e.g., marketing know-how, intellectual property, R&D capital).[2] In the words of AHS, "if firms do not own upstream and downstream units so the former can provide intermediate materials inputs for the latter, why do they?" The authors propose that "a primary purpose of ownership may be to mediate efficient transfers of intangible inputs", a rationale "consistent with small amounts of shipments within vertically structured firms, and even with an absence of internal shipments altogether" (p. 1121). Similarly, RRR ask "Why do multinationals own affiliates in industries downstream or upstream of those of the parent, if not for the shipment of goods along the vertical production chain? (...) Strong input-output links between two industries may signal the use of a common set of intangible inputs" (p. 56).

We reassess the evidence using newly available data that combines the complete mapping of U.S. MNEs' global production networks with their customs filings, thanks to recent data integration efforts between the U.S. Census Bureau and the BEA (Kamal, McCloskey and Ouyang, 2022). The key novelty of our approach, compared to prior work that used survey data on intrafirm trade, is that we leverage merchandise customs records maintained by the Census Bureau. Using the universe of shipments between U.S. parents and their foreign affiliates permits correcting for measurement error in survey data on intrafirm trade.

[2] For example, Bilir and Morales (2020) cite a "lack of physical shipments linking sites within the multi-plant firm" and a "similar lack of shipments across sites within U.S. multinational firms" as a rationale for theories of the firm in which ownership is driven by transfers of intangible rather than physical inputs.

Three main types of measurement error arise when using BEA direct investment surveys to study trade between U.S. parents and their foreign affiliates.[3] First, *respondent error* (e.g., survey fatigue or imperfect recall) implies that some transactions may not be recorded, resulting in false negatives (researchers may erroneously infer a lack of intrafirm trade flows) or may be wrongly recorded, resulting in false positives (researchers may erroneously infer positive intrafirm trade flows). Second, the BEA surveys collect the *total* trade between a parent and its affiliate. In the absence of more detailed information, researchers are forced to allocate all trade flows to the affiliate's main industry. In turn, this can lead to false positives (researchers may erroneously infer intrafirm trade flows involving the affiliate's primary industry) as well as missing data (researchers disregard trade flows involving the affiliates' other industries). Finally, the BEA surveys only collect data on intrafirm trade for affiliates *above a certain size threshold*. Lack of information on trade with smaller affiliates leads to additional sources of missing intrafirm trade data.

We correct survey-based measurement errors using customs records. First, administrative customs records enable observing all transactions between a parent and its foreign affiliates, allowing us to correct false negatives or positives in intrafirm trade. Second, customs records contain trade flows at the detailed product level, making it possible to observe the specific industries in which a parent trades with its foreign affiliates. This allows us to correct both false positives (in the affiliate's primary industry) and missing values (in the affiliate's other industries). Finally, there is no firm size reporting threshold in customs records, so we can trace transactions between parents and all of their foreign affiliates.

We examine the relationship between IO linkages and intrafirm trade using multinational's global production networks and customs filings in 2004, to retain comparability with prior analysis. Measuring the extensive margin of trade between parents and their foreign affiliates using BEA survey data on intrafirm trade implies that the binary dependent variable is measured with error. This is a form of non-classical measurement error, which leads to biased estimates (e.g., Aigner, 1973; Bollinger, 1996; Meyer and Mittag, 2017). Our results indicate that misclassification in survey data on intrafirm trade (false negatives, false positives, missing values) leads to both attenuation bias and higher error variance, making it harder to identify the role of IO linkages.[4]

[3]Survey responses are subject to measurement error (Bound, Brown and Mathiowetz, 2001). Thus, survey responses to inter-plant transfers used by AHS likely also suffer from measurement error. This could be corrected using administrative firm-to-firm transactions data. However, while such data are available for several countries, including Belgium (e.g., Bernard et al., 2022), Chile (e.g., Arkolakis et al., 2023), Turkey (e.g., Demir et al., 2009), India (e.g., Garg et al., 2023), they are not for the United States.

[4]Appendix A.1 discusses the conditions about the structure of misclassification that can give rise to downward-biased estimates with an application to our setting.

Once we correct each type of measurement error, the point estimate of the IO linkage measure becomes increasingly larger and more precisely estimated. The baseline estimates imply that increasing the direct requirement coefficient by 0.1 — i.e., the parent needs 10 cents more of the input supplied by one of its integrated units to produce $1 of its output — increases the probability that the parent imports from the integrated unit by 8.2 percentage points, which corresponds to a 29% increase in the average probability of parent-affiliate trade in our data. We also find a positive relationship between parent-affiliate IO linkages and their value of intrafirm trade.

These results underscore the importance of using detailed microdata to study the complex organization of multinational companies. Ruhl (2015) posits measurement error in BEA survey data on intrafirm trade as a possible source of the discrepancy between aggregate statistics on intrafirm trade based on Census customs records and those based on BEA survey data and advocated using the confidential microdata to understand the sources of the discrepancy.[5] The data integration efforts between the Census Bureau and BEA have made it possible to correct measurement error in survey data on intrafirm trade and thus to identify the role of vertical linkages in predicting trade between parents and their foreign affiliates.

We also qualify the second puzzle concerning the sparsity of intrafirm trade. We document that more than half of all foreign affiliates export to or import from their U.S. parents: 53% in 2004 and 57% in 2019. The likelihood of intrafirm trade increases significantly once we account for the regional structure of MNEs' supply chains: 73% (in both 2004 and 2019) of production units located in North America trade with their U.S. parents. These statistics should be considered as a lower bound on trade between vertically related units of the same multinational firm, for two main reasons. First, they are based only on direct trade flows between parents and affiliates (customs records do not allow us to observe affiliate-to-affiliate trade and indirect trade between parents and their affiliates). Second, they are not restricted to upstream (i.e., those that produce goods used as inputs by the parent) and downstream (i.e., those that use as inputs the goods produced by the parent) units.

The finding that (at least) three-quarters of North American affiliates trade with their U.S. parent is consistent with the regionalization of multinationals' global value chains, i.e., "Factory North America," "Factory Europe," and "Factory Asia" (Baldwin, 2013). Trading with affiliates in nearby countries entails lower transport and communication costs compared

[5]Ruhl (2015) documents, using publicly available data, that between 1992 and 2012, intrafirm import shares remained flat (at around 45%) using the Census data, while they trended down (ending at around 35%) using the BEA data.

to affiliates in more distant countries (Keller and Yeaple, 2013). Moreover, preferential tariffs and rules of origin in free trade agreements (FTAs) imply that final good producers have incentives to source inputs within the FTA (Conconi, García-Santana, Puccio and Venturini, 2018). There is also evidence of strong complementarities between input and output markets reflected in "round-trip" linkages in U.S. MNEs' trade flows (Flaaen, Kamal, Lee and Yi, 2025). A direct policy implication of our finding on the higher prevalence of regional intrafirm trade is that import tariffs can be extremely disruptive for U.S. MNEs when applied to regional trading partners. Indeed, U.S. automakers with extensive North American supply chains have advocated for the easing of the 2025 U.S. tariff increases on imports from Canada and Mexico (Wall Street Journal, 2025a).

A handful of studies use administrative data on intrafirm trade for other countries. Garg, Ghosh and Tan (2023) employ firm-to-firm transactions data for a large state in India (Karnataka) and find that, when a vertically integrated supplier exists, around 40% of products are sourced exclusively from within the firm. Using administrative data for South Korea, Hong (2021) finds that almost 90% of all manufacturing firms report either sales to or purchases from a related party. Lack of firm-to-firm transaction data for the United States prevents a direct comparison between the results of these studies to AHS for U.S. multi-plant firms. Berlingieri, Pisch and Steinwender (2021) is the only other paper to examine the relationship between IO linkages and intrafirm trade using customs records. They show that inputs that are technologically more important for a French multinational's output are substantially more likely to be sourced from affiliates parties than from independent suppliers. We are the first paper to combine data on the global production networks of U.S. multinationals with their customs records to study trade between U.S. parents and their foreign affiliates.[6] By focusing on the United States, we directly compare our results with those of previous influential studies based on U.S. survey data on intrafirm trade, which offers a unique opportunity to assess measurement errors in survey data by using a reliable measure of "truth" for survey variables (Celhay, Meyer and Mittag, 2024).

Our analysis shows that non-classical measurement error in survey data has led researchers to underestimate the importance of trade between vertically related units of the same firm. Rather than disproving theories emphasizing transfers of intangibles, these results restore the empirical relevance of physical-input trade, in line with traditional theories of firm boundaries. The analysis also demonstrates that administrative data should be considered the "gold standard" for studying intrafirm trade, underscoring the value of inter-agency

[6] Antràs, Fort, Fadeev and Tintlenot (2024) and Kamal and Kroff (2025) also use the linked Census-BEA data to study U.S. multinationals' trade patterns, but do not focus on intrafirm trade.

collaborations. In the absence of administrative data, survey design could be improved by collecting more disaggregated data and lowering the reporting thresholds for the integrated production units surveyed, to improve the allocation of trade flows across industries and minimize missing values.

The paper is organized as follows. Section 2 describes the data. Section 3 discusses the different types of measurement error that arise when using BEA survey data on intrafirm trade and how customs records can be used to correct them. Section 4 shows that using administrative data on intrafirm trade makes it possible to uncover a strong positive relationship between input-output linkages and trade between multinational parents and their affiliates, thus overturning prior findings based on survey data. Section 5 documents the prevalence of intrafirm trade, especially for geographically proximate units. Section 6 concludes, discussing the implications of our findings for the theoretical and empirical literature on firm boundaries and avenues for future research.

2 Data

We combine three datasets to examine the presence of trade flows within multinationals' global production networks and evaluate whether they are predicted by input-output relationships between parents and affiliates. The ability to combine data from the Census Bureau and the BEA is made possible by an inter-agency agreement. To link these datasets, researchers have developed crosswalks between firm identifiers used in the BEA surveys and firm identifiers in the Census Bureau's Business Register (Kamal, McCloskey and Ouyang, 2022).[7]

Specifically, we use: comprehensive data on the global production network of U.S. multinationals from the BEA; administrative records on intra-MNE trade, covering the universe of U.S. merchandise trade transactions, from the Census Bureau;[8] and industry input-output tables from the BEA. We describe each of these datasets and how we combine them.

[7]The Business Register covers all U.S. business establishments and companies with paid employees (DeSalvo, Limehouse and Klimek, 2016).

[8]"Administrative data refers to data collected and maintained by federal, state, and local governments, as well as some commercial entities," and is "collected and maintained by agencies or firms are used to administer (or run) programs and provide services to the public" (U.S. Census Bureau, 2025a).

2.1 Global Production Networks of U.S. Multinationals

We construct U.S. multinationals' global production networks using the Benchmark Survey of U.S. Direct Investment Abroad (Form BE-10), which provides detailed information on U.S. parents and their foreign affiliates. The foreign affiliate information is collected on a consolidated basis: if a parent owns multiple establishments operating in the same country, these are treated as one consolidated affiliate, for which the parent provides information about the industry(ies) of operation (see Section B.1.1 of the Online Appendix for details). These data are the source for official statistics on the activities of multinational enterprises providing the most comprehensive information on the scale of direct investment abroad and impacts on the U.S. economy due to multinational activities (U.S. Bureau of Economic Analysis, 2018b). They have also been widely used to examine the activities of U.S. MNEs (e.g., Yeaple, 2003; Hanson, Jr. and Slaughter, 2005; Bilir and Morales, 2020; Antràs, Fort, Fadeev and Tintlenot, 2024).

For comparability with RRR, our main analysis sample is restricted to the network of majority-owned affiliates (i.e., ownership share above 50 percent) of U.S. parents operating in the manufacturing sector in the 2004 survey. We construct a similarly defined sample using the 2019 survey to provide a long-term view of the prevalence of intrafirm trade (results reported in Section 5).

U.S. parents are required to report employment and sales information for (up to) ten industries with the highest sales. We use the reported sales to assign each U.S. parent, p, a main industry j based on its U.S. operations (see Figure B1). The U.S. parent is also required to report the country of location, c, and the industry, i of all its foreign affiliates. The industry detail reported varies by the size of the affiliate. For small foreign affiliates (with assets, sales, or net income less than $25 million) the U.S. parent must report the primary industry of the affiliate (see Figures B2 and B3);[9] for large foreign affiliates (with assets, sales, or net income greater than $25 million), the parent must report (up to) seven industries, including the primary industry, in which the affiliate is active (see Figure B4).[10] The affiliate's primary industry is defined as the industry with the highest reported sales.

