

Measuring and Understanding Unexplained Trade: A Gravity Approach

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Abstract

While countries can use transshipments to illegally circumvent tariffs levied on their exports, such illegal transshipments are difficult to measure or calculate. In this paper, we estimate gravity regressions for fourteen aggregated manufacturing sectors in the 1995-2022 period, and use the residuals from those regressions as 'unexplained trade' suggestive of the presence of transshipments. We find that the median unexplained trade value among all countries and sectors is negative, and has been decreasing between 1995 and 2022. We also find increasing unexplained exports from China to Vietnam and Cambodia but not Mexico and Canada, as well as high levels of unexplained trade between Russia and its geographic neighbors. We then estimate the relationship between countries' geopolitical characteristics and the value of unexplained trade they conduct, finding that a pair of countries is expected to have a substantially lower level of unexplained trade if one country, but not the other, is under international sanctions.

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1 Introduction

In recent years, gravity modeling has become the preferred tool for researchers wanting to examine the determinants of bilateral trade flows (Yotov et al., 2016; Larch et al., 2025). In its essence, the gravity model relates bilateral trade between two countries to various country-specific characteristics, such as the size of their respective economies, along with certain geographic, cultural, and political factors that can generate trade costs between trading partners. For example, a naive gravity model would predict, correctly, that bigger countries trade more than smaller ones and that countries located further apart trade less than those located in closer proximity. The flexible nature of the gravity framework has led it to be used in various applications related to understanding the effects of trade policies, international sanctions, FDI and taxation, and transport costs among other questions of interest.¹

While the gravity model has had tremendous success in explaining the bilateral determinants of trade, like any empirical model, it fails to capture all the factors that can lead a country to trade with another. For most country pairs, the residuals from a gravity model are likely just an artifact of regression mechanics and represent nothing more than statistical noise. However, for certain country pairs, the residuals may include a systematic component that is not accounted for by gravity specifications that only rely on factors such as distance, contiguity, common language, colonial ties, and trade and investment agreements as their proxies for bilateral trade costs. Our paper focuses on such cases of “unexplained trade” that may benefit from further empirical investigation.

In particular, the concept of unexplained trade can shed light on illegal transshipments, which have become an important topic of discussion in an environment of higher tariffs on targeted countries and sectors. Illegal transshipments are categorized as any re-routing of trade across third-party countries undertaken to explicitly avoid tariffs or sanctions.² Thus, an illegal transshipment occurs if countries are able to circumvent tariffs and sanctions by re-routing shipments through third-party countries and obscuring the country of origin of the shipped good. For example, Chinese firms could circumvent China-specific tariffs imposed by the United States by first sending the given product to its subsidiaries in Vietnam, where they are relabeled, and then exported to the United States as goods originating from Vietnam. Similarly, Russian firms could circumvent European sanctions by re-routing shipments through neighboring countries such as Kazakhstan and Armenia. These types of transshipments are of concern for policymakers because they circumvent the original goals of the imposed tariffs and sanctions. However, illegal transshipments are not directly observed

¹See Yotov (2024) for the evolution of the gravity model, from an a-theoretical application to a structural framework suitable for quantifying the general equilibrium effects that arise from changes in trade costs.

²Not all transshipments are illegal. For reasons of logistical efficiency, goods may pass through a third country en route to their eventual destination; these transshipments are legal if documented accurately. While the methodology of this paper could assist in detecting legal or illegal transshipments, illegal transshipments are the primary focus of discussion.

in the data and difficult to impute, with economists and governments having limited knowledge of where and to what extent they are occurring.

For our analysis, we rely on residuals obtained from a gravity estimation with panel trade data as our measure of unexplained trade. We run our gravity regressions for fourteen different sectors and in two different time periods: 1995-2009 and 2010-2022. The difference between trade observed in the data and trade predicted by a structural gravity equation is then used to assist us in identifying if there are other motivations for countries to trade with one another; while unexplained trade could be explained by other factors such as legal transshipments, it nevertheless can help illuminate the presence of illegal ones. Gravity residuals across most countries and sectors have become more negative over the last thirty years, meaning that bilateral trade has increasingly become lower relative to the trade predicted by gravity relationships between trade partners. To the degree that unexplained trade is suggestive of transshipments, we also find evidence that China is re-routing exports through Vietnam and Cambodia, but less evidence of China's re-routing exports through Canada and Mexico. Russia continues to have positive, and in some cases increasing, gravity residuals with certain European countries after the onset of the Russo-Ukraine War.

We supplement our analysis by testing if unexplained trade, as captured by the gravity residuals, is related to different measures of geopolitical distance between trading partners. With these additional regressions, we can understand if certain political characteristics, such as one country's being under sanction or both countries being considered democracies, affect the level of unexplained trade that is observed from traditional gravity estimations. Our results show that two countries are almost always predicted to have lower unexplained trade if at least one country is under sanction, while the interaction of trading partners' development levels has little predictive power over unexplained trade. Bilateral unexplained trade in the 2010-2022 period is predicted to be higher if both countries are considered dictatorships and lower if both countries are considered democracies.

Section 2 reviews related works examining transshipments and the role of geopolitical factors in bilateral trade. Section 3 discusses the data and methodology behind our gravity analysis. Section 4 explores patterns in unexplained trade and discusses what those patterns may be suggesting about transshipments. Section 5 examines geopolitical factors with gravity, including the data and methodology behind the set of country-specific regressions. Section 6 concludes.

2 Related Literature

2.1 Gravity and Transshipments

A limited number of studies apply a gravity approach to measure illegal transshipments. One exception is Tyazhelnikov and Romalis (2024) which also relies on a structural gravity approach to estimate the value of shipments that circumvented import controls on agricultural products that Russia implemented following its annexation of Crimea in 2014. To identify such suspicious activities, the authors compare predicted trade flows obtained from a structural general equilibrium gravity model with actual trade flows in 2015. While Tyazhelnikov and Romalis (2024) focused on full sanctions imposed by one country on a given set of products, our approach is more generalizable and can be used to understand the drivers of unexplained trade flows from all countries in the past thirty years.

A few studies have used the gravity model to investigate the causes and consequences of legal transshipments. For instance, Lankhuizen and Thissen (2019) discusses how re-exports can bias gravity regression results, and displays the results of gravity regressions that explicitly take re-exports into account. This paper’s methodology is in some sense the inverse of ours, in that it incorporates legal re-exports into a gravity model while our paper uses the results of a gravity model to draw conclusions about illegal re-exports. Andriamananjara et al. (2004), a USITC working paper, uses a gravity framework to show that re-exports from the United States respond more sensitively than domestic exports to variables such as distance and port policies.

Due to the unavailability of direct data, other studies on illegal transshipments have typically relied on on event studies rather than gravity models for their empirical analysis. Freund (2025) discusses potential Chinese evasion of Section 301 tariff duties, computing a measurement of such evasion using data at the Harmonized System 6-digit level from UN Comtrade. Iyoha et al. (2025) computes a similar measure of re-routing and uses it in a difference-in-differences regression to determine the effect U.S. tariffs on China had on transshipments through Vietnam. Chupilkin et al. (2023) performs a similar difference-in-difference estimation, but with Russia rather than China as the country of interest and total exports rather than re-routed exports as the outcome variable.

Beyond trade, there is a larger and more developed literature focused on measuring ‘phantom FDI’, the financial counterpart of unexplained trade. Applying a similar methodology as this paper, Ahmad et al. (2025) identify phantom FDI as the difference between observed FDI flows and the FDI flows predicted by a structural gravity regression. Paz (2022) uses a gravity model of international trade to estimate the misinvoicing of international trade transactions, which scholars have argued to be a frequent conduit for illicit financial flows. The IMF method introduced by Damgaard et al. (2024) and the implied investment

method introduced by Casella (2019) for UNCTAD are two prominent atheoretical methods of identifying phantom FDI.

2.2 Gravity and Geopolitical Factors

With the post-Cold war economic order facing significant headwinds in recent years, there has been a renewed interest in examining the influence geopolitical factors may have on trade and financial flows. Jones, Shikher, and Yotov (2025) estimate the effect of geopolitical factors on intermediate goods trade and final goods trade separately, finding that geopolitical risks have a noticeably smaller impact for intermediate goods. Gopinath et al. (2025) run a gravity model on cross-border flows of trade and investment with controls for country-level shocks and time-invariant factors; their gravity estimates support the argument that trade, investment, and capital flows may be fragmenting along geopolitical lines. Using a dynamic hierarchical factor model that takes popular indicators as noisy proxies for fragmentation, Fernández-Villaverde et al. (2024) also find that geopolitical fragmentation has been increasing since the financial crisis of 2007-08, with no signs of reversal. We complement that body of work by investigating the predictive effect of geopolitical differences on trade *residuals*, rather than bilateral trade.

A gravity framework has often been used in the literature to estimate the economic costs of geopolitical fragmentation. Using a general equilibrium trade model, Campos et al. (2024) analyze a hypothetical scenario of the global economy fragmenting into three trade blocs: Western, Eastern, and Neutral.³ They find that such fragmentation would reduce trade flows across bloc boundaries by more than 20 percent, with countries in the Eastern bloc suffering the highest welfare losses. Similarly, Bosone and Stamato (2024) use a structural gravity model to show that a 10 percent increase in geopolitical distance, as captured by the UN General Assembly voting patterns, decreases bilateral trade flows by 2.5 percent in 2021-22.⁴ Other economic studies have found that the cost to global output from ongoing trade fragmentation could range from 0.2 percent to up to 7 percent of global GDP (Aiyar et al., 2023).

3 Methodology

3.1 Trade and Gravity Data

Our trade data comes from the USITC’s International Trade and Production Database for Estimation (ITPD-E), which provides annual data on international and domestic trade for 170 industries and 264 countries from

³Countries are allocated to each of these blocs according to their vote on the 9th of April, 2021 in the United Nations (UN) General Assembly on the resolution concerning the suspension of the rights of membership of the Russian Federation in the Human Rights Council.

⁴Aiyar et al. (2024) use a similar setup to quantify the effect of geopolitical differences on FDI

1988 until 2022.⁵ We concentrate on manufacturing industries in this paper as recent policy actions have targeted this sector in particular for re-shoring. While the ITPD-E database subdivides manufacturing trade into 118 industries, we estimate our regressions using 14 broader categories to make our discussion less unwieldy. For a complete listing of industries featured in this paper’s analysis, see Appendix A.

We rely on the USITC’s Dynamic Gravity Dataset for information on the explanatory variables in our baseline gravity regression. The Dynamic Gravity Dataset has information on bilateral variables related to geographic characteristics, cultural relationships, and trade facilitation measures for a total of 286 countries between 1948 and 2019.⁶ Geographic characteristics include measures such as distance and mutual contiguity, cultural relationships include shared languages or legal systems, and trade facilitation measures refer to both countries’ participation in a trade agreement or other type of economic integration agreement. Appendix A provides descriptive statistics on the gravity variables used in the estimation.

Because the Dynamic Gravity Dataset does not have data after 2019, our trade data contains a few years of observations with no matching gravity data. While most of the bilateral explanatory variables in the gravity equation, such as distance or geographic contiguity, are not expected to change after 2019⁷, country pairs could very well have signed new trade agreements between 2019 and 2022. We thus supplement the Dynamic Gravity with information from the Design of International Trade Agreements (DESTA) dataset that catalogs all trade agreements signed prior to 2023, including information on both the year each agreement was signed and the year the agreement went into effect. So we use DESTA to get data on all country pairs who signed a trade agreement that went into effect after 2019 and before 2022, and add it to the available data on FTAs in the Dynamic Gravity Dataset.

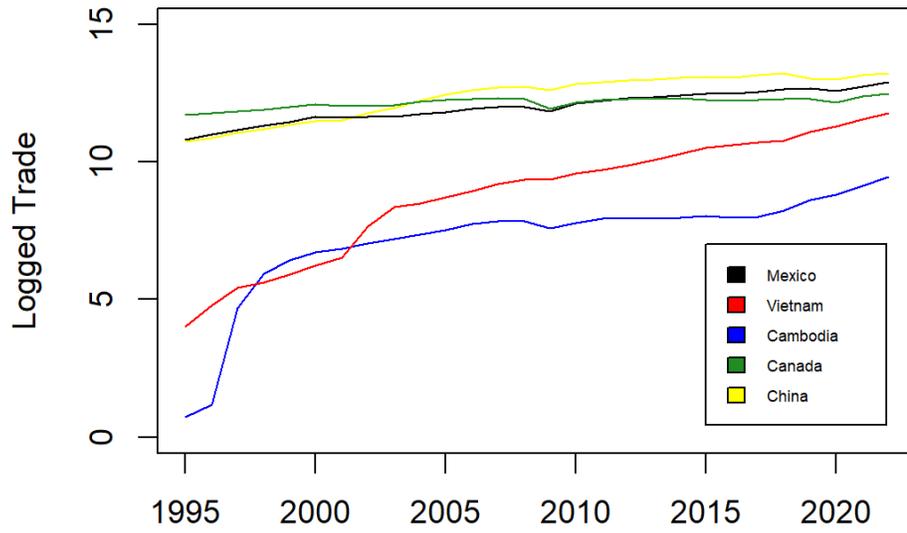
Figures 1a) and 1b) display, respectively, U.S. imports and Chinese exports, as a way of illustrating how trade dynamics have shifted over the past thirty years. Between 1995 and 2009, U.S. imports from China, Cambodia, and Vietnam grow rapidly, with U.S. imports from China overtaking U.S. imports from Canada and Mexico by 2009. In the 2010-2022 period, U.S. imports from China grow at about the same rate as those from Canada and Mexico, and while U.S. imports from the latter two countries only decrease in 2020, imports from China begin to decrease in 2018 before (slightly) recovering in 2021-2022. U.S. imports from Vietnam and Cambodia, however, continue to grow at a rapid rate, a rate that intensifies around 2018 when imports from China begin to stagnate. Figure 1b) shows rapidly increasing growth in Chinese exports to all four countries between 1995 and 2009, but Chinese exports to Canada and Mexico decelerate in the 2010-2022 period, while Chinese exports to Cambodia and Vietnam continued to grow at a fast pace.

