# International Trade Barriers

by

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# Abstract

Understanding potentially welfare-distorting barriers to international trade is a central issue in the trade research. Trade barriers are numerous and are not confined to direct trade policy instruments like tariffs or quotas. In fact, the majority of trade distortions are related to factors like transport infrastructure, institutions, legal framework, or culture. The recent literature has shifted towards discovering these latter, and much less understood, types of trade barriers. The first two chapters of this thesis provide direct contribution to the above line of research. Chapter 1 deals with the cost of time delays in international trade, while Chapter 2 is about trade costs associated with the administrative tasks of trading. In contrast, the contribution of Chapter 3 is methodological. It discusses some limitations of identifying the effects of trade barriers that are captured by dummies in gravity equations, the workhorse estimating model of trade.

Chapter 1 "Need for Speed: Is Faster Trade in the EU Trade-creating?" is an empirical contribution to the literature on the time cost of trade. The empirical evidence is based on the episode of the European Union's (EU) enlargement in 2004 and exploits the fact that trade within the EU is free of the time-consuming border controls and customs procedures. The estimation strategy is double difference-in-differences, where the estimates show how much more trade barriers fell for country pairs with 'new' members, relative to pairs of 'old' member countries, in time-sensitive, relative to not time-sensitive, industries. Unlike in typical gravity estimations, the dependent variable is a measure of bilateral trade costs, which ensures that unobserved trade barriers with third countries do not bias the results. A further contribution is the use of a novel indicator of the enlargement-induced decline in the trading time, which is the fall in the number of waiting hours at borders. The results suggest that time matters a lot in trade. The fall in trade costs due to EU enlargement was significantly larger for time-sensitive industries, and this differential effect was significantly

stronger for country pairs with a larger fall in the border waiting time. As for trade creation, a one hour fall in the border waiting time between two countries is estimated to create 5% more bilateral trade.

Chapter 2 "Administrative Barriers and the Lumpiness of Trade", a joint work with Miklós Koren, is a contribution to the literature that challenges the dominance of iceberg trade costs (trade costs proportional to the traded value) and to the literature that emphasizes the lumpiness of trade transactions. Most administrative trade costs (documentation, customs clearance and inspection) are not iceberg costs, but costs that occur after each shipment. Such 'per shipment' costs lead to more lumpiness in trade, since firms economize on these costs by sending fewer and larger shipments. The contribution of Chapter 2 is both theoretical and empirical. We build a 'circular city' discrete choice model, where consumers have preferences on the date of consumption and foreign suppliers decide when to send a shipment, while inventories are ruled out. Per shipment costs reduce shipment frequency, increase the shipment size and the product price and lead to welfare losses. We provide empirical evidence for these effects on detailed export data from the US and Spain. We find that US and Spanish exporters send fewer and larger shipments to countries with higher administrative barriers. However, we find no robust evidence that such destinations would command higher prices.

Chapter 3 "Gravity or Dummies? The Limits of Identification in Gravity Estimations" deals with an econometric identification problem in gravity estimations. Since trade barriers (both bilateral and multilateral) are often unobserved, empirical researchers tend to control for them by including some set of fixed effects in the gravity estimating equation. The theory-consistent estimating equation contains exporter and importer fixed effects in cross section estimations and country pair fixed effects with a full set of exporter-time and importer-time dummies in panels. Chapter 3 argues that the identification of trade policy effects, also captured by dummies, is severely limited, when one uses the above gravity specification. In most cases heterogeneous policy effects, i.e. more than one policy dummies, cannot be identified separately, because the policy dummies and the country-time dummies are perfectly collinear. Although a single policy dummy can be identified, the estimate may not be meaningful, because country-time dummies absorb too much of the useful variation of the data. Standard estimation techniques often do not reveal these problems. The paper demonstrates these arguments on four typical research questions on the effect of a trade policy. Empirical exercises on estimating the trade effects of EU enlargement complement the analytical findings.

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I spent the last years of the dissertation period in Austria, where I was a visiting researcher at the Vienna Institute for Economic Studies (wiiw) and later an early-stage researcher in the Marie Curie Initial Training Network "Globalization Investments and Services Trade" (GIST) at the Johannes Kepler Universität Linz. I appreciate the great hospitality of the Austrian professional community and the financial support of the European Commission. I am especially thankful to Joe Francois, my mentor in GIST, for his professional advice and support. I thank former colleagues at JKU Linz, especially Eddy Bekkers and Ana-Maria Vasilache-Freudenthaler, for the stimulating discussions. I am grateful for the help of wiiw directors and staff, especially Elisabeth Hagen, Michael Landesmann, Carolina Lennon, Sándor Richter and Robert Stehrer. I was honored by the possibility to present my research at the Foreign Research Division of the Austrian Central Bank. I am indebted to Julia Wörz for her kind support.

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# Contents

# List of Tables

# List of Figures

# Introduction

This thesis is centered around the topic of barriers to international trade. Despite the world-wide trade liberalization process of the past decades, academic interest in international trade barriers did not decline. The underlying reason is that, apparently, trade obstacles are far more numerous than previously thought. As it was documented in a series of papers initiated by McCallum (1995), trade across countries remained several times smaller than trade within national borders even for strongly integrated economies. What this so-called 'border puzzle' or 'home bias in trade puzzle' suggests is that distorting trade barriers do not vanish with the formation of free trade areas, customs unions, or even monetary and economic unions.

Trade distortions can cause large welfare losses to the economy. Finding out about their nature and relative importance is therefore of key importance for economic policy making. Moreover, as the seminal paper of Obstfeld and Rogoff (2000) concludes, understanding trade barriers and introducing them into macroeconomic modeling is presumably a major step towards solving all the six major puzzles of international macroeconomics.

What components constitute trade barriers and what is the relative importance of each? A comprehensive review on what we have so far learnt about trade barriers is Anderson and van Wincoop (2004). They state that, for a representative developed country, trade barriers in a broad sense are about 170 per cent of the traded value. This figure breaks down into 55 per cent local distribution cost and 74 per cent international trade cost, the latter being either transport- or border-related. Direct policy measures like tariffs or quotas make only a minor part of this figure. Trade distortions caused by other policies seem to be more important. These include, among others, transport infrastructure investments, law enforcement and related property-rights institutions, informational institutions, regulation, language, as listed in Anderson and van Wincoop (2004). While for direct trade policy measures more and more data is available, the latter components of trade barriers are in general rarely observed or at least hard to quantify.