For each U.S. multinational parent p (in primary industry j), we define its global production network as the comprehensive list of all its foreign "production units," i.e., the country-industry (c-i) pairs corresponding to its foreign affiliates.

[9] U.S. parents are not required to report information on intrafirm trade for their foreign affiliates with assets, sales, or net income less than $25 million.

[10] This is consistent with larger affiliates being more likely to operate in multiple industries. For example, multi-industry firms account for three-quarters of U.S. output (Ding, 2025).

2.2 Intrafirm Trade

We use the Longitudinal Firm Trade Transactions Database (LFTTD), maintained by the Census Bureau, to separately identify intrafirm and arm's-length merchandise export and import transactions of U.S. multinational firms. LFTTD links international shipments to individual firms in the United States (Bernard, Jensen and Schott, 2009; Kamal and Ouyang, 2020). The database combines merchandise export and import transactions from confidential customs declaration forms with administrative data on the universe of U.S. firms in the non-farm, private sector in the Census Bureau's Business Register. It covers the universe of imported shipments valued over US$2,000 and exported shipments valued over US$2,500.

We utilize LFTTD to measure a U.S. firm's exports and imports by detailed 10-digit traded product codes (Schedule B codes for exports; Harmonized Tariff Schedule (HTS) for imports), related-party trade status, and destination and source country, respectively. Related-party trade status is an indicator variable (U.S. Census Bureau, 2025d). For exports, it denotes relationships in which one firm owns a stake of at least 10% in the other as reported by U.S. exporters in the Electronic Export Information filings (U.S. Census Bureau, 2025b). For imports, it denotes relationships in which one firm owns a stake of at least 5% in the other as reported by U.S. importers in customs entry filings (U.S. Customs and Border Protection, 2025). We identify intrafirm trade transactions using the related-party indicator and aggregate export and import transactions at the parent-destination industry and parent-source industry levels, respectively.

2.3 Census-BEA Crosswalks

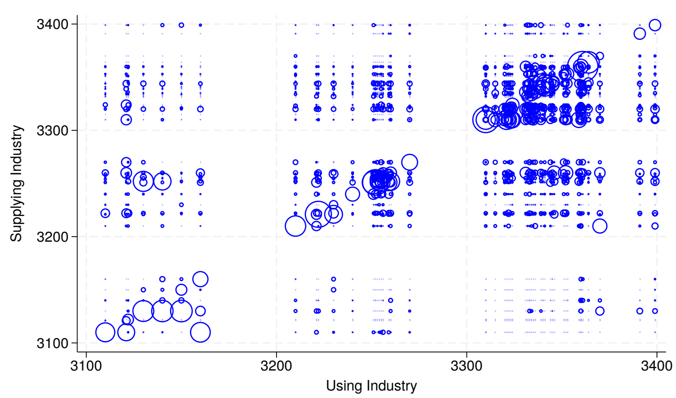
Confidential crosswalks that link enterprises reporting on BEA's multinational surveys to firms that engage in international goods transactions in LFTTD provide the central foundation for our analysis. Kamal, McCloskey and Ouyang (2022) describe the efforts from a multi-year project between the Census Bureau and the BEA that has resulted in the construction of confidential crosswalk files that enable a comprehensive identification of multinational firms in the U.S. economy. The crosswalks represent, on an employment-weighted basis, the vast majority (98%) of U.S. parent firms reporting in the BEA survey. These are high-quality matches evidenced by the majority of matches (about 94% on average) resulting from direct links between numeric tax identifiers.

2.4 Input-Output Linkages

To study vertical linkages between the activities of U.S. parents and their foreign affiliates, we calculate the direct requirement coefficients, IO_{ij}, from the "supply" and "use" tables published by BEA as part of the Input-Output accounts (U.S. Bureau of Economic Analysis, 2025b). For comparability with RRR, we use the 2002 direct requirement coefficients and focus on vertical linkages between manufacturing industries.[11]

The direct requirement coefficient is the value of goods needed from the supplying (upstream) industry i to produce one dollar of output in the using (downstream) industry j. To generate these coefficients, we aggregate BEA's use table (i.e., consumption of industry i's commodity by industry j) by 4-digit upstream and downstream industry. After obtaining total output by aggregating the supply table (i.e., total value of commodities produced by each industry) by 4-digit industry, we calculate IO_{ij} coefficients by dividing each "use" value (defined at the upstream–downstream industry level ij) by the total output of the relevant downstream industry j.

Figure 2. Input-Output Coefficients in U.S. Manufacturing, 2002



Notes: The figure plots direct requirements coefficients in manufacturing using the 2002 supply-use tables (U.S. Bureau of Economic Analysis, 2025b). The direct requirement coefficient is the value of goods needed from the supplying (upstream) industry to produce one dollar of output in the using (downstream) industry. Bubbles are proportional to the size of the direct requirement coefficient.

[11]Input-output linkages can also be constructed at the U.S. firm level such as in Feenstra and Jensen (2012); Antràs, Fort, Fadeev and Tintlenot (2024); Flaaen, Kamal, Lee and Yi (2025). We rely on industry input-output relationships to enable comparability with RRR and prior work on vertical integration (e.g., Acemoglu, Johnson and Mitton, 2009; Fajgelbaum, Grossman and Helpman, 2015; Alfaro, Conconi, Fadinger and Newman, 2016; Alfaro, Antràs, Chor and Conconi, 2019). Moreover, firm-level IO linkages are endogeneous to their trade decisions; aggregate IO tables are more informative about inter-industry linkages determined by technology (Acemoglu, Johnson and Mitton, 2009).

Figure 2 illustrates the variation in IO_{ij} for all manufacturing industries. We see strong clustering along the diagonal implying that industries often use inputs from within the same 4-digit industry. This is consistent with firms, including parents and affiliates, trading vertically related products within the same 4-digit NAICS. For example, 63 unique 6-digit HTS codes map to NAICS 3363 ("Motor Vehicle Parts Manufacturing") and these include a combination of industrial supplies, capital goods, autos and auto parts, and consumer goods as defined using a product's end-use classification.[12]

3 Measurement Error in Survey Data on Intrafirm Trade

We illustrate the different types of measurement error that arise when using BEA survey data to measure trade within U.S. multinationals using a hypothetical multinational production network. We then use the example to explain how U.S. customs records can be used to correct each type of error.

3.1 Hypothetical Example

Table 1 provides a hypothetical example of trade between a U.S. multinational parent and its foreign affiliates, following Tables B1-B2 in the Online Appendix. The example focuses on the extensive margin of the parent's imports from its affiliates, but similar considerations apply when looking at flows in the opposite directions (from the parent to its affiliates) and the intensive margin of trade.

Table 1. Hypothetical Example of Trade Between a Parent and Its Affiliates

	Large Affiliates						Small Affiliates	
Country of Affiliate	Affiliate A Mexico			Affiliate B Canada		Affiliate C Germany	Affiliate D France	Affiliate E China
Industry of Affiliate	Industry 1	Industry 2	Industry 3	Industry 1	Industry 2	Industry 1	Industry 1	Industry 1
Parent's imports	1	0	1	0	1	1	1	0

The first two rows of Table 1 illustrate the type of information on the production network of the U.S. parent that can be constructed using BEA's survey on direct investment abroad as described in Section 2.1. In this example, the parent has foreign affiliates in five countries (Mexico, Canada, Germany, France, and China). Three of these affiliates (A, B, and C) are large, while the other two (D and E) are small. All affiliates are active in industry 1, which

[12]The mean (median) number of 6-digit HTS products that map to a 4-digit NAICS manufacturing industry is 155 (99) based on unweighted calculations using the 2024 concordance between 10-digit HTS codes and 6-digit NAICS based on U.S. Census Bureau (2025c).

is their primary industry. For large affiliates, they are also active in other industries: A also operates in industries 2 and 3, and B in industry 2.

The parent has eight foreign production units (Mexico-industry 1, Mexico-industry 2, Mexico-industry 3, Canada-industry 1, Canada-industry 2, Germany-industry 1, France-industry 1, China-industry 1). The bottom row of the table shows whether or not the parent imports from each of these production units in a given year. For example, it imports from affiliate A in Mexico in industries 1 and 3, but not in industry 2.

3.2 Measurement Error in BEA Survey Data on Intrafirm Trade

Table 2 illustrates the different types of misclassification that can arise when a researcher has information on the production network of the U.S. parent but has to rely on survey data to populate intrafirm trade (indicated in the yellow-shaded row).

Table 2. Hypothetical Example of Trade Between a Parent and Its Affiliates: Intrafirm Trade in Survey Data

	Large Affiliates						Small Affiliates	
Country of Affiliate	Affiliate A Mexico			Affiliate B Canada		Affiliate C Germany	Affiliate D France	Affiliate E China
Industry of Affiliate	Industry 1	Industry 2	Industry 3	Industry 1	Industry 2	Industry 1	Industry 1	Industry 1
Parent's imports	1	0	1	0	1	1	1	0
BEA Survey	1			1		0		

First, *respondent error* (e.g., survey fatigue, imperfect recall, etc.) implies that some flows may not be recorded, leading to false negatives. For example, flows between affiliate C and its parent may not be recorded in the BEA survey on intrafirm trade, which could lead researchers to erroneously conclude that the parent does not import from affiliate C in industry 1. Respondent error may also lead to false positives (not illustrated in this example), i.e., the parent wrongly reports positive imports from an affiliate in its primary industry.

Second, survey data reports information on the *total amount of trade* between a parent and each of its affiliates. For this reason, researchers only consider the primary industry i of each affiliate and *allocate all flows to the affiliate's main industry.* In some cases, this can lead to false positives in the dependent variable, as in the case of affiliate B (which exports to the parent in industry 2 rather than 1). Further, the focus on the affiliate's primary industry implies missing values for the other industries. For example, researchers would not include observations corresponding to the extensive margin of trade between the parent and affiliate A in industries 2 and 3.

Finally, *reporting thresholds* in survey data lead to further missing values. In particular, the BE-10 survey only records intrafirm trade between U.S. parents and their large foreign affiliates. Researchers would thus have *no information on small affiliates* and whether or not a parent imports from affiliates D and E.

3.3 Using Customs Records to Correct Measurement Error

We can use the hypothetical example above to illustrate how customs records can be used to correct each type of measurement error in classifying the extensive margin of intrafirm trade. We proceed in four steps. In a first step, illustrated in Table 3, we correct false 0s (while still focusing on large affiliates and allocating all flows to the affiliate's primary industry). For example, customs records can allow us to observe parent's imports from affiliate C in Germany in industry 1.[13]

Table 3. Hypothetical Example of Trade Between a Parent and Its Affiliates: Correcting False Negatives

	Large Affiliates						Small Affiliates	
Country of Affiliate	Affiliate A Mexico			Affiliate B Canada		Affiliate C Germany	Affiliate D France	Affiliate E China
Industry of Affiliate	Industry 1	Industry 2	Industry 3	Industry 1	Industry 2	Industry 1	Industry 1	Industry 1
Parent's imports	1	0	1	0	1	1	1	0
BEA Survey	1			1		0		
Customs records	1			1		1		

In a second step, illustrated in Table 4, we can correct false positives in the dependent variable (while still focusing on large affiliates and allocating all flows to the primary industry). As mentioned above, survey data collects information on the total amount of trade between a parent and each of its affiliates, implying that researchers must allocate all flows to an affiliate's main industry. In some cases, this can lead to false positives in the dependent variable, as in the case of affiliate B. We can replace a 1 with a 0, if customs records show no flows between the parent and affiliate B in its primary industry.

Table 4. Hypothetical Example of Trade Between a Parent and Its Affiliates: Correcting False Positives

	Large Affiliates						Small Affiliates	
Country of Affiliate	Affiliate A Mexico			Affiliate B Canada		Affiliate C Germany	Affiliate D France	Affiliate E China
Industry of Affiliate	Industry 1	Industry 2	Industry 3	Industry 1	Industry 2	Industry 1	Industry 1	Industry 1
Parent's imports	1	0	1	0	1	1	1	0
BEA Survey	1			1		0		
Customs records	1			1		1		
Customs records	1			0		1		

[13]Customs records also allow correcting false positives due to respondent error (not illustrated in the example).

