# Sectoral Transport Mode Elasticities and International Trade

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**Abstract**

We estimate sector-specific transport-mode elasticities in international trade costs using newly available bilateral trade data disaggregated by mode and sector for 2016–2019. We rely on an instrumental-variable approach that exploits the interaction of global, mode-specific cost shocks with exogenous bilateral geography to identify elasticities for 21 manufacturing sectors. Our estimates reveal substantial heterogeneity, ranging from statistically insignificant values near zero to 11.4, with high value-to-weight sectors exhibiting greater sensitivity to transport-mode cost shocks. We embed these estimates in a multi-country, multi-sector general-equilibrium trade model with endogenous mode choice and input–output linkages. Counterfactual simulations of global changes in air-transport costs show that accounting for sectoral heterogeneity in transport-mode elasticities generates substantial differences in trade outcomes relative to a uniform-elasticity case.

**Keywords:** *Transport Mode Elasticities, Sectoral Heterogeneity, International Trade, Trade Costs*

**JEL-codes:** F10, F14, R40

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# 1 Introduction

The sorting of different goods across maritime, air, and land transportation is a fundamental feature of international trade, reflecting systematic differences among modes in terms of cost, speed, and reliability. Sector-specific elasticities of trade with respect to transport-mode costs are crucial for evaluating the effects of supply-chain disruptions and understanding the broader impacts of trade on multiple economic outcomes. Yet, empirical estimates of these sectoral transport-mode elasticities remain relatively scarce.

In this paper, we develop an estimation strategy for identifying sectoral transport-mode elasticities that can be applied to a wide range of sectoral classifications. The approach relies on an instrumental variables framework to estimate sector-level elasticities with respect to mode-specific transportation costs. We implement the method using data disaggregated by transport mode and sector, recovering elasticities for 21 manufacturing sectors. The estimates reveal substantial heterogeneity: sectors with high value-to-weight ratios are considerably more responsive to changes in transport costs, while bulk and heavy goods sectors display much lower sensitivity.

To quantify the implications of our estimates, we embed them into a multi-country, multi-sector general equilibrium trade model with endogenous mode choice and input–output linkages. We use this framework to evaluate how a counterfactual reduction in air-transportation costs would affect global trade patterns. The analysis shows that accounting for sectoral heterogeneity in transport-mode responses meaningfully alters both the magnitude and dispersion of predicted effects relative to models that impose uniform elasticities. To put these results into context, we further compare them to the case of a uniform trade elasticity, another key parameter governing sectoral responses to trade cost shocks, and find that while the quantitative relevance of transport-mode heterogeneity is smaller, it remains substantial and of a comparable order of magnitude.

This paper relates to three strands of literature. First, we connect to the extensive literature examining how bilateral barriers and transportation costs shape international trade and welfare (see Anderson and van Wincoop, 2004; Arkolakis et al., 2012; Costinot and Rodriguez-Clare, 2014). Additionally, our study aligns broadly with research investigating the effects of geography and infrastructure on transportation costs and trade (e.g., Limao and Venables, 2001; Hummels, 2007; Volpe Martincus and Blyde, 2013; Allen and Arkolakis, 2014, 2022; Jaworski et al., 2023; Fuchs and Wong, 2024). We extend this literature by highlighting substantial sectoral heterogeneity in responses to changes in transport mode costs.

Second, several studies examine the impacts and elasticities associated with specific transportation modes. Hummels and Schaur (2013) and Feyrer (2019) compare air and sea freight; Micco and Serebrisky (2006), Harrigan (2010), Söderlund (2023), and Besedeš et al. (2024) focus on air transport; Cosar and Demir (2018) and Jaworski and Kitchens (2019) study road transport. An extensive literature further explores maritime transport costs and technology (see, among others, Bernhofen et al., 2016; Cosar and Demir, 2018; Brancaccio et al., 2020; Wong, 2022; Ganapati et al., 2024). Our work builds on these papers by estimating transport mode elasticities comprehensively across multiple sectors.

Finally, this paper is closely related to studies estimating aggregate transport-mode elasticities (e.g., Lux, 2011; Fuchs and Wong, 2024; Tolva, 2024), though those analyses differ in data coverage, empirical design, and identification strategy. Existing aggregate estimates typically range from 0.6 to 1.8, whereas our pooled specification yields an aggregate elasticity between 0.8 and 2.44. More importantly, our results reveal pronounced sectoral heterogeneity, underscoring the need to account for sector-specific variation in transport-mode elasticities.

## 2 Data Description

This paper draws on several data sources for the empirical analysis in Section 3 and for calibrating the quantitative trade model with endogenous transport-mode choice in Section 5.1.

To estimate sectoral transport-mode elasticities, we use the newly available *Trade-and-Transport* dataset from the United Nations (COMTRADE, 2025). This dataset provides a monthly panel of bilateral trade flows disaggregated by transport mode under the HS6 product classification. A key feature is that trade values are reported at both *free on board* (FOB) and *cost, insurance, and freight* (CIF) terms, which allows us to construct ad valorem measures of mode-specific transport costs. We supplement these data with bilateral great-circle and maritime distances from CEPII (Mayer and Zignago, 2011) and CERDI (Bertoli et al., 2016). The empirical analysis covers the period from 2016 – the first year of data availability – through 2019, the final year before the onset of the COVID-19 pandemic.

For the quantitative model, we use data from the Global Trade Analysis Project (GTAP) version 11 (Aguiar et al., 2023) and the UNCTAD Global Transport Costs Dataset (Hoffmeister et al., 2022). We construct a value-weighted concordance between the two sources to allocate GTAP trade flows across transport modes. The resulting calibration covers 126 countries and 65 sectors for the benchmark year 2017.

### 2.1 Sectoral Patterns of Trade by Transport Mode

We start by arguing that sectors meaningfully differ in their transport mode dependence, dictated by the differences in relative cost, speed, and reliability. Using FOB values from COMTRADE (2025), we calculate the share of goods transported using three distinct modes: "air", "sea", and "road" alongside a residual category that subsumes all other observable modes.[1] In principle,

[1] The "other" category includes inland waterways, railways, pipelines, cables, postal consignments, courier shipments, self-propelled goods, and more. Due to data availability, we do not consider multi-modal transportation. See Fuchs and Wong (2024) for an approach that explicitly addresses multi-modal transport networks.

our estimation framework is general enough to accommodate other modes. However, our scope is dictated by data limitations; it is particularly challenging to obtain disaggregated trade-flows for uncommon modes in international trade, such as pipelines.

