Trade within Multinational Boundaries*

Laura Alfaro, Harvard University, CEPR, and NBER
Paola Conconi, Oxford University, CEPR, CESifo, and CEP
Fariha Kamal, Federal Reserve Board
Zachary Kroff, Analysis Group

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Abstract

We leverage newly linked data from the U.S. Census Bureau and the U.S. Bureau of Economic Analysis to study transactions within U.S. multinational enterprises (MNEs). We show that using administrative data on intrafirm trade allows us to correct for measurement error in survey data and to identify the positive relationship between input-output (IO) linkages and the probability of trade between U.S. parents and their foreign affiliates. We also document the prevalence of intrafirm trade: more than half (three-quarters) of affiliates worldwide (in North America) export to or import from their U.S. parent. Our findings provide strong empirical support for traditional theories of firm boundaries that predict trade between vertically linked units of the same firm, and underscore the importance of accounting for the trade frictions that shape MNEs' regional supply chains.

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*Author contact: `lalfaro@hbs.edu`, `paola.conconi@economics.ox.ac.uk`, `fariha.kamal@frb.gov`, `zachary.kroff@gmail.com`. Any opinions and conclusions expressed herein are those of the authors and do not represent the views of the Board of Governors of the Federal Reserve System, or their research staff. This paper was written while Kamal and Kroff were economists at the U.S. Census Bureau. Kroff is an advanced analytics specialist at Analysis Group. The views presented in this article are those of the authors and do not represent any opinions or positions of Analysis Group or its clients. The Census Bureau and Bureau of Economic Analysis have ensured appropriate access and use of confidential data and have reviewed these results for disclosure avoidance protection (Project 6907751: CBDRB-FY23-CES007-06, BEA-FY23-P6907751-R6, CBDRB-FY24-CES007-05, BEA-FY24-P6907751-R3, CBDRB-FY25-0110, BEA-FY25-P6907751-R1, CBDRB-FY25-CES007-06, BEA-FY25-P6907751-R2). We thank Pol Antràs, Emily Blanchard, Teresa Fort, Keith Head, Kalina Manova, Jessica McCloskey, Nathan Goldschlag, Natalia Ramondo, Kim Ruhl, Martha Stinson, Stephen Yeaple, Sean Wang, and conference participants at ETSG (Surrey), Workshop on International Economic Networks (WIEN), Kiel-CEPR Workshop on Firms in International Trade, and the CEPR ERWIT conference, for helpful comments. Conconi gratefully acknowledges financial support from the European Research Council (Advanced ERC Grant Agreement No. 834253).

1 Introduction

Recent decades have seen the emergence of global supply chains (e.g., Johnson and Noguera, 2012; Antràs and Chor, 2013). Multinational enterprises (MNEs) have played a key role, fragmenting different stages of their production processes across their subsidiaries in different countries. This results in intra-MNE trade flows in both intermediate and final goods. For example, General Motors (GM) has established several assembly plants in Mexico that produce cars using engines made in GM plants in the United States; and several vehicle models are then exported from GM's Mexico plants to the United States (Head, Mayer and Melitz, 2024). 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. goods imports and about a third of U.S. goods exports (Figure 1).[1]

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 U.S. Census Bureau Related Party Trade Database (U.S. Census Bureau, 2025d).

We study trade flows within U.S. MNEs using unique new data that combines the complete mapping of multinational production networks with customs records on all U.S. merchandise trade transactions. We provide strong empirical support for traditional theories of firm boundaries, which predict that, conditional on integration, firms should utilize inputs produced within their boundaries, leading to observable trade flows between vertically linked production units of the same firm.[2]

[1]This figure is based on public-use data on related-party trade published by the U.S. Census Bureau, which are jointly reported for U.S. and foreign MNEs.

[2]Since Coase (1937)'s seminal work, a large literature in organization economics has studied firms' vertical integration decisions. Traditional theories of firm boundaries emphasize various benefits of integration, such

Influential work by Atalay, Hortaçsu and Syverson (2014) (henceforth AHS) and Ramondo, Rapoport and Ruhl (2016) (henceforth RRR) found little evidence of intrafirm trade flows for U.S. firms. Both studies rely on intrafirm trade data collected from surveys:[3] AHS use the U.S. Commodity Flow Survey to study trade between different establishments of U.S. firms, while RRR employ survey data from the U.S. Bureau of Economic Analysis (BEA) on trade within U.S. multinational enterprises. Two puzzling findings emerge. First, while vertical linkages matter for integration choices, they do not affect intrafirm trade: the input–output (IO) coefficient linking the industries of operation of parents and affiliates does not predict whether they 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 challenge prevailing theories of firm boundaries, which posit that ownership should facilitate intrafirm transfers of inputs. 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?" Their answer is that ownership enables "the efficient transfer 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).

We reassess the evidence using administrative data on intrafirm trade (customs records) from the U.S. Census Bureau combined with data on multination production network from U.S. Bureau of Economic Analysis (BEA). This linked dataset allows us to correct for measurement error in survey data on intrafirm trade.[4]

We measure intra-MNE trade using customs records from the U.S. Census Bureau's Longitudinal Firm Trade Transactions Database (LFTTD).[5] This dataset covers the universe of U.S. merchandise trade transactions, including those between multinational parents and

as 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). The insights of these theories have been extended to MNEs (e.g., Helpman, 1984; Antràs, 2003; Antrás and Yeaple, 2014).

[3]Data on the universe of intrafirm trade flows is not widely available. For select countries, data from value-added tax (VAT) declarations allow observing transactions within domestic production networks. For example, data on firm-to-firm transactions are available for Belgium (e.g., Bernard et al., 2022), Chile (e.g., Arkolakis et al., 2023), and Turkey (e.g., Demir et al., 2009). However, these data provide information on the value of the transactions, not on what is being traded. Moreover, intrafirm transactions can only be observed if different establishments of the same firm have different VAT identifiers.

[4]"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).

[5]The ability to combine data from the U.S. Census Bureau and the BEA is made possible by an interagency agreement between the institutions. To link these datasets, researchers have developed crosswalks

their affiliates, defined as related-party trade. We link LFTTD to comprehensive data from BEA on the production networks of U.S. MNEs. We also utilize the supply and use tables published as part of BEA's Input-Output accounts to measure vertical linkages between industries.

Customs transaction records enable us to correct different types of measurement error that arise when using BEA survey data on goods trade flows between multinational parents and their affiliates.[6] First, *some transactions may not be recorded* in the BEA's survey (e.g., due to interviewer's or respondent's error or imperfect recall). As a result, researchers may erroneously infer a lack of intra-MNE trade flows. By contrast, LFTTD is based on administrative customs records; we can thus observe *all transactions* between a parent and its foreign affiliates, which allows us to correct false 0's in intra-MNE trade. Relatedly, the BEA foreign direct investment surveys only collect data on intrafirm trade for affiliates *above a certain size threshold*, such that intrafirm trade information for smaller affiliates is missing.[7] There is *no reporting threshold* for U.S. traders in the LFTTD, thus providing information on transactions between U.S. parents and *all* of their foreign affiliates. Second, the BEA's survey reports the *total* value of 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 generates two empirical challenges. First, researchers may erroneously infer intra-MNE trade flows involving the affiliate's primary industry. Second, they may disregard trade flows involving the affiliates' other industries. LFTTD records 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 1s (in the affiliate's primary industry) and missing values (in the affiliate's other industries).