In a third step, illustrated in Table 5, we can include observations associated with affiliates' secondary industries (while still focusing on large affiliates). For example, we can add observations involving flows in the secondary industries of affiliate A, coding them with a 0 when there are no parents' related-party imports (e.g., from Mexico, in industry 2) and as a 1 when we observe positive related-party imports (e.g., from Mexico, in industry 3).

Table 5. Hypothetical Example of Trade Between a Parent and Its Affiliates: Including Large Affiliates' Secondary Industries

	Large Affiliates						Small Affiliates	
Country of Affiliate	Affiliate A Mexico			Affiliate B Canada		Affiliate C Germany	Affiliate D France	Affiliate E China
Industry of Affiliate	Industry 1	Industry 2	Industry 3	Industry 1	Industry 2	Industry 1	Industry 1	Industry 1
Parent's imports	1	0	1	0	1	1	1	0
BEA Survey	1			1		0		
Customs records	1			1		1		
Customs records	1			0		1		
Customs records	1	0	1	0	1	1		

Finally, using customs data allows us to include observations associated with smaller affiliates, as shown in Table 6. We can, for example, include observations related with trade between the parent and affiliates D and E, coding them with a 1 if we observe related-party imports (e.g., from France, in industry 1) and with a 0 if there are no records in the customs data of parent's related-party imports (e.g., from China, in industry 1).

Table 6. Hypothetical Example of Trade Between a Parent and Its Affiliates: Including Small Affiliates

	Large Affiliates						Small Affiliates	
Country of Affiliate	Affiliate A Mexico			Affiliate B Canada		Affiliate C Germany	Affiliate D France	Affiliate E China
Industry of Affiliate	Industry 1	Industry 2	Industry 3	Industry 1	Industry 2	Industry 1	Industry 1	Industry 1
Parent's imports	1	0	1	0	1	1	1	0
BEA Survey	1			1		0		
Customs records	1			1		1		
Customs records	1			0		1		
Customs records	1	0	1	0	1	1		
Customs records	1	0	1	0	1	1	1	0

4 Intrafirm Trade and Input-Output Linkages

Previous work based on survey data on intrafirm trade did not find a robust relationship between IO linkages and the extensive and intensive margins of trade between U.S. MNEs and their foreign affiliates. In this section, we re-examine this relationship leveraging administrative data on intrafirm trade combined with a complete mapping of MNEs' production networks. We focus on the extensive margin of intrafirm trade (the results on the intensive margin are discussed at the end of Section 4.2).

We estimate the following linear probability model:

$$\mathbb{I}(Imports_{p(j)ci}) = \beta_0 + \beta_1 IO_{ij} + \delta_c + \delta_i + \delta_p + \epsilon_{p(j)ci}. \tag{1}$$

The dependent variable, $\mathbb{I}(Imports_{p(j)ci})$, is an indicator for whether parent p (operating in industry j) imports from a foreign production unit, i.e., a country-industry pair (c, i) in which the U.S. multinational parent has a foreign affiliate. The unit of analysis is thus a parent-foreign production unit. IO_{ij} is the direct requirement coefficient of input industry i to output industry j. δ_c, δ_i, δ_p are affiliate-country, affiliate-industry, and parent fixed effects, respectively.

In supplemental analysis, we also estimate an analogous specification for parent p's exports:

$$\mathbb{I}(Exports_{p(j)ci}) = \beta_0 + \beta_1 IO_{ji} + \delta_c + \delta_i + \delta_p + \epsilon_{p(j)ci}. \tag{2}$$

The dependent variable, $\mathbb{I}(Exports_{p(j)ci})$, is an indicator for whether parent p (operating in industry j) exports to a foreign production unit located in country c and operating in industry i. IO_{ji} is the direct requirement coefficient of input industry j to output industry i. Similar to Equation (1), δ_c, δ_i, δ_p are affiliate-country, affiliate-industry, and parent fixed effects, respectively.

We include the diagonal of the IO matrix, i.e., IO_{jj} when estimating (1) and IO_{ii} when estimating (2) to retain comparability with RRR. Our findings are robust to excluding the diagonal (results available upon request).

4.1 Non-Classical Measurement Error When Using Survey Data

Misclassification of a binary dependent variable is a type of non-classical measurement error—not additive and correlated with true value. As discussed below, in linear probability models like Equations (1) and (2), measurement error leads to biased estimates rather than simply adding noise as in the case of classical measurement error.[14] Under certain conditions about the structure of misclassification, the estimates based on survey data will suffer from an attenuation bias, consistent with our findings.[15]

[14]See Chen, Hong and Nekipelov (2011) for an overview of the literature on measurement error in nonlinear models.

[15]Appendix A.1 outlines conditions about the structure of misclassification under which mismeasurement in intrafirm trade leads to an attenuation bias in the estimates of IO_{ij}.

To build intuition on the general case, consider the following linear probability model: $y = x'\delta + \varepsilon$, where the misclassification varies with x. If $y = 1$, the probability of misclassification is: $P(y^* = 0 \mid y = 1, x) = \alpha(x) = \alpha_0 + \alpha_1 x$. If $y = 0$, the probability of misclassification is: $P(y^* = 1 \mid y = 0, x) = \beta(x) = \beta_0 + \beta_1 x$, where $\alpha(x)$ and $\beta(x)$ capture heterogeneous misclassification that varies with x; $\alpha_1 \neq 0$ and $\beta_1 \neq 0$ introduce correlation between x and the misclassification probabilities.

Using the law of iterated expectations and substituting and expanding the terms, the conditional expectation of y^* given x is:

$$E[y^* \mid x] = \beta_0 + \beta_1 x + (1 - \alpha_0 - \beta_0 - \alpha_1 x - \beta_1 x)x'\delta. \tag{3}$$

If we estimate the regression $y^* = \gamma_0 + x'\gamma_1 + \eta$ by OLS, the estimated coefficient γ_1 is:

$$\gamma_1 = (1 - \alpha_0 - \beta_0 - \alpha_1 E[x] - \beta_1 E[x])\delta. \tag{4}$$

Note that *heterogeneous misclassification* leads to different directions of the bias: if $\alpha_1 > 0$, the probability of misclassifying $y = 1$ as $y^* = 0$ increases with x, biasing the coefficient downward; if $\beta_1 > 0$, the probability of misclassifying $y = 0$ as $y^* = 1$ also increases with x, biasing the coefficient upward. The net effect depends on the relative sizes of α_1 and β_1. If the misclassification is symmetric ($\alpha_1 = \beta_1$), the bias can still be non-zero (vanishing only in knife-edge cases as noted in Meyer and Mittag (2017)). The expectation of x among misclassified observations affects the direction of the bias, and the bias is amplified as the misclassification increases.

The results presented in Sections 4.2 and 4.3 indicate that measurement error in survey data on intra-MNE trade leads to estimates of the input-output coefficients that are noisy and downward biased: after correcting each type of measurement error, the point estimate of the IO linkage measure becomes increasingly larger and more precisely estimated.

4.2 Comparing Results With Administrative and Survey Data

In Table 7, we compare the results of estimating Equation (1) using administrative data from customs records to construct the dependent variable with the corresponding results from RRR based on BEA survey data.[16]

[16] The unit of observation in these regressions is a parent-foreign production unit. The foreign production units are all the country-industry pairs in which the parent's affiliates are active. In all specifications, the analysis is restricted to majority-owned affiliates in 2004 and to parent-affiliate industry pairs in the manufacturing sector.

Table 7. Input-Output Linkages and Parents' Imports From Their Affiliates Administrative Versus Survey Data on Intrafirm Flows

Dependent Variable	$\mathbb{I}(Imports_{p(j)ci})$			
	(1)	(2)	(3)	(4)
IO_{ij}	0.008	-0.135	0.566***	0.819***
	(0.215)	(0.227)	(0.150)	(0.192)
Observations	4,901	4,901	7,500	7,200
Affiliate Country FE	Yes	Yes	Yes	Yes
Affiliate Industry FE	Yes	Yes	Yes	Yes
Parent FE	No	Yes	No	Yes
Intrafirm Trade Flows	Survey	Survey	Customs	Customs

Notes: Columns 1 and 2 display the results of estimating Equation (1) using only BE-10 and BEA input-output tables; these estimates are reproduced from RRR (columns 3 and 4, Table 3). Columns 3 and 4 display the results of estimating Equation (1) using LFTTD, BE-10, and BEA input-output tables, controlling for affiliate employment (and parent employment, when excluding parent fixed effects). Observation counts in columns 3 and 4 are rounded to comply with Census Bureau disclosure avoidance rules. Robust standard errors, clustered by MNE, in parentheses. Significance levels: *** 0.01, ** 0.05, * 0.1.

Columns 1 and 2 report the results using BEA survey data from RRR. Columns 3 and 4 display the results from estimating Equation 1 using data from customs records to measure intrafirm trade. Not surprisingly, the number of observations increases significantly when measuring intrafirm trade using customs records compared to survey data, where analysis is restricted to large affiliates and to trade flows in the large affiliates' primary industries.

The estimates based on customs records stand in sharp contrast with the corresponding estimate based on BEA survey data: the coefficient of IO_{ij} is small and not statistically significant in columns 1 and 2; the coefficient becomes large and highly significant in columns 3 and 4. Comparing columns 2 and 4 in Table 7 shows that the IO_{ij} coefficient is much larger when controlling for parent fixed effects. This result suggests that the estimate in column 2 suffers from omitted variable bias and underscore the importance of accounting for parent-specific characteristics that can affect intrafirm trade (e.g., productivity, industry specialization).[17]

[17] The regressions in columns 3 and 4 are estimated using Stata's "reghdfe" command (Guimaraes and Portugal, 2010). This estimation approach drops groups with only one observation for a given fixed effect, implying that there is no variation to be estimated within that group i.e., "singletons". Even if not a singleton, a group might be dropped if all observations within that group have the same value for the outcome variable, as there is no within-group variation to be estimated. When including parent fixed effects in column 4, observations with no variation within a parent are thus dropped, leading to a lower number of observations. By contrast, the regressions in columns 1 and 2 are estimated by Ordinary Least Squares (OLS), implying that observations are retained even if there is no identifying variation.

The estimates in column 4 imply that increasing IO_{ij} by 10 percentage points raises the probability that the parent imports from the affiliate by 8.2 percentage points. In turn, this implies a 29% increase in the probability of intrafirm trade relative to the average probability that the foreign affiliates export to their parents, which is 29.6% (see Table 9). Alternatively, a one standard deviation increase in IO_{ij} leads to a 6.9% increase in the probability of intrafirm trade.

Overall, the estimates in Table 7 show that measurement error in survey data on intrafirm trade (false negatives, false positives, missing values) leads to biased estimates and higher error variance, making it harder to identify the role of input-output linkages. Replacing survey data with administrative data reveals that vertical linkages between multinational parents and their foreign affiliates *do* predict whether they trade with each other. In Table 8 in the next section, we show how we can obtain the estimate of IO_{ij} in column 4 of Table 7 after successively correcting for each type of measurement error.

We next examine two additional outcomes, which further underscore the importance of using customs records to measure intrafirm trade flows. These results are reported in Appendix A.2. First, we study whether input-output linkages predict the probability that parents export to their affiliates. In Table A1, we compare the results of estimating Equation (2) using administrative data on intrafirm trade with the corresponding results based on survey data. Like in Table 7, the input-output coefficient linking the industry of the parent and its foreign production unit is positive and highly significant, but only when using administrative data.[18] The estimate in column 4 implies that increasing IO_{ji} by 10 percentage points raises the probability that the parent exports to the affiliate by 9.5 percentage points. In turn, this implies a 21% increase in the probability of intrafirm trade relative to the average probability that foreign affiliates import from their parents, which is 44.7%.

Second, we examine the intensive margin of trade between parents and affiliates, specifically the value of parents' imports from affiliates. RRR find that the input-output coefficients linking the industries of the parents and the affiliates do not predict the intensity of parents' imports from their affiliates. The estimates reported in Table A2 show that using customs records enables us to identify the role of input-output linkages on the intensive margin of intrafirm trade.[19] Notice that the number of observations is several orders of magnitudes

[18]The specifications that exclude parent fixed effects differ slightly: column 1 (column 3) includes parent-industry (affiliate-industry) fixed effects, which control for the sending (receiving) industry, respectively.