⁵See Larch et al. (2025) for more details on how the dataset was construction.

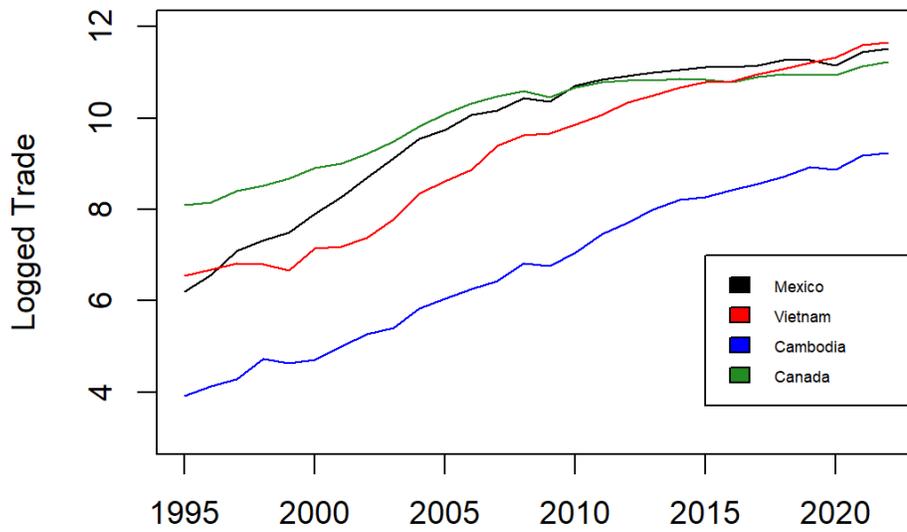
⁶See Gurevich and Herman (2018) for more information on the Dynamic Gravity Dataset.

⁷The Dynamic Gravity Dataset does weight different cities by population when computing distance measures, and population is not time-invariant. However, we assume that the population *weights* would not have changed substantially between 2019 and 2022.

These time series of U.S. trade and Chinese trade provide qualitative evidence in favor of Chinese firms' increasingly using secondary countries to transship their goods to the United States after 2018. U.S. imports from China drop *before* the pandemic, unlike imports from Canada and Mexico, while U.S. imports from Cambodia and Vietnam accelerate around the same time that imports from China shrink. However, exports from China to Cambodia and Vietnam grow rapidly in the first half of the 2010s as well, and U.S. imports from China recover in 2021-2022. In the next section, we use residuals from a gravity regression to develop a more systematic approach for quantifying the portion of trade that cannot be explained by traditional gravity factors.



(a) U.S. Imports



(b) China exports

Figure 1: Time series of (logged) aggregate trade data from ITPD

3.2 Gravity Equation and Baseline Results

We rely on the following specification for our gravity analysis:

$$\text{Trade}_{ijt} = \vec{\beta} \cdot \overrightarrow{\text{Geographic}}_{ijt} + \vec{\alpha} \cdot \overrightarrow{\text{Cultural}}_{ijt} + \gamma \text{Agreement}_{ijt} + \delta \text{DOM}_{ijt} + \phi_{it} + \eta_{jt} + \varepsilon_{ijt} \quad (1)$$

where Trade_{ijt} are trade flows from exporter i to importer j in year t . $\overrightarrow{\text{Geographic}}_{ijt}$ is a vector of bilateral geographic characteristics, namely the logged distance between i and j , a binary variable equal to one if i and j share a border, a binary variable equal to one if either i or j is landlocked, and a binary variable equal to one if either i or j is an island nation.⁸ $\overrightarrow{\text{Cultural}}_{ijt}$ is a vector of shared cultural characteristics, namely common language, common legal system, and colonial ties.⁹ Agreement_{ijt} is a single binary variable equal to 1 if countries i and j both participate in a free trade agreement. Finally, following Yotov et al. (2016), we include a binary variable DOM_{ijt} that is equal to one if the given bilateral flow represents trade within the same country, or domestic trade, and zero otherwise.

Our specified gravity model follows the latest recommendations from the trade literature (Larch et al., 2025). In particular, we include exporter-year (ϕ_{it}) and importer-year (η_{jt}) fixed effects so that the outward and inward multilateral resistance terms, representing the theory-consistent aggregates of trade costs, are accounted for each trading partner. Moreover, we include domestic trade flows to capture the trade-diversion effects of bilateral policies such as FTAs. Our estimations are also performed using panel data for consecutive years at the disaggregate sector-level. Lastly, we use a Poisson Pseudo-Maximum Likelihood estimator to account for any potential heteroskedasticity and zero flows in the trade data (Santos-Silva, 2005).

We run a total of twenty-eight gravity regressions: one for each aggregated industry during the 1995-2009 period, and one for each aggregated industry during the 2010-2022 period. Tables 5 and 6 in Appendix A display our gravity regression results. The estimates on the gravity coefficients are in line with the trade literature. The effect of logged distance on trade ranges from -0.319 to -1.77, with all coefficients statistically significant at the one percent level, and contiguity only has a negative impact on trade for one out of twenty-eight regressions. Other gravity variables display the expected relationship with trade, with the exception of colonial ties, which had a negative relationship with trade for six sectors in the 2010-2022 regressions and three in the 1995-2009 regressions.¹⁰

Consistent with the broader literature, we find that an FTA between trading partner leads to higher

⁸Because the Dynamic Gravity Dataset allows some of the gravity variables to vary by year, explanatory variables in this regression have a time index along with indices for exporter and importer.

⁹We consider two countries i and j to have colonial ties if i was a colony of j or j was a colony of i . Both relationships are included as indicator variables in the Dynamic Gravity Dataset.

¹⁰In theory, colonial ties could logically lead to lower bilateral trade if the countries' colonial history leads to a more strained geopolitical relationship.

trade flows for most of the sectors in our sample. We do caution that our FTA estimates may be upward biased due to issues of endogeneity and reverse causality. Traditionally, the literature has accounted for such concerns by adding country-pair fixed effects in the estimation (Baier and Bergstrand, 2007). However, the inclusion of pairwise fixed effects comes with a cost as it also absorbs all time-invariant bilateral determinants of trade including geographical, historical and cultural characteristics. Since the main objective of our paper is to examine trade that is not explained by traditional gravity variables, and not on assessing the impact of an FTA on trade, we do not include country-pair fixed effects when running our gravity estimations.

We can now use the gravity estimates in Tables 5 and 6 to compute our measure of unexplained trade for further empirical investigation. We define unexplained trade in a particular sector k as the difference between actual trade flows between exporter i and importer j in year t :

$$Unexplained.Trade_{ijt}^k = Trade_{ijt}^k - \widehat{Trade}_{ijt}^k. \quad (2)$$

Based on our definition, we will have a positive trade residual if actual exports from country i to country j in sector k in year t are higher than the exports predicted by a standard gravity model (more trade is taking place than expected). Conversely, we will have a negative trade residual in sector k if actual exports from country i to country j in year t are lower than what is predicted from a standard gravity model (less trade is taking place than expected). In sections 4 and 5, we explore some other factors that may be contributing to these unexplained trade flows.

We further note that the adjusted pseudo R-squared values in Tables 5-6 are consistently large, meaning that gravity variables explain almost all of the variation in trade. This result bolsters confidence in the importance of ‘unexplained’ trade as a measurement; if traditional gravity variables perform well in predicting trade movements, the unexplained portion of those movements becomes all the more important and may indicate the presence of external factors such as tariff evasion.

We consider a range of robustness exercises to confirm the validity of our gravity estimates. We alternatively consider both an aggregation and disaggregation of the gravity model, running both a single regression that pools all sectors and a set of regressions that separates bilateral trade by year. We further consider expanding the menu of explanatory variables to include measurements provided by the Dynamic Gravity Dataset for other factors, including economic integration agreements, currency unions, and distinguishing between goods- and services-specific trade agreements. None of these alterations make any significant difference to results.

Finally, we consider the role of investment in bilateral trade. A bilateral investment deal (BIT) between two countries could spur further trade between those countries, or alternatively predict lower trade as the

BIT leads to higher levels of FDI that substitute for exports. An investment agreement between country pairs could therefore account for some of the bilateral trade not explained by other gravity variables. Nonetheless, the inclusion of a binary variable for countries having a BIT in a given year does not significantly affect our other gravity regression coefficients or our gravity residuals.

4 Observed Trends in Unexplained Trade

This section discusses trends and patterns in unexplained trade generated by the gravity regressions in the previous section. We start by discussing worldwide trends in unexplained trade, leveraging our methodology’s ability to provide estimates of unexplained trade for more than two hundred countries. Since one of the drivers of unexplained trade could be transshipments to avoid tariffs or sanctions, this section also features discussion of the United States, China, and Russia.

When comparing values of unexplained trade across countries and years, a “naive” analysis would be biased toward countries with larger economies, as those countries would have higher levels of unexplained trade simply because they have higher levels of trade in general. Comparing countries and years by their residuals as a fraction of bilateral trade avoids this problem, but is also misleading for country pairs with very low levels of trade because it would lead to the mistaken belief that large volumes of unexplained trade are happening.¹¹ Because no measurement approach is perfect, this section presents results using both methods of measurement, with a preference toward unexplained trade as a fraction of overall trade when discussing large countries such as the United States and China.

4.1 Worldwide Trends

We begin by providing an overview of unexplained trade across all countries in our dataset. Figure 2 shows that the median gravity residual across all countries in 2022 is negative for every sector, meaning that a majority of trade flows in each sector are lower than gravity modeling would predict. However, the median residual is also close to 0 for most sectors, indicating that gravity predictions are generally close to observed trade and that slightly under half of trade flows in 2022 are *higher* than their gravity predictions. Agriculture, fuel, and metals have more negative median residuals than other sectors.

Median unexplained trade results become more negative after dividing by trade flows (Figure 1b) due to the low trade flow values observed for a majority of country pairs.¹² After dividing gravity residuals by

¹¹Countries with the highest levels of unexplained trade as a fraction of observed trade are all small island nations, such as the Marshall Islands or Tokelau. This pattern occurs even though regressions include indicator variables representing island status.

¹²All analysis in Section 4.1 involving residuals as a fraction of observed trade excludes origin-destination-sector observations with bilateral trade below \$1000. Nonetheless, 70% of trade flow observations are below \$1 million.

their respective trade flows, agriculture and metals display unexpected trade in 2022 that is more similar to the other sectors. Fuel, though, continues to have especially low observed trade flows relative to its gravity predictions.

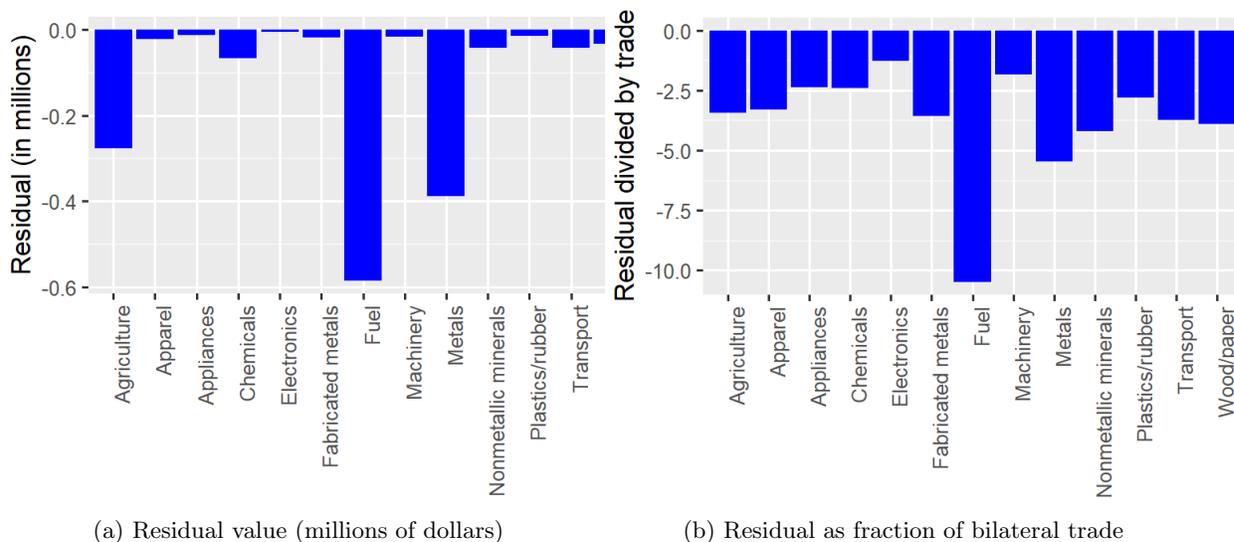


Figure 2: Median residual in 2022 by sector among all countries

We next break out median trade residuals across time. Figure 3 displays time series of median unexplained trade flows in all countries and sectors, both as a value (Figure 3a) and as a fraction of trade (Figure 3b). Figure 3 also shows 95% confidence intervals for the set of trade residuals in each year.