Since both our estimation and model calibration rely on the GTAP sectoral classification, we aggregate trade flows reported at the HS6 level to 21 manufacturing sectors as defined in GTAP. We then compute transport-mode shares for each sector, summarized in Table 1. The results reveal pronounced heterogeneity in modal usage across sectors. For instance, 75.6% of trade in ferrous metals is transported by sea and another 20.1% by road, with only 0.2% shipped by air. In contrast, among basic pharmaceuticals, 34.5% of trade moves by air and 51.2% by road, while just 12.8% relies on sea transport.

Table 1: Sectoral Trade Shares by Transport Mode

| GTAP Sector | Description | Air (%) | Sea (%) | Road (%) | Other (%) |
|---|---|---|---|---|---|
| AFP | Agriculture and food processing | 1.80 | 63.23 | 32.48 | 2.48 |
| BPH | Basic pharmaceutical products | 34.50 | 12.79 | 51.21 | 1.50 |
| CHM | Chemical products | 2.08 | 65.86 | 28.56 | 3.50 |
| EEQ | Electrical equipment | 8.31 | 38.50 | 50.48 | 2.71 |
| ELE | Computer, electronic and optical prod. | 38.71 | 25.42 | 34.09 | 1.78 |
| ENG | Energy | 0.20 | 89.31 | 6.29 | 4.20 |
| FMP | Metal products | 6.38 | 39.83 | 50.89 | 2.91 |
| I_S | Ferrous metals | 0.18 | 75.63 | 20.14 | 4.05 |
| LEA | Leather products | 10.76 | 42.65 | 42.55 | 4.05 |
| MVH | Motor vehicles and parts | 0.81 | 47.26 | 46.19 | 5.74 |
| NFM | Metals n.e.c. | 45.74 | 33.24 | 20.49 | 0.53 |
| NMM | Mineral products n.e.c. | 2.67 | 50.33 | 42.53 | 4.47 |
| OFD | Food products n.e.c. | 0.83 | 49.50 | 44.82 | 4.85 |
| OME | Machinery and equipment n.e.c. | 7.23 | 50.58 | 39.98 | 2.20 |
| OMF | Manufactures n.e.c. | 9.87 | 17.05 | 23.16 | 49.91 |
| OTH | Goods and services n.e.c. | 0.69 | 55.10 | 38.95 | 5.26 |
| OTN | Transport equipment n.e.c. | 24.59 | 38.44 | 33.02 | 3.95 |
| PPP | Paper products, printing | 2.14 | 60.54 | 34.18 | 3.14 |
| RPP | Rubber and plastic products | 3.13 | 40.66 | 52.77 | 3.44 |
| TEX | Textiles | 2.09 | 67.47 | 27.35 | 3.10 |
| WAP | Wearing apparel | 8.94 | 33.34 | 55.95 | 1.76 |
| **Average** | | 10.08 | 47.46 | 36.96 | 5.50 |
| **Std. dev.** | | 13.68 | 18.83 | 12.87 | 10.26 |

*Notes:* This table lists the percentage shares of bilateral trade values by sector and transport mode. Trade values are based on FOB export values for 152 countries across 21 GTAP manufacturing sectors between 2016 and 2019. *Source*: UN COMTRADE.

Variation in modal shares reflects key differences in sectoral characteristics, particularly value-to-weight ratios and time sensitivity (Hummels, 2007; Harrigan, 2010). Sectors producing lighter, high-value goods where speed substantially lowers trade costs (e.g., pharmaceuticals) favor air transport whereas sectors with heavier or bulkier products (e.g., ferrous metals) rely on maritime shipping to cover longer distances at lower per-unit costs. This heterogeneity suggests that incorporating sector-specific transport mode choices and elasticities is crucial for calculating the responsiveness of international trade flows to different transport cost shocks.

## 3 Estimation

In this section, we propose a framework for estimating sectoral transport-mode elasticities based on a general discrete-choice model with multiple alternatives. Estimating these elasticities poses two major empirical challenges. First, conventional gravity-based identification strategies, developed to estimate aggregate trade elasticities (e.g., Caliendo and Parro, 2014; Fontagné et al., 2022), typically exploit tariff variation across sectors. Because tariffs do not vary at the transport-mode level, these methods cannot be directly applied. Second, transportation modes are endogenously chosen by exporters and importers, so estimation requires valid instruments at the sector-mode level.

Our estimation framework overcomes these challenges by (i) explicitly incorporating measured sector- and transport-mode-specific costs and (ii) constructing plausibly exogenous instrumental variables from global technological and logistical innovations in transportation, while remaining consistent with a broad class of structural models of international trade that yield a log-linear gravity equation for trade flows.

### 3.1 Estimating Framework

In this paper, we estimate transport-mode elasticities for 21 aggregate sectors consistent with the GTAP classification used in the quantitative analysis in Section 5, but our strategy is generalizable to any sectoral classification for which suitable data are available. The estimation is conducted at the $m \times ij \times h \times s \times t$ level, where $m$ denotes transport modes, $ij$ represents exporter–importer country pairs, $h$ and $s$ are narrow and broad economic sectors with $h \in s$, and $t$ indexes monthly observations from 2016 to 2019. We improve identification using within-sector variation in $h$ to leverage subsector differences across modes and country pairs within broad sectors $s$.

Within a general discrete choice framework, the share of goods shipped by mode $m$ from exporter $i$ to importer $j$ in sector $(h, s)$ at time $t$ can be expressed as:

$$\pi^m_{ij,t}(h,s) = \frac{\left[\kappa^m_{i,t}(s)\,\chi_{ij,t}(h,s)\,\zeta^m_{ij}(s)\,\varphi^m_{j,t}(s)\right]\,\tau^m_{ij,t}(h,s)^{-\rho(s)}}{\sum_{m'}\left[\kappa^{m'}_{i,t}(s)\,\chi_{ij,t}(h,s)\,\zeta^{m'}_{ij}(s)\,\varphi^{m'}_{j,t}(s)\right]\,\tau^{m'}_{ij,t}(h,s)^{-\rho(s)}}, \tag{1}$$

where $\tau^m_{ij,t}(h,s)$ represent sector-specific ad valorem transport-mode costs. The other terms reflect economic factors that shape the attractiveness of each transportation mode:

- $\kappa^m_{i,t}(s)$: exporter–time–mode factors, such as improvements in air-cargo capacity or port infrastructure in exporting countries, which may vary by sector $s$.

- $\chi_{ij,t}(h,s)$: exporter–importer–time factors, including bilateral trade barriers or regulatory standards, that apply to goods in subsector $h \in s$.

- $\zeta_{ij}^{m}(s)$: fixed exporter–importer–mode factors, such as the presence of direct maritime or air routes, or limitations in overland connectivity, that are specific to sector $s$.