[19]These estimates are comparable with those reported in columns 5 and 6 of Table 3 in RRR, in which the share of affiliates' exports to their parents is regressed on IO_{ji}, with both variables in log terms. These specifications include the same set of fixed effects as in columns 3 and 4 of Table A2. For select specifications we report qualitative results to comply with Census Bureau disclosure avoidance rules.

smaller than when looking at the extensive margin, thus we lose variation to identify the role of input-output linkages. Notwithstanding this, the coefficient of IO_{ij} is positive and significant in the specifications reported in columns 1–3. However, when we include the full set of fixed effects (affiliate-country, affiliate-industry, and parent) in column 4, the coefficient of IO_{ij} loses statistical significance. sThis suggests that there is less variation within than across multinationals in the intensive margin of parent-affiliate trade.

4.3 Correcting Each Type of Measurement Error

In this section, we show how the baseline estimates of the β_1 coefficient reported in column 4 of Table 7 can be obtained after using customs records to subsequently correct each type of measurement error (false positives, false negatives, and missing data) that can arise when using survey data on intrafirm trade.

In columns 1-3, we restrict the analysis to large foreign affiliates required to report on intrafirm trade in the BEA survey. In columns 4-6, we consider the entire production network of U.S. parents, including their affiliates below the reporting threshold.

In column 1, we correct only for possible measurement error associated with false negatives and positives in survey data on intrafirm trade that may arise due to respondent error (in the hypothetical example above, this step is illustrated by Table 3). Customs records allow us to observe trade flows between a parent p and its foreign affiliate a across all industries in which the affiliate is active. If we observe related-party imports in any of these industries, we allocate these flows to the affiliate's primary industry. This allows us to deal with instances in which the parent is importing (not importing) from an affiliate in its primary industry, but these flows are not recorded (recorded) in the BEA survey data on intrafirm trade. In this sample of large majority-owned affiliates, the IO_{ij} coefficient is positive but not statistically significant.[20] This result suggests that false negatives or positives in flows between U.S. parents and their large foreign affiliates due to respondent error are not the

[20]These estimates are comparable to those reported in column 2 of Table 7, in which the coefficient of IO_{ij} is negative, but not statistically significant. Note that the number of observations is smaller, although the regressions are based on the sample of multinational parents and their large affiliates, because we consider only flows in the affiliate's primary industry. The difference is largely driven by the fact that we estimate Equation (1) using Stata's "reghdfe" command, which drops observations when there is no variation within a group, while RRR use OLS (see footnote 17). The number of observations may also differ due to differences in firm definitions. BEA survey data on intrafirm trade are collected by BEA parent firm identifiers in the BE-10 form. In contrast, we use intrafirm trade data from customs records, and thus obtain the parent firm identifier from the Census Bureau's Business Register. Multiple BEA firm identifiers may be linked to a single Census firm identifier. See Kamal, McCloskey and Ouyang (2022) for details on the crosswalk construction. We also exclude from our sample U.S. parents that also report being a foreign affiliate (see Section B.1.1 of the Online Appendix).

main reason why previous work has not been able to identify the role of input-output linkages in predicting intrafirm trade flows.

In column 2, we still focus on the primary industry i of each foreign affiliate a, but code the dependent variable as 1 only if customs records show that p imports from a goods that fall within industry i. This allows us to correct for measurement error associated with false 1s in survey data on intrafirm trade (in the hypothetical example above, this step is illustrated by Table 4). The IO_{ij} coefficient increases from 0.270 (not significant) in column 1 to 0.598 (significant at the 5% level) in column 2. This result shows that using more disaggregated trade data allows to allocate intra-MNE flows to the correct industry, which helps to identify the role of input-output linkages in predicting trade between parents and affiliates.

In column 3, we extend the analysis to consider all industries i in which a foreign affiliate a may be active (in the hypothetical example above, this step is illustrated by Table 5). We use customs data to correctly allocate trade flows to each affiliate industry: we code the dependent variable as 1 only if we observe that p imports from a goods that fall in affiliate's industry i. This allows us to correct for measurement error associated with missing values in intrafirm flows in the affiliates' secondary industries. Notice that the sample increases (from 3,900 in columns 1 and 2 to 4,900 in column 3) and the IO_{ij} coefficient increases in magnitude to 0.847 (significant at the 1% level). This result indicates that not being able to observe intrafirm trade in all industries in which foreign affiliates are active leads to estimates of IO_{ij} that are downward biased.

In the next three columns, we reproduce the same structure of columns 1–3 with available information on all foreign affiliates of a parent. This enables us to address the problem of missing intrafirm trade values that arise due to the survey reporting threshold (as illustrated in Table 6). As a result, sample size increases substantially: from 3,900 in columns 1 and 2 to 6,200 observations in columns 4 and 5; from 4,900 in column 3 to 7,200 in column 6.

In column 4, we code the dependent variable as 1 if customs records show positive import flows of p from a in any of the industries in which the affiliate is active. We allocate all flows to the affiliate's primary industry. In this specification, we effectively correct for "potential" false negatives or positives, which could arise if all affiliates (even those below the $25 million reporting threshold) were included in the BEA survey on intrafirm trade. The IO_{ij} coefficient is positive and statistically significant. Comparing this specification with column 1 shows that including MNEs' production networks in their entirety helps to identify the role of vertical linkages.

Table 8. Input-Output Linkages and Parents' Imports From Their Affiliates
Correcting Measurement Error Using Census-BEA Linked Data

Dependent Variable	$\mathbb{I}(Imports_{p(j),c,i})$					
	(1)	(2)	(3)	(4)	(5)	(6)
Sample	Large foreign affiliates			All foreign affiliates		
Affiliate Industry	Primary only	Primary only	All	Primary only	Primary only	All
IO_{ij}	0.270	0.598**	0.847***	0.363**	0.574***	0.819***
	(0.228)	(0.255)	(0.22)	(0.177)	(0.195)	(0.192)
Observations	3,900	3,900	4,900	6,200	6,200	7,200
Affiliate Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Affiliate Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Parent FE	Yes	Yes	Yes	Yes	Yes	Yes
Affiliate Employment	Yes	Yes	Yes	Yes	Yes	Yes
Intrafirm Trade Flows	Customs	Customs	Customs	Customs	Customs	Customs
Type of Measurement Error Correction	False 0/1s	False 1s	Missing Data	False 0/1s	False 1s	Missing Data

Notes: This table displays the results from estimating Equation (1) using LFTTD, BE-10, and BEA supply-use tables on two separate samples. In columns 1-3, we focus on trade flows between multinational parents and their large foreign affiliates (i.e., those with assets, sales, or net income greater than $25 million); in columns 4-6, we include trade flows between parents and all their affiliates. "Type of Measurement Error Correction" indicates the type of measurement error being corrected in each column. Within a sample of affiliates, each correction is additive across columns, e.g., in column 3 (6), we correct for false negatives (0s), false positives (1s), and missing data associated with large (all) affiliates. Observation counts are rounded to comply with Census Bureau disclosure avoidance rules. Robust standard errors, clustered by MNE, in parentheses. Significance levels: *** 0.01, ** 0.05, * 0.1.

In column 5, we code the dependent variable as 1 as long as we observe positive import flows by p from a in its primary industry, correcting for false 1s. The results confirm that false positives due to the incorrect allocation of trade flows to the affiliate's primary industry lead to biased and inefficient estimates: the coefficient of IO_{ij} increases from 0.363 (significant at the 5% level) in column 4 to 0.574 (significant at the 1% level) in column 5.

Finally, in column 6, we consider all industries in which large foreign affiliates are active and the primary industry of small affiliates, and code the dependent variable as 1 if we observe positive import flows by p from a in industry i. The coefficient further increases to 0.819 (significant at the 1% level), which confirms the importance of being able to observe more disaggregated intrafirm trade flows.

Overall, the results in Table 8 show that different types of measurement error in survey data on intrafirm trade, and in particular false positives and missing values due to survey design and threshold requirements, lead to biased estimates and increase error variance, making it harder to identify the role of IO linkages.

5 The Prevalence of Intrafirm Trade

Earlier studies based on survey data on intrafirm trade emphasize that transactions between vertically related units of the same firm are very sparse: using surveys of domestic freight shipments, AHS find that almost one-half of upstream establishments in the United States do not report making shipments inside their firms; based on direct investment surveys on intrafirm trade, RRR document that the median foreign affiliate of a U.S. multinational does not trade with the rest of the corporation.

In this section, we combine data on MNEs' production networks (BE-10) with intrafirm trade flows (LFTTD) to document the prevalence of trade between multinational parents and their foreign production units (i.e., all country-industry pairs in which parent p's affiliates are active). Table 9 reports the share of foreign production units that trade with their parents in 2004 and 2019 (the most recent available benchmark year for which we can construct these statistics).

When we consider only one direction of flows (p's related-party imports from country c in industry i), we find less than 30% (40%) of units ship anything to their parents in 2004 (2019). When we consider trade flows in the opposite direction (p's related-party exports to country c in industry i) we find that around 45% (48%) of foreign integrated units imported from their parent in 2004 (2019). However, when allowing for two-way trade, the share of units trading with their parent increases to over half (around 53% in 2004; and 57% in 2019).

Table 9. Foreign Production Units Trading With Their U.S. Parent

Direction of Trade	Share in 2004	Share in 2019	Affiliate Location
Parent's imports	29.6%	36.4%	All countries
Parent's exports	44.7%	48.1%	All countries
Parent's imports or exports	53.3%	56.6%	All countries
Parent's imports or exports	73.7%	73.3%	North America

Notes: The table reports the share of foreign production units (country-industry pairs of the foreign affiliates of a multinational) trading with their U.S. parents in 2004 and in 2019 using BE-10 and LFTTD.

The statistics reported in Table 9 represent a lower bound on trade between vertically related units of the same multinational firm, for two main reasons. First, they are based only on direct trade flows between parents and affiliates. U.S. customs records do not allow us to observe trade flows between affiliates. We also cannot observe indirect trade flows between parents and affiliates (e.g., an input produced by an affiliate is processed by an independent firm which then sells it to the parent). Alfaro et al. (2019) show that this type of indirect trade arises whenever integration is infeasible for certain segments of the value chain (e.g., because of exogenous technological or regulatory factors). Second, they are based on all production units. We would expect higher shares if the sample was restricted to upstream units (i.e., those that produce goods used as inputs by the parent) and downstream units (i.e., those that use as inputs the goods produced by the parent).[21]

Several studies point out that, due to trade frictions related to distance (e.g., transport costs, tariffs, rules of origin in regional trade agreements), MNEs organize their production along regional supply chains (e.g., Baldwin, 2013; Keller and Yeaple, 2013; Conconi, García-Santana, Puccio and Venturini, 2018). Table 9 shows that accounting for the regional nature of MNEs' supply chains significantly increases the likelihood of trade between multinational parents and their affiliates: the share of foreign affiliates trading with their US parent increases to around 75% (in both 2004 and 2019) when restricting the sample to affiliates in North America. Again, for the three reasons discussed above, this should be considered a lower bound on the share of vertically related units engaged in intrafirm trade.

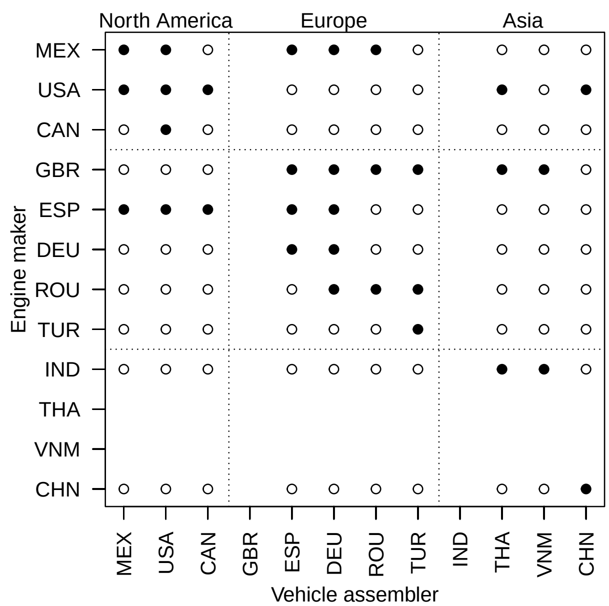
Buyer-supplier linkages in the auto industry offer an illustrative example of the regionalization of multinationals' supply chains.[22] Figure 3 shows the distribution of vehicle assembly

[21]An additional reason for why the shares in Table 9 should be considered a lower bound is that we can only focus on related-party exports in goods that map to the manufacturing industries of the foreign production units (see Section B.1.2 of the Online Appendix for a detailed discussion).