Barriers to trade are not only of monetary nature. Some of them are better captured with the time delay they cause in the trading process. Trading time can vary substantially with the quality of the transport and port infrastructures, as well as with the efficiency and the amount of required administrative processes. An import transaction is completed within 3 days in Singapore and within 3 months in Chad or Uzbekistan, as reported by the World Bank's Doing Business survey in 2009. Meanwhile, timely trade is increasingly demanded, partly in a self-reinforcing manner. The development of transport technologies enabled the spread of international production fragmentation, which in turn increasingly requires timeliness (Hummels (2007)). Empirical evidence confirms that firms are willing to pay a premium for fast air (instead of sea) transportation that far exceeds the interest cost of time (Hummels (2001b), Harrigan (2010)), and that longer trading time significantly reduces the volume of trade (Djankov, Freund and Pham (2010)).

Chapter 1 of this thesis "Need for Speed: Is Faster Trade in the EU Trade-creating?" is an empirical contribution to the literature on the cost of time in trade. I apply an empirical strategy that has been so far rarely used in trade studies and that is more powerful in controlling for the unobserved heterogeneity in the gravity equation than the methods applied in the earlier empirical literature. I take the episode of the European Union (EU) enlargement in 2004 as a quasi-experiment and exploit the fact that EU membership improves the timeliness of trade by eliminating the customs procedures and border controls in cross-border trade of members. The estimation method is double difference-in-differences (double DID) on a calculated bilateral and industry-specific trade cost index that was propagated in Novy (2008) and Jacks, Meissner and Novy (2008), in the spirit of Head and Ries (2001). The DID estimate captures the fall in the trade cost index from the pre-enlargement to the post-enlargement period for country pairs with at least one entrant, relative to pairs within the pre-2004 EU. The double DID estimate compares the DID estimate for time sensitive industries to the DID estimate for non-time-sensitive industries.

Another contribution of the first chapter is the use of a novel timeliness of trade variable as a treatment intensity indicator in the estimation. The timeliness variable captures the enlargement-induced decline in the border waiting time on the route from the exporter to the importer country. The double DID estimate above is only able to tell whether the decline in trade costs was stronger for time sensitive industries than for non-time-sensitive ones. When the treatment intensity indicator is applied, one can check whether the additional decline in the trade costs for time sensitive industries was larger for country pairs, where the border waiting time fell more. The estimation results suggest that declining time costs contributed significantly to the overall decline in trade barriers around EU enlargement. The trade cost decline is estimated to be significantly stronger for time sensitive industries, and this extra effect was larger for country pairs with a larger decline in the border waiting time. In terms of trade-creation, a one hour decline in the border waiting time is estimated to create 5% more bilateral trade in the first two-three years.

Recent literature challenges the dominance of the iceberg assumption on trade costs. Hummels and Skiba (2004) argue that at least part of total trade costs are proportional to the number of traded units (per unit costs) and not to the traded value. Relaxing the iceberg assumption has important theoretical implications on relative prices and welfare, as it is shown in the heterogeneous firms model of Irarrazabal, Moxnes and Opromolla (2010). Per unit costs alter the within-country relative prices of different goods and lead to larger welfare costs than iceberg costs. Similarly, the recent literature also calls for the existence of trade costs that occur after each trade transaction (shipment). To economize on these fixed transaction costs or, in other words, per shipment trade costs, trading firms may change their behavior regarding shipping frequency, inventory holdings, or transport mode choice. Alessandria, Kaboski and Midrigan (2010) argue that per shipment costs lead to the lumpiness of trade transactions: firms economize on these costs by shipping products infrequently and in large shipments and maintaining large inventory holdings.

Chapter 2 of this thesis "Administrative Barriers and the Lumpiness of Trade", a joint work with Miklós Koren, is a contribution both to the literature on per shipment costs and the lumpiness of trade and to the literature on the time cost of trade. The chapter builds on the assumption that most administrative trade barriers, such as the preparation of trade documents and the customs procedure, are per shipment costs. A trading firm can save on these costs by sending fewer and larger shipments, i.e. reducing the shipment frequency and increasing the shipment size. This adjustment is at a cost: a firm that sends fewer shipments sacrifices on flexibility and timeliness. We build a discrete choice model in the spirit of the circular city model of Salop (1979). Consumers are heterogeneous in their preferred dates of consumption and are distributed uniformly along a circle that represents the time points in a year. They suffer utility loss from consuming in dates other than the preferred one. Exporting firms decide on entering the market and choose the timing of their shipment. Per shipment administrative costs make firms send shipments less frequently and with a larger quantity of products, increase the product price and reduce welfare. Our modeling approach is complementary to Alessandria, Kaboski and Midrigan (2010), who look at the trade-off between saving on per shipment costs by reducing shipment frequency versus holding larger inventories. We rule out inventories and focus on the utility loss consumers face, when consumption does not occur at the preferred date.

The contribution of Chapter 2 is also empirical. We estimate the effects of administrative costs (captured by Doing Business survey data) on the frequency, size and price of shipments on export transaction data from both the US and Spain. We decompose export flows into several margins and run both product-level and aggregate country cross section regressions. In the aggregate analysis we are also able to see adjustments in the shipment size via changing the transport mode or the exported product mix. We find that both the US and Spain exports larger-sized shipments less frequently to countries with higher administrative barriers. We find no robust evidence for a price adjustment, adjustment in the transport mode or in the export product mix.

What is the proper theory-consistent way to estimate gravity equations is still an unresolved issue in the literature. The seminal paper of Anderson and van Wincoop (2003) has put the gravity equation on firm theoretical grounds and showed that bilateral trade between two countries does not only depend on income and bilateral trade costs, but also on the trade barriers of the two countries with all the countries in the world (Multilateral Trade Resistance, MTR). Since then, the primary challenge in gravity estimations was to control for the unobservable and nonlinear MTR terms in the theoretical gravity equation. Because structural estimation, as in Anderson and van Wincoop (2003), is computationally burdensome, a more parsimonious though still powerful method is needed. In the first chapter of this thesis I opt for using the trade cost index of Novy (2008), which is already net of the MTR terms. The second chapter applies the method of Baier and Bergstrand (2009), who propose a first-order Taylor series approximation of the MTRs to generate a linear reduced-form gravity equation. As a methodological contribution, Chapter 2 shows how the method of

Baier and Bergstrand (2009) can be applied to a trade cost variable that does not have a bilateral variation.

In contrast, most empirical trade studies estimate gravity equations with some set of country, country pair, or country-time dummies, where dummies also aim at controlling for the MTRs. The use of dummies as controls is often preferred to alternative methods, because dummies are simple and powerful controls and data on trade barriers is typically deficient and not good quality. In cross section applications, the theory-consistent way to control for the MTRs with dummies is to include a full set of exporter and importer dummies in the estimating equation. In panel applications, the time-varying MTRs require a full set of exporter-time and importer-time dummies to be included. Accordingly, Baltagi, Egger and Pfaffermayr (2003) and Baldwin and Taglioni (2006) propose a panel gravity specification with country pair fixed-effects and exporter-time and importer-time dummies as the proper panel specification of the gravity equation. I call this gravity specification the "fixed-effects country-time dummies specification".