Figure 3a) shows that the median unexplained trade value in every year is slightly negative, indicating that the median trade flow is slightly lower than the trade flows predicted by gravity. As in Figure 2, median residuals are close to zero and substantial heterogeneity continues to exist across origin-destination-sector pairs, with slightly fewer than half of all gravity residuals being positive. After dividing gravity residuals by bilateral trade, unexplained trade becomes more consistently negative, with 95% of observations falling below zero in all years. By 2010, the median unexplained trade value is three times as high as the median bilateral trade flow.

A major takeaway from Figure 3 is that gravity residuals, and the unexplained trade they represent, have become more negative over the past thirty years. This increased discrepancy between observed trade and predicted trade is especially prominent in Figure 3b). The increasing negativity of gravity residuals' could be explained by a gradual dissolution of the post-Cold War consensus of a fully integrated global economy due to the War on Terror, the global financial crisis, and, in more recent years, the heightened interest from advanced economies to reduce their reliance on global supply chains. As the global economy fragments, standard gravity variables such as FTAs will play a lesser role in explaining global trade. This

result dovetails with Fernández-Villaverde et al. (2024), which finds that geopolitical fragmentation has been increasing since the global financial crisis. However, our residual estimations are most useful as indicators for future study, and should not be associated with any single causal interpretation.

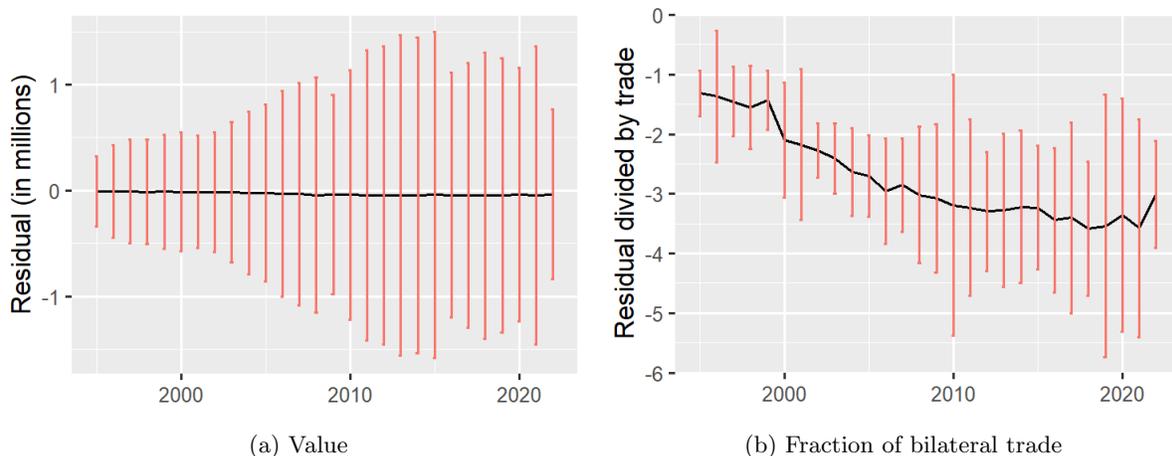


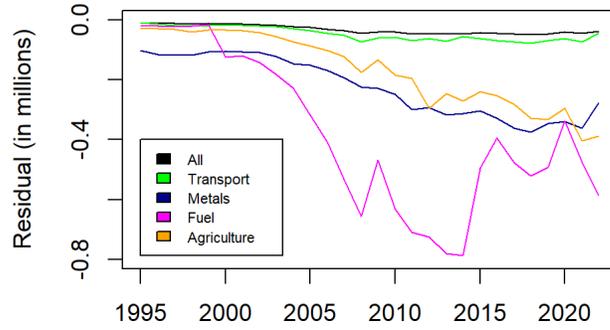
Figure 3: Time series of the median residual among all countries, sectors

Finally, we separate out time series by sector. Figure 4 shows that the decrease in gravity residuals across time is especially pronounced for fuel; median unexplained trade fuel is similar to that of other sectors in 1995 but substantially lower by 2010. Metals show a steeper decline in Figure 4a) compared to Figure 4b), while transport equipment shows the opposite pattern.

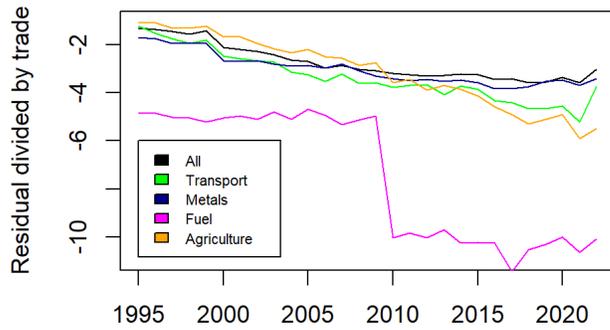
4.2 U.S. Unexplained Trade

Figure 5 provides information on U.S. unexplained trade as a fraction of observed trade flows. The median trade residual for the United States is negative, indicating the median trade observation is lower than what bilateral gravity relationships would predict. In other words, for the majority of origin/sector/year combinations, U.S. imports and exports are lower than the levels indicated by shared geographic characteristics, cultural characteristics, and trade agreements that the United States has with other countries. This negative relationship is more pronounced for U.S. imports compared to exports. Since transshipments are more likely to affect U.S. imports than exports, we concentrate on unexplained U.S. imports in the remaining discussion.

Our estimated median residual-to-trade ratios for U.S. imports differ by sector and time period. The U.S. has a large negative median ratio for imports of transport equipment, but median ratios are less negative for imports of other sectors such as apparel and food. U.S. import residual-to-trade ratios are generally more negative in the 1995-2009 period than in 2010-2022, with the exception of food manufactures and apparel imports. For imports of transport equipment, median unexplained trade in 1995-2009 is significantly larger in magnitude than median unexplained trade in 2010-2022.

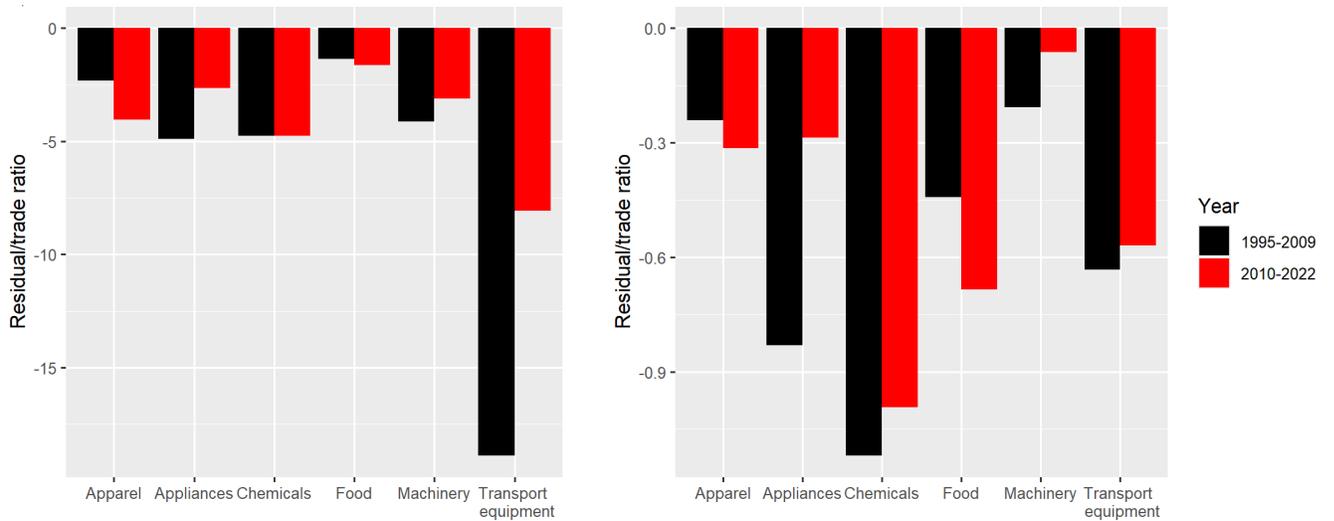


(a) Value



(b) Fraction of bilateral trade

Figure 4: Time series of the median residual-to-trade ratio for selected sectors



(a) US imports

(b) US exports

Figure 5: Median residual-to-trade ratio for gravity regression results featuring the United States

U.S. total import residuals for transport equipment across the entire 1995-2022 period are strongly positive for Germany and Austria, both in value and as a fraction of imports. Meanwhile, import residual

values for transport equipment are strongly negative for Brazil, Spain and India, while import residual fractions are strongly negative for island nations due to the low volume of observed trade flows. Unexplained export values for appliances and food are most positive for China, Japan, Korea and Mexico; and most negative for Brazil, India, and several European countries. Export residual fractions in food are most positive for the Netherlands and New Zealand, while strongly negative for several African countries.

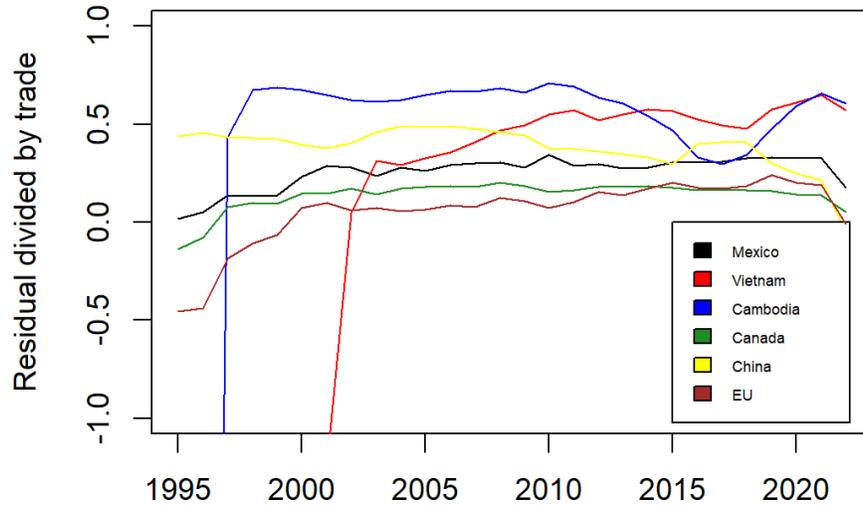
We next present time series of U.S. unexplained imports from 1995 to 2022 for China, Canada, Mexico, Cambodia, and Vietnam. China was chosen due to geopolitical importance and the other four countries because China could plausibly re-route manufacturing output through those countries to the United States.

We find that total U.S. residual-to-trade ratios from China are positive, but trending downward over time (Figure 6a, see next page). The most recent decrease in unexplained U.S. imports from China, which started in 2018, coincide with an increase in unexplained U.S. imports from Vietnam and Cambodia, whose trends are similar to China's before 2015, but have since diverged. Unexplained imports as a fraction of total imports from Canada and Mexico have remained stable across the 1995-2022 period, with U.S. imports from Mexico slightly higher than gravity predictions and U.S. imports from Canada slightly lower.

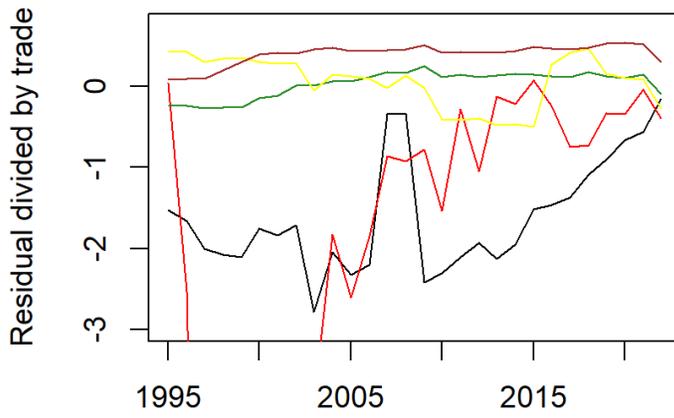
Turning to the sector-specific time series, trends largely follow the overall trends shown in Figure 6a). We find that the U.S. has largely positive import residuals with China in machinery and chemicals/pharmaceuticals, but negative import residuals in metals and transport equipment. We also see that the recent decrease in U.S. unexplained imports from China in manufacturing sectors coincides with an increase in U.S. unexplained imports from Vietnam and Cambodia, with both countries having positive residual values in recent years. For instance, the residual value for U.S. imports of metals from Vietnam is almost as large as actual import values since 2010.