- $\varphi_{j,t}^{m}(s)$: importer–time–mode factors, such as infrastructure investments in destination ports or airports, that may vary across sectors $s$.

Under the functional-form assumption from equation (1), the estimating equation for bilateral sector-specific transport-mode shares takes the log-additive form:

$$\log \pi_{ij,t}^{m}(h,s) = \delta_{ij,t}(h,s) + \delta_{i,t}^{m}(s) + \delta_{j,t}^{m}(s) + \delta_{ij}^{m}(s) - \rho(s)\log \tau_{ij,t}^{m}(h,s) + \epsilon_{ij,t}^{m}(h,s), \tag{2}$$

where $\delta$ terms represent fixed effects and $\epsilon_{ij,t}^{m}(h,s)$ is a stochastic error term. As our identification relies on both sectoral and subsectoral variation in transport-mode usage, we assume that transport-mode elasticities are constant across subsectors $h \in s$.

Estimating equation (2) requires: (i) observed bilateral mode shares at the subsector level ($\pi_{ij,t}^{m}(h,s)$), (ii) an appropriate set of fixed effects ($\delta$'s), and (iii) measures of sector-specific transport mode costs ($\tau_{ij,t}^{m}(h,s)$). While (i) can be directly calculated from the data and (ii) involves standard econometric controls, direct measurement of (iii) is empirically challenging.

In our data, bilateral trade flows by transport mode are reported using both cost-insurance-freight ($\mathrm{CIF}_{ij,t}^{m}(h,s)$) and free-on-board ($\mathrm{FOB}_{ij,t}^{m}(h,s)$) valuations. We restrict our sample to country pairs and transport modes with at least 36 monthly observations and define modal trade shares as:

$$\pi_{ij,t}^{m}(h,s) = \frac{\mathrm{CIF}_{ij,t}^{m}(h,s)}{\sum_{m'} \mathrm{CIF}_{ij,t}^{m'}(h,s)}.$$

Given the availability of CIF and FOB values, we measure mode-specific ad valorem transport costs as:

$$\tau_{ij,t}^{m}(h,s) = \frac{\mathrm{CIF}_{ij,t}^{m}(h,s)}{\mathrm{FOB}_{ij,t}^{m}(h,s)}.$$

While intuitive, our measure of $\tau_{ij,t}^{m}(h,s)$ captures not only pure transport costs but also insurance, duties, and related fees. This is not necessarily problematic if broader cost measures accurately reflect factors influencing substitution between transport modes, including insurance-related considerations. Further, pure transportation costs may still be isolated if the following assumption holds:

**Assumption 1.** *Pure transportation costs vary at the $\{m \times ij \times h \times s \times t\}$ level, whereas additional components such as insurance and duties vary only at the more aggregated $\{m \times ij \times s \times t\}$ level and are thus absorbed by the respective fixed effects.*

Table 2: Estimates of Transport Mode Elasticities by GTAP Sector

| | | OLS | | IV | | |
|---|---|---|---|---|---|---|
| **Sector** | **Description** | **Coef.** | **Obs.** | **Coef.** | **Obs.** | **First-Stage F-stats** |
| TOT | All sectors pooled | -0.87<br>(0.18) | 2,658,761 | -2.44<br>(0.53) | 2,643,861 | 86,505 |
| AFP | Agriculture and food processing | -1.99<br>(1.38) | 16,531 | -4.87<br>(2.18) | 14,731 | 2,365 |
| BPH | Basic pharmaceutical products | -2.77<br>(0.75) | 25,482 | -11.36<br>(2.47) | 24,724 | 230,226 |
| CHM | Chemical products | -1.22<br>(0.20) | 188,977 | -3.13<br>(0.60) | 186,241 | 8,152 |
| EEQ | Electrical equipment | -1.12<br>(0.34) | 354,945 | -2.88<br>(1.11) | 341,738 | 31,435 |
| ELE | Computer, electronic and optical | -1.04<br>(0.42) | 290,916 | -1.67<br>(0.95) | 280,380 | 8,434 |
| ENG | Energy | -0.63<br>(0.25) | 4,420 | -11.08<br>(1.17) | 4,420 | 18 |
| FMP | Metal products | -1.03<br>(0.23) | 262,131 | -4.08<br>(0.98) | 257,234 | 4,272 |
| I_S | Ferrous metals | -1.04<br>(0.26) | 36,059 | -5.21<br>(1.13) | 36,059 | 47,673 |
| LEA | Leather products | -0.35<br>(0.38) | 47,236 | -0.78<br>(0.72) | 45,939 | 5,218 |
| MVH | Motor vehicles and parts | -0.13<br>(0.08) | 170,866 | -0.60<br>(0.27) | 164,889 | 6,165 |
| NFM | Metals nec | -1.94<br>(0.54) | 16,627 | -5.81<br>(1.71) | 16,627 | 82,777 |
| NMM | Mineral products nec | -0.88<br>(0.15) | 61,743 | -2.68<br>(0.44) | 61,303 | 144,435 |
| OFD | Food products nec | 0.12<br>(0.35) | 17,901 | 0.39<br>(0.39) | 16,605 | 1,866 |
| OME | Machinery and equipment nec | -0.91<br>(0.28) | 522,438 | -3.17<br>(0.89) | 509,274 | 13,879 |
| OMF | Manufactures nec | -1.34<br>(0.35) | 115,791 | -3.34<br>(1.28) | 111,268 | 3,073 |
| OTH | Goods and services nec | -0.21<br>(0.34) | 8,974 | -1.60<br>(1.61) | 8,758 | 461 |
| OTN | Transport equipment nec | -1.64<br>(0.37) | 12,401 | -4.47<br>(1.52) | 12,074 | 91,868 |
| PPP | Paper products, publishing | -0.50<br>(0.16) | 55,506 | -1.01<br>(0.59) | 53,284 | 3,232 |
| RPP | Rubber and plastic products | -0.73<br>(0.17) | 235,012 | -2.46<br>(0.79) | 227,325 | 66,788 |
| TEX | Textiles | -1.53<br>(0.28) | 76,128 | -4.05<br>(0.87) | 75,100 | 69,544 |
| WAP | Wearing apparel | -0.62<br>(0.24) | 200,755 | -3.21<br>(1.13) | 195,888 | 1,660 |

*Notes:* This table displays OLS (columns 3-4) and IV (columns 5-7) estimates of transport-mode elasticities. Sectors are pooled to estimate aggregate elasticities in the first row. Subsequent rows report sector-specific elasticities. Each specification includes pair-time-subsector ($\delta_{ij,t}(h,s)$), exporter-time-mode-sector ($\delta^m_{i,t}(s)$), importer-time-mode-sector ($\delta^m_{j,t}(s)$), and pair-mode-sector ($\delta^m_{ij}(s)$) fixed effects described in equation (2). Standard errors are clustered by country pairs.