Chapter 3 of the thesis "Gravity or Dummies? The Limits of Identification in Gravity Estimations" is centered around the problems of econometric identification, when the above fixed-effect country-time dummies gravity specification is used. I argue that the full set of country-time dummies absorb too much of the variation in the data, the consequence of which is that trade policy dummies (currency union dummy, e.g.) often cannot be identified or the estimated effects are not meaningful. Unidentification is due to perfect collinearity among the country-time dummies and the policy dummy and it is especially likely to occur, when the estimating equation includes more than one policy dummies. Being aware of this limitation is important, because standard estimation techniques (like FE-LSDV or OLS on the demeaned variables) might not report the problem clearly. The chapter takes four typical research questions on the effects of a trade policy, checks identifiability and derives the estimated effects. The analytical findings are complemented with estimation exercises on the trade effects of EU enlargement.

# Chapter 1

# Need for Speed: Is Faster Trade in the EU Trade-creating?

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## 1.1 Introduction

Time matters in trade and it has been growing in importance in recent decades. Timely trade is demanded for several reasons. Some traded goods are inherently perishable such as fresh food and need fast deliveries. Others, such as fashion articles, depreciate quickly and need to be sourced frequently because of varying consumer tastes. And, most importantly, the spread of international production fragmentation in the recent decades increasingly requires timely trade.[1] The importance of timeliness is multiplied if several intermediate production stages at different parts of the world should be synchronized in a timely fashion.

This paper provides empirical evidence on the effect of timeliness on trade, while using a novel estimation strategy. I take the episode of the European Union (EU)

[1] Evidence on the growing importance of international production fragmentation is provided, among others, by Feenstra and Hanson (1996) for the US, Hummels, Ishii and Yi (2001) for OECD countries and Breda, Cappariello and Zizza (2008) for seven of the EU-15 countries.

enlargement in 2004 as a quasi-experiment and exploit the fact that EU enlargement eliminated the time-consuming customs procedures and border controls in cross-border trade of the new member states with the EU-15 and with each other. The estimation method is double difference-in-differences (double DID) on a calculated bilateral and industry-specific trade cost index that was propagated in Novy (2008) and Jacks, Meissner and Novy (2008), in the spirit of Head and Ries (2001). Differences of the trade cost index are taken across the pre-enlargement and post-enlargement periods, treatment and control country pairs, and across industries that are classified either as sensitive or non-sensitive to the timeliness of trade.

I argue that the enlargement of the EU with the eight Central and Eastern European countries[2] can be considered as a quasi-experiment from a trade policy point of view, because traditional trade policy barriers (tariffs, quantitative restrictions, rules of origin) between these eight countries and the countries of the pre-enlargement EU, as well as among the eight themselves, had already been abolished or harmonized by around 2000 in the trade of most manufactured products. This no-(trade)-policy-change environment offers the possibility to study the impact of some non-conventional trade barriers, such as the time cost of trade.

The trade cost index is calculated on a data set of country pairs, formed by 22 EU countries (14 countries of the pre-enlargement EU[3] and the 8 Central and Eastern European countries that joined the EU in 2004), and 19 manufacturing industries over the period 2000-2006. I call the eight new member states 'new countries', the fourteen others 'old countries'. The choice of countries, industries and years ensures that the no-policy-change environment applies in the entire panel. Country pairs with at least one new country form the treatment group, country pairs of old countries are the control group. Hence, a country pair is treated, if *one or both* countries of the pair

[2]Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia.

[3]Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom.

were outside the EU before 2004, but became EU members in 2004. Industries are classified whether they are sensitive or not sensitive to the timeliness of trade (time-sensitive versus non-time-sensitive). The classification is first based on the estimates of Hummels (2001b), then, as a robustness check, on a measure of international production fragmentation within the industry.

The double DID estimate captures the fall in the trade cost index from the pre-enlargement to the post-enlargement period for treatment, relative to control, country pairs in time-sensitive, relative to non-time-sensitive, industries. The identification is further refined with the use of a novel treatment intensity indicator, which is the change in the waiting time at land border crossings on the route between the two countries of the pair. When this treatment intensity indicator is applied, the estimated effect shows whether the above fall in the trade cost index was larger for country pairs with a larger decline in the border waiting time.

The results confirm that the trade cost indices in industries that are classified as time-sensitive declined significantly stronger (more than twice larger) than trade costs in non-time-sensitive industries. In terms of trade creation this translates into an *additional* bilateral trade growth of 17% in time-sensitive industries, on the top of a 10% trade growth in non-time-sensitive industries. Estimates with the treatment intensity indicator reveal that in time-sensitive industries the decline in the trade cost index was larger for country pairs with larger decline in the border waiting time. A one hour larger decline in the waiting time is associated with a 0.8 percentage point larger fall in the trade cost index, which is consistent with a 5% bilateral (international relative to domestic) trade growth.

Several robustness checks confirm the main results. Most importantly, it is tested whether the measured effect depends on the mode of transport according to the expectations. The treatment intensity indicator is expected to be valid only for land transport, and no effect is expected for sea transportation, where the abolition of the customs procedure did not take place with EU enlargement. To learn about transport mode choices within the EU, I estimate a discrete choice model that provides projections for transport mode choice probabilities (land, air or sea) in intra-EU trade with the help of extra-EU trade data. Then, I define transport mode subsamples in intra-EU trade and cross-check the main estimates by subsample.

This paper is a contribution to the empirical literature on the cost of time in trade. Hummels (2001b) estimates the cost of time as the premium firms pay for air instead of sea transportation. Djankov, Freund and Pham (2010) infer the effect of time on trade flows from a country cross section of the *Doing Business* database.[4] Beyond that it takes a fairly different identification approach, this paper I believe applies an econometric strategy that is more powerful in controlling for the unobserved heterogeneity across countries and industries. First, the double DID estimation controls for all time-invariant country and industry heterogeneity; identification entirely comes from the time dimension. Second, the paper identifies from an episode that is close to a quasi-experiment from a trade policy point of view, hence, time-varying heterogeneity in traditional trade policies is ruled out. Third, with the use of the trade cost index as the dependent variable, I implicitly control for any effects coming from trade barriers with third countries (the so-called Multilateral Trade Resistances in Anderson and Van Wincoop (2003)). Finally, the sampled countries are relatively similar for they are all European countries, which reduces the unobserved country heterogeneity.

The results of this paper are in line with the implications of the theoretical literature on the time cost of trade (Deardorff (2002), Evans and Harrigan (2005), Harrigan and Venables (2006)). The theory of timeliness implies that time costs can hinder the outsourcing of time-sensitive production to more distant and/or less developed

[4] Hummels (2001b) estimates the premium paid for air transportation to be 0.5% of the product value per day. Djankov, Freund and Pham (2010) find that in country relations, where trading time is one day longer, the volume of trade is 1% smaller.

locations, thereby reducing the volume of international trade. Harrigan and Venables (2006) also point out that the effect of timeliness is amplified by the uncertainty associated with time delays. The possibility of delays in trade, especially if production stages are located in different venues, makes it uncertain when the product can reach the final market. If delays are expected, production should be started and orders must be placed earlier, even before demand and cost conditions are known. This suggests that demand for timeliness should be especially strong in the case of fragmented production processes.