It is well known that measurement error in a binary dependent variable 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 BEA survey data on intrafirm trade (false 0s, false 1s, missing values) leads both to attenuation and higher error variance, making it harder to identify the role of IO linkages: after correcting each type of measurement error, the point estimate of the IO linkage measure becomes increasingly

between firm identifiers used in the BEA data and the firm identifiers in the Census Bureau's Business Register used in customs records (Kamal et al., 2022).

[6] Ruhl (2015) points to measurement error as a possible source of the discrepancy between aggregate statistics on intra-MNE trade based on Census customs records and those based on BEA survey data. He shows that during 1992-2012, intra-MNE import shares remained flat (at around 45%) in the Census data, while they trended down (ending at around 35%) in the BEA data. As he underscores, understanding the role of measurement error in explaining this gap requires studying the underlying confidential microdata.

[7] The threshold is based on assets, sales, or net income (loss) greater than $25 million.

larger and more precisely estimated.

By replacing survey data on intra-MNE trade with administrative data, we can thus overturn the first puzzle concerning the role of vertical linkages: the IO coefficient linking the industries of operation of parents and affiliates *do* predict the extensive margin of trade between them. In our baseline specification, a 10 percentage point (pp) increase in the IO linkage increases the probability that the parent imports from (exports to) foreign production units by 29% (21%) relative to the average probability of intra-firm trade in our data.

We also qualify the second puzzle concerning the sparsity of intrafirm trade. As mentioned before, previous studies document that 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 results have been interpreted as evidence of a "lack of physical shipments linking sites within the multiplant firm" and a "similar lack of shipments across sites within U.S. multinational firms," providing a rationale for theories of the firm in which ownership is driven by transfers of intangibles (Bilir and Morales, 2020).

Using our newly linked survey and administrative data, we document that more than half of all foreign affiliates trade with their U.S. parents (53% in 2004, 57% in 2019). The prevalence of intrafirm trade increases significantly once we account for the regional nature of MNE's supply chains: when focusing on production units in North America, we find that three quarters of them (73%, in both 2004 and 2019) trade with their U.S. parents. This is not surprising, given that multinationals tend to organize their production along regional supply chains, described as "Factory North America," "Factory Europe," and "Factory Asia" (Baldwin, 2013).[8] Trading with foreign affiliates in nearby countries involves lower transport and communication costs compared to affiliates in more distant countries (Keller and Yeaple, 2013). In the case of U.S. multinationals, trading with affiliates in Canada and Mexico also involves lower tariffs, conditional on complying with the rules of origin of the North American Free Trade Agreement (NAFTA), which entered into force in 1994 and was replaced by the United States-Mexico-Canada Agreement (USMCA) in 2020 (Conconi et al., 2018).

These statistics should be considered lower bounds of the share of affiliates trading with their parents, for two reasons. First, they are based on direct exports and imports between affiliates and their parents; trade flows that go through other affiliates or third-party firms cannot be traced in our data. Second, administrative customs records do not account for

[8]For example, Head et al. (2025) show that U.S. MNEs in the motor vehicles industry own vertically related plants in many countries around the world, but mostly source inputs from their North American subsidiaries for production in North America.

intra-MNE trade flows in all industries.[9]

The finding that three-quarters of affiliates in North America trade with their parent suggests that U.S. tariffs can be extremely disruptive for U.S. MNEs, particularly when applied to regional trading partners. Indeed, U.S. automakers with extensive North American supply chains have advocated fo the easing of the 2025 U.S. tariff increases on imports from Canada and Mexico (Wall Street Journal, 2025b).

This is the first paper to combine data on the production network of U.S. multinationals with U.S. customs records to study the relationship between input-output linkages and intra-MNE trade flows and to document a regional bias in these flows.[10] Our analysis is related to a series of recent papers that have used administrative data on intrafirm trade from other countries. Using customs data from France, Berlingieri et al. (2021) examine the relationship between input-output linkages and the intensity of intra-MNE flows. They find that French MNEs tend to source technologically more important inputs from affiliated parties.[11] Using firm-to-firm data for India and South Korea respectively, Garg et al. (2023) and Hong (2021) document the prevalence of transactions within domestic multi-plant firms. Garg et al. (2023) find that around 40% of products are sourced by establishments exclusively from within the firm when a vertically integrated supplier exists. Hong (2021) finds that almost 90% of all manufacturing firms report either sales to or purchases from a related party. These findings contrast with those of AHS based on survey data on trade within multi-plant firms in the United States.

This paper is organized as follows. Section 2 describes the data used in our empirical analysis. In Section 3, we show how using transaction-level data on intrafirm goods trade allows us to correct measurement error in survey data and to identify the role of input-output linkages. In Section 4, we document the prevalence of trade within U.S. MNEs, particularly after accounting for the regional nature of their supply chains. Section 5 concludes, discussing the implications of our findings for the theoretical and empirical literatures on firm boundaries and avenues for future research.

[9] LFTTD does not cover trade flows in services. Moreover, when looking at parents' related-party exports, we cannot account for parents' related-party exports in all of their affiliates' manufacturing sectors. See Appendix A.1.2 for details on how we code related-party imports and exports in MNE production networks.

[10] Building on Kamal et al. (2022), Antràs et al. (2024) also link MNE production networks to customs records to examine patterns in U.S. parents' trade with both affiliated and unaffiliated parties to rationalize these patterns in a model featuring fixed costs of sourcing and sales that are shared across MNE's plants.

[11] The authors examine how input-output linkages affect the intensity of French MNEs' imports from affiliated versus unaffiliated parties. We examine instead whether IO linkages predict the extensive margin of trade between U.S. multinational parents and their foreign affiliates.

2 Data

In our analysis, we combine three datasets to examine the existence of trade flows within MNE production networks and evaluate whether they are predicted by input-output relationships between parents and affiliates: comprehensive data from the BEA on the production network of U.S. multinationals; customs records from the U.S. Census Bureau on the universe of U.S. merchandise trade transactions; and input-output tables from the BEA. In this section, we describe each of these datasets and how we link them thanks to a joint project between the Census Bureau and BEA.

2.1 Production Networks of U.S. Multinationals

We utilize data from BEA's confidential and mandatory direct investment surveys to obtain the most comprehensive available information on the industrial structure of U.S. multinational firms. These data are widely used in the literature examining U.S. MNEs, as they provide detailed information about each parent company and its foreign affiliates (e.g., Yeaple, 2003; Hanson et al., 2005; Bilir and Morales, 2020; Antràs et al., 2024). They also form the basis for official statistics on the activities of multinational enterprises, which provide 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).

In our main analysis, we use the 2004 Benchmark Survey of U.S. Direct Investment Abroad (Form BE-10) (U.S. Bureau of Economic Analysis, 2019c), for comparability with RRR, and focus on majority-owned affiliates (i.e., ownership share above 50 percent).[12] We further use the 2019 Benchmark Survey of U.S. Direct Investment Abroad to provide a long-term view of the main results and reported in Section 4.