[22]Detailed information on the inputs used by MNEs is rarely available, but specific industry studies offer valuable insights. In addition to auto-specific case studies, Del Prete, Fajgelbaum, Khandelwal and Macchiavello (2026) collect buyer-supplier relationships in the coffee industry from customs records, focusing

and engine-producing plants owned by Ford Motor Company, located in various countries in North America, Europe, and Asia.[23] The black dots indicate cases in which a Ford assembly plant in one country (e.g., Mexico) sources engines from a Ford plant in another country (e.g., the United States); the white dots indicate cases in which there is no trade between engine-producing and assembly plants in two countries (conditional on Ford having plants in both countries); empty rows indicate cases in which Ford does not own an engine-producing plant in a country (Thailand or Vietnam); empty columns reflect cases in which Ford does not own assembly plant in a country (India and United Kingdom).

Figure 3. Trade Between Ford Assembly and Engine Plants



Notes: The figure plots trade between the engine and assembly plants of Ford Motor Company located in different countries in North America, Europe, and Asia. Conditional on the presence of vertically related plants, black (white) dots indicate trade (no trade) between them.

Figure 3 shows that intrafirm trade is generally sparse: when considering all Ford engine and assembly plants worldwide, the probability that they trade with each other is 0.31; this is the share of all black dots (31) divided by all dots (100). However, intrafirm trade is

on the 14 major coffee producing countries. They show that MNEs source inputs from integrated suppliers. For example, Nestlé sources green coffee beans from 12 of the 14 countries in the sample and own affiliate operating in the coffee sector in seven of them. For four of these countries (Ecuador, Indonesia, Mexico, and Vietnam), the share of coffee beans sourced from integrated suppliers is substantial (between 38.4% for Indonesia and 99.9% for Mexico).

[23]We thank Keith Head for generating this figure using data from Head, Mayer, Melitz and Yang (2025).

prevalent within regions: when considering Ford engine and assembly plants located in the same region, the average probability that they trade with each other increases to 0.60; this is the share of all black dots (21) divided by all dots (35) in the diagonal squares in the figure. Moreover, with probability 1 all Ford assembly plants source engines from at least one Ford engine plant in the same region. Notice also that around 70% of the Ford establishments trading with each other are located in the same region: 21 of the 31 black dots are in the diagonal squares.

The prevalence of intrafirm trade within regional supply chains has important implications for the measurement of vertical integration. There is a large empirical literature on the determinants of firms' vertical integration decisions, usually with a view to assessing the importance of different tradeoffs that determine firm boundaries, or to examining effects of vertical integration on market outcomes. Many studies use the methodology proposed by Fan and Lang (2000) to measure vertical integration, by combining data on input-output linkages between industries with data on the production activities of different establishments and ownership linkages between them (e.g., Acemoglu, Johnson and Mitton, 2009; Alfaro and Charlton, 2009; Fajgelbaum, Grossman and Helpman, 2015; Alfaro, Conconi, Fadinger and Newman, 2016; Alfaro, Antràs, Chor and Conconi, 2019). Our results suggest that, when applying this methodology to multinational firms, researchers may want to measure integration using information on establishments located in the same region (e.g., countries in the same continent, neighboring countries, members of regional trade agreements), which are more likely to trade with each other.

6 Conclusions

We conclude by discussing the implications of our findings for the theoretical and empirical literatures on firm boundaries and important avenues for future research.

Traditional theories of vertical integration highlight different trade-offs driving a firm's choice to produce an input within its boundaries or source it from the market. While these theories emphasize different benefits of integration (e.g., reductions in transaction costs, alignment of control and incentives, improved multi-tasking incentives, or improved coordination), all imply that we should observe trade between vertically related units of the same firm. Prior influential studies relying on survey-based information on intrafirm goods trade for the United States did not find empirical support for this theoretical prediction.

In our analysis, based on newly linked data from the Census Bureau and the BEA, we replace survey-based data on intrafirm goods trade used in previous studies with administrative data from customs transactions. We find that input-output linkages between parents and their foreign production units do predict transactions between them. We show that correcting different types of misclassification in survey data on intrafirm trade (in particular, missing values and false positives) is key to identifying these effects. Finally, we show that intrafirm trade in tangible inputs is prevalent: around 55% of foreign production units worldwide and 75% of production units in North America trade with their U.S. parent. These shares are a lower bound on trade between vertically related units of the same MNE because they do not account for trade flows between foreign affiliates and for indirect trade (i.e., independent firms processing goods traded between U.S. parents and their foreign affiliates) and are not restricted to downstream and upstream units.

More work is needed to understand how different types of trade frictions shape the production structure of firms. Atalay, Hortaçsu and Syverson (2019) show that U.S. multi-plant firms systematically engage in more intrafirm shipments over longer distances, implying that internal transactions confer a "distance premium." In the case of U.S. multinational firms, we find that parents trade mostly with their North American affiliates. The regional nature of MNEs' supply chains can be rationalized using models of international production that feature trade costs. In the model of Tyazhelnikov (2022), the presence of trade costs makes firms cluster their production geographically. The model of multi-stage production of Head, Mayer, Melitz and Yang (2025) can also give rise to regional concentration in intrafirm trade, e.g., batteries produced in plants in North America (Europe) are used by assembly plants in North America (Europe).

Accounting for MNEs' regional supply chains is key to understanding the implications of the 2025 U.S. tariff increases. Our analysis suggests that raising trade barriers can be extremely detrimental for U.S. multinationals, particularly when they are applied on imports from Canada and Mexico. Data from (U.S. Bureau of Economic Analysis, 2022b) reveal that 42% (45%) of U.S. MNEs' exports to (imports from) majority-owned foreign affiliates in 2022 were with those located in Canada and Mexico. These statistics are even higher within the transportation equipment sector (defined as 3-digit NAICS 336): 76% (85%) of intrafirm exports (imports) were with majority-owned affiliates in North America (authors' calculations from U.S. Bureau of Economic Analysis, 2022b). As Ford Motor Company CEO Jim Farley noted, given American automakers reliance on parts and equipment made in Canada and Mexico, higher trade barriers across North American borders would "blow a hole" in the U.S. auto industry (Wall Street Journal, 2025b).

Our findings restore the empirical relevance of physical-input trade between different units of the same MNE, corroborating aggregate trade patterns (see Figure 1) and traditional theories of firm boundaries. Transfers of intangible inputs are thus not necessary to rationalize why firms own upstream and downstream units. Of course, this does not invalidate the idea that ownership may also mediate transfers of intangible inputs. Recent decades have witnessed the "servitization" of manufacturing: in many countries, there is a trend toward more production, use, and sale of services by manufacturing firms and services account for the majority of GDP and employment globally (e.g., Buera and Kaboski, 2012; Ding, Fort, Redding and Schott, 2022; Kamal and Kroff, 2025). It would thus be instructive to study whether intrafirm trade in intangible inputs also depends on IO linkages between different units of a firm.

Studying intrafirm trade in intangibles is, however, empirically challenging, for three main reasons. First, an analysis of the determinants of intrafirm flows in services trade would need to rely on survey data, given that there are no customs collections for services trade transactions (United Nations Statistics Division, 2010). Most U.S. statistics on trade in services are based on data collected by the BEA through its survey programs (U.S. Bureau of Economic Analysis, 2018a). As shown in this paper, reliance on survey data to measure intrafirm trade can give rise to key measurement challenges that make it harder to identify the role of input-output linkages. Second, the classification of traded services is much coarser than that used for goods trade collection. Finally, profit-shifting motives may worsen misreporting errors, particularly in intellectual property and other business services (Jenniges, Mataloni, Stutzman and Xin, 2018). We leave the exploration of input-output linkages in predicting intrafirm intangible flows for future research.

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Appendix

A.1 Measurement Error in Survey Data on Intra-MNE Trade

We discuss the conditions under which using survey data on intra-MNE trade to estimate Equation (1) would yield estimates of IO_{ij} that are downward-biased.[24]

The BEA survey data on intrafirm trade within U.S. multinational firms are subject to several sources of measurement error, as illustrated in Table 2:

1. **Respondent error (false negatives, false positives)**: some flows may fail to be reported or be erroneously reported, e.g., due to survey fatigue or imperfect recall. (e.g., no flows between the parent and affiliate C in industry 1).

2. **Primary-industry assignment (false positives and missing flows)**: BEA survey forms report total parent-affiliate trade, but not its allocation across affiliates' industries. Researchers thus assign all flows to the affiliate's primary industry. This can generate:

   - *false positives* (e.g., affiliate B trades with the parent, but not in its primary industry); and
   - *missing observations* for the affiliate's secondary industries (e.g., industries 2 and 3 of affiliate A).

3. **Reporting thresholds (missing flows)**: the BE-10 survey only records intrafirm trade for affiliates with assets, sales, or net income above $25 million. Imports from small affiliates (e.g., affiliates D and E) are therefore systematically missing.

Missing data can be considered "as an extreme form of measurement error" (Blackwell, Honaker and King, 2017). They can be intentional or unintentional. Intentional missing data occurs when data are deliberately excluded by the data collector such as through matrix sampling, questionnaire routing, censored survival times, or other sampling decisions such as to reduce respondent burden. For example, only enterprises above a certain size threshold are required to respond to BEA's direct investment surveys. On the other hand, unintentional missing data results from unforeseen circumstances beyond the data collector's

[24]We thank Frank DiTraglia for very heplful discussions about the conditions in a general setting, also described in DiTraglia (2021).

control, such as skipped survey items, data transmission errors, participant dropout, or refusal to participate. When the data is missing at random and does not significantly affect the estimation process unless efficiency is a concern, it is considered ignorable (Griliches, Intriligator, Heckman and Leamer, 1983). A second type occurs when the missing data is systematically related to the phenomenon being studied, in which case ignoring the issue can lead to inconsistencies in the estimators.[25]

The existence of false negatives, false positives, and missing data implies that the survey measure $\widetilde{Y}$ is a misclassified version of the true indicator Y. Let α denote the probability of a false positive (recording a flow that does not exist) and β the probability of a false negative (failing to record an existing flow). In this setting:

- false negatives (β) arise from missing flows and reporting thresholds;
- false positives (α) arise from primary-industry aggregation.

Assumptions on Structure of Misclassification

Let the true and observed import indicators be

$$Y_{p(j)ci} = \mathbb{I}(Imports_{p(j)ci}), \qquad \widetilde{Y}_{p(j)ci} \in \{0, 1\}.$$

Define the misclassification probabilities:

$$\alpha(Z_{p(j)ci}) := \Pr(\widetilde{Y} = 1 \mid Y = 0, Z_{p(j)ci}), \qquad \beta(Z_{p(j)ci}) := \Pr(\widetilde{Y} = 0 \mid Y = 1, Z_{p(j)ci}),$$

where $Z_{p(j)ci} = (\delta_p, \delta_c, \delta_i)$ collects parent, affiliate-country, and affiliate-industry fixed effects.

Assume:

(i) **Misclassification does not depend on IO_{ij}**
This condition allows false negatives and false positives to vary systematically with

[25] Rubin (1976) classifies missing data into three categories. Under *Missing Completely at Random* (MCAR), the probability of missingness is independent of both observed and unobserved data. In this case, missing data does not introduce bias into estimators, but only reduces the effective sample size and increases variance (reducing efficiency). When the data is *Missing at Random* (MAR), the probability of missingness depends only on observed data and not the missing (unobserved) values. In this case, maximum likelihood or multiple imputations can provide consistent and asymptotically unbiased estimates if the model is correctly specified. *Missing Not at Random* (MNAR) occurs when the probability of missing data is systematically related to unobserved data, which can lead to biased estimates; see also Graham (2009).

parent, affiliate-country, and affiliate-industry characteristics, but *not* with the input-output coefficients:

$$\alpha(Z_{p(j)ci}),\ \beta(Z_{p(j)ci}) \quad \text{do not depend on} \quad IO_{ij}.$$

(ii) **Sign Preservation (More Accurate than Random Guessing)**

$$\alpha(Z_{p(j)ci}) + \beta(Z_{p(j)ci}) < 1.$$

This condition requires that the BEA measure is informative: the probability of recording the correct category ($Y = \widetilde{Y}$) exceeds the probability of recording the incorrect one. If $\alpha + \beta = 1$, the survey would be no better than a coin flip; if $\alpha + \beta > 1$, it would be systematically misleading. Assumption A(ii) is therefore a *sign-preservation assumption*, ensuring that the observed slope has the same sign as the true slope.