The paper is structured as follows. Section 1.2 introduces the trade cost index and presents its evolution around EU enlargement. Section 1.3 builds the empirical framework, presents the classification of industries according to time-sensitivity, and describes the construction and the use of the treatment intensity indicator. Section 1.4 presents the baseline estimation results. Section 1.5 describes the projection of intra-EU transport mode choice probabilities and cross-checks the main results by transport mode subsamples. Section 1.6 presents other robustness checks. Section 2.7 concludes.

## 1.2 Measuring bilateral trade costs

The first step of the empirical strategy is to construct an index of trade costs that will serve as the dependent variable in the empirical exercise. I use the trade costs index that is developed by Novy (2008) in the spirit of an earlier paper of Head and Ries (2001). Originally, Novy (2008) derives the index from the gravity theory of Anderson and Van Wincoop (2003), but Jacks, Meissner and Novy (2011) show that the same index measure can be derived from several competing trade theories.[5]

[5] Such as the models of Eaton and Kortum (2002), Chaney (2008), as well as Melitz and Ottaviano (2008).

A big advantage of applying this index over the traditional way of inferring trade barriers from the gravity estimation is that the index completely wipes out the Multilateral Trade Resistance (MTR) terms from the gravity equation, i.e. it fully controls for the evolution of trade barriers with third countries. The MTRs are mostly unobservable and can cause omitted variable bias in the traditional gravity estimation.[6]

### 1.2.1 The trade cost index

I model trade costs at the industry level based on the industry-specific gravity equation of Anderson and van Wincoop (2004). A similar approach is taken in Chen and Novy (2009) and Jacks, Meissner and Novy (2008). The gravity equation for exports from country $i$ to country $j$ of products specific to industry $k$ is

$$X_{ij}^k = \frac{Y_i^k E_j^k}{Y_W^k} \left( \frac{T_{ij}^k}{\Pi_i^k P_j^k} \right)^{1-\sigma^k}, \tag{1.1}$$

where $Y_i^k$ is output in the exporting country, $E_j^k$ is expenditure in the importing country on products of industry $k$, $Y_W^k$ is world output in the same industry, and $T_{ij}^k$ is international trade cost between country $i$ and $j$ for the same industry. Exports, output and expenditure are in current values. The terms $\Pi_i^k$ and $P_j^k$ are the outward- and inward-oriented MTR terms for the exporter and the importer country, respectively, specific to industry $k$. The elasticity of substitution among varieties $\sigma^k$ is also industry-specific.

Accounting for the multilateral trade resistance terms in the empirical applications of the gravity equation is often problematic, for $\Pi_i^k$ and $P_j^k$ are not observable. In the following, the aim is to express trade costs without these two terms. For this

[6] A potential disadvantage of the Novy/Head-Ries index is that it cannot treat direction-specific trade flows separately, since it is only the average of them, which enters the expression. In reality, bilateral trade barriers can be asymmetric and policy changes can have asymmetric effects on the direction-specific trade costs. Discovering such asymmetries is however out of the scope of the current analysis.

to achieve, notice that the gravity equation also holds for domestic trade, i.e. the domestic sale of domestically produced goods. The domestic analogue of the gravity equation for trade *within* country $i$ of products from industry $k$ is

$$X_{ii}^k = \frac{Y_i^k E_i^k}{Y_W^k} \left( \frac{T_{ii}^k}{\Pi_i^k P_i^k} \right)^{1-\sigma^k}, \tag{1.2}$$

where $T_{ii}^k$ is now the trade cost *within* country $i$. Express the product $\Pi_i^k P_i^k$ from (1.2) and $\Pi_j^k P_j^k$ from the similar domestic gravity equation for country $j$. Then take the product of two international gravity equations: equation (1.1) and the equation for the reverse flow of $X_{ji}^k$. Then, substitute back the expressions for $\Pi_i^k P_i^k$ and $\Pi_j^k P_j^k$. After simple manipulations one can get the ratio of international to domestic trade costs, expressed as a function of the domestic to foreign trade ratio. Finally, take the geometric mean of the equation and get

$$\Theta_{ij}^k \equiv \left( \frac{T_{ij}^k T_{ji}^k}{T_{ii}^k T_{jj}^k} \right)^{\frac{1}{2}} = \left( \frac{X_{ii}^k X_{jj}^k}{X_{ij}^k X_{ji}^k} \right)^{\frac{1}{2(\sigma^k-1)}}, \tag{1.3}$$

the average bilateral trade cost between country $i$ and country $j$, denoted by $\Theta_{ij}^k$.

The index reflects that trade costs between two countries is larger the less open the countries are in terms of the ratio of domestic to international trade. Note that $\Theta$ is only a relative measure: the level of cross-country barriers is compared to the level of within-country ones. In theory, the lower bound is $\Theta = 1$, when international trade is just as costly as domestic trade. A special case is frictionless trade, when $T_{ij} = T_{ji} = T_{ii} = T_{jj} = 1$. At the other extreme, for a closed economy with zero international trade $\Theta$ approaches infinity.

The trade cost index also corrects for the level of the substitution elasticity between home and foreign goods ($\sigma$). This is the point, where the index of Novy (2008) differs from the one proposed by Head and Ries (2001). When $\sigma$ is high, demand shifts strongly towards domestic goods even in response to a small (foreign-to-domestic) relative price increase, induced by increasing trade costs. Hence, with high $\sigma$, an economy with relatively small trade barriers can be considerably closed. On the contrary, when $\sigma$ is low, the economy can be considerably open even under large trade barriers.

### 1.2.2 Data and index calculation

I calculate the trade cost index (henceforth, $\Theta$) in equation (1.3) for country pairs and industries within the enlarged EU for years between 2000 and 2006. It is important to note that interpreting the $\Theta$s as trade barriers for different points in time requires the assumption that the gravity equation holds in each year.

The data set is a panel of yearly data for 7 years between 2000 and 2006. Foreign trade data is bilateral exports in euros from Eurostat.[7] The set of countries includes 22 EU members (14 old and 8 new), altogether the EU-25 less Greece, Cyprus and Malta.[8,9] 19 manufacturing industries are considered in the 2-digit NACE classification. I exclude food and beverages as well as energy manufactures, because most of these products were not traded freely by new members before enlargement.[10]

An empirical challenge in the calculation of the $\Theta$s is to measure domestic trade ($X_{ii}$ and $X_{jj}$). A good candidate is gross domestic sales, which can be calculated as gross production minus total exports within an industry, i.e. the total value of goods

[7] Original data is available either in 6-digit HS or in 5-digit SITC product-level breakdown, which was classified into 2-digit NACE industries using the relevant correspondence tables.