We use the combination of parent and its main industry along with foreign affiliate-by-industry as the basis for identifying the complete production network of U.S. parent firms. We restrict attention to all parent–affiliate industry pairs in the manufacturing sector. Appendix Section A.1 provides details about the sample construction.

[12] In the BEA data, the term "foreign affiliate" refers to a single foreign business enterprise owned by a U.S. parent or a consolidated group of foreign business enterprises owned by the same U.S. parent, located in the same country, and with the same primary 4-digit industry or that are "integral parts of the same business operation" (U.S. Bureau of Economic Analysis, 2004).

2.2 Intrafirm Trade

We use the Longitudinal Firm Trade Transactions Database (LFTTD), maintained by the U.S. 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 et al., 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 of merchandise goods.

We utilize LFTTD to measure a U.S. firm's exports and imports by detailed 10-digit Harmonized System (HS) product, 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 transactions in LFTTD provide the central foundation for our analysis. Kamal et al. (2022) describe the efforts from a multi-year project between the U.S. 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.[13] The crosswalks are developed by linking firm-level surveys on direct investment conducted by BEA and the U.S. Census Bureau's Business Register (BR), spanning the universe of employer businesses using information on business tax identifiers, name, address,

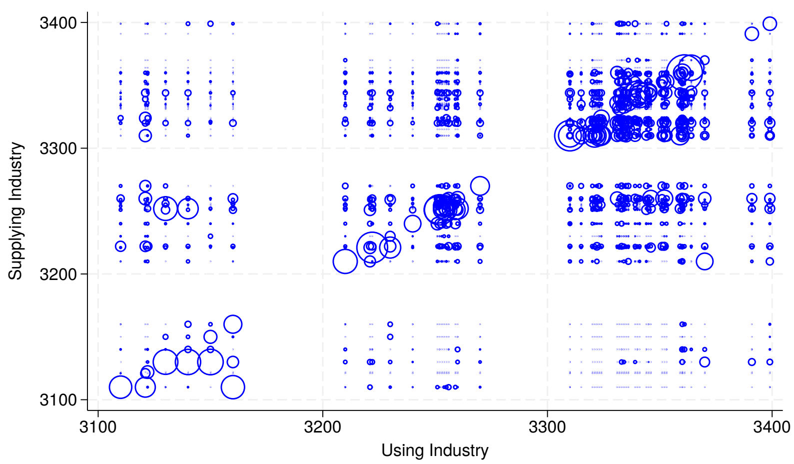
[13] Relatedly, Antràs et al. (2024) build on the matching methods developed within the inter-agency project to augment ownership information in the BEA surveys with the U.S. Census Bureau's Company Organization Survey that provided the sole direct source of information on any changes in multi-establishment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

industry, and employment. The crosswalks were available beginning in 1997 and updated as new years become available.

2.4 Input-Ouput 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-Ouput accounts (U.S. Bureau of Economic Analysis, 2025b).[14] We use the 2002 supply and use tables and focus on vertical linkages between manufacturing industries.

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



Notes: The figure plots direct requirements coefficients from the 2002 BEA input-output tables, focusing on manufacturing industries. The direct requirement coefficient is the value of goods needed from the supplying (upstream) industry in order to produce one dollar of output in the using (downstream) industry. Bubbles are proportional to the size of the direct requirement coefficient.

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

[14] A recent body of research measures input-output linkages at the U.S. firm level, linking import transactions in the LFTTD to detailed materials usage reported by manufacturing establishments in the Census of Manufactures (e.g., Feenstra and Jensen, 2012; Antràs et al., 2024; Flaaen et al., 2025). We rely on aggregate input-output relationships to enable comparability with prior work on vertical integration (e.g., Acemoglu et al., 2009; Fajgelbaum et al., 2015; Alfaro et al., 2016, 2019). Moreover, firm-level input-output linkages are endogeneous to their trade decisions; aggregate input-output tables are more informative of linkages across industries that are determined by technology (Acemoglu et al., 2009).

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 illustrates variation in IO_{ij} for all manufacturing industries.

3 Intrafirm Trade and Input-Output Linkages

Previous work based on survey data did not find a robust relationship between IO linkages and the existence of trade between foreign affiliates and their U.S. parents. In this section, we re-examine this relationship leveraging administrative data on intrafirm trade combined with a complete mapping of MNEs' production networks.

To identify the role of IO linkages in the extensive margin of intra-MNE trade, we estimate the following linear probability model:

$$\mathbb{I}(\textit{Intrafirm Imports}_{p(j),a(c,i)}) = \beta_0 + \beta_1 IO_{ij} + \delta_c + \delta_i + \delta_p + \epsilon_{p(j),a(c,i)}. \quad (1)$$

The dependent variable, $\mathbb{I}(\textit{Intrafirm Imports}_{p(j),a(c,i)})$, is an indicator for whether parent p (operating in industry j) imports from its foreign affiliate a (located in country c and operating in industry i). The unit of analysis is a parent-foreign production unit, where a foreign production unit is a country-industry pair (c, i) in which the U.S. multinational parent has a foreign affiliate. 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 supplemetal analysis, we also estimate an analogous specification for parent p's exports:

$$\mathbb{I}(\textit{Intrafirm Exports}_{p(j),a(c,i)}) = \beta_0 + \beta_1 IO_{ji} + \delta_c + \delta_i + \delta_p + \epsilon_{p(j),a(c,i)}. \quad (2)$$

The dependent variable, $\mathbb{I}(\textit{Intrafirm Exports}_{p(j),a(c,i)})$, is an indicator for whether parent p (operating in industry j) exports to its 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. 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.[15] Moreover, parents and affiliates may trade 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.[16]

3.1 Measurement Error in Survey Data on Intrafirm Trade

In what follows, we present a hypothetical example to illustrate the different types of measurement error that arise when using BEA survey data to measure trade within U.S. MNEs. We then discuss how non-classical measurement error leads to biased estimates and higher error variance when estimating equations (1) and (2).

Hypothetical Example

Table 1 provides a hypothetical example of trade between a U.S. parent and its foreign affiliates (building on Table A1 in the Appendix). The example focuses on a parent's imports from its affiliates, but the same considerations apply when looking at intra-MNE flows in the opposite direction.

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	Industry 2
Parent's imports	1	0	1	0	1	1	1	0	1

The table shows a multinational parent that has foreign affiliates in five countries (Mexico, Canada, Germany, France, and China). Three of these affiliates (A, B, and C) are large (in terms of assets, sales, and net income), while the other two (D and E) are small. All affiliates are active in industry 1, which is their primary industry. Some affiliates are also active in other industries: A also operates in industries 2 and 3, B and E in industry 2.

The bottom row of the table shows that the parent imports from all affiliates, but not from all production units (the country-industry pairs in which the affiliates are active). For example, it imports from affiliate A in industries 1 and 3, but not in industry 2. Similarly, it imports from affiliates B and E in industry 2, but not in industry 1.

[15] Our findings are robust to excluding the diagonal (results available upon request).

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

Table 2 illustrates the different types of misclassification that can arise when a researcher has comprehensive information from the BEA about the MNE's production structure, but relies on BEA survey data to populate intra-MNE trade (indicated in the yellow-shaded row).