(iii) **Non-degeneracy**

$$\alpha(Z_{p(j)ci}) + \beta(Z_{p(j)ci}) > 0.$$

This condition implies that some misclassification occurs. This rules out the trivial case $\alpha = \beta = 0$, where the BEA perfectly measures trade flows.

Together, (ii) and (iii) imply:

$$0 < 1 - \alpha(Z_{p(j)ci}) - \beta(Z_{p(j)ci}) < 1.$$

Mapping Between True and Observed Probabilities

Let

$$m(IO_{ij}, Z_{p(j)ci}) := \Pr(Y = 1 \mid IO_{ij}, Z_{p(j)ci}), \qquad m^*(IO_{ij}, Z_{p(j)ci}) := \Pr(\widetilde{Y} = 1 \mid IO_{ij}, Z_{p(j)ci}).$$

Under the assumptions described above,[26]

$$m^*(IO_{ij}, Z_{p(j)ci}) = \alpha(Z_{p(j)ci}) + \left[1 - \alpha(Z_{p(j)ci}) - \beta(Z_{p(j)ci})\right] m(IO_{ij}, Z_{p(j)ci}). \tag{1}$$

[26] $\widetilde{Y} = 1$ occurs either when $Y = 0$ is misclassified upward (false positive) or when $Y = 1$ is correctly recorded: $m^*(IO_{ij}, Z_{p(j)ci}) = \alpha(Z)\Pr(Y = 0 \mid IO_{ij}, Z_{p(j)ci}) + [1 - \beta(Z)]\Pr(Y = 1 \mid IO_{ij}, Z_{p(j)ci})$. Substitute $m^*(IO_{ij}, Z_{p(j)ci}) := \Pr(\widetilde{Y} = 1 \mid IO_{ij}, Z_{p(j)ci})$ and simplify.

Proposition: Sign Preservation and Attenuation Bias

Suppose,

$$m(IO_{ij}, Z_{p,c,i}) \approx \theta_0 + \theta_1 IO_{ij} + Z'_{p,c,i}\phi.$$

Estimating the linear probability model

$$\widetilde{Y}_{p(c,i,j)} = \beta_1 IO_{ij} + \delta_p + \delta_c + \delta_i + \varepsilon_{p(c,i,j)}$$

yields the population coefficient:

$$\beta_1 = \mathbb{E}[1 - \alpha(Z_{p,c,i}) - \beta(Z_{p,c,i})]\,\theta_1. \tag{2}$$

Consequently:

(i) **Sign preservation** Because Assumption (ii) ensures $1 - \alpha(Z) - \beta(Z) > 0$ for all Z, the estimated slope has the same sign as the true effect:

$$\text{sign}(\beta_1) = \text{sign}(\theta_1).$$

It follows that β_1 and θ_1 share the same sign.

(ii) **Attenuation bias** Because $1 - \alpha(Z) - \beta(Z) < 1$, the estimated coefficient is strictly smaller in magnitude:

$$|\beta_1| < |\theta_1|.$$

Proof. Substitute the approximation for $m(\cdot)$ into equation (1):

$$m^*(IO_{ij}, Z_{p(j)ci}) = \alpha(Z) + [1 - \alpha(Z) - \beta(Z)]\big[\theta_0 + \theta_1 IO_{ij} + Z'_{p,c,i}\phi\big].$$

Within each fixed-effect group Z, the slope is

$$\theta_1^*(Z) = [1 - \alpha(Z) - \beta(Z)]\theta_1.$$

Assumptions (ii)-(iii) imply $0 < 1 - \alpha(Z) - \beta(Z) < 1$, so the sign is preserved and the magnitude shrinks. □

A.2 Additional Results

Table A1. Input-Output Linkages and Parents' Exports to Their Affiliates Administrative Versus Survey Data on intrafirm Flows

Dependent Variable	$\mathbb{I}(Exports_{p(j),c,i})$			
	(1)	(2)	(3)	(4)
IO_{ji}	0.313	-0.170	0.854***	0.950***
	(0.197)	(0.212)	(0.190)	(0.265)
Observations	4,901	4,901	7,500	7,200
Affiliate Country FE	Yes	Yes	Yes	Yes
Parent FE	No	Yes	No	Yes
Affiliate Industry FE	Yes	Yes	No	Yes
Parent Industry	No	No	Yes	No
intrafirm Trade Flows	Survey	Survey	Customs	Customs

Notes: Columns 1 and 2 display the results of estimating Equation (2) using only BE-10 and BEA input-output tables; these estimates are taken from RRR (columns 7 and 8, Table 3). Columns 3 and 4 display the results of estimating Equation (2) using LFTTD, BE-10, and BEA supply-use tables, controlling for affiliate employment (and parent employment, when excluding parent fixed effects); observation counts in these columns are rounded to comply with Census Bureau disclosure avoidance rules. Robust standard errors, clustered by MNE, in parentheses. Significance levels: *** 0.01, ** 0.05, * 0.1.

Table A2. Input-Output Linkages and Parents' Imports From Their Affiliates Intensive Margin

Dependent Variable	$log(Imports_{p(j),c,i})$			
	(1)	(2)	(3)	(4)
$log(IO_{ij})$	+***	0.102**	+**	0.071
	-	(0.052)	-	(0.058)
Observations	-	1,800	-	1,800
Affiliate Country FE	Yes	Yes	Yes	Yes
Affiliate Industry FE	No	No	Yes	Yes
Parent FE	No	No	No	Yes
Affiliate Employment	Yes	Yes	Yes	Yes
Parent Employment	Yes	No	Yes	No
intrafirm Trade Flows	Customs	Customs	Customs	Customs

Notes: The dependent variable is the log of $Imports_{p(j),c,i}$, the value of imports of parent p (operating in industry j) from affiliate a (located in country c and operating in industry i). IO_{ji} is the direct requirement coefficient of input industry j to output industry i expressed in log term. The results in columns 1 and 3 have only been disclosed qualitatively. Observation counts in columns 2 and 4 are rounded to comply with Census Bureau disclosure avoidance rules. Robust standard errors, clustered by MNE, in parentheses. Significance levels: *** 0.01, ** 0.05, * 0.1.

Online Appendix

B.1 Sample Construction

In our analysis, we combine three datasets: comprehensive data on the global production network of U.S. multinationals from the BEA; administrative data on intra-MNE trade from customs records, covering the universe of U.S. merchandise trade transactions, from the Census Bureau; and industry input-output tables from the BEA. In this section, we describe each of these datasets and how we combine them.

B.1.1 U.S. Parents and their Foreign Production Units

We use the Benchmark Survey on U.S. Direct Investment Abroad to map individual MNE's global production networks. For comparability with RRR, we use the 2004 survey for the regression results in Section 4. We also the 2019 survey to provide a long-term view of the prevalence of intrafirm trade in Section 5.

Multinationals have complex ownership structures where a U.S. affiliate of a foreign multinational may own other U.S. affiliates and thus report on both the surveys of direct investment abroad as well as the surveys of foreign direct investment in the United States (U.S. Bureau of Economic Analysis, 2025a)—i.e., they appear as both U.S. parents *and* U.S affiliates of foreign parents. Our sample excludes multinational firms that are foreign-owned. We identify these firms by searching for Census firm identifiers that are on both surveys (applying Census–BEA crosswalks) and using an algorithm developed in Kamal, McCloskey and Ouyang (2022).[27] This ensures that our sample consists exclusively of U.S. multinational parents (not U.S. affiliates of foreign parents) and their foreign affiliates.

For comparability with RRR, we restrict attention to parent-foreign affiliate pairs in the manufacturing sector. We exclude affiliates that operate in tax havens—Bermuda, Cayman Islands, Hong Kong, and Singapore (Dharmapala and Hines, 2009).[28]

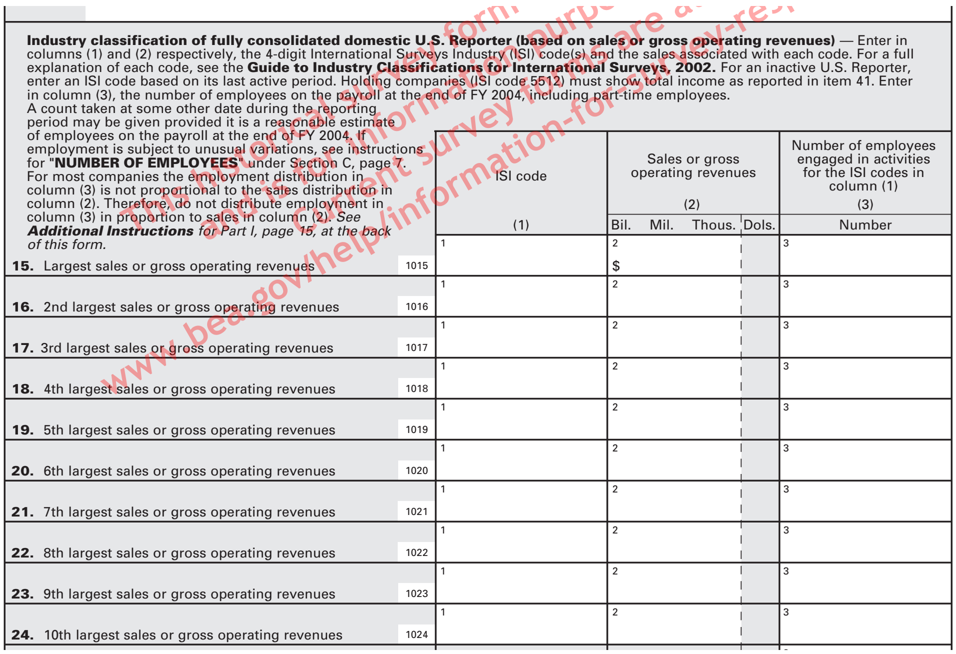
The benchmark survey collects employment and sales information of the U.S. parent for (up to) ten industries with the highest sales (see Figure B1). For our analysis, we assign

[27] An alternative methodology to determine ultimate ownership is employed in Antràs et al. (2024) who build on the matching methods developed within the inter-agency project by augmenting ownership information in the BEA surveys with the U.S. Census Bureau's Company Organization Survey that provided the sole direct source of information on any changes in multi-establishment company organization and industry classification at the establishment level prior to 2023 (U.S. Census Bureau, 2022).

[28] We keep tax havens that have a population of ≥ 1 million, which include Ireland, Switzerland, and Benelux (i.e., Belgium, Netherlands, and Luxembourg).

each U.S. parent, p, a main industry j based on its U.S. operations. We use sales reported in the BE-10 and assign the main industry as the one with predominant sales using an iterative assignment method rather than simply choosing the single industry with the most sales.[29]

Figure B1. U.S. Parent Industry Information (2004)
Form BE-10A



Industry classification of fully consolidated domestic U.S. Reporter (based on sales or gross operating revenues) — Enter in columns (1) and (2) respectively, the 4-digit International Surveys Industry (ISI) code(s) and the sales associated with each code. For a full explanation of each code, see the **Guide to Industry Classifications for International Surveys, 2002.** For an inactive U.S. Reporter, enter an ISI code based on its last active period. Holding companies (ISI code 5512) must show total income as reported in item 41. Enter in column (3), the number of employees on the payroll at the end of FY 2004, including part-time employees. A count taken at some other date during the reporting period may be given provided it is a reasonable estimate of employees on the payroll at the end of FY 2004. If employment is subject to unusual variations, see instructions for **"NUMBER OF EMPLOYEES"** under Section C, page 7. For most companies the employment distribution in column (3) is not proportional to the sales distribution in column (2). Therefore, do not distribute employment in column (3) in proportion to sales in column (2). *See* ***Additional Instructions*** *for Part I, page 15, at the back of this form.*

		ISI code (1)	Sales or gross operating revenues (2) Bil. Mil. Thous. Dols.	Number of employees engaged in activities for the ISI codes in column (1) (3) Number
15. Largest sales or gross operating revenues	1015	1	2 $	3
16. 2nd largest sales or gross operating revenues	1016	1	2	3
17. 3rd largest sales or gross operating revenues	1017	1	2	3
18. 4th largest sales or gross operating revenues	1018	1	2	3
19. 5th largest sales or gross operating revenues	1019	1	2	3
20. 6th largest sales or gross operating revenues	1020	1	2	3
21. 7th largest sales or gross operating revenues	1021	1	2	3
22. 8th largest sales or gross operating revenues	1022	1	2	3
23. 9th largest sales or gross operating revenues	1023	1	2	3
24. 10th largest sales or gross operating revenues	1024	1	2	3

Notes: This figure displays an excerpt from the 2004 Form BE-10A indicating the industry information reported by the U.S. parent. See U.S. Bureau of Economic Analysis (2004b) for the full form.