We estimate equation (2) using OLS and report results in Table 2. Pooling all sectors, we precisely estimate a single elasticity parameter $\rho$ of $-0.87$. Estimated $\rho(s)$ values exhibit significant heterogeneity across sectors with individual estimates ranging from approximately 0.1 (statistically indistinguishable from zero) to $-2.8$. Sector level elasticities broadly align with observations made in Table 1 regarding differences in sectoral characteristics. These findings further underscore the importance of adopting a sector-specific approach.

### 3.2 Instrumental Variable Approach

Although informative, reverse causality and measurement errors may bias OLS estimates. To address potential endogeneity, we employ an instrumental variables (IV) approach related to Feyrer (2019) and Nigai (2023).

Our instrument isolates variation in transport costs driven by global mode-specific shocks, such as technological improvements in a particular transport mode, interacted with exogenous bilateral geographic characteristics. Intuitively, global shocks vary only across time and sectors, uniformly affecting all country pairs, while geographic characteristics are fixed and plausibly exogenous. Their interaction therefore generates exogenous, predicted variation in mode- and sector-specific transport costs. By construction, this variation is independent of pair-specific, time-varying factors that influence transport-mode choices across sectors and country pairs, providing a valid and powerful instrument.

We construct our instrument using two bilateral geographic measures: the great-circle distance (in logs), $\log cirdist_{ij}$, and sea distance (in logs), $\log seadist_{ij}$. The idea behind using two different measures of distance is similar to Feyrer (2019): the two measures affect different transport modes differently across time. Our first-stage regression estimates how these geographic characteristics shape the responsiveness of country pairs to global transportation shocks, separately for each sector–mode combination $(s, m)$:

$$\log \tau^m_{ij,t}(h,s) = \mu^m_{i,t}(s) + \mu^m_{j,t}(s) + \mu^m_{ij}(h,s) + \sum_t \xi^{cir,m}_t(s) \log cirdist_{ij} + \sum_t \xi^{sea,m}_t(s) \log seadist_{ij} + e^m_{ij,t}(h,s). \quad (3)$$

The fixed effects $\mu^m_{i,t}(s)$ and $\mu^m_{j,t}(s)$ absorb exporter- and importer-mode-sector-time shocks, while $\mu^m_{ij}(h,s)$ captures time-invariant bilateral mode-sector characteristics. The estimated coefficients, $\hat{\xi}^{cir,m}_t(s)$ and $\hat{\xi}^{sea,m}_t(s)$, measure global mode-sector-time-specific shocks. Using these estimates, we construct instruments:

$$z^m_{ij,t}(h,s) = \hat{\mu}^m_{ij}(h,s) + \sum_t \hat{\xi}^{cir,m}_t(s) \log cirdist_{ij} + \sum_t \hat{\xi}^{sea,m}_t(s) \log seadist_{ij}. \quad (4)$$

By construction, time-series variation in $z^m_{ij,t}(h,s)$ is generated solely by the interaction of global shocks and exogenous geography, which satisfies the exclusion restriction and motivates the following assumption:

**Assumption 2.** *Global mode-sector-specific transportation shocks in equation* (3) *affect bilateral transport mode shares* $\log \pi_{ij}^{m}(h,s)$ *only through changes in predicted mode-sector-specific trade transport costs calculated as in equation* (4)*.*

We run equation (2) using IVs and report results in Table 2. First-stage F-statistics suggest that the generated instruments $z_{ij,t}^{m}(h,s)$ do not suffer from weak identification. The IV estimates of transport mode elasticities also suggest that OLS coefficients are subject to attenuation or endogeneity bias; for example, the IV estimate of $\rho$, pooled across sectors, is $-2.44$, nearly three times larger in magnitude than its OLS counterpart of $-0.87$. Sector-specific estimates increase similarly in magnitude across the board.

To explore sectoral drivers of transport-mode elasticities, we first construct a sector level measure of value per weight:

$$VPW(s) = \frac{\sum_{m,ij,h,t} \text{FOB}_{ij,t}^{m}(h,s)}{\sum_{m,ij,h,t} \text{Net Weight}_{ij,t}^{m}(h,s)}.$$

We then plot the estimated IV elasticities against $VPW(s)$ in Panel A of Figure 1, which reveals a clear negative relationship. Intuitively, because transport costs are a large share of total value in low value-per-weight sectors (e.g., paper products), these sectors are primarily reliant on the cheapest bulk shipping modes, which severely restricts viable alternatives and results in relatively inelastic transport-mode choice.

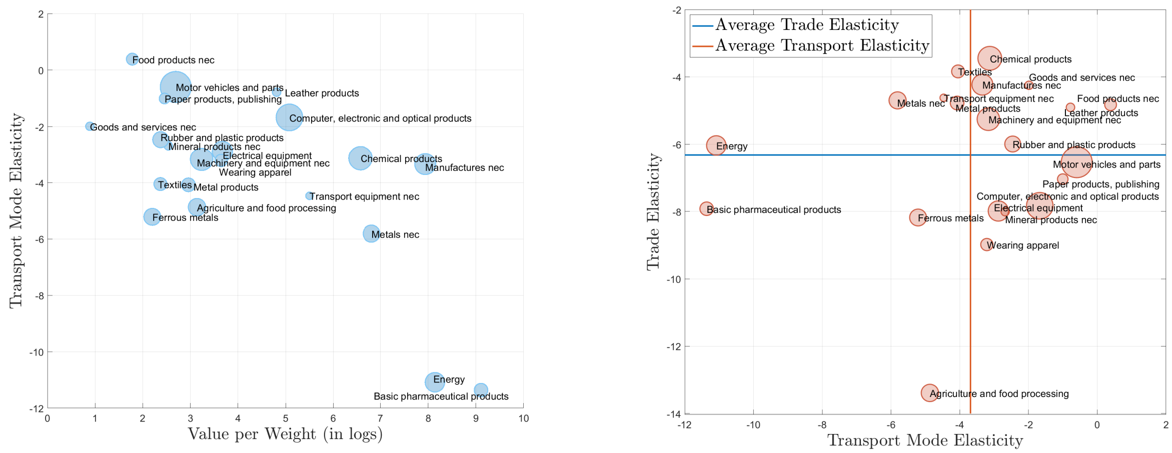
While our estimates of $\rho(s)$ capture how firms substitute between transport modes, the ultimate effect on total trade flows is also mediated by the standard trade elasticity of substitution between goods, which we denote $\theta(s)$. As we derive in Section 4, the theory-consistent elasticity of international trade with respect to a change in a single mode's cost is a function of both parameters, equal to $-\frac{\theta(s)}{\rho(s)}$. Since the focus of this paper is on the transport-mode elasticity $\rho(s)$, we borrow established estimates of sectoral trade elasticities, $\theta(s)$, from Fontagné et al. (2022), who provide them at our required level of aggregation.[2]