[8] These three countries are excluded because the natural experiment argument does not hold for them. It is because of Greece's late euro area entry and the different pre-2004 trade policies of Cyprus and Malta towards the then EU from the trade policies of the Central and Eastern European countries. Moreover, land transportation, for which my treatment intensity indicator applies, cannot be used in trade with the latter two countries.

[9] Note that, out of the 14 old EU countries, Ireland and the UK are not members of the Schengen area, which allows for the free movement of persons. Similarly, the 8 new countries were not yet part of Schengen during the sample period.

[10] More precisely, the two excluded industries are Manufacture of food products and beverages (NACE codes 15 and 16) and Manufacture of coke, refined petroleum products and nuclear fuel (23).

that are produced by an industry domestically but not sold abroad.[11] There is however one important discrepancy in this definition: exports also include re-exports, which is then mistakenly subtracted from domestic production. To overcome this problem I correct for re-exports with the help of national input-output tables.[12] Industry-specific elasticities of substitution ($\sigma^k$) are taken from Chen and Novy (2009), who borrow the estimates from Hummels (2001a), and transform them to the NACE industry classification.[13]

While export data is fully available for all country pairs, industries and years, gross production is missing for 14 data points (Ireland and UK in NACE industry 36 for all years). A further - and more serious - data limitation is that the calculated domestic trade variable sometimes takes negative values. Production and trade statistics may not always be consistent (e.g. due to inventories), and my correction for re-exports is only approximately correct. Overall, domestic trade is negative in almost one-forth of the observations.[14] In these cases, I impose domestic trade to be zero. After taking the log of $\Theta$, these observations ultimately drop out from the estimation sample.

I construct a balanced panel sample, keeping only those country pair - industry panels, where none of the observations are missing (either because of true missings or zero-imposed $\Theta$s) throughout the sample period. Summary statistics of the balanced panel are presented in Tables 1.A.1 and 1.A.2. In the balanced panel, 59% of the

[11] Gross output data by 2-digit NACE industries is either from Eurostat or the OECD STAN database, current value flows in euros.

[12] The share of re-exports in total exports can be especially sizeable for countries with important maritime ports such as the Netherlands. The re-export share is calculated for each country and 2-digit NACE industry from input-output tables for year 2000 (the year for which I-O tables for most countries are reported by Eurostat). The same re-export share is assumed for all years in the sample.

[13] Hummels (2001a) estimates the $\sigma$'s on a 2-digit SITC breakdown, which classifies all traded goods into 63 product categories. I take the weighted averages of the 3-digit $\sigma$s in Chen and Novy (2009) for each 2-digit NACE industry, where the weight is the average share of the 3-digit industry in the corresponding 2-digit industry in total intra-EU export value during the 2000-2006 period. The $\sigma$'s for the 2-digit NACE industries are shown in Table 1.A.1.

[14] There are two countries and two industries with relatively large shares of negative domestic sales figures: Luxembourg (65%), Belgium (43%), Rubber and plastic manufactures (83%) and Office machinery and computers (61%). The share of negatives increases with the years (18% in 2000 to around 30% in 2006), probably reflecting the preliminary nature of more recent data.

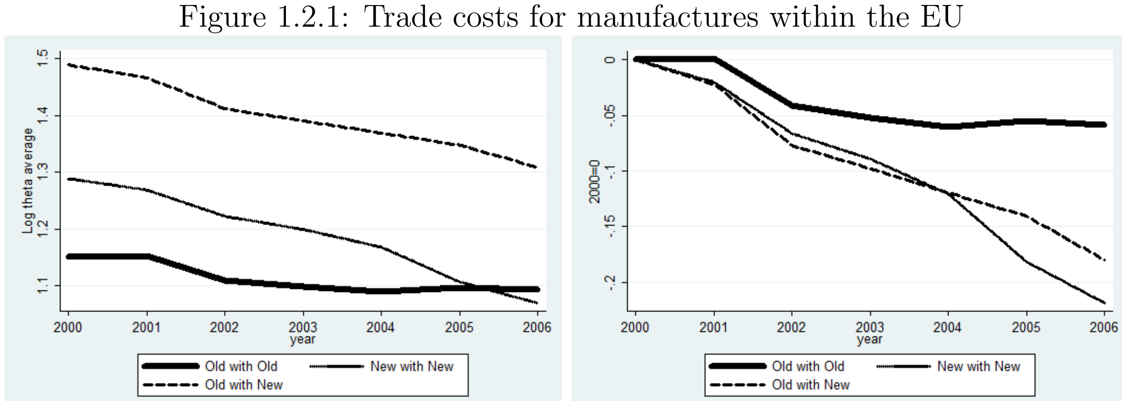
maximum possible country pair - industry panels are retained (5170 out of 8778). Hence, the total number of observations for the 7 years is 36,190. Almost 40% of the sample belongs to country pairs, where both countries were EU members already before 2004 (control country pairs in the estimation).

### 1.2.3 Trade costs around EU enlargement

Figure 1.2.1 presents the time path of trade costs ($\Theta$ in logs) within the EU between 2000 and 2006. The plotted lines are averages across the 19 manufacture industries and three groups of country pairs: country pairs with two old countries (old with old), with two new countries (new with new) and with one old and one new countries (old with new).

On the left panel of the chart, the levels of the trade cost indices (in logs) are shown. On the right panel, the same variables are normalized to year 2000. The graphs read as follows. A value of 1.1 on the left panel means that trade costs in international trade (the numerator of the index) is 3 ($= e^{1.1}$) times larger than trade costs in domestic trade (the denominator). And a decline of 0.2 in the value of the index is approximately 20 percentage points decline in international trade costs (relative to domestic trade costs) in ad valorem tariff equivalent terms.

Figure 1.2.1: Trade costs for manufactures within the EU



The index reflects trade costs in the broadest possible sense. It accounts for all the factors that hinder cross-border trade, be they of geographical, cultural, institutional, political or psychological nature. Hence, the differences in the levels of the index by country pair groups can be explained by the fact that, in many of these factors, old countries are closer to other old countries and new countries to other new countries. Trade costs for old-new pairs is considerably higher even at the end of the period than trade costs for either old-old or new-new pairs.

The right hand panel of the chart is more suited for observing the developments over time. Trade costs for old-old country pairs are relatively stable over the period, apart from a slight decline in the early years. In contrast, trade barriers seem to have declined steadily among new countries and between new and old countries. It suggests that, regardless the possible one-off event of EU enlargement, an overall trade integration process was present in new countries' trade during the whole period.