Unexplained U.S. imports from Canada and Mexico are more stable and do not vary as much during the time period surveyed, although unexplained imports from Mexico show a steady uptick in chemicals/pharmaceuticals and metals. In metals, the U.S. has gone from having positive import residuals with Canada to negative import residuals with Canada. Unexplained U.S. imports from Vietnam and Cambodia, smaller countries with initially low levels of U.S. trade, display more fluctuations prior to 2015.

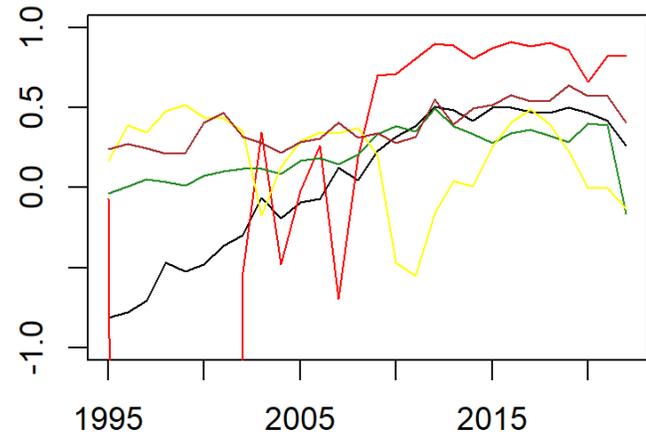
Finally, we look at the spatial distribution of U.S. unexplained imports (Figure 7). Following the criterion set by Tyazhelnikov and Romalis (2024), we present countries whose residual exports to the United States in 2022 are in the top ten percent or bottom ten percent among all countries, measuring residuals both in values and as a fraction of observed imports. The United States has high levels of unexplained imports with Canada and Mexico in 2022. Less predictably, it also has high positive import residuals with several Southeast Asian countries, including Thailand, Vietnam and Indonesia. Trade is lower than its gravity-predicted value for China and Russia, as well as most countries in South America and Eastern Europe.



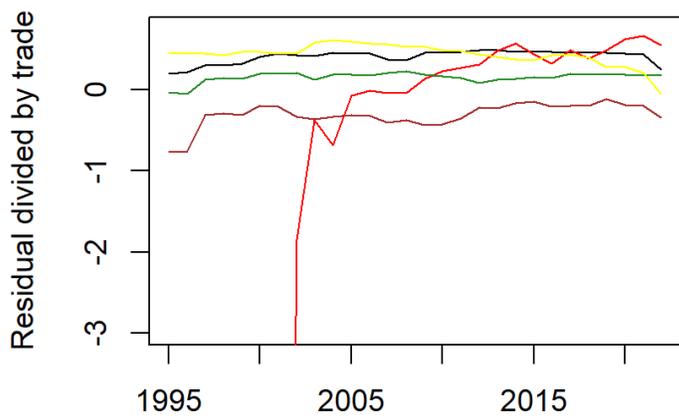
(a) Aggregate across all sectors



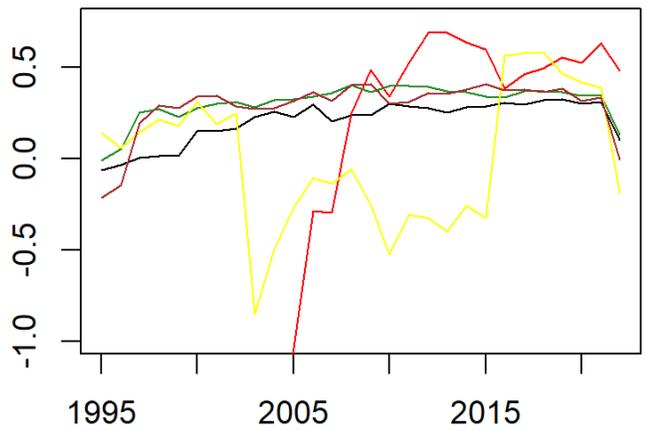
(b) Chemicals/pharmaceuticals



(c) Metals

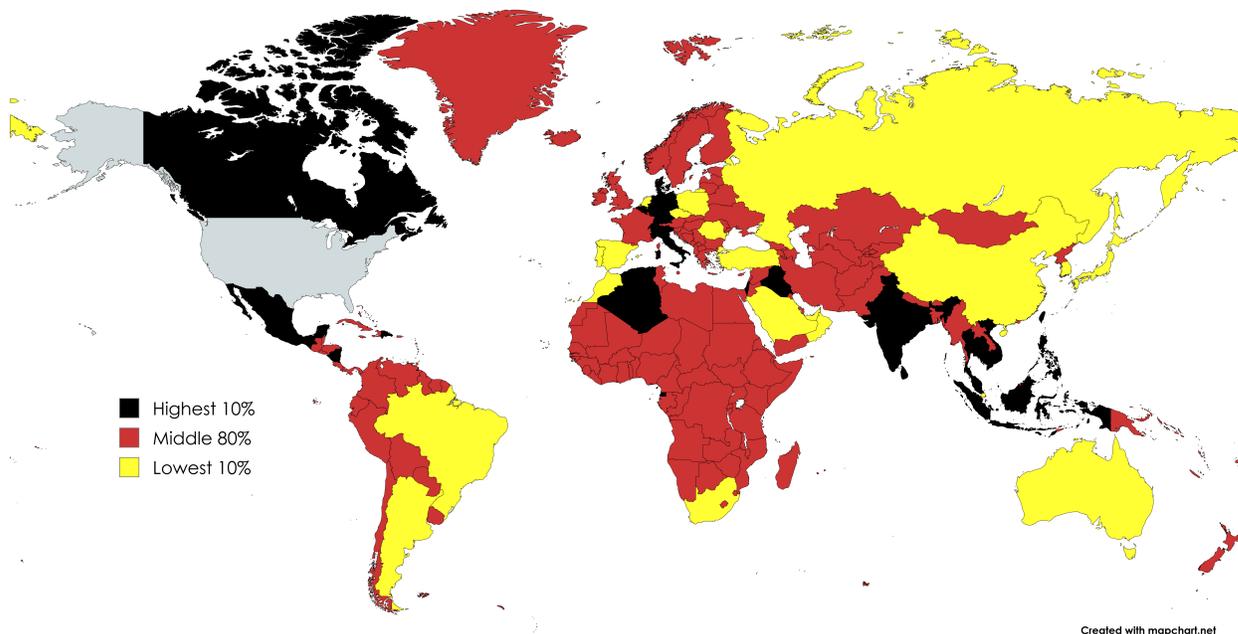


(d) Machinery

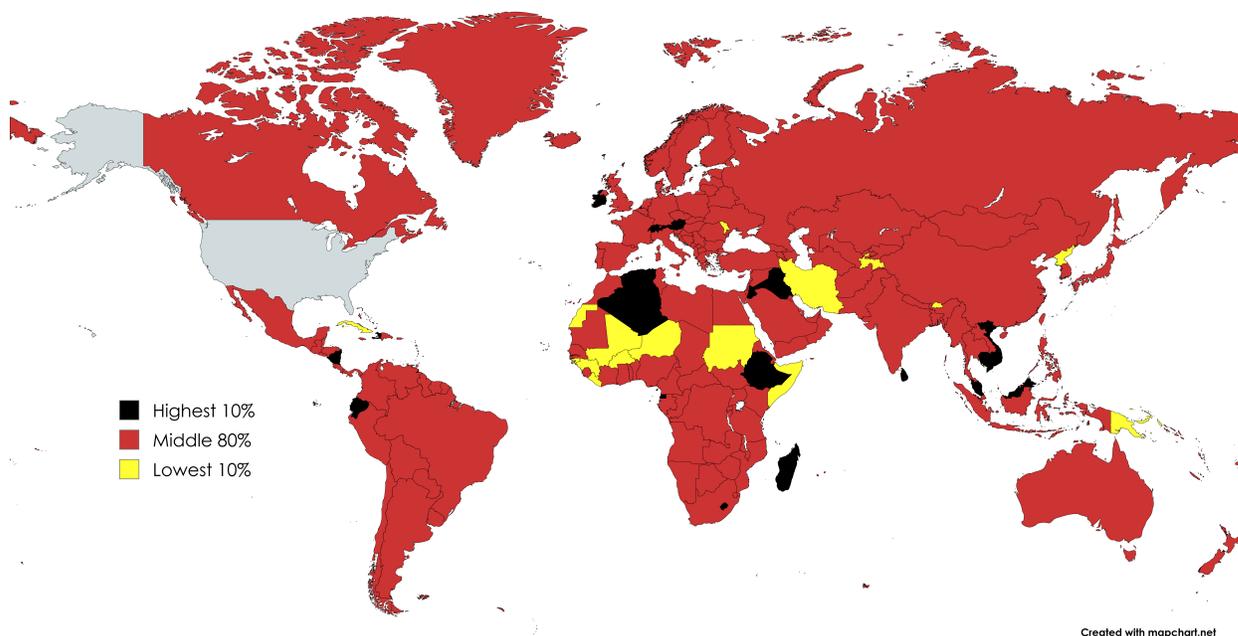


(e) Transport equipment

Figure 6: Time series of United States unexplained imports



(a) Residuals (millions of dollars)



(b) Residuals divided by trade

Figure 7: Map of countries with highest and lowest unexplained exports to United States

4.3 Unexplained Exports from China

We next turn our attention to exports from China. Figure 8 on page 19 plots time series of unexplained exports from China to Canada, Mexico, Vietnam, Cambodia and Russia.

Figure 8a) shows that gravity residuals as a fraction of exports increase for all five trading partners

between 1995 and 2022. However, with the exception of Cambodia since 2015 and Mexico since 2004, China has negative export residuals with these countries, meaning that China exports fewer goods by value to these countries than bilateral gravity characteristics would suggest.

While China's exports to the five countries shown exhibit some volatility, particularly in metals and transport equipment, a few trends stand out. In our sample period, China has a negative export residuals in chemicals/pharmaceuticals with all five countries; however, an uptick in unexplained exports was seen for this sector in all five destinations from 2016 onward. China also has positive export residuals with Canada and Mexico in metals, with residuals increasing in recent years. China's export residuals to these two countries in machinery have remained stable over this period.

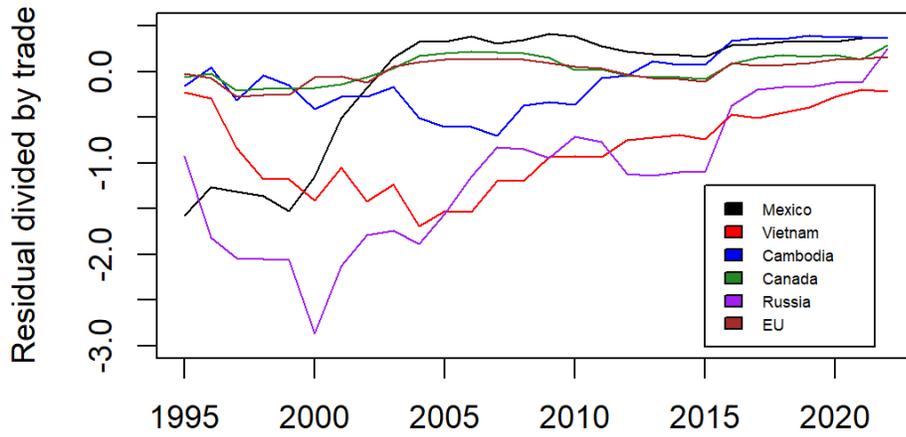
Looking at the spatial distribution of Chinese unexplained exports, positive outliers include Canada, Mexico, Russia, and most countries in South America. Exports are substantially less than predicted with several other Asian and South Asian nations, including Vietnam, India, Japan, the Philippines, and South Korea. The few negative outliers for Chinese unexplained exports as a fraction of observed exports are the Central African Republic, Botswana, Bhutan, and Greenland.

4.4 Role of Transshipments in Unexplained U.S. Trade

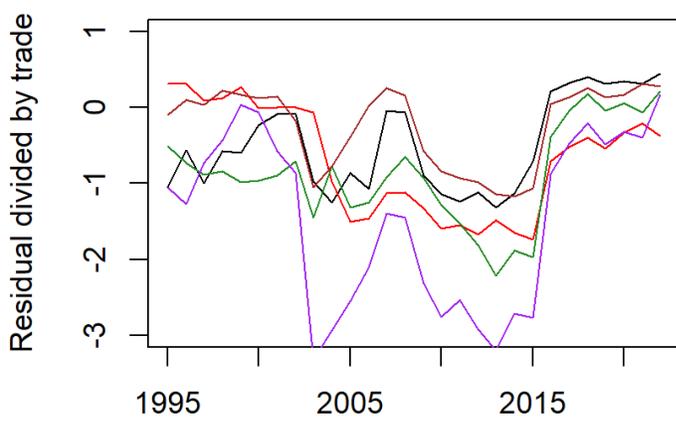
Figure 5 shows that the median residual-to-trade ratio for U.S. imports is negative for multiple sectors both in 1995-2009 and 2010-2022. While the United States could still have high positive levels of unexplained trade in its commerce with specific countries, this finding suggests that the United States is not receiving substantial transshipment quantities overall.