Panel B of Figure 1 examines the relationship between our estimated IV sectoral transport-mode elasticities and the corresponding trade elasticity. The figure is divided into four quadrants determined by the average value of each elasticity, offering a typology of sectors according to their sensitivity to transport-specific and general trade cost shocks. Most sectors cluster in the first and

[2] Fontagné et al. (2022) provide trade elasticities at GTAP vers. 11 aggregation at `https://sites.google.com/view/product-level-trade-elasticity`. We follow the same aggregation for $\rho(s)$, taking a simple average across more disaggregated categories in AFP, ENG, and OTH.

Panel A: Transport-mode Elasticities and Value per Weight

Panel B: Transport-mode Elasticities and Trade Elasticities




*Notes:* These figures illustrate the relationship between transport mode elasticities and key sectoral traits. Panel A plots IV estimates of transport mode elasticities, $\rho(s)$, against the logarithm of $VPW(s)$, measured in dollars per kilogram. Panel B categorizes sectors by their transport mode elasticities and trade elasticities (from Fontagné et al. (2022)) each expressed relative to their average values. In both panels, marker size is scaled by the total nominal FOB value of international trade from 2016 to 2019.

Figure 1: Sectoral Characteristics and Transport Mode Elasticities

fourth quadrants indicating limited substitution across transport modes regardless of their general trade-cost sensitivity while sectors with relatively elastic transport-mode substitution are rare. We quantitatively assess the relevance of these patterns within the structural framework presented in Section 4.

### 3.3 Sensitivity Analysis

Our baseline estimates rely on monthly data from 2016 to 2019, which may raise the question of whether they capture short-run or long-run responses.[3] We address this concern by estimating horizon-specific elasticities following the local projections approach of Jordà (2005), recently applied in Boehm et al. (2023) to estimate trade elasticities, which traces the impulse response of trade flows to a transport-cost shock over several months.

To estimate the local projections for each time horizon $n$, we regress the log of transport-mode shares at time $t+n$, $\log \pi^m_{ij,t+n}(h,s)$, on the log of transport cost at time $t$, $\log \tau^m_{ij,t}(h,s)$. This specification is analogous to our baseline model and includes the same set of fixed effects and uses the same instruments for transport costs as in equation (4):

$$\log \pi^m_{ij,t+n}(h,s) = \delta^n_{ij,t}(h,s) + \delta^{n,m}_{i,t}(s) + \delta^{n,m}_{j,t}(s) + \delta^{n,m}_{ij}(s) - \rho^n(s) \log \tau^m_{ij,t}(h,s) + \epsilon^{n,m}_{ij,t}(h,s),$$

[3]Trade elasticities are known to differ in the short and long run (e.g., see Crucini and Davis, 2016; Anderson and Yotov, 2020; Boehm et al., 2023).

where the elasticity $\rho^n(s)$ varies across projection horizons $n$. Using three-month intervals from 2016 to 2019, we estimate twelve local projections.

We find that the horizon-specific elasticities, $\rho^n(s)$, typically deepen before converging to a level consistent with our main IV estimates from Table 2, and for a majority of sectors (16 out of 21) the point estimates of $\rho^n(s)$ remain within the 95% confidence interval of the baseline elasticity at all horizons. Furthermore, when restricting to estimates of $\rho^n(s)$ that are statistically significant at the 10% level, we find a strong relationship ($r = 0.94$) between the baseline elasticity $\rho(s)$ and the maximum long-run elasticity, $\max_n\{\rho^n(s)\}$. Taken together, these findings indicate our results are not driven purely by short-run dynamics and are robust to longer adjustment horizons.

# 4 Model

To assess the implications of our elasticity estimates, $\rho(s)$, we embed them in a general equilibrium trade model. In this section, we present an Armington model of international trade with endogenous transport-mode choices and sectoral input-output linkages. This model builds on the frameworks developed in Allen and Arkolakis (2014) and Jaworski et al. (2023).

There are $J$ countries in the world populated by $L_j$ workers across $S$ sectors. Workers are mobile across sectors but not across countries. Production in each sector uses labor and intermediate inputs. Consumers in country $j$ have an upper-tier Cobb-Douglas utility function with weights $\alpha_j(s)$ that sum to unity across sectors. The associated indirect utility function is:

$$W_j = \frac{I_j}{P_j}, \text{ where } P_j = \prod_{s \in S} \left( \frac{P_j(s)}{\alpha_j(s)} \right)^{\alpha_j(s)}, \tag{5}$$

where $I_j$ is total nominal consumer income which includes labor income, $V_j = L_j w_j$, and a lump-sum transfer, $T_j$.

Within each sector $s$, countries produce distinct varieties, $q_i(s)$, which are aggregated prior to consumption by consumers and firms according to a constant elasticity of substitution (CES) function of the form:

$$Q_j(s) = \left( \sum_i q_i(s)^{\frac{\theta(s)}{\theta(s)+1}} \right)^{\frac{\theta(s)+1}{\theta(s)}}.$$

Producers in sector $s$ and country $i$ have a level of productivity, $A_i(s)$, and employ labor $L_i$ at a wage $w_i$ together with intermediate inputs $Q_i(s)$ at price $P_i(s)$ such that their marginal production cost is specified as:

$$M_i(s) = C_i(s) \frac{w_i^{\gamma_i(s)} \mathbb{P}_i(s)^{1-\gamma_i(s)}}{A_i(s)}, \text{ where } \gamma_i(s) \in (0, 1), \tag{6}$$

where $C_i(s)$ is a constant and $\mathbb{P}_i(s)$ is a CES function that aggregates inputs as follows:

$$\mathbb{P}_i(s) = \prod_{\dot{s} \in S} \left( \frac{P_i(\dot{s})}{\eta_i(\dot{s}s)} \right)^{\eta_i(\dot{s}s)}, \text{ where } \sum_{\dot{s} \in S} \eta_i(\dot{s}s) = 1, \tag{7}$$

with $\dot{s}$ denoting the sector that supplies intermediate inputs to sector $s$ and $\eta_i(\dot{s}s)$ the parameters that govern input-output linkages.