Table 2. Hypothetical Example of Trade Between a Parent and Its Affiliates: Measurement 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	Industry 2
Parent's imports	1	0	1	0	1	1	1	0	1
BEA Survey	1			1		0			

First, *some flows may not be recorded* (e.g., due to survey fatigue, imperfect recall, etc.), leading to false 0s. For example, flows between affiliate C and its parent may not be recorded in the survey form, which could lead researchers to erroneoulsy conclude that the parent does not import from affiliate C in industry 1.

Second, survey data collects 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 1s in the dependent variable, as in the case of affiliate B. 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 (i.e., those with assets, sales, or net income (loss) greater than $25 million). Researchers relying on this survey would thus have *no information on small affiliates* a parent's imports from these affiliates, as in the case of imports from affiliate D in industry 1 and imports from affiliate E in industry 2.

Non-Classical Measurement Error

The example above illustrates that using survey data to estimate (1) and (2) gives rise to measurement error in the dependent variable, due to misclassification (false 0s and false 1s) or missing data. As discussed below, this results in non-classical measurement error, leading to biased estimates and higher error variance.

Data often correspond only imperfectly to the theoretical constructs presented in the model (Greene, 2003). The difference between the true value of a variable and its observed value can significantly impact statistical analyses. The implications vary based on the type of measurement error, the variable involved, and the statistical method applied.

Missing data can at times can be considered "as an extreme form of measurement error" (Blackwell et al., 2017). Missing data 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 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 et al., 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.[17]

Misclassification of a binary dependent variable is a type of non-classical measurement error (not additive and correlated with true value). In linear probability models like the one estimated in equations (1) and (2), measurement error leads to biased estimates rather than simply adding noise as in the case of classical measurement error (Aigner, 1973; Bollinger, 1996; Meyer and Mittag, 2017).[18] As an illustration, consider this linear probability model:

$$y = x'\delta + \varepsilon, \tag{3}$$

where the misclassification varies with x.

If $y = 1$, the probability of misclassification is:

$$P(y^* = 0 \mid y = 1, x) = \alpha(x) = \alpha_0 + \alpha_1 x. \tag{4}$$

[17] 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).

[18] See Chen et al. (2011) for an overview of the literature on measurement error in nonlinear models. Papers examining surveys have found high misclassification in binary variables, e.g., Bound et al. (2001).

If $y = 0$, the probability of misclassification is:

$$P(y^* = 1 \mid y = 0, x) = \beta(x) = \beta_0 + \beta_1 x. \tag{5}$$

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, the conditional expectation of y^* given x is:

$$E[y^* \mid x] = (1 - \alpha(x))P(y = 1 \mid x) + \beta(x)P(y = 0 \mid x). \tag{6}$$

Substituting $P(y = 1 \mid x) = x'\delta$ and $P(y = 0 \mid x) = 1 - x'\delta$, and expanding the terms, we obtain:

$$E[y^* \mid x] = \beta_0 + \beta_1 x + (1 - \alpha_0 - \beta_0 - \alpha_1 x - \beta_1 x)x'\delta. \tag{7}$$

If we estimate an OLS regression of y^* on x:

$$y^* = \gamma_0 + x'\gamma_1 + \eta, \tag{8}$$

the estimated coefficient γ_1 is:

$$\gamma_1 = (1 - \alpha_0 - \beta_0 - \alpha_1 E[x] - \beta_1 E[x])\delta. \tag{9}$$

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.

When using survey data to study the extensive margin of trade between a parent and its affiliate ($\mathbb{I}(\textit{Intrafirm Imports}_{p(j),a(c,i)})$ or $\mathbb{I}(\textit{Intrafirm Exports}_{p(j),a(c,i)})$), the direction of the bias of the input-output (IO) coefficient is thus an empirical question. As shown below, our results using administrative customs records on intra-firm trade indicate that misclassification in the intra-firm trade indicator leads to noisy and downwards biased estimates of the input-output coefficient (see Table 7).

3.2 Correcting Measurement Error with Customs Records

We next show how we can use Census customs records to correct each type of measurement error that arises when using BEA survey data on intrafirm trade.

Hypothetical Example

We go back to the hypothetical example above to illustrate how we can use data from LFTTD to correct each type of measurement error. We proceed in 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, we can correct a 0 with a 1 if customs records show parent's related-party imports from Germany in industry 1 (which are not recorded in the BEA survey data).

Table 3. Hypothetical Example of Trade Between a Parent and Its Affiliates: Correcting False 0s

	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	Industry 2
Parent's imports	1	0	1	0	1	1	1	0	1
BEA Survey	1			1		0			
Customs records	1			1		1			

In a second step, illustrated in Table 4, we can correct false 1s 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 allocate all flows to an affiliate's main industry. In some cases, this can lead to false 1s 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 1s

	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	Industry 2
Parent's imports	1	0	1	0	1	1	1	0	1
BEA Survey	1			1		0			
Customs records	1			1		1			
Customs records	1			0		1			

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 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	Industry 2
Parent's imports	1	0	1	0	1	1	1	0	1
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 and all their associated industries, as shown in Table 6. We can, for example, include observations related with trade between the parent and the production units corresponding to affiliate E, coding them 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) and with a 1 if we observe related-party imports (e.g, from China, in industry 2).

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	Industry 2
Parent's imports	1	0	1	0	1	1	1	0	1
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	1

Empirical Application

We next show how we can use actual administrative customs records to correct each type of measurement error that arises when using survey data on intrafirm trade. Table 7 illustrates how correcting false positives, false negatives, and missing data helps us to identify the β_1 coefficient in equation (1).[19]

[19] As discussed before, the unit of observation in these regressions is a parent-foreign production unit, where the foreign production units are all the country-industry pairs in which the parent's affiliates are active. In the hypothetical example of Table 1, the relevant production units 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; China, Industry 2.

In column 1, we only consider U.S. parents' imports from their large foreign affiliates (i.e., those with assets, sales, or net income (loss) greater than $25 million) and restrict the sample of intra-MNE trade in the affiliate's primary industry. In this exercise, we use data on total trade flows between foreign affiliate a and parent p to construct the dependent variable. By doing so, we correct only for possible measurement error associated with false 0s in survey data. The coefficient of IO_{ij} is positive but not statistically significant.

In column 2, we extend the analysis to all foreign affiliates, addressing the problem of missing values that arise due to the BEA reporting threshold. Comparing columns 1 and 2, this leads to a substantial increase in sample size (from 3,900 to 6,200 observations); the coefficient of IO_{ij} increases in magnitude and becomes significant at the 5% level.

In columns 3–4, we reproduce the same structure of columns 1-2, still restricting the analysis to affiliates' primary industry (the number of observations is unchanged). However, we correct additional measurement error in the dependent variable by only coding it as 1 if we observe in the customs data trade flows between a and p involving the affiliate's primary industry (i.e., correcting for measurement error associated with false 1s in survey data). As a result, the coefficient of IO_{ij} increases in both size and significance. For example, in the restricted sample of large affiliates, this changes from 0.27 (not significant) in column 1 to 0.598 (significant at the 5% level) in column 3. Similarly, when including all affiliates, the coefficient of IO_{ij} increases from 0.363 (significant at the 5% level) in column 2 to 0.574 (significant at the 1% level) in column 4.