When looking at China in particular, Figures 6 and 8 suggest that China could be re-routing exports through Vietnam and Cambodia. U.S. unexplained imports from China decrease around the same time that unexplained imports from Vietnam and Cambodia rise, and Chinese unexplained exports to Vietnam and Cambodia also rise during that time. Evidence of transshipments through Canada and Mexico is weaker, because although unexplained exports from China to those countries have increased recently, unexplained U.S. imports from those countries have stayed flat over the last 25 years. Figures 6 and 8 show stronger evidence of transshipments through Mexico in specific sectors, such as chemicals/pharmaceuticals and metals.

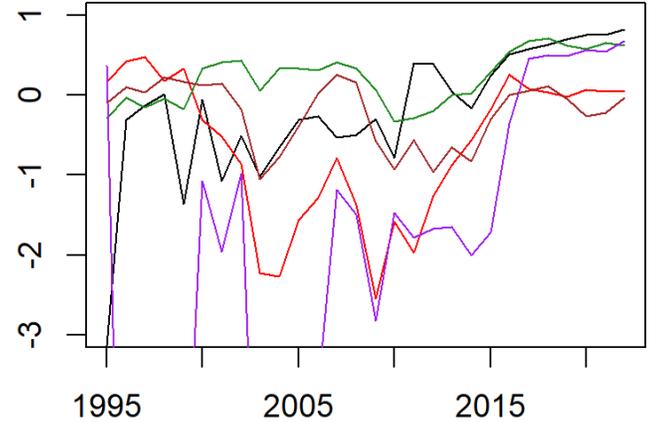
The above takeaways are by no means certain, because the unexplained trade residuals computed in this paper do not directly correspond to illegal transshipments. However, they do provide suggestive evidence that illegal transshipments may be occurring, and this evidence is helpful given the paucity of direct measurements for illegally re-routed trade.



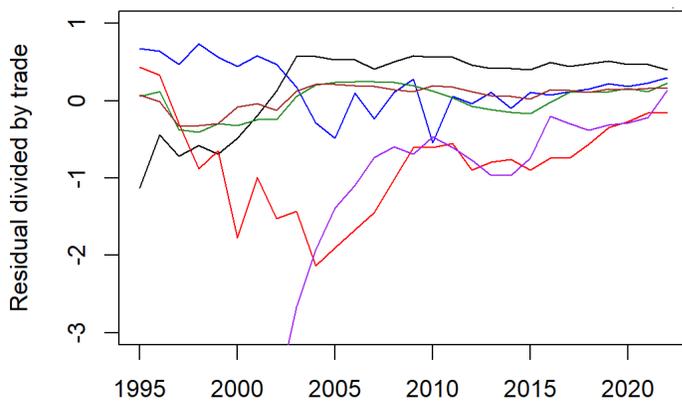
(a) Aggregate across all sectors



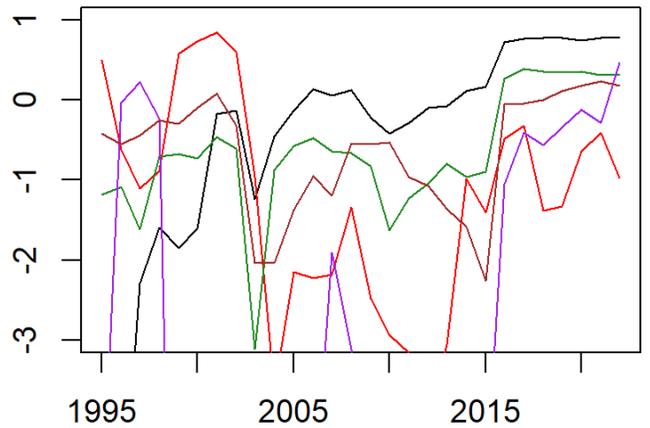
(b) Chemicals/pharmaceuticals



(c) Metals

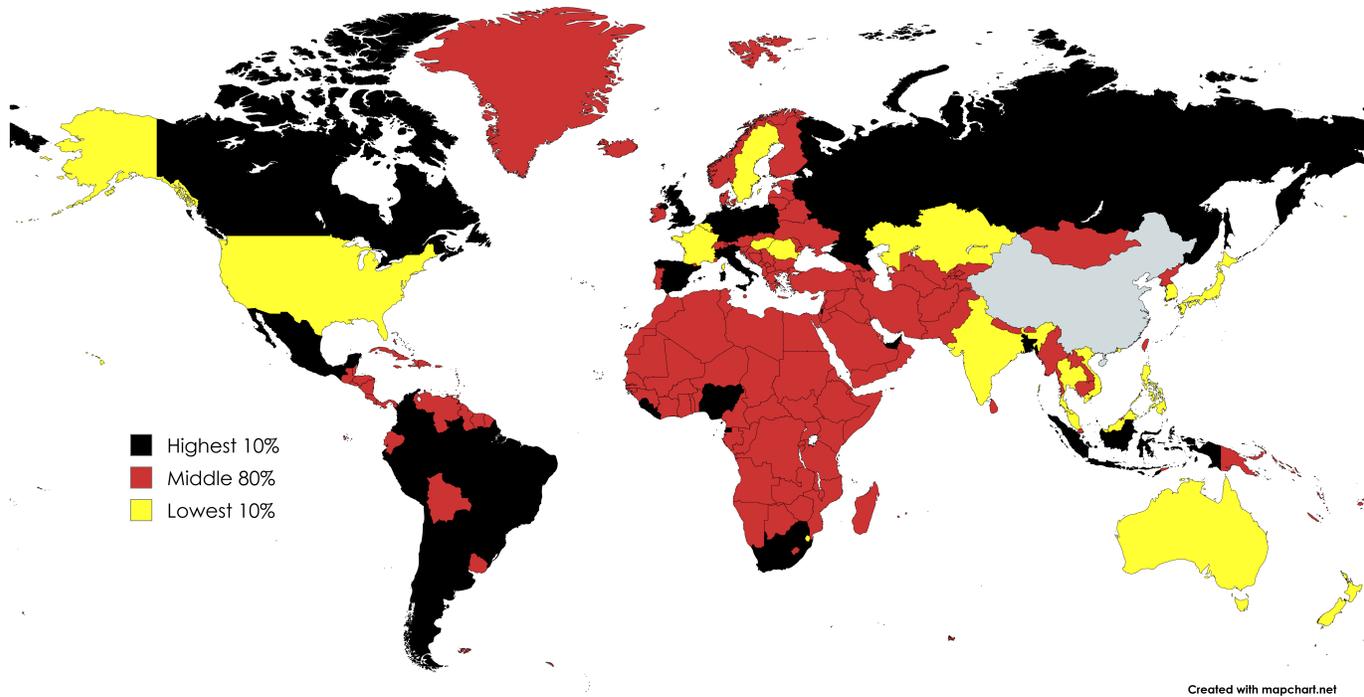


(d) Machinery

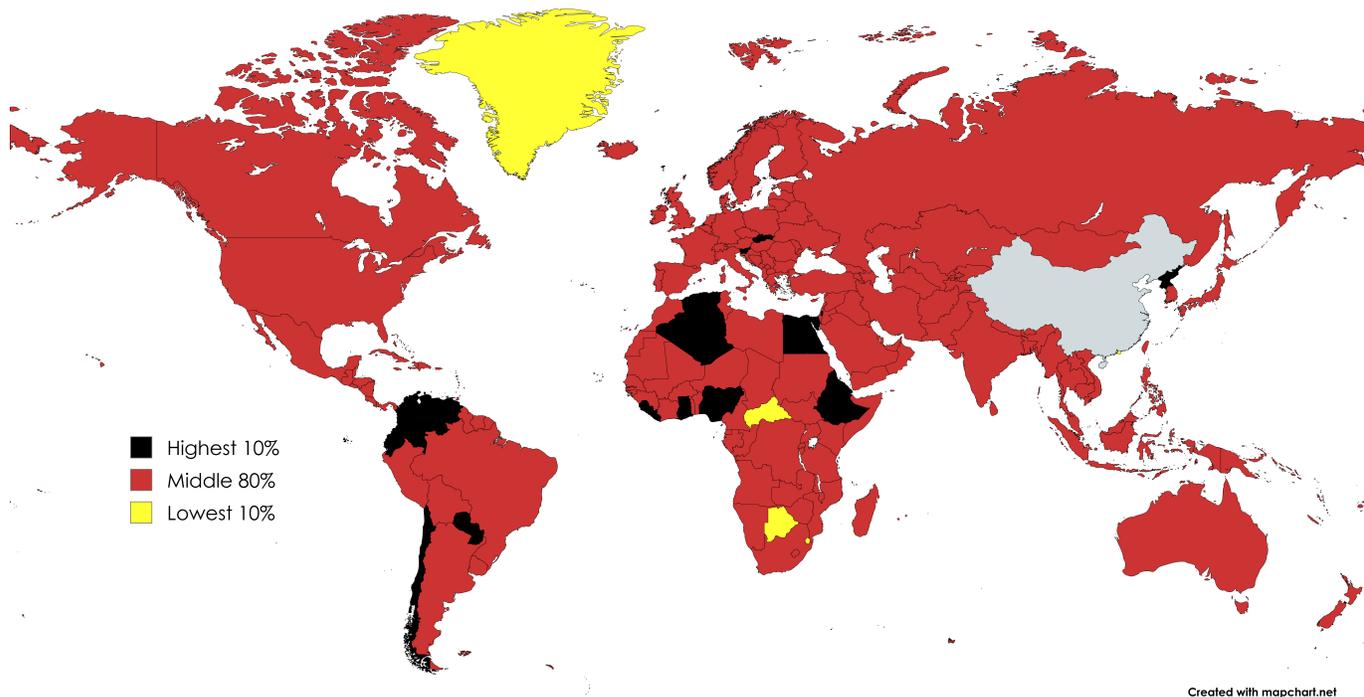


(e) Transport equipment

Figure 8: Time series of China unexplained exports



(a) Residuals (millions of dollars)



(b) Residuals divided by trade

Figure 9: Map of countries with highest and lowest unexplained imports from China

4.5 Russia's Unexplained Trade after Ukraine Invasion

Because the data used in this paper is only available until 2022, we are unable to analyze multi-year effects of the Russo-Ukraine war using unexplained trade. We instead discuss how Russia's exports change between

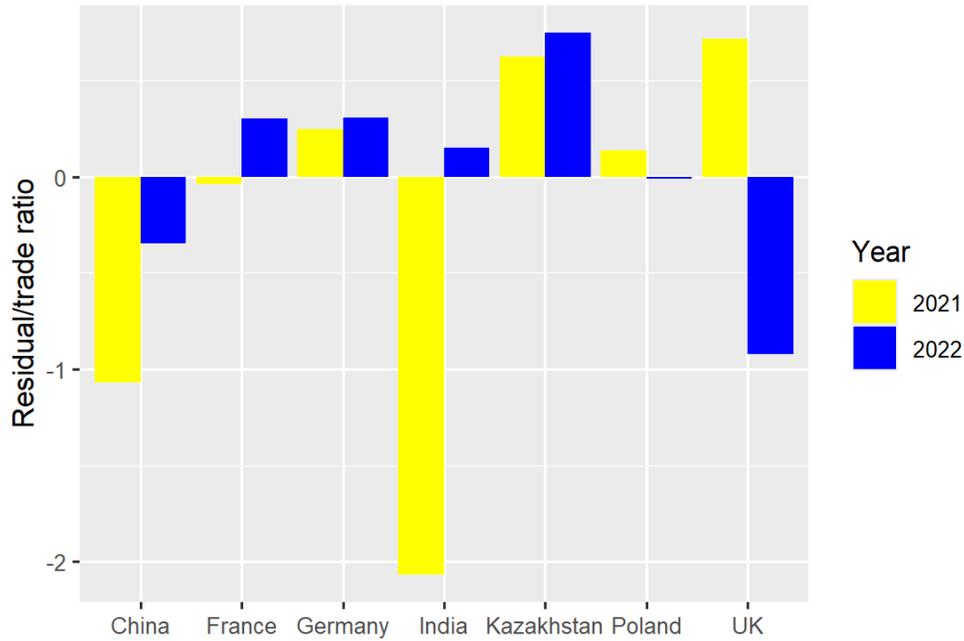
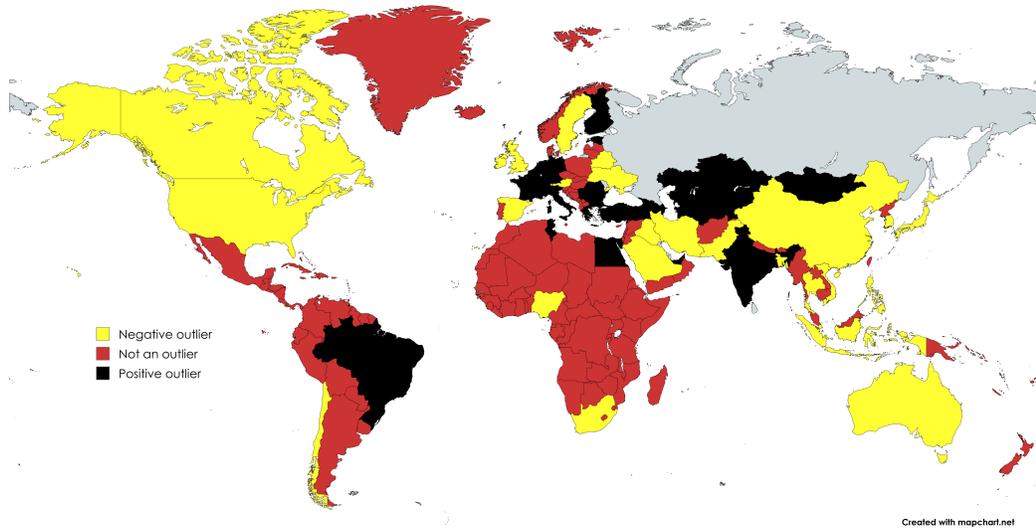