There are some signs that the above declining trend accelerated after 2004, especially for trade within new members, which suggests that EU enlargement also played a role in the development of trade barriers. The break in the trend around 2004 is more apparent from some of the industry trade cost indices, presented on Figures 1.A.1 to 1.A.3 in the Appendix. The group of affected industries mainly include technology intensive branches such as machinery and equipment, office machinery, electrical machinery, or motor vehicles, but also some others like wood manufactures, chemicals, or basic metals.



## 1.3 Empirical strategy

What explains the change in the time path of the trade cost indices for new countries after 2004 and why is the change more apparent in some industries and not in others? Improved timeliness is a possible explanation. Before EU enlargement lengthy customs and border crossing procedures hindered trade between new member states. And certain products were more sensitive to such barriers than others. In the following, I describe the empirical strategy that aims to identify the role of the improvement in timeliness in the decline of trade barriers around EU enlargement.

### 1.3.1 Double difference-in-differences

As an empirical strategy I opt for a quasi-experiment setup and double difference-in-differences (double DID) estimation.[15] I take the episode of EU enlargement as a quasi-experiment, which helps identify the effects of changes in non-policy-related trade barriers.

Trade policy in the enlarged EU area, comprising the countries considered in this study, guaranteed free trade of most (non-food) manufactured products basically from year 2000 onwards, i.e. several years before 2004. This no-policy-change environment at the time of EU enlargement was the result of the formation of several free trade agreements during the 1990's. These were the Europe Agreements between the old EU and the 8 new countries, signed during the first half of the 1990's, the CEFTA (Central European Free Trade Agreement), formed in 1993, the BAFTA (Baltic Free Trade Agreement), formed in 1994, as well as bilateral trade agreements between each pair of CEFTA and BAFTA members, which entered into force during the second half of the 1990's.[16]

The double DID estimation identifies from three dimensions. The first is the time dimension: how much did trade costs decline from the pre-enlargement to the post-enlargement period? The second is the country pair dimension: how much larger was the above decline for country pairs that became intra-EU in 2004, relative to the old-old country pairs? And the third is the industry dimension: how much larger

[15] Description of the method is provided, among others, in Meyer (1995) and Angrist and Krueger (2000).

[16] Hornok (2010) gives a more detailed description on the trade policy environment around EU enlargement.

was the above excess decline for country pairs that became intra-EU in 2004 in the time-sensitive (treatment sensitive), relative to the non-time-sensitive, industries?

More formally, the double DID estimation is built up as follows. The time of the EU enlargement is denoted with the dummy $d_t$, taking value 1 for years larger than or equal to 2004 and 0 otherwise.[17] I differentiate between country pairs that are always inside the EU (old-old pairs) and country pairs that get inside only in 2004 (all pairs involving at least one new member) and call the former control, the latter treatment country pairs. The corresponding dummy is $d_{ij}$, which equals 1 for the treatment pairs and 0 otherwise. Note that the treatment is defined as two countries *jointly* becoming members of the EU. This involves the case when one country is already a member and the case when neither of them is a member before the treatment takes place. Such a treatment definition implies that it is the joint (and not the individual) EU membership that reduces bilateral trade costs.

I introduce a treatment sensitivity dummy, $d^k$, which takes value 1 if the industry is classified as treatment sensitive (time-sensitive) and 0 otherwise. Timeliness is ultimately important for products that are, for whatever reason, sensitive to time, and may be irrelevant for non-time-sensitive products. Notice that taking the difference along the time-sensitive versus non-time-sensitive industry dimension has the advantage that the estimation controls for any unobservable differences in the trends between the treatment and the control country pairs, as long as these differences are the same for time-sensitive and non-time-sensitive industries. Such heterogeneity may e.g. come from an EU enlargement-induced increase in the political stability of new members or from a decrease in informational costs in trade with new countries.

The double DID treatment effect can be captured by estimating an equation that includes the above three dummies $d_{ij}$, $d_t$, $d^k$ and their first- and second-order in-

[17] Notice that, because of the annual frequency of the data, I need to take the whole year 2004 as treated, though enlargement took place only in May. If it causes any bias in the estimated effect, that should be a downward bias, since it puts a couple of untreated months in the treatment part of the sample.

teractions. The double DID estimate is the coefficient estimate on the second-order interaction term ($d^k_{ij,t} = d_{ij} \cdot d_t \cdot d^k$). In panel estimation the estimating equation can be simplified by using a full set of country pair-industry and industry-year effects as follows:

$$\theta^k_{ij,t} = \delta^k_{ij} + \delta^k_t + \beta_1 d_{ij,t} + \beta_2 d^k_{ij,t} + \varepsilon^k_{ij,t}, \tag{1.4}$$

where $\theta = \ln \Theta$, $\delta^k_{ij}$ are country pair-industry fixed effects and $\delta^k_t$ denotes a full set of industry-year dummies. The fixed effects and the industry-year dummies control for any time-constant country and industry characteristics as well as any industry-specific trends that are common across country pairs.

The regressors of interest are the first-order interaction term $d_{ij,t} = d_{ij} \cdot d_t$ and the second-order interaction term $d^k_{ij,t} = d_{ij} \cdot d_t \cdot d^k$. The coefficient of the first ($\beta_1$) shows the magnitude of the EU enlargement-induced trade cost decline for industries that are not sensitive to time. The coefficient of the second ($\beta_2$) shows how much different this trade cost decline was for time-sensitive, relative to non-time-sensitive, industries. A negative and significant estimate for the latter would show that trade costs in time-sensitive industries declined more than trade costs in non-time-sensitive industries, which could indicate the contribution of the declining trading time costs to the overall trade cost decline.

### 1.3.2 Time-sensitivity of industries

Classifying industries to time-sensitive and non-time-sensitive categories is not a straightforward exercise. Most previous attempts were restricted to a narrow subset of products, where time-sensitivity can be relatively easily defined.[18] The only comprehensive estimation for time-sensitivity, to my knowledge, is Hummels (2001b).

[18] Fresh foodstuff is clearly more time-sensitive than preserved foodstuff, for instance. Evans and Harrigan (2005) restrict attention to apparel products and use a special database to distinguish between replenishment versus non-replenishment clothing.

He uses information on the choices between the fast and expensive air and the slow and cheap ocean transportation in US imports and estimates the premium that trading firms are willing to pay for a faster delivery.

Table 1.3.1: Industries classified by time-sensitivity

| Time-sensitive | | Non-time-sensitive | |
|---|---|---|---|
| NACE | industry | NACE | industry |
| 29 | Machinery and equipment | 17 | Textiles |
| 30 | Office machinery and computers | 18 | Wearing apparel |
| 31 | Electrical machinery and apparatus | 19 | Leather, luggage, footwear, etc. |
| 32 | Radio, tv and communication equip. | 20 | Wood, excl. furniture |
| 33 | Medical, precision and optical instr. | 21 | Pulp, paper products |
| 34 | Motor vehicles, trailers, semi-trailers | 22 | Publishing, printing |
| 35 | Other transport equipment | 26 | Other non-metallic mineral prods |
| | | 27 | Basic metals |

Notes: Own classification, based on Hummels (2001b).