Following Allen and Arkolakis (2014), we assume every exporter country $i$ and importer country $j$ has a mass of identical traders who choose to transport goods via different modes $m \in \{1, ..., M\}$. Each transport mode is characterized by its iceberg trade cost $\tau_{ij}^m(s) \geq 1$. Traders draw i.i.d. shocks from an extreme value distribution with scale parameter $\chi_{ij}^m(s)$ that captures non-transport determinants influencing how likely traders are to choose mode $m$, and shape parameter $\rho(s)$. We then specify the share of goods from sector $s$ transported using mode $m$ from $i$ to $j$ as:

$$\pi_{ij}^m(s) = \frac{\chi_{ij}^m(s)\tau_{ij}^m(s)^{-\rho(s)}}{\sum_{m'} \chi_{ij}^{m'}(s)\tau_{ij}^{m'}(s)^{-\rho(s)}}. \tag{8}$$

It is well known in the literature that trade costs include components unrelated to transport costs. Therefore, we assume that countries incur other trade costs when exporting goods from $i$ to $j$, common to all modes $m$, that are captured by $t_{ij}(s)$. Then, the total trade costs between countries $i$ and $j$ can be specified as:

$$d_{ij}(s) = T(s)t_{ij}(s) \left( \sum_m \chi_{ij}^m(s)\tau_{ij}^m(s)^{-\rho(s)} \right)^{-\frac{1}{\rho(s)}},$$

where $T(s)$ is a constant.

With this specification of trade costs, we can characterize bilateral trade shares:

$$\lambda_{ij}(s) = \left( C_i(s) \frac{w_i^{\gamma_i(s)} \mathbb{P}_i(s)^{1-\gamma_i(s)}}{A_i(s)} \right)^{-\theta(s)} P_j(s)^{\theta(s)} d_{ij}(s)^{-\theta(s)}, \tag{9}$$

defining the CES price index as:

$$P_j(s) = \left( \sum_k \left[ C_k(s) \frac{w_k^{\gamma_k(s)} \mathbb{P}_k(s)^{1-\gamma_k(s)}}{A_k(s)} \right]^{-\theta(s)} d_{kj}(s)^{-\theta(s)} \right)^{-\frac{1}{\theta(s)}}. \tag{10}$$

Then, the nominal trade flow from $i$ to $j$ in sector $s$ is specified as $X_{ij}(s) = \lambda_{ij}(s)Y_j(s)$, where $Y_j(s)$ is the total demand for goods from sector $s$ in country $j$, consisting of final consumer and intermediate firm demands:

$$Y_i(s) = \sum_{\dot{s}} (1 - \gamma_i(s))\eta_i(s\dot{s}) \sum_j \lambda_{ij}(s) Y_j(s) + \alpha_i(s) I_i, \tag{11}$$

where $I_i = L_i w_i + D_i$ includes $D_i$ as an exogenous deficit constant. We close the model by specifying the trade balance condition:

$$\sum_s \sum_j \lambda_{ji}(s) Y_i(s) - D_i = \sum_s \sum_j \lambda_{ij}(s) Y_j(s). \tag{12}$$

We define equilibrium as follows:

**Definition 1.** *Given economic primitives related to consumer preferences $\{\alpha_i(s), \theta(s)\}$, production functions $\{\gamma_i(s), \eta_i(\dot{s}s)\}$, transport mode choices $\{\chi_{ij}^m(s), \tau_{ij}^m(s)\}$, trade costs $\{t_{ij}(s)\}$, and deficit constants $\{D_i\}$, an equilibrium is a vector of wages, $\mathbf{w} \in \mathbb{R}_+$, and prices, $\mathbf{P} \in \mathbb{R}_+$, such that the conditions in* (5), (6), (7), (8), (9), (10), (11), *and* (12) *are satisfied for all m, s, i and j.*

Following the approaches of Dekle et al. (2007) and Caliendo and Parro (2014), we reformulate the model in terms of relative changes. This allows us to solve for counterfactual equilibria subject to arbitrary shocks to $\tau_{ij}^m(s)$ using the hat algebra. Let $a'$ denote a counterfactual value of variable $a$ such that $\widehat{a} = a'/a$ reflects its relative change. Conditional on observing $\{\eta_i(\dot{s}s), \pi_{ij}^m(s), \lambda_{ij}(s), V_i\}$, we solve the following system of equations:

(i) *Change in marginal cost:* $\widehat{M}_i(s) = \widehat{w}_i^{\gamma_i(s)} \widehat{\mathbb{P}}_i(s)^{1-\gamma_i(s)}$

(ii) *Chang in price of intermediates:* $\widehat{\mathbb{P}}_i(s) = \prod_{\dot{s} \in S} \widehat{P}_i(\dot{s})^{\eta_i(\dot{s}s)}$

(iii) *Change in trade costs:* $\widehat{d}_{ij}(s) = \left( \sum_m \pi_{ij}^m(s) \widehat{\tau}_{ij}^m(s)^{-\rho(s)} \right)^{-\frac{1}{\rho(s)}}$

(iv) *Counterfactual trade shares:* $\lambda'_{ij}(s) = \lambda_{ij}(s) \left[ \widehat{d}_{ij}(s) \widehat{M}_i(s) / \widehat{P}_j(s) \right]^{-\theta(s)}$

(v) *Change in CES prices:* $\widehat{P}_i(s) = \left( \sum_k \lambda_{ki}(s) \left[ \widehat{d}_{ki}(s) \widehat{M}_k(s) \right]^{-\theta(s)} \right)^{-\frac{1}{\theta(s)}}$

(vi) *Counterfactual absorption:* $Y'_i(s) = \sum_{\dot{s}} (1 - \gamma_i(s))\eta_i(s\dot{s}) \sum_j \lambda'_{ij}(s) Y'_j(s) + \alpha_i(s)(\widehat{w}_i V_i + D_i)$

(vii) *Change in wages:* $\sum_s \sum_j \lambda'_{ji}(s) Y'_i(s) - D_i = \sum_s \sum_j \lambda'_{ij}(s) Y'_j(s)$

# 5 Quantitative Analysis

This section outlines the calibration strategy for the key structural parameters used in our model and presents a set of counterfactual simulations that illustrate the benefit of incorporating heterogeneous transport-mode elasticities into trade analyses.

## 5.1 Calibration

We calibrate the model to the benchmark year of 2017 for 126 countries with bilateral trade-transport data, covering 46 manufacturing sectors and 19 service sectors listed in the Appendix. We begin by adopting values for the model parameters $\{\theta(s), \alpha_i(s), \gamma_i(s), \eta_i(\dot{s}s)\}$:

- $\theta(s)$ are borrowed from Fontagné et al. (2022). For sectors where $\theta(s)$ was not available, we substituted the average value of the corresponding GTAP broad sector category.