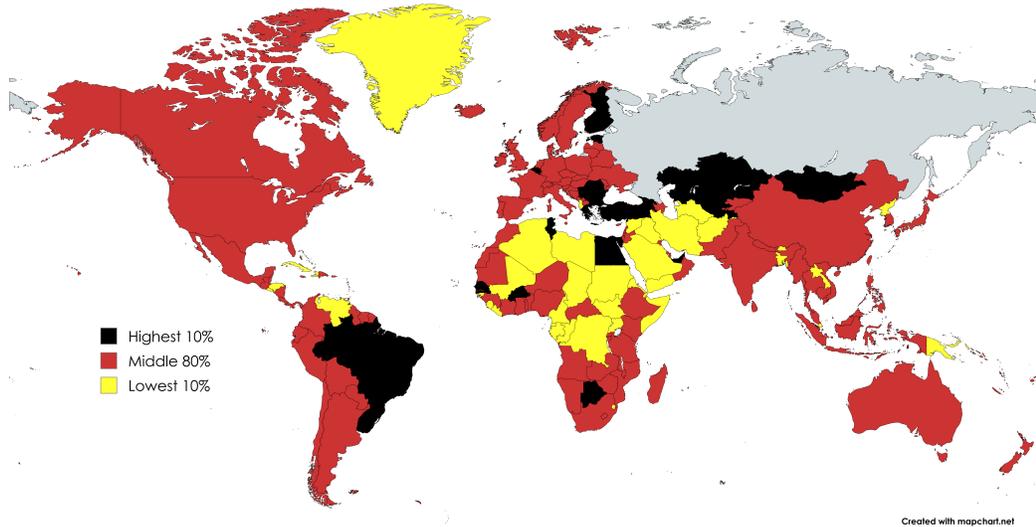
Figure 10: Unexplained exports from Russia to selected countries in 2021 and 2022

2021 and 2022, then present information on the spatial distribution of Russian exports in 2022. A comparison of trade with European countries (Figure 10) reveals varying results, as unexplained trade with France and Germany increases in 2022 compared to 2021 but unexplained trade with Poland and the United Kingdom decreases. Residual-to-trade ratios are strongly negative with China and India before the war and increase sharply in 2022. Unexplained exports to Kazakhstan are positive in 2021 but become still more positive in 2022.

Russia’s positive outliers for unexplained trade are distinguished by their spatial proximity to Russia, while no such characteristics unite the countries in Figures 7 and 9. Turkey, Mongolia, and former Soviet countries continue to be positive outliers when measuring by residuals as a fraction of trade, as does Brazil, while the United States is neither a positive outlier nor a negative outlier. Despite the beginning of the war and accompanying sanctions in January 2022, several European countries (France, Italy, Germany) have high levels of unexplained trade with Russia. Other European countries—Spain, the United Kingdom, Sweden and of course Ukraine—are negative outliers. Interestingly, Russia has very low levels of unexplained exports as a percentage of trade with several allied or friendly countries, including Belarus, China, and Iran.



(a) Residuals (millions of dollars)



(b) Residuals divided by trade

Figure 11: Map of countries with highest and lowest unexplained exports from Russia

5 Unexplained Trade and Geopolitical Factors

This section introduces a framework for determining the geopolitical factors, beyond traditional gravity, that may help predict trade. Employing a second-stage regression with gravity residuals and bilateral indexes measuring democracy and corruption, we aim to gain insight into what types of countries trade at rates higher than their geographical and cultural characteristics would predict. These relationships provide broad insight into where unexplained trade is most likely to occur, and can help in predicting where unexplained trade will occur in the future.

5.1 Data

V-Dem at Our World in Data provides indices measuring democracy and corruption from 1789 until 2024, covering the 1995-2022 time period for which we have computed gravity residuals. The democracy index estimates the extent to which elections are free and fair and freedom of association and expression are guaranteed, and ranges from 0 to 1 with 1 being most democratic. The corruption index estimates the extent to which the executive branch, judiciary branch, legislative branch and bureaucracy engage in bribery and corruption, and ranges from 0 (no corruption) to 1 (highly corrupt). A higher corruption index therefore indicates that Our World in Data considers the country to be more corrupt, and a higher democracy index indicates that Our World in Data considers the country to be more democratic.

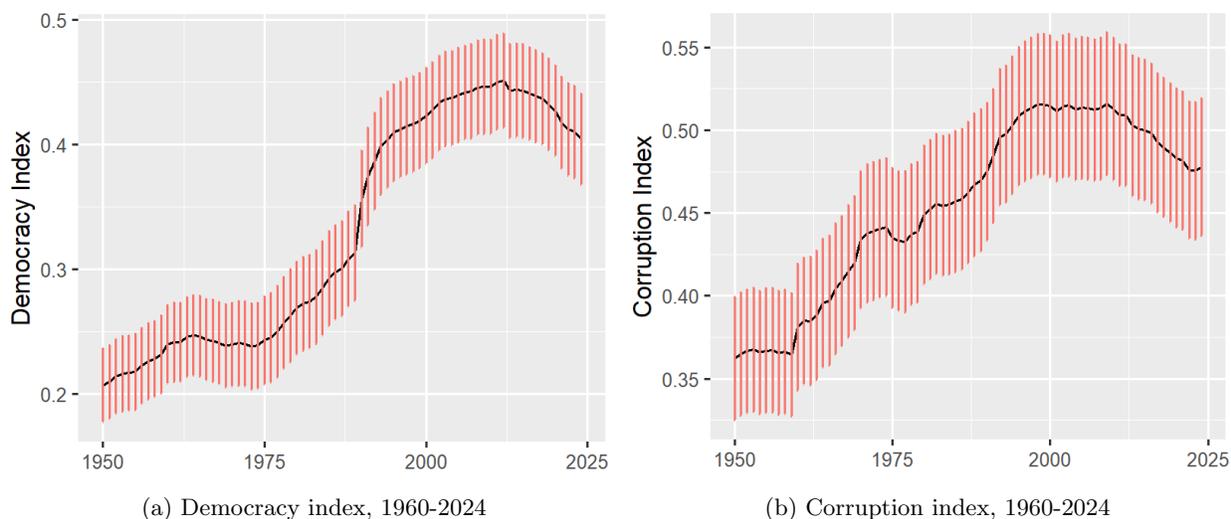


Figure 12: Time series of mean democracy and corruption indices, with 95% confidence intervals

As shown in Figure 12, the average democracy measurement among world nations has increased over time, from slightly higher than 0.2 in 1950 to slightly higher than 0.4 in 2024. During the 1995-2009 time period, the average democracy index rises at first before plateauing and falling slightly during the 2010s. Mean corruption has, interestingly, also increased over time, reaching a plateau during the 2000s and falling by about five percentage points between 2010 and 2025. The confidence intervals for the corruption index are slightly wider than those for the democracy index.

The World Bank provides indicators of each country’s development, as included in the categories ‘low income’, ‘lower middle income’, ‘upper middle income’, and ‘upper income’. It determines these categories by comparing each country’s GNI (Gross National Income) per capita to a set of year-specific thresholds. In order to prevent our regression results from becoming too unwieldy, we combine ‘low income’ with ‘lower middle income’ and ‘upper middle income’ with ‘upper income’ to form two categories representing upper

and lower income countries. 141 out of 225 countries surveyed were considered upper or upper-middle income countries in 2024, while 79 out of 225 countries were considered upper or upper-middle income countries in 1995.¹³

Lastly, we also control for sanctions in the estimation. Information on sanctions comes from the Global Sanctions Database, which provides information on sanctions between pairs of countries from 1949 to 2023. The database records sanctions according to the sanctioning and sanctioned countries, the sanctions' start and end dates, and whether the sanction in question applied to trade, arms sales, financial flows, travel, or other. We focus on the subset of sanctions related to trade and further eliminate sanctions that only applied to a subset of exports, as the dataset does not provide information on what specific sectors were targeted by partial sanctions. Seven countries—Armenia, Cuba, Spain, Lebanon, North Korea, Russia, and Venezuela—were under complete trade sanctions from at least one other country in 2022, while fourteen countries were under complete trade sanctions in 1995.

We do not have an obvious expectation of how many of the country characteristics considered in this section would impact unexplained trade. For example, since sanctions aim to restrict trade, a country that is under sanction would be expected to conduct lower bilateral trade than what would be predicted from a gravity model due to the presence of said sanctions. However, if this country is the source or destination of re-routed exports intended to avoid sanctions, then a bilateral sanctions variable would predict higher gravity residuals.

5.2 Second-Stage Estimation

Our second-stage estimation relies on the residuals from the gravity regressions, discussed in Section 2.2, as the dependent variable. We run a separate regression for each sector and divide years into the 1995-2009 and 2010-2022 blocs. All regressions include origin-year and destination-year fixed effects. We use the country-specific indices discussed in Section 5.1 to create bilateral explanatory variables between countries.

With regard to the democracy and corruption variables, we are interested in whether unexplained trade is more likely to happen between countries with similar observed characteristics—for example, two democracies or two corrupt nations—or two countries that are dissimilar. Since the corruption and democracy indices are continuous variables, we create two types of bilateral measures for each. One variable aims to capture the continuous response of unexplained trade to country differences, and therefore consists of the absolute value of the difference between the index for the origin country and destination country. The other variables aim to capture the binary effect of countries' being more or less democratic, and include a binary indicator equal

¹³As a robustness check, we also run our regressions with interaction terms between all four disaggregated income categories. Results do not differ in any substantial way.

to 1 if both countries have democracy indices above 0.75 and another indicator equal to 1 if both countries have democracy indices below 0.25. For corruption, we include a binary variable equal to 1 if both countries have corruption indices below 0.5, indicating that both countries are relatively less corrupt.¹⁴

We similarly design bilateral categories for the World Bank’s development indicator. The regression includes three binary variables: a variable equal to one if both origin and destination are upper-income countries, a variable equal to one if the origin is an upper-income country but the destination is not, and a variable equal to one if the destination is an upper-income country but the origin is not. The omitted category therefore consists of pairs of countries that are both low-income in year t , and all coefficient estimate results are in comparison to this category.

Finally, we create a sanctions indicator equal to one if one country is under sanction and the other country is not.¹⁵ The regression equation is as follows:

$$\begin{aligned} \text{Residual}_{ijt} = & \beta_1 |\text{Dem}_{it} - \text{Dem}_{jt}| + \beta_2 \text{DICT}_{ijt} + \beta_3 \text{DEMO}_{ijt} \\ & + \beta_4 |\text{Corr}_{it} - \text{Corr}_{jt}| + \beta_5 \text{HighCorr}_{ijt} + \beta_6 \text{LowCorr}_{ijt} \\ & + \beta_7 \text{Sanc}_{ijt} + \vec{\alpha} \cdot \overrightarrow{\text{INCOME}}_{ijt} + \gamma \log(\text{Trade}_{ijt}) + \phi_{it} + \phi_{jt} + \varepsilon_{ijt} \end{aligned}$$

where $\text{DICT}_{ijt} = 1$ if both countries are considered dictatorial in year t , $\text{DEMO}_{ijt} = 1$ if both countries are considered democracies, and $\text{LowCorr}_{ijt} = 1$ if both countries are considered less corrupt. $\text{Sanc}_{ijt} = 1$ if one country is under complete sanction, and $\overrightarrow{\text{INCOME}}_{ijt}$ is the vector of interaction terms between i ’s development level and j ’s development level. Finally, we control for the logged level of trade between countries i and j , because country characteristics could be related to the total trade between two countries rather than the unexplained component of that trade.

5.3 Second-Stage Regression Results

Complete tables of regression results are located in Appendix B. This section provides an overview of results, with Table 1 and Table 2 listing the number of sector-level regressions where each geopolitical factor has a positive, negative, or statistically insignificant relationship with unexplained trade. Our analysis features a total of 14 aggregated sectors.

Of all country characteristics, the presence of sanctions has the strongest predictive power on unexplained trade in both time blocs. Nearly all sectors display a negative relationship between computed gravity residuals and the Sanc_{ijt} variable, with the sole exception being apparel in the 2010-2022 period. This result implies

¹⁴The inclusion of a variable equal to 1 if both countries have corruption indices above 0.5 results in perfect multicollinearity when the regression includes origin-time and destination-time fixed effects.