A U.S. multinational parent is required to report in the BE-10 form the country of location and the industry(ies) of its foreign affiliates.[30] This information is collected on a consolidated basis:[31] if a parent owns multiple establishments in a country, they are treated as one consolidated affiliate, for which the parent provides information about the industry(ies) of operation.

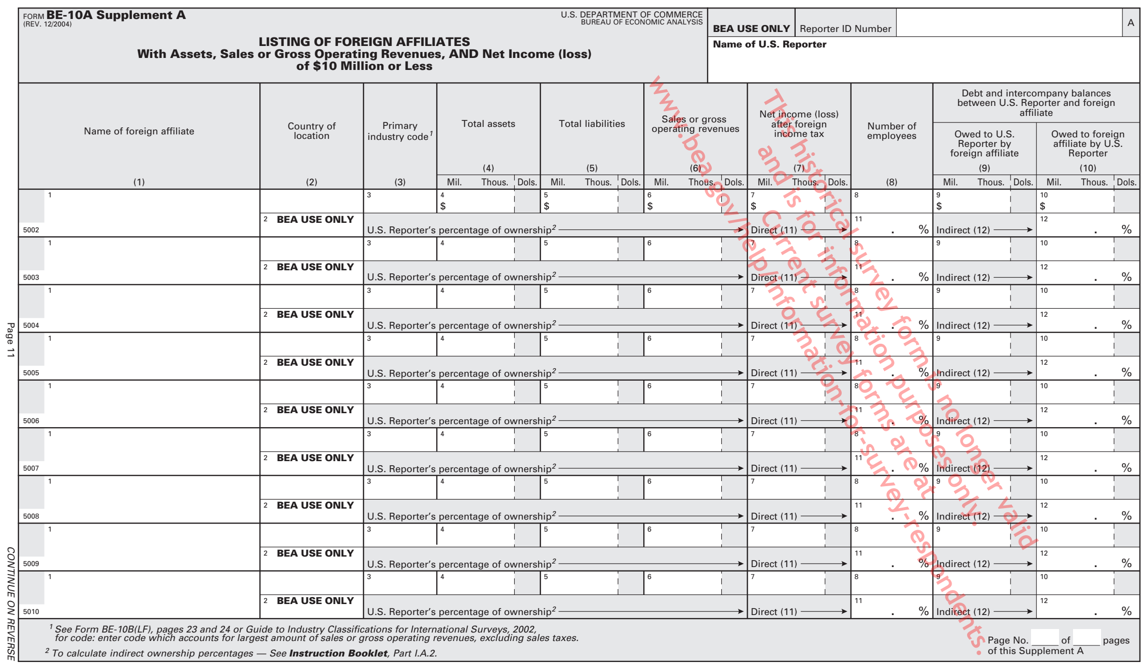
[29]For example, suppose a firm has establishments across three manufacturing 4-digit NAICS with sales of \$10 million in each and one services 4-digit NAICS with sales of \$20 million. Under a simple ranking methodology, the firm's main industry would be in services since that industry has the highest total sales (\$20 million). Under the iterative method, we first identify a predominant sector (i.e., 2-digit industry), which would be manufacturing since total manufacturing sales are \$30 million. Next, we consider the 3-digit industry with the highest sales *within* the predominant 2-digit industry. And finally, we assign the main 4-digit industry as the one with the highest sales within the predominant 3-digit industry.

[30]The forms in 2004 that contain affiliate information are BE-10B(LF), BE-10B(SF), and BE-10B Mini. The correspoding forms in 2019 are the BE-10B, BE-10C, and BE-10D, respectively.

[31]See BE-10 instruction booklet Section 1.B.2.d.1 (U.S. Bureau of Economic Analysis, 2004a).

The industry detail reported varies by the size of the affiliate. For small foreign affiliates (with assets, sales, or net income less than $25 million) the U.S. parent must report the primary industry of the foreign affiliate; for large foreign affiliates (with assets, sales, or net income greater than $25 million) the U.S. parent must report up to seven industries including the primary industry in which the affiliate is active. The affiliate's primary industry is defined as the industry with the highest reported sales. Figure B2 shows an excerpt from the BE-10 form in which the U.S. parent reports the country and primary industry of its affiliates with assets, sales, or net income less than $10 million.

Figure B2. Small Foreign Affiliates (2004)
Form BE-10A Supplement A


FORM BE-10A Supplement A
(REV. 12/2004)
U.S. DEPARTMENT OF COMMERCE
BUREAU OF ECONOMIC ANALYSIS
BEA USE ONLY | Reporter ID Number | A
Name of U.S. Reporter
LISTING OF FOREIGN AFFILIATES
With Assets, Sales or Gross Operating Revenues, AND Net Income (loss) of $10 Million or Less

Name of foreign affiliate (1)	Country of location (2)	Primary industry code[1] (3)	Total assets (4) Mil. Thous. Dols.	Total liabilities (5) Mil. Thous. Dols.	Sales or gross operating revenues (6) Mil. Thous. Dols.	Net income (loss) after foreign income tax (7) Mil. Thous. Dols.	Number of employees (8)	Debt and intercompany balances between U.S. Reporter and foreign affiliate: Owed to U.S. Reporter by foreign affiliate (9) Mil. Thous. Dols.	Owed to foreign affiliate by U.S. Reporter (10) Mil. Thous. Dols.
5002 1	2 BEA USE ONLY	3 U.S. Reporter's percentage of ownership[2]	4 $	5 $	6 $	7 $ Direct (11)	8 11 . %	9 $ Indirect (12)	10 $ 12 . %
5003 1	2 BEA USE ONLY	3 U.S. Reporter's percentage of ownership[2]	4	5	6	7 Direct (11)	8 11 . %	9 Indirect (12)	10 12 . %
5004 1	2 BEA USE ONLY	3 U.S. Reporter's percentage of ownership[2]	4	5	6	7 Direct (11)	8 11 . %	9 Indirect (12)	10 12 . %
5005 1	2 BEA USE ONLY	3 U.S. Reporter's percentage of ownership[2]	4	5	6	7 Direct (11)	8 11 . %	9 Indirect (12)	10 12 . %
5006 1	2 BEA USE ONLY	3 U.S. Reporter's percentage of ownership[2]	4	5	6	7 Direct (11)	8 11 . %	9 Indirect (12)	10 12 . %
5007 1	2 BEA USE ONLY	3 U.S. Reporter's percentage of ownership[2]	4	5	6	7 Direct (11)	8 11 . %	9 Indirect (12)	10 12 . %
5008 1	2 BEA USE ONLY	3 U.S. Reporter's percentage of ownership[2]	4	5	6	7 Direct (11)	8 11 . %	9 Indirect (12)	10 12 . %
5009 1	2 BEA USE ONLY	3 U.S. Reporter's percentage of ownership[2]	4	5	6	7 Direct (11)	8 11 . %	9 Indirect (12)	10 12 . %
5010 1	2 BEA USE ONLY	3 U.S. Reporter's percentage of ownership[2]	4	5	6	7 Direct (11)	8 11 . %	9 Indirect (12)	10 12 . %

[1] See Form BE-10B(LF), pages 23 and 24 or Guide to Industry Classifications for International Surveys, 2002, for code: enter code which accounts for largest amount of sales or gross operating revenues, excluding sales taxes.
[2] To calculate indirect ownership percentages — See **Instruction Booklet**, Part I.A.2.
Page No. ____ of ____ pages of this Supplement A
Page 11
CONTINUE ON REVERSE

Notes: This figure displays an excerpt from 2004 Form BE-10A Supplement A indicating the country and primary industry reported by the U.S. parent for its foreign affiliates with assets, sales, or net income less than $10 million. See U.S. Bureau of Economic Analysis (2004b) for the full forms.

Figure B3 shows excerpts from the BE-10 form in which the U.S. parent reports the country and primary industry of its affiliates with assets, sales, or net income between $10 and $25 million. Figure B4 shows the corresponding excerpts for affiliates with assets, sales, or net income greater than $25 million using the BE-10B form, for which parents are required to list their sales in (up to seven, including the primary) industries.[32]

[32] See U.S. Bureau of Economic Analysis (2004b) for the full forms.

Figure B3. Small Foreign Affiliates (2004)
Form BE-10B Mini

3. Country of location — Country in which this foreign affiliate's physical assets are located or where its primary activity is carried out — *Mark (X) one.*

1007

601 ☐ Australia	307 ☐ France	614 ☐ Japan	327 ☐ United Kingdom
202 ☐ Brazil	308 ☐ Germany	213 ☐ Mexico	☐ Other — *Specify*
100 ☐ Canada	611 ☐ Hong Kong	319 ☐ Netherlands	
650 ☐ China	314 ☐ Italy	325 ☐ Switzerland	

(a) Country

11. Industry classification of foreign affiliate (based on sales or gross operating revenues) — Enter the 4-digit International Surveys Industry (ISI) code(s) for the industry group that accounts for the largest amount of the affiliate's sales. A list and an explanation of, the ISI codes are given in the **Guide to Industry Classifications for International Surveys, 2002**. A summary list of ISI codes is included on Forms BE-10B(LF) and (SF). 1039

(b) Industry

Notes: This figure displays excerpts from 2004 Form BE-10B Mini indicating the country and primary industry information of foreign affiliates with assets, sales, or net income between $10 and $25 million.

Figure B4. Large Foreign Affiliates (2004)
Form BE-10B(SF)

6. Country of incorporation or organization of this foreign affiliate — *Mark (X) one.*

1006

601 ☐ Australia	307 ☐ France	614 ☐ Japan	327 ☐ United Kingdom
202 ☐ Brazil	308 ☐ Germany	213 ☐ Mexico	☐ Other — *Specify*
100 ☐ Canada	611 ☐ Hong Kong	319 ☐ Netherlands	
650 ☐ China	314 ☐ Italy	325 ☐ Switzerland	

(a) Country

Industry classification of foreign affiliate (based on sales or gross operating revenues) — Enter the 4-digit International Surveys Industry (ISI) code(s) and the sales or gross operating revenues associated with each code. For a full explanation of each code, see the **Guide to Industry Classifications for International Surveys, 2002.** For an inactive affiliate, enter an ISI code based on its last active period. Holding companies (ISI code 5512) must show total income as reported in item 45. Holding companies see **Additional Instructions** on page 12 for Part I, items 30-38.	ISI code (1)	Sales or gross operating revenues (2) Bil. Mil. Thous. Dols.
30. Largest sales or gross operating revenues 1030	1	2 $
31. 2nd largest sales or gross operating revenues 1031	1	2
32. 3rd largest sales or gross operating revenues 1032	1	2
33. 4th largest sales or gross operating revenues 1033	1	2
34. 5th largest sales or gross operating revenues 1034	1	2
35. 6th largest sales or gross operating revenues 1035	1	2
36. 7th largest sales or gross operating revenues 1036	1	2
37. Sales or gross operating revenues not accounted for above 1037		2
38. TOTAL SALES OR GROSS OPERATING REVENUES — ***Sum of items 30 through 37*** *(Must equal item 41 and also item 100, column (1).)* → 1038		2 $

(b) Industry

Notes: This figure displays an excerpt from 2004 Form BE-10B(SF) indicating the country and industry information of foreign affiliates with assets, sales, or net income greater than $25 million.

A MNE's global production network in our analysis comprises all combinations of a parent (with corresponding main industry) and its foreign production units, i.e., the country-industry pair corresponding to the parent's foreign affiliates. Our sample thus includes all observed combinations (in the manufacturing sector) of parent industry (j) reported in BE-10A (primary industry only) and affiliated country (c) - industry (i) reported in BE-10B (maximum of seven industries per affiliate).