- The remaining parameters are calculated directly from GTAP data: (i) $\alpha_i(s)$ is the share of income spent on goods in sector $s$ from observed consumption, (ii) $\gamma_i(s)$ are the ratio of value-added to output in sector $s$ and (iii) $\eta_i(\dot{s}s)$ are the share of total spending in sector $s$ on intermediate inputs from sector $\dot{s}$.

We then determine $\{\lambda_{ij}(s), V_i, \pi^m_{ij}(s)\}$ at the benchmark equilibrium :

- (i) $\lambda_{ij}(s)$ is calculated as the share of trade flows from $i$ to $j$ in sector $s$, using bilateral import data from the GTAP [4], (ii) the total value-added by country $i$, $V_i$, is computed as the sum of sectoral value-added.

- We cannot observe $\pi^m_{ij}(s)$ for all country-pair-sector triads. For missing values, we rely on imputations developed in Hoffmeister et al. (2022), converting their estimates from HS6 to GTAP classification based on Aguiar (2016).

## 5.2 Counterfactual Analysis

Using the calibrated model, we quantitatively evaluate the importance of our central empirical finding—substantial heterogeneity in transport-mode elasticities across sectors. To do so, we simulate a counterfactual 30 percent reduction in air-transport costs, setting $\hat{\tau}^{air}_{ij}(s) = 0.7$ for all sectors and country pairs. While our results are robust to alternative shocks affecting other modes, focusing on air transport is particularly instructive because this mode has experienced large and persistent cost declines in recent decades (see Hummels, 2007; Feyrer, 2019).

We compare outcomes under heterogeneous $\rho(s)$, as reported in Table 2, to those obtained when all sectors share a single aggregate elasticity, $\bar{\rho} = 2.4$. To put the magnitude of this heterogeneity in context, we benchmark its quantitative relevance against the well-studied heterogeneity in trade elasticities, $\theta(s)$ (see Caliendo and Parro, 2014; Costinot and Rodriguez-Clare, 2014). We use $\bar{\theta} = 5.8$ to denote the average trade elasticity across sectors.

Our analysis focuses on two outcomes of interest, welfare gains from trade and changes in bilateral

[4] For intranational observations, trade values are the sum of domestic firm, consumer, government, and investment purchases at purchaser price.

trade shares, defined respectively as

$$\Delta W_i = 100 \times (\hat{w}_i / \hat{P}_i - 1), \qquad \Delta\lambda_{ij}(s) = 100 \times (\hat{\lambda}_{ij}(s) - 1).$$

We compute these changes under three scenarios: (i) heterogeneous $\rho(s)$ and $\theta(s)$ (baseline), (ii) homogeneous $\rho(s) = \bar{\rho}$ with heterogeneous $\theta(s)$, and (iii) heterogeneous $\rho(s)$ with homogeneous $\theta(s) = \bar{\theta}$.

For each variable $a$, we measure the deviation from the fully heterogeneous baseline as:

$$\mathcal{D}(a, \bar{\rho}) = \Delta a(\bar{\rho}, \theta(s)) - \Delta a(\rho(s), \theta(s)), \qquad \mathcal{D}(a, \bar{\theta}) = \Delta a(\rho(s), \bar{\theta}) - \Delta a(\rho(s), \theta(s)).$$

These deviations quantify the degree to which imposing homogeneity in either transport-mode or trade elasticities overstates the welfare gains and trade-share adjustments relative to the fully heterogeneous benchmark.

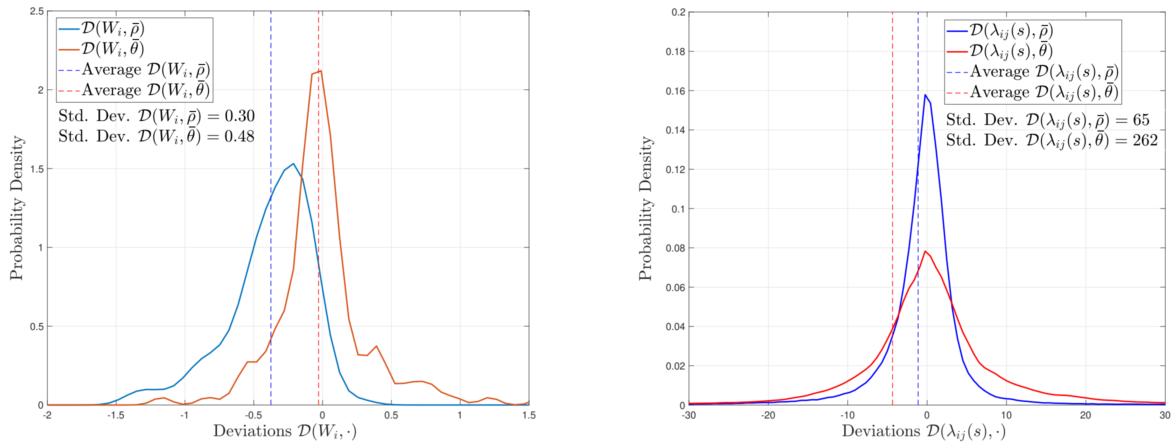
In Panel A of Figure 2, we plot the kernel density of deviations in welfare gains from trade resulting from a counterfactual 30% reduction in international air-transportation costs. The average deviations under the two scenarios, denoted $\mathcal{D}(W_i, \bar{\rho})$ and $\mathcal{D}(W_i, \bar{\theta})$, are -0.38 and -0.03, respectively. This indicates that, on average, ignoring heterogeneity in $\rho(s)$ tends to understate the gains from trade. More informative for our purposes, however, are the measures of dispersion in $\mathcal{D}(W_i, \bar{\rho})$ and $\mathcal{D}(W_i, \bar{\theta})$. Measured by standard deviation, these are 0.30 and 0.48, respectively. Hence, both simplifying assumptions meaningfully affect counterfactual estimates of welfare gains, with the consequences of assuming a homogeneous $\rho$ slightly smaller in magnitude but broadly comparable to those of assuming a homogeneous $\theta$.

In Panel B of Figure 2, we plot the kernel density of deviations in trade-share changes resulting from the same counterfactual shock. The distributions of $\mathcal{D}(\lambda_{ij}(s), \bar{\rho})$ and $\mathcal{D}(\lambda_{ij}(s), \bar{\theta})$ are both left-skewed, indicating that assuming homogeneous values of $\rho$ or $\theta$ tends to underpredict changes in trade shares. The standard deviations of these deviations are 65 and 262, respectively. This suggests that while the assumption of a uniform trade elasticity $\theta$ has quantitatively larger implications for counterfactual trade-share calculations, the effect of imposing a single $\rho$ remains economically meaningful – approximately one quarter of the magnitude of the $\theta$ case.