¹⁵The inclusion of other sanctions categories also results in multicollinearity when we run the regression with fixed effects.

Variable	Positive, significant	Negative, significant	Not significant
$ \text{Dem}_{it} - \text{Dem}_{jt} $	10	0	4
DEM_{ijt}	2	10	2
DICT_{ijt}	12	2	0
$ \text{Corr}_{it} - \text{Corr}_{jt} $	4	5	5
$\text{LowCorr}_{ijt} = 1$	9	1	4
Sanc_{ijt}	0	13	1
$U_{it} = 1, U_{jt} = 1$	0	2	12
$U_{it} = 0, U_{jt} = 1$	1	2	11
$U_{it} = 1, U_{jt} = 0$	0	2	12

Table 1: Count of result type by explanatory variable, 2010-2022

Variable	Positive, significant	Negative, significant	Not significant
$ \text{Dem}_{it} - \text{Dem}_{jt} $	5	1	8
DEM_{ijt}	6	2	6
DICT_{ijt}	5	0	9
$ \text{Corr}_{it} - \text{Corr}_{jt} $	1	13	0
$\text{LowCorr}_{ijt} = 1$	0	0	14
Sanc_{ijt}	0	14	0
$U_{it} = 1, U_{jt} = 1$	0	1	13
$U_{it} = 0, U_{jt} = 1$	1	0	13
$U_{it} = 1, U_{jt} = 0$	1	1	12

Table 2: Count of result type by explanatory variable, 1995-2009

that sanctions evasion is limited, or at the very least is not widespread enough to affect results of regressions featuring every country in the world. Differences in corruption also have a consistently negative relationship with unexplained trade in the 1995-2009 period, but not in the 2010-2022 period. Metals are the only sector not to have a significantly negative coefficient in the earlier period, but apparel, plastics/rubber, fabricated metals, and machinery do so in 2010-2022. Bilateral development indicators, however, have consistently little to no relationship with unexplained trade in either time period surveyed, suggesting that income levels have hardly any predictive power over the portion of world trade that gravity regressions cannot explain.

In 2010-2022, and to a lesser extent in 1995-2009, the absolute difference in two countries' democracy scores between two countries predicts higher trade between those two countries in comparison to gravity relationships. Food, apparel, machinery, and appliances all have positive coefficients for $|\text{Dem}_{it} - \text{Dem}_{jt}|$ in both regressions. Compared to pairs of countries with dissimilar democracy scores, pairs of democracies are predicted to have lower unexplained trade in the 2010-2022 period, and pairs of dictatorships are predicted to have higher unexplained trade in the 2010-2022 period. In other words, dictatorships trade with each other more than their gravity relationships would predict, while democracies trade less. However, during the 1995-2009 period the coefficients on DICT_{ijt} and DEM_{ijt} are both positive more often than they are

negative; only apparel and metals have lower predicted unexplained trade between two democratic countries in both periods.

At first glance, the results mentioned in the previous paragraph appear to contradict findings in the literature that greater geopolitical distance predicts lesser trade, especially in more recent years. However, those papers were investigating absolute levels of trade while this paper is investigating trade *residuals*, and so the dual findings may coexist. It is at once possible for two countries with democratic systems to have higher predicted bilateral trade but lower predicted bilateral trade compared to what their cultural, geographic, and economic indicators would suggest.

In addition to being the most consistently significant, sanctions have the strongest effect in magnitude on unexplained trade. β_2 and β_3 also have large magnitudes, but in the 2010-2022 period more than the earlier 1995-2009 one. By contrast, bilateral development indicators have relationships with unexplained trade that are generally small in magnitude, even in the few cases that they are significant.

6 Conclusion

Our paper focuses on the determinants of trade that are not explained by traditional gravity variables. For instance, the re-routing of international shipments is a relevant topic for international trade economists, particularly if countries use this re-routing to circumvent tariffs illegally. However, transshipments are exceptionally difficult to measure and standard gravity regressions do not capture them. This paper introduces the idea of unexplained trade as a lens for detecting potential illegal transshipment by comparing observed trade with predicted trade levels from gravity regressions.

We run gravity regressions across a panel of 14 sectors and over 200 countries, in the time periods of 1995-2009 and 2010-2022. Results show that median gravity residuals across all countries in the world are slightly negative and have been decreasing over the past thirty years. Gravity residuals for U.S. imports and exports are also generally negative, indicating that the United States generally conducts less trade than its gravity variables would predict. The recent increase in unexplained exports from China to Vietnam and Cambodia and from Vietnam and Cambodia to the United States provides some evidence that China may be re-routing goods through these countries to avoid tariffs; our results show less evidence of China's re-routing goods through Canada and Mexico because while unexplained exports from China to those countries have gone up, unexplained exports from Canada and Mexico to the United States have not.

It is important to remember that the unexplained trade measured and discussed in this paper is not equivalent to the value of transshipments, and higher unexplained trade does not necessarily imply higher illegal transshipments. However, the presence of higher trade than standard gravity variables cannot explain

provides a *guide* of where these illegal transshipments may be happening, especially since adjusted pseudo R-squared values are generally above 90% and gravity variables therefore explain the vast majority of trade that passes between countries. Given the inherent difficulties in measuring or imputing values for transshipments, we believe our unexplained trade measure to be useful. Future research in this area should distinguish unexplained trade levels for products considered to be intermediate inputs versus unexplained trade levels for final goods.

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7 Appendix A

This appendix discusses in greater detail the inputs and results of the gravity regressions introduced in Section 2.

Variable	2010-2022	1995-2009
Contiguity	1.85%	1.87%
Colonial ties	1.50%	1.53%
Common legal origin	5.92%	6.15%
Common language	37.0%	37.0%
FTA agreement	8.50%	18.4%
At least one country landlocked	31.4%	30.3%
At least one island country	39.3%	42.6%

Table 3: Summary statistics for binary gravity regressors

Since all regressors other than distance are categorical variables, Table 3 shows the percentage of origin-destination-year observations in the two time blocs where the variable takes a value of one—for example, two countries’ sharing a border as opposed to not sharing a border. Fewer than two percent of pairs share a border or had colonial ties, but nearly forty percent have a common language. Categorical variables are generally consistent across both the surveyed intervals of time. The sole exception is the FTA agreement, as free trade agreements proliferated during the 2000s.

	Min	Mean	Median	Max
2010-2022	1	7666	7298	19868
1995-2009	1	7673	7287	19868

Table 4: Summary statistics for distance

Table 4 displays summary statistics for the population-weighted distance variable. Distances are also, as expected, stable across time periods. In both time periods the maximum distance between trading partners was 19,868 kilometers (the Pitcairn Islands and Bahrain), with the median bilateral distance between countries about 7300 kilometers.

Variable	Food	Apparel	Wood/ paper	Fuel	Chemicals/ pharma	Plastics/ rubber	Nonmetallic minerals
log(Distance)	-0.619*** (0.0264)	-0.761*** (0.0360)	-0.791*** (0.0281)	-1.14*** (0.0255)	-0.553*** (0.0247)	-0.975*** (0.0204)	-1.02*** (0.0273)
Contiguity	0.679*** (0.0327)	0.201*** (0.0421)	0.789*** (0.0283)	0.251*** (0.0429)	0.291*** (0.0406)	0.471*** (0.0314)	0.436*** (0.0426)
Colonial Ties	-0.0653* (0.0397)	-0.211*** (0.0510)	0.0160 (0.0414)	-0.314*** (0.0549)	0.0211 (0.0567)	0.0984** (0.0525)	-0.0648 (0.0453)
Legal Origin	0.480*** (0.0362)	0.664*** (0.0731)	0.483*** (0.0391)	0.235*** (0.0500)	0.428*** (0.0601)	0.346*** (0.0525)	0.424*** (0.0654)
Language	0.493*** (0.0287)	0.0698* (0.0379)	0.241*** (0.0262)	0.615*** (0.0338)	0.326*** (0.0323)	0.127*** (0.0247)	0.375*** (0.0341)
FTA	0.861*** (0.0314)	0.431*** (0.0371)	0.572*** (0.0353)	0.329*** (0.0380)	0.665*** (0.0404)	0.466*** (0.0371)	0.468*** (0.0463)
Landlocked	-0.877*** (0.0628)	-0.221* (0.126)	0.111 (0.0718)	-1.16*** (0.121)	-0.171*** (0.0566)	0.273*** (0.0616)	0.0760 (0.0900)
Island	0.133** (0.0600)	0.338*** (0.115)	-0.361*** (0.0838)	0.202 (0.160)	0.129 (0.2)	-0.610 (0.0551)	-0.606*** (0.0841)
Domestic trade	3.79*** (0.0645)	1.88*** (0.0990)	3.11*** (0.0685)	3.02*** (0.0932)	1.77*** (0.0883)	2.28*** (0.0535)	3.04*** (0.0770)
Adjusted pseudo R-squared	0.978	0.953	0.979	0.929	0.957	0.977	0.983
Variable	Metals	Fabricated metals	Machinery	Appliances	Electronics	Transportation equipment	Misc.
log(Distance)	-0.687*** (0.0306)	-0.772*** (0.0351)	-0.467*** (0.0254)	-0.825*** (0.0218)	-0.435*** (0.0297)	-0.502*** (0.0278)	-0.533*** (0.0407)
Contiguity	0.247*** (0.0401)	0.636*** (0.0381)	0.440*** (0.0388)	-0.0803** (0.0369)	0.135*** (0.0413)	0.791*** (0.0439)	0.305*** (0.0789)
Colonial Ties	-0.249*** (0.0659)	-0.0342 (0.0406)	0.0977*** (0.0358)	-0.0226 (0.0438)	0.281*** (0.0425)	0.134** (0.0632)	-0.814*** (0.0774)
Legal Origin	0.494*** (0.0475)	0.475*** (0.0522)	-0.449 (0.0843)	0.236*** (0.0839)	0.105* (0.0606)	0.126* (0.0755)	0.543*** (0.0992)
Language	0.537*** (0.0421)	0.156*** (0.0313)	0.260*** (0.0313)	0.196*** (0.0430)	0.235*** (0.0428)	0.199*** (0.0385)	0.479*** (0.0716)
FTA	0.748*** (0.374)	0.477*** (0.0409)	0.419*** (0.0377)	0.109*** (0.0333)	0.240*** (0.0335)	0.795*** (0.0551)	0.117* (0.0610)
Landlocked	-0.0772 (0.113)	0.311*** (0.0792)	0.0546 (0.0762)	-0.184* (0.106)	0.00 (0.0765)	-0.242*** (0.0831)	0.336** (0.160)
Island	0.450** (0.213)	-0.330*** (0.0681)	-0.221*** (0.0581)	-0.170** (0.0718)	-0.120 (0.0765)	0.0309 (0.0787)	-0.338*** (0.0967)
Domestic	2.26*** (0.0889)	2.84*** (0.0854)	1.72*** (0.683)	0.864*** (0.0684)	1.09*** (0.0899)	2.58*** (0.107)	1.74*** (0.144)
Adjusted pseudo R-squared	0.942	0.977	0.965	0.957	0.957	0.954	0.930