In columns 5–6, we address the problem of missing values in BEA survey data associated with trade flows involving affiliates' secondary industries. For this purpose, we extend the sample to all industries in which foreign affiliates are active and use customs data to correctly allocate trade flows to each industry. This leads to an increase in sample size. For example, the number of observations increases from 3,900 in column 3 to 4,900 in the corresponding specification of column 5. Crucially, the coefficient IO_{ij} is now significant at the 1% level in all specifications and becomes larger (e.g., it increases from 0.598 in column 3 to 0.847 in the corresponding specification in column 5).

The results in Table 7 suggest that different types of misclassification in survey data on intrafirm trade (false 0s, false 1s, missing values) lead to biased estimates and increase error variance, making it harder to identify the role of IO linkages. The large and significant estimates that we obtain once we correct for measurement error indicate that production linkages strongly predict intrafirm trade.

Table 7. Input-Output Linkages and Intra-MNE Trade Flows
Correcting Measurement Error Using BEA-Census Linked Data

Dependent Variable	$\mathbb{I}(\mathit{Intrafirm\ Imports}_{p(j),a(c,i)})$					
	(1)	(2)	(3)	(4)	(5)	(6)
Affiliate Sample	Large	All	Large	All	Large	All
Affiliate Industry	Primary only		Primary only		All	
IO_{ij}	0.270	0.363**	0.598**	0.574***	0.847***	0.819***
	(0.228)	(0.177)	(0.255)	(0.195)	(0.22)	(0.192)
Observations	3,900	6,200	3,900	6,200	4,900	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
Intra-MNE Trade Flows	Census administrative customs records					
Measurement Error Correction	False 0s	Missing Data	False 1s	Missing Data	Missing Data	Missing Data

Notes: This tables displays the results of estimating equation (1) on different samples using LFTTD, BE-10, and BEA supply and use tables. "Measurement Error Correction" indicates the type of measurement error being corrected in each column; each correction is additive across columns (e.g., in column 2, we correct for both false 0s and missing data associated with small affiliates). Robust standard errors, clustered by MNE, in parentheses. Significance levels: *** 0.01, ** 0.05, * 0.1. Observation counts rounded to comply with Census Bureau disclosure avoidance rules.

3.3 Comparison with Results Based on BEA Survey Data

In Table 8, we compare the results of estimating equation (1) using administrative data on intrafirm trade with the corresponding results based on survey data.

Table 8. Input-Output Linkages and Parents' Imports From their Affiliates
Administrative Versus Survey Data on Intra-MNE Flows

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

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

Column 1 of Table 8 reproduces column 6 of Table 7, in which we estimate equation (1) correcting for all types of measurement error that arises when using survey data on intrafirm trade. The positive and significant coefficient of IO_{ij} indicates that input-output linkages between parents and affiliates predict the probability of trade between them. In terms of magnitude, 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 standard deviation increase in IO_{ij} leads to a 6.9% increase in the probability of intrafirm trade.

The estimate in column 1 stands in sharp contrast with the corresponding estimate from RRR based on BEA survey data (column 2). Not surprisingly, the number of observations is much smaller than in column 1, given that using BEA survey data forces researchers to restrict the analysis to large affiliates and to trade flows in the affiliates' primary industry.[20]

[20] Similar to our analysis, observations are defined at the level of a parent-foreign production unit, where a foreign production unit is a country-industry pair corresponding to a foreign affiliate. However, RRR use

The coefficient of IO_{ij} is small and not statistically significant.

Column 3 reproduces column 1 excluding parent fixed effects (while controlling for parent employment). The coefficient of IO_{ji} remains positive and significant at the 1% level but is much smaller in size than in column 1. These results suggest that the estimate in column 3 suffers from omitted variable bias and underscore the importance of accounting for parent-specific characteristics that can affect intra-MNE trade (e.g., productivity, industry specialization).[21]

Column 4 reproduces column 2 excluding parent fixed effects. This specification is taken from RRR (Table 3, column 3). The coefficient of IO_{ji} is again not significant when using BEA survey data to code multinational parents' imports from their affiliates.

Overall, the estimates in Table 8 confirm the message of Table 7: measurement error in survey data on intrafirm trade (false 0s, false 1s, missing values) leads to biased estimates and increase 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.

A similar conclusion can be reached when examining parents' exports to their affiliates, as shown in Appendix Table A3: the coefficient of IO_{ji} is positive and significant at the 1% level, but only when using administrative data on intra-MNE trade.

4 The Prevalence of Intrafirm Trade

As discussed in the Introduction, earlier studies based on survey data on intrafirm trade emphasize that transactions between vertically related units of the same firm are very sparse: using the U.S. Commodity Flow Survey, AHS find that almost one-half of upstream establishments in the United States do not report making shipments inside their firms; based on BEA survey data 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 MNE's production networks (BE-10) with intrafirm

BEA survey data on intrafirm trade and thus the BEA parent firm identifier in the BE-10 form; we instead use intrafirm trade data from customs records, and thus the firm identifier for the parent obtained from the Census Bureau's Business Register. Multiple BEA firm identifiers may be linked to a single Census firm identifier. See Kamal et al. (2022) for details on the crosswalk construction. The samples may also differ due to the fact that RRR exclude some affiliates for which intrafirm trade data is extrapolated in the BEA survey and we exclude affiliates located in some countries classified as tax havens (see Section A.1.1).

[21] The regressions in columns 1 and 3 are estimated using Stata's "reghdfe" command which drops singleton groups (Guimaraes and Portugal, 2010). In our context, observations with no variation within a parent are dropped leading to a lower number of observations when including parent fixed effects.

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).

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). This is only a small increase compared to RRR, who find that half of affiliates exported to or imported from their parents in 2004. One important takeaway of this exercise is that, while combining administrative data on trade flows with a complete mapping of MNEs' production networks is crucial to identifying the positive relationship between IO linkages and the extensive margin of intrafirm trade, using data from the BEA only yields similar results on the broad patterns about the prevalence of intra-MNE trade.

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

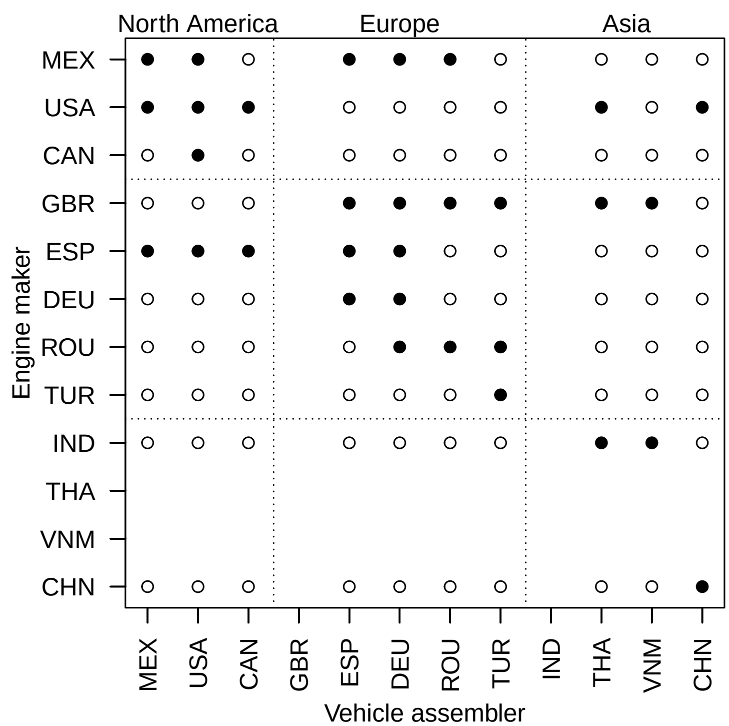
Direction of Trade	Share in 2004	Share in 2019	Affiliate Location
Parent's imports	29.6%	36.4%	All countries
Parent's exports	44.7%	48.1%	All countries
Parent's imports or exports	53.3%	56.6%	All countries
Parent's imports or exports	73.7%	73.3%	North America

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

Finally, we show that accounting for the regional nature of MNEs' supply chains increases significantly the likelihood of trade between multinational parents and their affiliates. 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 et al., 2018). When focusing on foreign production units in North America, we find that around three-quarters of them trade with their U.S. parent. This share is remarkably stable over the fifteen-year period between 2004 and 2019.