Table B1 illustrates the information on a parent's foreign affiliates that can be extracted from the BE-10 forms. In this hypothetical example, a U.S. parent p has 5 foreign affiliates across Mexico (a_1), Canada (a_2), Germany (a_3), France (a_4), and China (a_5).[33] All affiliates are active in industry 1, which is their primary industry. Some affiliates are also active in other industries (a_1 and a_2 also operate in industries 2; a_1 also operates in industry 3). Some affiliates (a_1, a_2, a_3) are large (i.e., exceed the size threshold above which the BEA collects information on total trade between the parent and the affiliate), others (a_4, a_5) are small (i.e., below the size threshold at which BEA does not collect information on intrafirm trade).

Table B1. Hypothetical Foreign Affiliates of a U.S. Multinational Parent

Parent	Affiliate	Country	Industry	Large
p	a_1	Mexico	1, 2, 3	1
p	a_2	Canada	1,2	1
p	a_3	Germany	1	1
p	a_4	France	1	0
p	a_5	China	1	0

Notes: This table illustrates the hypothetical network structure of a U.S. MNE based on forms BE-10A Supplement A, BE-10B(SF), and BE-10B Mini. "Large" refers to whether the affiliate meets the threshold for reporting intrafirm trade.

Table B2 illustrates all the foreign production unit in this example, i.e., the country-industry pairs corresponding to the parent's foreign affiliates. In this hypothetical example, these are: Mexico, industry 1; Mexico, industry 2; Mexico, industry 3; Canada, industry 1; Canada, industry 2; Germany, industry 1; France, industry 1; China, Industry 1.

[33]An affiliate is not equivalent to an establishment. As discussed before, information on affiliates is collected on a consolidated basis. If a parent has multiple estabslishments in the same country, it provides consolidated information about them in the same BE-10 form.

Table B2. Hypothetical Production Units of a U.S. Multinational Parent

Parent	Foreign Production Units		BEA Collects Data on Intrafirm Trade
	Country	Industry	
p	Mexico	1	yes
p	Mexico	2	yes
p	Mexico	3	yes
p	Canada	1	yes
p	Canada	2	yes
p	Germany	1	yes
p	France	1	no
p	China	1	no

Notes: This table illustrates the unit of observation in a hypothetical MNE global production network.

Researchers relying on BEA survey data on intrafirm trade could not include in their analysis the production units in France and Germany, since these correspond to small affiliates (i.e., assets, sales, or net income smaller than $25 million). As discussed in Section 3 of the paper and Section A.1 of the Appendix, beyond the missing flows due to the reporting threshold, survey data on trade between a parent and its foreign production units suffer from other type of measurement error, which make it hard to identify the role of IO linkages: false negatives and false positives (due to respondent error) and from false positive and missing industry-specific flows (due to reporting only total intrafirm trade in the BEA surveys).

B.1.2 Mapping Intrafirm Trade in Customs Records to MNEs' Global Production Networks

We use the LFTTD to trace trade flows within U.S. multinationals. Customs data enable us to identify all trade flows between parent p and its "related parties" in a foreign country. We use any related-party transactions by country to identify an intrafirm flow. Figure B5 (B6), item 36.C (1.c), shows an excerpt of the information filed by U.S. importers (exporters) indicating whether a transaction takes place between related parties. The LFTTD does not contain any information on the industry in which a foreign buyer (in an export transaction) or foreign supplier (in an import transaction) operates. We rely on the mapping between the HTS classification of the traded product and a 4-digit NAICS to identify the affiliated country-industry pair in an intrafirm trade flow.

When identifying an intrafirm import flow, we consider parents' related-party imports of products (HTS codes) from a country that map to an affiliate country-industry. Using the hypothetical example of Tables B2- B1, we consider that parent p imports from the production unit located in Mexico and operating in industry 1 if we observe a related-party import transaction from Mexico by parent p in products that map to industry 1.

When identifying an intrafirm export flow, we analogously consider parents' related-party exports of products (Schedule B codes) to country that map to an affiliate country-industry. Going back to the hypothetical production network in Table B2-B1, we consider that parent p exports to the production unit located in Mexico and operating in industry 1 if we observe a related-party export transaction to Mexico by parent p in products that map to industry 1.[34]. Using trade statistics by industry and product (U.S. Census Bureau, 2025e), we calculate that, on average, around 60% (70%) of the products at the 6-digit Schedule B level that are exported (imported) are also imported (exported) by firms in a single 4-digit manufacturing NAICS industry. Given the high degree of overlap between exported and imported products within an industry, our approach is likely to capture most intrafirm export flows in manufacturing.

[34]We thus do not consider related-party exports of goods that fall in the main industry of the parent, unless they also fall in the industry of the affiliate country-industry

Figure B5. Intrafirm Imports
Sample Form 7501

DEPARTMENT OF HOMELAND SECURITY
U.S. Customs and Border Protection
ENTRY SUMMARY

OMB CONTROL NUMBER 1651-0022
EXPIRATION DATE 11/30/2025

1. Filer Code/Entry Number	2. Entry Type	3. Summary Date	4. Surety Number	5. Bond Type	6. Port Code	7. Entry Date

8. Importing Carrier	9. Mode of Transport	10. Country of Origin	11. Import Date
12. B/L or AWB Number	13. Manufacturer ID	14. Exporting Country	15. Export Date

16. I.T. Number	17. I.T. Date	18. Missing Docs	19. Foreign Port of Lading	20. U.S. Port of Unlading

21. Country of Melt and Pour	22. Primary Country of Smelt
23. Secondary Country of Smelt	24. Country of Cast
25. Location of Goods/G.O. Number 26. Consignee Number	27. Importer Number 28. Reference Number
29. Ultimate Consignee Name (Last, First, M.I.) and Address Street City State Zip	30. Importer of Record Name (Last, First, M.I.) and Address Street City State Zip

31. Line No.	32. Description of Merchandise: 33. A. HTSUS No. B. AD/CVD No.	34. A. Gross Weight B. Manifest Qty.	35. Net Quantity in HTSUS Units	36. A. Entered Value B. CHGS C. Relationship	37. A. HTSUS Rate B. AD/CVD Rate C. IRC Rate D. Visa Number	38. Duty and IR Tax: Dollars Cents

Other Fee Summary (for Block 39)	39. Total Entered Value $ Total Other Fees $

CBP USE ONLY		TOTALS
A. LIQ Code	B. Ascertained Duty	41. Duty
REASON CODE	C. Ascertained Tax	42. Tax
	D. Ascertained Other	43. Other
	E. Ascertained Total	44. Total

40. Declaration of Importer of Record (Owner or Purchaser) or Authorized Agent

I declare that I am the Importer of record and that the actual owner, purchaser, or consignee for CBP purposes is as shown above, OR owner or purchaser or agent thereof. I further declare that the merchandise was obtained pursuant to a purchase or agreement to purchase and that the prices set forth in the invoices are true, OR was not obtained pursuant to a purchase or agreement to purchase and the statements in the invoices as to value or price are true to the best of my knowledge and belief. I also declare that the statements in the documents herein filed fully disclose to the best of my knowledge and belief the true prices, values, quantities, rebates, drawbacks, fees, commissions, and royalties and are true and correct, and that all goods or services provided to the seller of the merchandise either free or at reduced cost are fully disclosed.
I will immediately furnish to the appropriate CBP officer any information showing a different statement of facts.

45. Declarant Name (Last, First, M.I.)	Title	Signature	Date

46. Broker/Filer Information Name (Last, First, M.I.) and Phone Number	47. Broker/Importer File Number

CBP Form 7501 (07/25) Page 1 of 26

Notes: This figure displays an excerpt of Form 7501 filed by U.S. importers at the time of importation.

Figure B6. Intrafirm Exports
Sample Shipper's Export Declaration Form

U.S. DEPARTMENT OF COMMERCE - BUREAU OF THE CENSUS - INTERNATIONAL TRADE ADMINISTRATION

FORM **7525-V** (1-1-88) **SHIPPER'S EXPORT DECLARATION** OMB No. 0607-0018

1a. Exporter *(Name and address including ZIP code)*

ZIP CODE

2. DATE OF EXPORTATION

3. BILL OF LADING/AIR WAYBILL NO.

b. EXPORTER'S EIN (IRS) NO.

c. PARTIES TO TRANSACTION ☐ Related ☐ Non-related

4a. ULTIMATE CONSIGNEE

b. INTERMEDIATE CONSIGNEE

5. FORWARDING AGENT

6. POINT (STATE) OF ORIGIN OR FTZ NO.

7. COUNTRY OF ULTIMATE DESTINATION

8. LOADING PIER (Vessel only)

9. MODE OF TRASPORT (Specify)

10. EXPORTING CARRIER

11. PORT OF EXPORT

12. PORT OF UNLADING (Vessel and air only)

13. CONTAINERIZED (Vessel only) ☐ Yes ☐ No

14. SCHEDULE B DESCRIPTION OF COMMODITIE } *(Use columns 17-19)*
15. MARKS, NOS., AND KINDS OF PACKAGES }

D/F (16)	SCHEDULE B NUMBER (17)	CHECK DIGIT	QUANTITY - SCHEDULE B UNIT(S) (18)	SHIPPING WEIGHT *(Kilos)* (19)	VALUE (U.S. dollars, omit cents) (Selling price or cost if not sold) (20)

21. VALIDATED LICENSE NO./GENERAL LICENSE SYMBOL

22. ECCN *(When required)*

23. Duly authorized officer or employee — The exporter authorizes the forwarder named above to act as forwarding agent for export control and customs purposes.

24 I certify that all statements made and all information contained herein are true an correct and that I have read and understand the instructions for preparation of this document, set forth in the **"Correct Way to Fill Out the Shipper's Export Declaration."** I understand that civil and criminal penalties, including forfeiture and sale, may be imposed for making false or fraudulent statements herein, failing to provide the requested information or for violation of U.S. laws on exportation (13 U.S.C. Sec. 305; 22 U.S.C. 401; 18 U.S.C. Sec. 1001; 50 U.S.C. App. 2410).

Signature — **Confidential** - For use solely for official purposes authorized by the Secretary of Commerce (13 U.S.C. 301 (g)).

Title — Export shipments are subject to inspection by U.S. Customs Service and/or Office of Export Enforcement

Date — **25.** Authentication *(When required)*

This form may be printed by private parties provided it conforms to the official form. For sale by the Superintendent of Documents, Government Printing Office, Washington, D.C. 20402, and local Customs District Directors. The **"Correct Way to Fill Out the Shipper's Export Declaration"** is available from the Bureau of the Census, Washington, D.C. 20233

--- INTERNET VERSION -- USE AS STATISTICAL COPY ---

Clear fields 1-13

Clear fields 16-20

Clear fields 21-25

Notes: This figure displays an excerpt of Shipper's Export Declaration filed by U.S. exporters at the time of exportation.

B.1.3 Industry Concordances

Our analysis requires the application of multiple concordances since different industry classifications are used to collect information in BEA's multinational surveys, BEA's use and supply tables, and Census's customs merchandise trade data. The BE-10 survey collects information using the international surveys industry (ISI) classification (U.S. Bureau of Economic Analysis, 2022a), which is approximately equivalent to a 4-digit North American Industry Classification System (NAICS). BEA's use and supply tables compile information using a different set of industry codes (also related to NAICS), which we refer to as IO industry codes. Finally, the customs merchandise trade data (LFTTD) is collected using 10-digit Harmonized Tariff Schedule (HTS) product codes.

In order to assign a direct requirement coefficient to all possible industry pairs between a U.S. parent and its foreign affiliates, we concord the ISI to IO industry codes. First, we concord ISI to NAICS codes using concordances published by BEA (U.S. Bureau of Economic Analysis, 2022a). The majority of ISI industries are equivalent to 4-digit NAICS industries. Then we utilize a concordance between NAICS and IO industry codes (U.S. Bureau of Economic Analysis, 2007).

In order to assign industry information to merchandise trade transactions in LFTTD, we must also concord 10-digit trade product codes (HTS) for imports and Schedule B for exports) to IO industry codes. We first concord the 10-digit codes to 6-digit NAICS using concordances between 10-digit traded codes and 6-digit NAICS codes published by the Census Bureau (U.S. Census Bureau, 2025c).[35] We can then link to IO codes using BEA's IO and NAICS concordance (U.S. Bureau of Economic Analysis, 2007). The final analysis sample is at the parent-foreign production unit level, where parent and foreign production units are associated with IO industries at the 4-digit level.

[35]For our main analysis, which uses 2004 trade flows, we rely on the 2005 concordance because this is the earliest available concordance. For the 2019 analysis, we use the 2017 concordance.