Table 5: Gravity regression results for the 2010-2022 period

Variable	Food	Apparel	Wood/ paper	Fuel	Chemicals/ pharma	Plastics/ rubber	Nonmetallic minerals
log(Distance)	-0.577*** (0.0276)	-0.779*** (0.0305)	-0.762*** (0.0257)	-1.14*** (0.0383)	-0.502*** (0.0314)	-0.781*** (0.0405)	-0.880*** (0.0270)
Contiguity	0.598*** (0.0326)	0.270*** (0.0358)	0.730*** (0.0273)	0.414*** (0.0607)	0.290*** (0.0471)	0.668*** (0.0383)	0.692*** (0.0316)
Colonial Ties	0.0480 (0.0410)	0.149*** (0.0385)	0.0852** (0.0427)	0.00720 (0.0707)	0.239*** (0.0515)	0.261*** (0.0417)	-0.0278 (0.0427)
Legal Origin	0.529*** (0.0362)	0.271*** (0.0602)	0.162*** (0.0417)	0.0159 (0.0.0655)	0.305*** (0.0540)	0.242*** (0.0460)	0.364*** (0.0545)
Language	0.561*** (0.0267)	0.305*** (0.0376)	0.437*** (0.0276)	0.540*** (0.0391)	0.262*** (0.0278)	0.212*** (0.0257)	0.328*** (0.0276)
FTA	0.904*** (0.0372)	0.638*** (0.0524)	0.546*** (0.0390)	0.156*** (0.0441)	0.879*** (0.0545)	0.729*** (0.0606)	0.389*** (0.0520)
Landlocked	-1.07*** (0.0813)	-0.0943 (0.0784)	-0.0929 (0.0905)	-1.37*** (0.151)	-0.482*** (0.0726)	-0.0789 (0.0790)	-0.0896 (0.0793)
Island	-0.0254 (0.0618)	0.169** (0.0756)	-0.0196 (0.0625)	0.965*** (0.150)	0.120* (0.0672)	0.243*** (0.0493)	0.303*** (0.0536)
Domestic trade	3.99*** (.0656)	2.07*** (0.0873)	3.39*** (0.0766)	3.26*** (0.101)	2.34*** (0.0829)	3.02*** (0.103)	3.44*** (0.0780)
Adjusted pseudo R-squared	0.985	0.955	0.988	0.964	0.967	0.983	0.987
Variable	Metals	Fabricated metals	Machinery	Appliances	Electronics	Transportation equipment	Misc.
log(Distance)	-0.848*** (0.0244)	-0.707*** (0.0504)	-0.277*** (0.0315)	-0.320*** (0.0504)	-0.672*** (0.0367)	-0.434*** (0.0281)	-0.406*** (0.0451)
Contiguity	0.389*** (0.0361)	0.811*** (0.0427)	0.467*** (0.0414)	0.486*** (0.579)	0.260*** (0.0420)	0.787*** (0.0447)	0.572*** (0.0559)
Colonial Ties	-0.0538 (0.0481)	0.176*** (0.0386)	0.184*** (0.0356)	0.188*** (0.0518)	0.283*** (0.0601)	0.231*** (0.0593)	-0.345*** (0.0804)
Legal Origin	0.353*** (0.0397)	0.112*** (0.0542)	-0.0637 (0.0631)	-0.0978 (0.0648)	0.0664 (0.0692)	-0.101 (0.0778)	0.212** (0.105)
Language	0.375*** (0.0314)	0.310*** (0.0322)	0.367*** (0.0322)	0.466*** (0.0512)	0.180*** (0.0533)	0.187*** (0.0362)	0.383*** (0.0603)
FTA	0.756*** (0.376)	0.478*** (0.0701)	0.670*** (0.0519)	0.580*** (0.0771)	-0.365*** (0.0617)	1.17*** (0.0615)	0.510*** (0.0795)
Landlocked	-0.220*** (0.0849)	-0.0683 (0.0983)	-0.464*** (0.0929)	-0.784*** (0.105)	-0.0374 (0.131)	-0.230*** (0.101)	-0.416*** (0.120)
Island	0.601*** (0.0765)	0.149*** (0.0522)	-0.129*** (0.0484)	0.0794 (0.0879)	0.366*** (0.00990)	0.319*** (0.0572)	0.0419 (0.0814)
Domestic	2.33*** (0.0619)	3.30*** (0.129)	2.15*** (0.0972)	2.00*** (0.152)	0.904*** (0.111)	3.05*** (0.0572)	3.10*** (0.169)
Adjusted pseudo R-squared	0.967	0.984	0.968	0.956	0.963	0.970	0.961

Table 6: Gravity regression results for the 1995-2009 period

8 Appendix B

This appendix discusses in greater detail the inputs and results of the regressions introduced in Section 4.

Variable	2010-2022	1995-2009
Both Dem > .75	3.39%	11.0%
Both Dem < .25	4.33%	12.6%
Both Cor > .5	27.0%	31.1%
Both Cor < .5	22.3%	18.7%
At least one country under sanction	10.0%	14.0%
Both upper-income	6.93%	3.16%
Only origin upper-income	19.3%	14.7%
Only destination upper-income	19.2%	14.3%

Table 7: Summary statistics for binary variables

Table 7 shows the percentage of country pairs in each period that satisfy each categorical variable in the regression. The percentage of country pairs under sanction has decreased across the two periods, while the fraction of countries considered upper-income has increased.

	Min	Mean	Median	Max
Democracy, 2010-2022	0.00	0.316	0.279	0.892
Democracy, 1995-2009	0.00	0.323	0.283	0.892
Corruption, 2010-2022	0.00	0.360	0.319	0.969
Corruption, 1995-2009	0.00	0.361	0.317	0.892

Table 8: Summary statistics for continuous variables

Table 8 displays summary statistics for the absolute value of the difference between the democracy and corruption indices of origin/destination pairs. The minimum values of 0.00 correspond to domestic trade, while the maximum differences are nearly one and correspond to trade between Denmark and Eritrea, for the democracy index, and Denmark and Venezuela for the corruption index.

Variable	Food	Apparel	Wood/ paper	Fuel	Chemicals/ pharma	Plastics/ rubber	Nonmetallic minerals
$ \text{Dem}_{it} - \text{Dem}_{jt} $	13.3** (5.60)	23.7*** (3.58)	4.42** (2.03)	5.88 (5.45)	-15.2 (12.9)	12.0*** (2.83)	1.78 (1.49)
DEM_{ijt}	-7.23 (5.33)	-38.5*** (3.43)	6.86*** (1.92)	-26.2*** (4.84)	-41.7*** (12.3)	-4.33 (2.68)	-8.38*** (1.38)
DICT_{ijt}	11.6*** (4.03)	9.48*** (2.56)	3.46** (1.47)	2.04 (4.13)	14.7 (9.29)	8.42*** (2.05)	2.25** (1.09)
$ \text{Corr}_{it} - \text{Corr}_{jt} $	-6.71 (5.18)	5.76* (3.30)	-0.759 (1.88)	-12.8** (5.12)	-16.6 (11.9)	4.59* (2.63)	-2.35* (1.39)
$\text{LowCorr}_{ijt} = 1$	16.4*** (4.35)	10.3*** (2.76)	4.39*** (1.58)	-12.8*** (4.32)	13.8 (9.97)	13.8*** (2.20)	3.63*** (1.16)
Sanc_{ijt}	-55.8*** (5.54)	-1.50 (3.64)	-22.3*** (2.08)	-32.5*** (5.90)	-80.9*** (13.0)	-21.3*** (2.88)	-13.1*** (1.49)
$U_{it} = 1, U_{jt} = 1$	-10.9* (6.47)	-0.178 (4.15)	1.37 (2.41)	-5.16 (6.36)	2.19 (14.7)	2.63 (3.36)	-0.336 (1.73)
$U_{it} = 0, U_{jt} = 1$	0.447 (1.66)	1.07 (1.07)	0.571 (0.607)	-3.34** (1.66)	-10.5*** (3.83)	0.484 (0.850)	0.196 (0.449)
$U_{it} = 1, U_{jt} = 0$	-1.32** (6.18)	0.0438 (3.97)	1.32 (2.30)	-5.26 (6.07)	0.310 (1.40)	1.65 (3.22)	-1.27 (1.65)

Variable	Metals	Fabricated metals	Machinery	Appliances	Electronics	Transportation equipment	Misc.
$ \text{Dem}_{it} - \text{Dem}_{jt} $	25.6*** (8.73)	7.57*** (2.25)	31.0*** (9.86)	102*** (11.1)	13.9*** (2.83)	-16.5 (16.5)	32.1*** (4.61)
DEM_{ijt}	-81.7*** (8.03)	-1.31 (2.13)	-53.0*** (9.46)	-27.2** (10.6)	9.05*** (2.64)	-89.5*** (15.6)	-18.3*** (4.35)
DICT_{ijt}	27.5*** (6.47)	3.98** (1.63)	13.1* (7.04)	46.0*** (8.01)	4.00* (2.07)	15.9*** (11.9)	7.69** (3.34)
$ \text{Corr}_{it} - \text{Corr}_{jt} $	-26.2*** (8.20)	6.01*** (2.09)	22.7** (9.07)	-4.59 (10.3)	-9.73*** (2.64)	-14.5 (15.3)	-7.29** (4.28)
$\text{LowCorr}_{ijt} = 1$	-9.96 (6.88)	9.89*** (1.74)	33.7*** (7.60)	36.0*** (8.64)	-0.910 (2.21)	24.7* (12.8)	-0.673 (3.58)
Sanc_{ijt}	-63.5*** (8.79)	-23.1*** (2.31)	-42.6*** (10.1)	-87.2*** (11.5)	-8.31** (2.86)	-92.5*** (16.9)	-42.0*** (4.69)
$U_{it} = 1, U_{jt} = 1$	9.95 (10.2)	-1.41 (2.65)	2.58 (11.5)	6.16 (13.4)	-3.66 (3.37)	-25.8 (19.8)	-9.76* (5.33)
$U_{it} = 0, U_{jt} = 1$	5.53** (2.65)	0.00 (0.674)	-0.0393 (2.94)	2.62 (3.33)	0.733 (0.850)	-5.36 (4.93)	-0.0782 (1.39)
$U_{it} = 1, U_{jt} = 0$	13.8 (9.79)	-0.0657 (2.54)	2.37 (11.0)	-5.54 (12.8)	-1.92 (3.23)	-29.8 (18.9)	-10.1** (5.09)

Table 9: Country characteristics regression results for 2010-2022

Variable	Food	Apparel	Wood/ paper	Fuel	Chemicals/ pharma	Plastics/ rubber	Nonmetallic minerals
$ \text{Dem}_{it} - \text{Dem}_{jt} $	4.60* (2.68)	9.34*** (2.35)	0.898 (1.74)	3.43 (2.87)	9.43 (6.64)	1.45 (1.40)	-1.58** (0.761)
DEM_{ijt}	12.1*** (2.44)	-27.1*** (2.15)	1.16 (1.58)	6.77*** (2.45)	38.3*** (6.03)	4.99*** (1.27)	-1.08 (0.678)
DICT_{ijt}	5.35*** (1.89)	29.7* (1.63)	-1.06 (1.22)	3.90* (2.11)	11.2** (4.65)	0.553 (0.983)	0.779 (0.541)
$ \text{Corr}_{it} - \text{Corr}_{jt} $	-8.47*** (2.37)	-9.38*** (2.07)	-11.4*** (1.54)	-9.23*** (2.58)	-16.9*** (5.87)	-8.90*** (1.24)	-4.03*** (0.679)
$\text{LowCorr}_{ijt} = 1$	1.53 (19.7)	-1.78 (17.5)	-3.39 (12.9)	1.19 (19.7)	0.746 (49.3)	-2.59 (10.4)	-0.675 (5.54)
Sanc_{ijt}	-16.1*** (1.87)	-21.2*** (1.68)	-12.8*** (1.26)	-11.3*** (2.19)	-44.8*** (4.75)	-10.5*** (1.01)	-9.74*** (0.541)
$U_{it} = 1, U_{jt} = 1$	2.85 (3.46)	-1.66 (3.09)	-1.31* (2.32)	0.705 (3.55)	-9.07 (8.66)	0.565 (1.81)	-0.209 (0.969)
$U_{it} = 0, U_{jt} = 1$	-0.323 (.0842)	1.36* (0.749)	-0.396 (0.548)	-1.56 (0.890)	0.311 (2.09)	0.533 (0.443)	-0.445 (0.240)
$U_{it} = 1, U_{jt} = 0$	1.39 (3.14)	-0.441 (2.82)	-0.140 (2.13)	2.74 (3.23)	-8.37 (7.92)	-0.414 (1.65)	-0.422 (0.882)

Variable	Metals	Fabricated metals	Machinery	Appliances	Electronics	Transportation equipment	Misc.
$ \text{Dem}_{it} - \text{Dem}_{jt} $	-4.20 (3.35)	0.243 (1.36)	21.9*** (6.23)	33.6*** (7.44)	3.26 (2.08)	6.88 (8.65)	7.27** (2.20)
DEM_{ijt}	-35.0*** (2.96)	0.689 (1.23)	6.00 (5.70)	-5.20 (6.77)	3.96** (1.86)	8.36*** (7.82)	0.160 (1.99)
DICT_{ijt}	3.43 (2.41)	-0.737 (0.952)	-0.879 (4.32)	0.0201 (5.18)	-2.29 (1.48)	16.3*** (6.05)	0.883 (1.55)
$ \text{Corr}_{it} - \text{Corr}_{jt} $	-1.03 (3.00)	-7.43*** (1.20)	-4.16*** (5.48)	-31.8*** (6.57)	-8.79*** (1.85)	-26.7*** (7.66)	-12.2*** (1.95)
$\text{LowCorr}_{ijt} = 1$	9.10 (24.0)	-1.99 (10.0)	-1.41 (46.2)	-17.7 (54.8)	-5.39 (15.0)	-3.25 (6.38)	-4.55 (16.2)
Sanc_{ijt}	-23.2*** (2.39)	-12.8*** (0.980)	-9.17*** (4.61)	-47.8*** (5.36)	-4.45*** (1.48)	-10.5*** (6.23)	-15.7*** (1.59)
$U_{it} = 1, U_{jt} = 1$	1.45 (4.278)	-0.482 (1.81)	-3.96 (8.06)	-2.05 (9.81)	-0.108 (2.63)	-7.07 (11.3)	-1.79 (2.89)
$U_{it} = 0, U_{jt} = 1$	2.13** (1.06)	0.555 (0.429)	-2.06 (1.97)	2.47 (2.35)	-0.212 (0.652)	-1.19 (2.73)	-1.57** (0.700)
$U_{it} = 1, U_{jt} = 0$	1.96 (3.88)	-0.732 (1.66)	-1.31 (7.33)	-8.35 (8.94)	-0.904 (2.40)	-6.91 (10.3)	-1.54 (2.63)

Table 10: Country characteristics regression results for 1995-2009