Figure 3 illustrates the regional nature of MNEs' supply chains.[22] It shows the distribution of vehicle assembly and engine-producing plants owned by Ford Motor Company, located in various countries in North America, Europe, and Asia. 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 using. Black dots indicate trade between vertically related plants. White dots indicate no trade between them (conditional on the presence of plants).

The figure shows that intra-MNE trade is generally sparse: when considering all Ford engine and assembly plants worldwide, the probability that they trade with each other is 0.31.[23] However, intra-MNE trade is prevalent within regions: when considering Ford engine

[22]We are grateful to Keith Head for generating this figure using data described in Head et al. (2025).
[23]This is the share of all black dots (31) divided by all dots (100) in Figure 3.

and assembly plants located in the same region, the average probability that they trade with each other increases to 0.60.[24] 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.[25,26]

The estimates reported in Table 9 should be considered a lower bound on intra-MNE trade, for two main reasons. First, customs records do not allow us to observe affiliate-to-affiliate trade and indirect trade (i.e., independent firms processing goods traded between U.S. parents and their affiliates). The shares of affiliates trading with the rest of the corporation are thus likely to be much larger than the shares of affiliates trading directly with their parent.[27] Second, LFTTD does not allow us to include trade flows between multinational parents and their affiliates in all sectors.[28]

The prevalence of intrafirm trade within regional supply chains has important implications for the measurement of vertical integration.[29] 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 et al., 2009; Alfaro and Charlton, 2009; Fajgelbaum et al., 2015; Alfaro et al., 2016, 2019). Our results suggest that, when applying this methodology to multinational firms, one 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.

[24]This is the share of all black dots (21) divided by all dots (35) in the diagonal squares in Figure 3.

[25]21 of the 31 black dots are in the diagonal squares in Figure 3.

[26]The degree of regional interconnectedness of automobile supply chain is exemplified by parts going back and forth multiple times during the production of a vehicle. For example, pistons (critical components of combustion engines used to convert fuel into energy to power the wheels) cross the North American border six times within the three countries through final assembly of a vehicle (Wall Street Journal, 2025a). Flaaen, Kamal, Lee and Yi (2025) document the prevalence of U.S. manufacturers' round-trip trade within North American value chains.

[27]When considering affiliates in all countries, RRR find that around three-quarters of them trade with the rest of the corporation (compared to half when looking at trade flows with their parents only).

[28]Our analysis does not include services trade flows. Also, when looking at intra-firm exports, we focus on related-party exports in goods that fall in the manufacturing industries of the foreign production units (see Appendix Section A.1.2 for a detailed discussion).

[29]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. Lafontaine and Slade (2007) provides an excellent survey.

5 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 U.S. 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. And intrafirm trade in tangible inputs is prevalent once we account for the regional structure of MNEs' supply chains.

Our finding that three-quarters of North American foreign production units trade with their U.S. parent could be rationalized using a model of multinational multi-stage production with trade costs à la Head et al. (2025).[30] However, more work is needed to understand how trade frictions shape the production structure of firms. For example, Atalay et al. (2019) show that U.S. firms systematically engage in more intrafirm shipments over longer distances, implying that internal transactions confer a "distance premium."

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. In 2022, 42% (45%) of U.S. MNEs' exports to (imports from) majority-owned foreign affiliates were with those located in Canada and Mexico. These statistics are even higher within the transportation equipment sector: 76% (85%) of intra-MNE exports (imports) were with majority-owned affiliates in North America.[31] As pointed out by Ford Motor Company CEO Jim Farley, given American automakers reliance on parts

[30] In their model, MNEs in the electric vehicle industry choose in which countries to locate battery and assembly plants. This model can give rise to regional concentration in intra-MNE trade, e.g., batteries produced in plants in North America (Asia) are used by assembly plants in North America (Asia).

[31] These shares are calculated using Tables II.H1, II.H5, II.H13 (U.S. Bureau of Economic Analysis, 2022b). Transportation equipment is defined as 3-digit NAICS 336.

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, 2025c).

Our findings provide empirical support for traditional theories of firm boundaries, such as transaction cost models and property rights models. They suggest that a key reason why firms own upstream and downstream units is that the former can supply inputs for the latter. Of course, this is not to say that other motives may not be at work. In particular, ownership may also mediate transfers of intangible inputs, as posited by AHS and RRR. However, the existence of such transfers is not needed to rationalize integration choices.

An interesting avenue for future research is to extend the analysis to 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 et al., 2022; Kamal and Kroff, 2023). Standard theories of firm boundaries apply to both tangible and intangible inputs. We would thus expect intrafirm trade in intangible inputs to also depend on IO linkages between different units of a firm.

Studying intrafirm trade in intangibles is, however, more 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).[32] As shown in this paper, reliance on survey data to measure intrafirm trade can pose key measurement challenges that make it harder to identify the role of input-output linkages. Second, services trade data are collected at the level of broad industries (intellectual property, telecommunications, computer, and information services, and other business services such as professional and management consulting, research and development services, and technical services), which is much coarser than the HS system used for trade in goods. Finally, profit-shifting motives may worsen misreporting errors, particularly in intellectual property and other business services (Jenniges et al., 2018). We leave the exploration of input-output linkages in predicting intrafirm intangible flows for future research.

[32] Confidential crosswalks have also been developed between the Census Bureau's BR and BEA's international services trade surveys: select business services and intellectual property (Kamal and Ouyang, 2022); insurance (Kamal and Ouyang, 2023b); financial services (Kamal and Ouyang, 2023a). These crosswalks are available to qualified researchers in the Federal Research Statistical Data Centers.

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A Appendix

A.1 Construction of the Sample

This section describes the construction of the sample used in our main analysis and classification rules to determine firms' output and input sectors.

A.1.1 U.S. Parents and Their Foreign Affiliates

We restrict attention to U.S. parents whose primary activity is manufacturing (see discussion below for how we assign parents a predominant industry). 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 BE-10 and BE-15 (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. To identify these firms, we search for Census firm identifiers that are on both BE-10 and BE-15 data files (applying Census–BEA crosswalks), as well as using an algorithm developed in Kamal et al. (2022). This ensures that our sample consists exclusively of U.S. multinational parents (not U.S. affiliates of foreign parents) and their foreign affiliates.