Hummels (2001b) reports the estimates for 2-digit SITC product groups. I create a broad correspondence between SITC groups and NACE industries and determine two sets of industries: time-sensitive and non-time-sensitive ones (Table 1.3.1).[19] Not all industries are classified however: if the estimates for the SITC groups corresponding to an industry are mixed, the industry is left out from both categories.[20]

The resulting classification suggests that time-sensitivity is associated mostly with higher technology industries. One reason for this may be that preferences change rapidly for fast developing high technology products. Moreover, these are the industries that are more strongly affected by the geographical fragmentation of production, where timely deliveries of intermediates between the different production platforms is very important.[21] As a robustness check in Subsection 1.6.1 I classify industries according to the prevalence of international production fragmentation to capture treatment sensitivity.

[19]Evaluation is based on results in Table 3 in Hummels (2001b). An SITC product group is time-sensitive, when the estimate for the Days/Rate ratio is significantly positive.

[20]Four of the 19 industries are left out: NACE codes 24, 25, 28, 36.

[21]Industry-specific evidence on international production fragmentation in some EU countries is provided in Breda, Cappariello and Zizza (2008).

### 1.3.3 Identification with treatment intensity

The identification can be refined with the use of some indicator that explicitly captures the magnitude of the timeliness gain due to enlargement and its variation across the treatment country pairs. In this case, the treatment is described by a variable of treatment intensity and not by a simple dummy variable.[22] An important advantage of identifying with treatment intensity is that it offers a way to check whether the direction of the measured effect corresponds to the a priori expectations (larger time gain, larger effect).

I construct a treatment intensity indicator that captures the change in the waiting time at national borders from the pre- to the post-enlargement period. With the opening of national borders to the free movement of goods after May 2004, border waiting times between old and new member states and among new members were almost completely eliminated.[23] Variation in the enlargement-induced timeliness gain across country pairs comes from the fact that countries with inefficient pre-2004 border procedures experienced a larger improvement in timeliness than countries with fast procedures.

The treatment intensity indicator is based on data on the pre-enlargement waiting time at borders and on the assumption that border waiting time within the EU is zero. Let us denote the pre-enlargement border waiting time for each country pair by $h_{ij}$. It takes value zero for control country pairs and positive values for treatment country pairs. Then, define the time-varying indicator for treatment intensity, $h_{ij,t}$, as follows:

[22] Angrist and Pischke (2008) discuss this approach referring to Card (1992), who uses regional variation to measure the effect of the federal minimum wage.

[23] Though EU enlargement immediately guaranteed the free movement of goods within the enlarged EU area, border police controls of persons' movements remained in place up until the 8 new EU members entered the Schengen Area in December 2007. However, most of the pre-enlargement border waiting time for cargos was due to the customs clearance at the border, which was completely eliminated at May 2004.

$$h_{ij,t} = \begin{cases} h_{ij} & if \quad d_{ij,t} = 0 \\ 0 & if \quad d_{ij,t} = 1, \end{cases}$$

i.e. border waiting time equals the pre-enlargement waiting time in the untreated part of the sample, which falls to zero for treatment country pairs after they got the treatment.

The estimating equation with treatment intensity is similar to equation (1.4), with $h_{ij,t}$ replacing $d_{ij,t}$,

$$\theta^k_{ij,t} = \delta^k_{ij} + \delta^k_t + \gamma_1 h_{ij,t} + \gamma_2 h^k_{ij,t} + \varepsilon^k_{ij,t}, \tag{1.5}$$

where $h^k_{ij,t} = h_{ij,t} \cdot d^k$. The interpretation of the two coefficients ($\gamma_1$ and $\gamma_2$) are now in terms of the unit of treatment intensity (unit of time). More precisely, $\gamma_1$ measures the marginal response of trade costs in non-time-sensitive industries to a one hour decline in the border waiting time, while $\gamma_2$ shows the *additional* trade cost change for time-sensitive, relative to non-time-sensitive, industries to a one hour decline in the border waiting time.

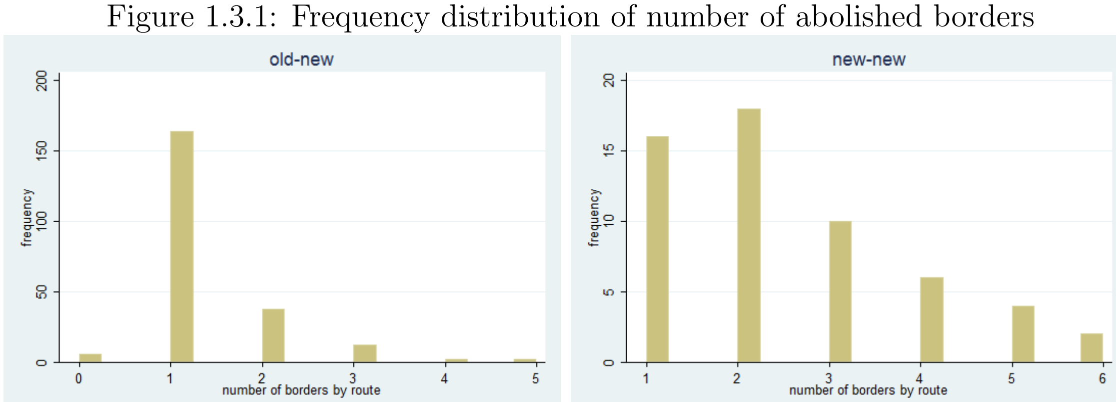
### 1.3.4 Pre-enlargement border waiting time

I describe the construction of the pre-enlargement border waiting time variable ($h_{ij}$). The constructed variable is route-specific and captures the number of hours that a truck had to wait on average at national borders before EU enlargement on its way from the exporting to the importing country. The construction of the variable involves two steps. First, the optimal transport route from the exporting to the importing country is determined. Second, the pre-enlargement number of waiting hours at the corresponding borders are summed up.

The transport routes are determined with the help of an online route planner.[24] The economically optimal route between the capitals of the two countries for a 40-tonne truck is taken. In some cases, routes may also involve the taking of a freight ferry to cross the sea. The optimal route determines the borders that the transport route crossed and that were eliminated with EU enlargement (number of abolished borders). Borders with third countries (no change in waiting time assumed) are not taken into account.[25]

The frequency distribution of the number of abolished borders by route is shown in Figure 1.3.1. The figure does not contain old-old country pairs, since the number of abolished borders for them is always zero. For old-new country pairs most routes had to cross only one border. All the 8 new members are either neighbors to the old EU block or have a direct sea access (the Baltic states). In contrast, for new-new country pairs, the number of abolished borders are in most of the cases larger than one.