Taken together, Panels A and B indicate that the assumption of a single transport-mode elasticity is nearly as consequential as the assumption of a single trade elasticity. Although the quantitative effects of imposing a uniform $\rho$ are somewhat smaller, they remain sizable and systematic across welfare and trade-share outcomes. These findings underscore that sectoral heterogeneity in $\rho(s)$ is not a second-order detail but a first-order determinant of how economies adjust to transport-cost shocks. Accounting for this heterogeneity is therefore essential for accurate counterfactual analysis in trade models with transportation costs.

Panel A: Deviations in Welfare Gains

Panel B: Deviations in Trade-Share Changes




*Notes:* The figures show deviations, in percentage points, between scenarios with homogeneous transport-mode or trade elasticities and the benchmark case where both elasticities are heterogeneous. Panel A presents kernel density estimates of the deviations in welfare gains from trade, while Panel B presents the corresponding deviations in trade-share changes.

Figure 2: Deviations from the Fully Heterogeneous Benchmark

# 6 Conclusions

This paper develops an empirical and quantitative framework to estimate and apply sectoral transport-mode elasticities in international trade. Using newly available data and an instrumental variables strategy, we provide the first comprehensive evidence on the heterogeneity of sectoral responses to changes in transport-mode-specific costs. The estimated elasticities range substantially across sectors and align closely with observable value-to-weight ratios.

To assess the quantitative relevance of this heterogeneity, we embed the estimated elasticities into a multi-country, multi-sector general equilibrium model with endogenous transport mode choice and input–output linkages. Counterfactual simulations of a 30% reduction in air-transportation costs show that assuming a single transport-mode elasticity can substantially change counterfactual predictions. Our comparison indicates that imposing uniformity in transport-mode elasticities leads to distortions of similar order to those generated by assuming a single trade elasticity.

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# Appendix

Table A1: Sectors and Countries Used in the Analysis

| Sectors (65) | Countries (126) |
|---|---|
| Accommodation, Food, and Service Activities (AFS); Air Transport (ATP); Basic Pharmaceutical Products (BPH); Beverages and Tobacco Products (B_T); Chemical Products (CHM); Communication (CMN); Bovine Meat Products (CMT); Construction (CNS); Coal (COA); Cattle, Sheep, Goats, and Horses (CTL); Sugar Cane and Sugar Beet (C_B); Dwellings (DWE); Education (EDU); Electrical Equipment (EEQ); Computer, Electronic and Optical Products (ELE); Electricity (ELY); Fabricated Metal Products (FMP); Forestry (FRS); Fishing (FSH); Gas Manufacture and Distribution (GAS); Dairy Products (GDT); Cereal Grains (GRO); Human Health and Social Work (HHT); Insurance and Pension Services (INS); Ferrous Metals (I_S); Leather Products (LEA); Wood Products (LUM); Raw Milk (MIL); Motor Vehicles and Parts (MVH); Non-Ferrous Metals (NFM); Mineral Products n.e.c. (NMM); Other Animal Products (OAP); Business Services n.e.c. (OBS); Other Crops (OCR); Food Products n.e.c. (OFD); Financial Services n.e.c. (OFI); Oil (OIL); Machinery and Equipment n.e.c. (OME); Manufactures n.e.c. (OMF); Meat Products n.e.c. (OMT); Oil Seeds (OSD); Public Administration and Defense (OSG); Transport Equipment n.e.c. (OTN); Other Transport (OTP); Extraction n.e.c. (OXT); Processed Rice (PCR); Paddy Rice (PDR); Plant-Based Fibers (PFB); Paper Products and Printing (PPP); Petroleum and Coke Products (P_C); Raw Milk and Dairy Cattle (RMK); Recreation and Other Services (ROS); Rubber and Plastic Products (RPP); Real Estate Activities (RSA); Sugar (SGR); Textiles (TEX); Trade (TRD); Vegetable Oils and Fats (VOL); Vegetables, Fruits, and Nuts (V_F); Wearing Apparel (WAP); Warehousing and Support Activities (WHS); Wheat (WHT); Wool and Silk-Worm Cocoons (WOL); Water Transport (WTP); Water Collection, Treatment, and Supply (WTR). | Afghanistan (AFG); Albania (ALB); United Arab Emirates (ARE); Argentina (ARG); Armenia (ARM); Australia (AUS); Austria (AUT); Azerbaijan (AZE); Belgium (BEL); Benin (BEN); Burkina Faso (BFA); Bulgaria (BGR); Bahrain (BHR); Belarus (BLR); Bolivia (BOL); Brazil (BRA); Botswana (BWA); Central African Republic (CAF); Switzerland (CHE); Chile (CHL); China (CHN); Côte d'Ivoire (CIV); Cameroon (CMR); Democratic Republic of the Congo (COD); Colombia (COL); Comoros (COM); Costa Rica (CRI); Cyprus (CYP); Czech Republic (CZE); Germany (DEU); Denmark (DNK); Dominican Republic (DOM); Algeria (DZA); Ecuador (ECU); Egypt (EGY); Spain (ESP); Estonia (EST); Ethiopia (ETH); Finland (FIN); France (FRA); United Kingdom (GBR); Georgia (GEO); Ghana (GHA); Greece (GRC); Guatemala (GTM); Hong Kong (HKG); Hungary (HUN); India (IND); Indonesia (IDN); Iran (IRN); Ireland (IRL); Israel (ISR); Italy (ITA); Japan (JPN); Jordan (JOR); Kazakhstan (KAZ); Kenya (KEN); South Korea (KOR); Kuwait (KWT); Lebanon (LBN); Lithuania (LTU); Luxembourg (LUX); Latvia (LVA); Malaysia (MYS); Morocco (MAR); Mexico (MEX); Netherlands (NLD); New Zealand (NZL); Nigeria (NGA); Norway (NOR); Pakistan (PAK); Peru (PER); Philippines (PHL); Poland (POL); Portugal (PRT); Qatar (QAT); Romania (ROU); Russia (RUS); Saudi Arabia (SAU); Singapore (SGP); South Africa (ZAF); Sweden (SWE); Switzerland (CHE); Thailand (THA); Tunisia (TUN); Turkey (TUR); United States (USA); Ukraine (UKR); United Arab Emirates (ARE); Vietnam (VNM); Zambia (ZMB); Zimbabwe (ZWE). |