We also exclude foreign affiliates of U.S. parents that are unlikely to be involved in production. Specifically, we exclude foreign affiliates that:

1. Engage in distribution-only activities.[33]

2. Operate in tax havens—Bermuda, Cayman Islands, Hong Kong, and Singapore (Dharmapala and Hines, 2009).[34]

The benchmark survey collects employment and sales information of the U.S. parent for (up to) ten industries with the highest sales (see Figure A1). For our analysis, we assign 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. For this assignment, we apply an iterative method rather than simply choosing the single industry with the most sales.[35]

[33]These foreign affiliates are identified based on responses to Question 28 "Major activity of foreign affiliate" in Form 10B and if the response is: "seller of goods the foreign affiliate does not produce" (U.S. Bureau of Economic Analysis, 2004).

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

[35]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

Figure A1. U.S. Parent Industry Information, Form 10-A

Part II — Sales and Employment by Industry Classification

Industry Classification, Total Sales, and Employees of Fully Consolidated U.S. Reporter

Enter the 4-digit International Surveys Industry (ISI) code(s) and the sales and employment associated with each code in items 20 through 29.

Holding company (ISI code 5512) is often an invalid industry classification for a conglomerate. A conglomerate must determine its industry code based on the activities of the fully consolidated domestic U.S. business enterprise.

Column 1 – ISI Code — See the Summary of Industry Classifications on pages 18 and 19. For a full explanation of each code, see the *Guide to Industry Classifications for International Surveys, 2017* located at **www.bea.gov/naics2017**. **For an inactive U.S. Reporter, base the industry classification(s) on its last active period; for "start-ups" with no sales, show the intended activities.**

Column 2 – Sales

INCLUDE

- Total sales or gross operating revenues, excluding sales taxes, returns, allowances, and discounts.
- Fees and commissions.
- Revenues generated during the year from the operations of a discontinued business segment.
- ONLY finance and insurance companies and units should report dividends and interest.
- Total income of holding companies (ISI code 5512) as reported in item 47.

EXCLUDE

- Investment gains and losses reported in item 45.
- Sales or consumption taxes levied directly on the consumer.
- Excise taxes levied directly on manufacturers, wholesalers, and retailers.
- Gains or losses from DISPOSALS of discontinued operations and gains and losses from derivative instruments (report as certain gains (losses) in item 45).
- Dividends and interest earned by non-finance and non-insurance companies and units (report as other income in item 46).

NOTE: *Dealers in financial instruments and finance, insurance, and real estate companies see* ***Special Instructions*** *on page 17.*

Column (3) – Number of employees — INCLUDE all full-time and part-time employees on the payroll at the end of FY 2019 associated with each ISI code. **EXCLUDE** contract workers and other workers not carried on the payroll of this U.S. Reporter. If employment at the end of FY 2019 was unusually high or low because of temporary factors (e.g., a strike), give the number of employees that reflects normal operations. If the business enterprise's activity involves large seasonal variations, give the average number of employees for FY 2019. If precise figures are not available, provide your best estimate.

NOTE: For most U.S. Reporters, the employment distribution in column 3 is not proportional to the sales distribution in column 2. Therefore, do not distribute employment by industry in proportion to sales by industry.

What are the sales or gross operating revenues and employment by ISI code for the U.S. Reporter?

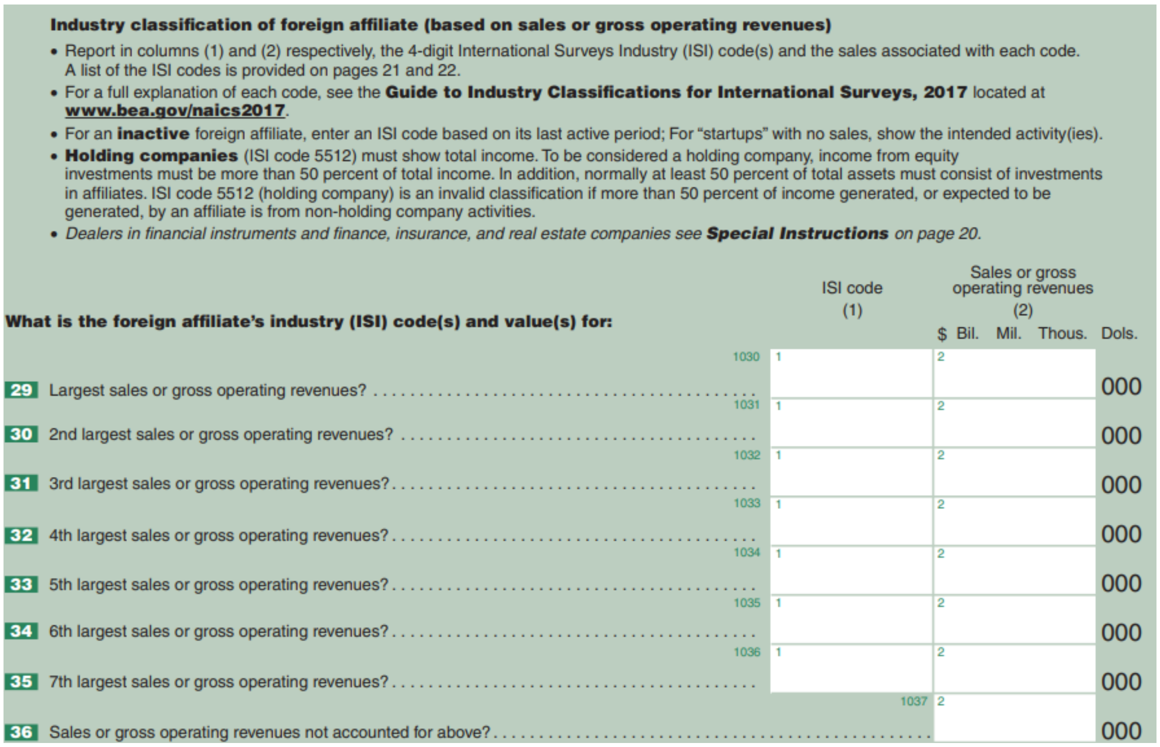
		ISI code (1)	Sales or gross operating revenues, excluding sales taxes (2) $ Bil. Mil. Thous. Dols.	Number of employees engaged in activities for the ISI codes in column (1) (3)
20 Largest sales or gross operating revenues	1015	1	2 000	3
21 2nd largest sales or gross operating revenues	1016	1	2 000	3
22 3rd largest sales or gross operating revenues	1017	1	2 000	3
23 4th largest sales or gross operating revenues	1018	1	2 000	3
24 5th largest sales or gross operating revenues	1019	1	2 000	3
25 6th largest sales or gross operating revenues	1020	1	2 000	3
26 7th largest sales or gross operating revenues	1021	1	2 000	3
27 8th largest sales or gross operating revenues	1022	1	2 000	3
28 9th largest sales or gross operating revenues	1023	1	2 000	3
29 10th largest sales or gross operating revenues	1024	1	2 000	3

Notes: This figure displays an excerpt from Form BE-10A indicating the industry information reported by the U.S. parent. See U.S. Bureau of Economic Analysis (2019a) for the full form.

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.

To construct the production network of U.S. multinationals, we use information from the BE-10B Form on the industries (up to seven) in which foreign affiliates have the highest sales (see Figure A2).[36]

Figure A2. Foreign Affiliate Industry Information, Form 10-B



Industry classification of foreign affiliate (based on sales or gross operating revenues)

- Report in columns (1) and (2) respectively, the 4-digit International Surveys Industry (ISI) code(s) and the sales associated with each code. A list of the ISI codes is provided on pages 21 and 22.
- For a full explanation of each code, see the **Guide to Industry Classifications for International Surveys, 2017** located at **www.bea.gov/naics2017**.
- For an **inactive** foreign affiliate, enter an ISI code based on its last active period; For "startups" with no sales, show the intended activity(ies).
- **Holding companies** (ISI code 5512) must show total income. To be considered a holding company, income from equity investments must be more than 50 percent of total income. In addition, normally at least 50 percent of total assets must consist of investments in affiliates. ISI code 5512 (holding company) is an invalid classification if more than 50 percent of income generated, or expected to be generated, by an affiliate is from non-holding company activities.
- *Dealers in financial instruments and finance, insurance, and real estate companies see* ***Special Instructions*** *on page 20.*

What is the foreign affiliate's industry (ISI) code(s) and value(s) for:		ISI code (1)	Sales or gross operating revenues (2) $ Bil. Mil. Thous. Dols.
29 Largest sales or gross operating revenues?	1030	1	2 000
30 2nd largest sales or gross operating revenues?	1031	1	2 000
31 3rd largest sales or gross operating revenues?	1032	1	2 000
32 4th largest sales or gross operating revenues?	1033	1	2 000
33 5th largest sales or gross operating revenues?	1034	1	2 000
34 6th largest sales or gross operating revenues?	1035	1	2 000
35 7th largest sales or gross operating revenues?	1036	1	2 000
36 Sales or gross operating revenues not accounted for above?	1037		2 000

Notes: This figure displays an excerpt from Form BE-10B indicating the industry information reported by the U.S. parent for its foreign affiliates located in a given country. See U.S. Bureau of Economic Analysis (2019b) for the full form.

We consider all combinations of parent (with corresponding main industry) and its affiliate–industry pairs as the most comprehensive mapping of individual MNE production networks. Our sample includes all observed combinations, in the manufacturing sector, of parent industry (j) reported in BE-10A (primary industry only) and affiliate industry (i) reported in BE-10B (maximum of seven per affiliate).[37]

[36]The information is collected on a consolidated basis within a country and primary industry *or* within a country and "business operation" (if multiple enterprises are "intergral parts" of that same function)—see BE-10 instruction booklet Section 1.B.2.d.1 (U.S. Bureau of Economic Analysis, 2004).

[37]In 2004, the three possible forms for a given affiliate were BE-10B(LF), BE-10B(SF), and BE-10B Mini. Currently (and by the time of the 2019 survey), the same corresponding forms are now called BE-10B, BE-10C, and BE-10D, respectively.

Table A1 illustrates the information that can be extracted from the BE-10 forms. In this hypothetical example, a U.S. parent p has 7 foreign affiliates: two (a_1 and a_2) in Mexico, two in Canada two (a_3 and a_4), one in Germany (a_5), one in France (a_6), and one in China (a_7). All affiliates are active in industry 1, which is their primary industry. Some affiliates are also active in other industries (a_1, a_4, and a_7 also operate in industries 2, a_2 also operates in industry 3). Some affiliates (a_1 to a_5) are large (i.e., exceed the size threshold above which the BEA collects information on intra-MNE trade), others (a_6 and a_7) are small.

Table A1. Hypothetical MNE Production Network: Raw Data

Parent	Affiliate	Country	Industry	Large
p	a_1	Mexico	1,2	1
p	a_2	Mexico	1,3	1
p	a_3	Canada	1	1
p	a_4	Canada	1,2	1
p	a_5	Germany	1	1
p	a_6	France	1	0
p	a_7	China	1,2	0

Notes: This table illustrates the hypothetical network structure of a U.S. MNE based on Form BE-10B.

Table A2 illustrates how we convert the raw data for our analysis. Thus, an observation in our analysis is a U.S. parent-foreign production unit pair.

Table A2. Hypothetical MNE Production Network: Unit of Analysis

Parent		Production Units	
	Country	Industry	Large
p	Mexico	1	1
p	Mexico	2	1
p	Mexico	3	1
p	Canada	1	1
p	Canada	2	1
p	Germany	1	1
p	France	1	0
p	China	1	0
p	China	2	0

Notes: This table illustrates the hypothetical network structure of a U.S. MNE used in our analysis.

In our analysis, we define an affiliate as a country-industry pair, which we also refer to as a foreign production unit. From Table A1, the relevant production units for parent p 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; China, Industry 2.

A.1.2 Mapping MNE Production Networks in Customs Records

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, which includes any affiliate in that country. We thus use any related-party transactions by country to identify an intra-MNE flow. However, 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. Thus, we rely on the mapping between the HS classification of the traded product and a 4-digit NAICS to identify the foreign production unit i.e., country-industry in an intra-MNE trade flow.

When identifying an intrafirm import flow, we consider parents' related-party imports of products (HTSUS codes) that fall in the industry of the affiliate located in the source country. Using the hypothetical production network in Table A2, 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 HS codes) that fall in the industry of the affiliate located in the destination country. Going back to the hypothetical production network in Table A2, 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.[38] 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 HS 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.

[38] 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. This is because, without any additional information on the industry of the related party in a destination, export flows cannot be allocated to individual production units when there are multiple units in a country (as it is the case for Mexico, Canada, and China in the hypothetical example in Table A2).

A.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 is collected (and included in LFTTD) using 10-digit Harmonized System (HS) product codes.

In order to assign a direct requirement coefficient to all possible industry pairs between a U.S. parent and its foreign affiliate, 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).[39] Then we utilize a concordance between NAICS and IO industry codes (Appendix A, U.S. Bureau of Economic Analysis, 2007).[40]

In order to assign industry information to merchandise trade transactions in LFTTD, we must also concord 10-digit HS product codes to IO industry codes. We first concord the 10-digit HS codes to 6-digit NAICS using concordances between 10-digit HS and 6-digit NAICS codes published by the Census Bureau (U.S. Census Bureau, 2025c).[41] 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.[42]

A.1.4 Additional Results

In Table A3, 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 8, the input-output coefficient linking the industry of the parent with that one foreign production

[39]The majority of ISI industries are equivalent to 4-digit NAICS industries.

[40]A spreadsheet version of this concordance can be found under "Supplemental Data and Additional Information" on BEA's Input-Output Accounts webpage (`https://www.bea.gov/data/industries/input-output-accounts-data`).

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

[42]For our 2019 analysis, when we use the 2017 concordance, the name of the IO level on the concordance file is "U.Summary."

unit positive and highly significant, but only when using administrative data.[43] In terms of magnitude, the estimate in our preferred specification that includes parent fixed effects 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% (see Table 9).

Table A3. Input-Output Linkages and Parents' Exports to their Affiliates Administrative Versus Survey Data on Intra-MNE Flows

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

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

[43] The specifications that exclude parent fixed effects differ slightly: column 3 (column 4) includes parent-industry (affiliate-industry) fixed effects, which control for the sending (receiving) industry, respectively.