Figure 1.3.1: Frequency distribution of number of abolished borders




The border waiting time data is provided by the International Road Union (IRU) and is based on regular (daily, from Monday to Friday), but voluntary, reportings by

[24]http://www.routenplaner-50.com/

[25]In trade of Lithuania with some old EU countries, the optimal route involves crossing the Lithuanian-Russian border and taking a ferry from Russia (Kalinyingrad) to Germany. In this case, the number of abolished borders is zero, since borders with Russia were not eliminated with EU enlargement.

transport companies and authorities, as well as bus and truck drivers.[26] Raw data is presented in Table 1.A.3. Waiting time is direction-specific and reported in hours for one or more border crossing points by national border. If there are more crossing points at the same border, I take the average of waiting times and not only the crossing point the optimal route determines. Not all trucks start from or are destined to the capital city, and trucks may also deviate from the optimal route for certain reasons. I retain the direction-specific nature of the data. To capture the pre-enlargement situation, I take the averages of the waiting times in years 2000-2002.

Table 1.3.2: Calculation of waiting hours on route Austria-Poland

| Border | Crossing point | Waiting hours (2000-2002) |
|---|---|---|
| AT to CZ | Wullowitz-Dolni Dvorista | 1.33 |
| | Drasenhofen-Mikulov | 0.43 |
| | Haugsdorf-Hate | 0.87 |
| | **Average of crossing points** | **0.88** |
| CZ to PL | Kudowa Slone-Nachod | 7.67 |
| | Chalupki-Novy Bohumin | 0.83 |
| | Clesyzn-C.Tesin | 7.13 |
| | **Average of crossing points** | **5.21** |
| **Waiting hours on route from AT to PL** | | **6.09** |

Source: Own calculations based on IRU data.

Table 1.3.2 illustrates it on an example how the pre-enlargement border waiting time by route is calculated. If a truck goes from Austria to Poland, it has to cross the Austrian-Czech and the Czech-Polish borders along the optimal route. Along the Austrian-Czech border there are three border crossing points IRU provides data for: Wullowitz-Dolni Dvorista, Drasenhofen-Mikulov and Haugsdorf-Hate. They give the average waiting hours at the Austrian-Czech border in the pre-accession years (average of the three crossing points), which is 0.88 hours. Similarly, there are three crossing points on the Czech-Polish border with average pre-enlargement waiting time of 5.21 hours. Hence, the total waiting time on the optimal route from Austria to Poland is the sum of 0.88 and 5.21, i.e. 6.09 hours.

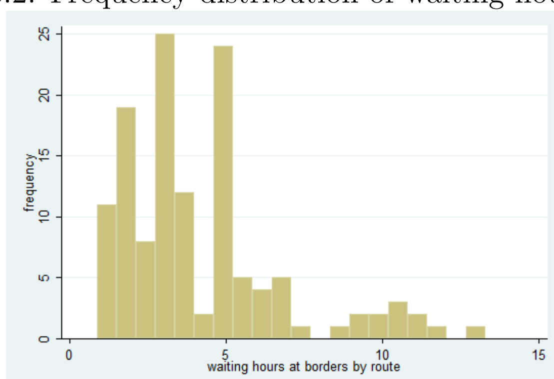
The waiting time data is unfortunately not available for Estonia and Latvia, and only partly available for Slovenia (Slovenian-Hungarian border only). More-

[26] I express my gratefulness to Peter Krausz (IRU) for providing me the data.

over, routes may also involve the taking of a sea ferry, and there is no waiting time information for sea ferry ports. Most of the ferry cases involve trade of Estonia and Latvia, for which there is no data anyway, but part of them are routes involving Lithuanian and Polish trade. Altogether waiting time data is missing for 152 out of the 280 treatment country pairs.[27]

The frequency distribution of the pre-enlargement border waiting time by routes is shown on Figure 1.3.2. The waiting time on most routes is not more than 5 hours, and there are only a few routes with more than 10 hours of waiting. If there were no missing observations, the distribution would most probably be denser at the higher values, since the routes between the Baltic states and other (continental) countries cross more borders than other routes.

Figure 1.3.2: Frequency distribution of waiting hours by route




Notice that border waiting time (or more precisely, the decline in the border waiting time) as a measure of the improvement in timeliness is relevant only for land transportation. Although land transportation is the dominant transport mode in intra-EU trade, later I will explicitly control for the mode of transport.

[27]Section 1.6 experiments with other treatment intensity measures with better data coverage.

## 1.4 Estimation

I estimate equation (1.4) and equation (1.5) on the panel of country pairs and industries with 7 years. The balanced panel database is described in Section 1.2.2. In the error structure I allow for arbitrary patterns of correlation and/or heteroskedasticity within country pairs. Hence, I apply cluster-robust standard error estimation with country pair clusters and not with country pair-industry clusters. The latter would require a stronger assumption on the independence across country pair-industry groups. The number of observations vary with the specification, due to unclassified industries in terms of time-sensitivity and missing data on the border waiting time.

An additional control variable that captures the differences in the macroeconomic convergence trends is also included in the estimating equation. Chen and Novy (2009) note that, apart from pure trade costs, the value of the trade cost index may depend on the nature of trade as well. The index tends to be smaller if trade is mainly intra-industry trade and larger if trade is based on comparative advantage driven by technology or factor endowment differences. With economic convergence to the more developed EU, the trade of new EU countries shifted more and more towards intra-industry trade, causing a steady decline in their trade cost indices. I capture such convergence trends with the absolute difference between the GDP per capitas in the exporter and the importer countries. Formally, $gap_{ij,t} = \mid \ln GDPPC_{i,t} - \ln GDPPC_{j,t} \mid$, where $\ln GDPPC_{i,t}$ denotes the natural logarithm of GDP per capita in country $i$ at time $t$. Since the GDP per capitas are in current (euro) prices, the gap reflects both real and price convergence trends.[28] The corresponding coefficient estimate is expected to be positive: a declining gap (convergence) comes with a declining trade cost index.

The results are presented in Table 1.4.1, estimates of equation (1.4) in the first column, estimates of equation (1.5) in the second column. Due to the construction of

[28]The source of the GDP per capita data is Eurostat.

Table 1.4.1: Main results

| Variable | w/o treatment intensity | with treatment intensity |
|---|---|---|
| Treatment | -0.024*** | |
| | [0.008] | |
| Treatment x Sensitive | -0.026*** | |
| | [0.007] | |
| Treatment intensity | | 0.001 |
| | | [0.002] |
| Treatment intensity x Sensitive | | 0.008*** |
| | | [0.002] |
| GDP per capita gap | 0.217*** | 0.360*** |
| | [0.037] | [0.051] |
| Country pair - industry effects | yes | yes |
| Industry - year effects | yes | yes |
| Number of observations | 29316 | 20860 |
| Number of groups, of which: | 4188 | 2980 |
| - treatment, of which: | 2402 | 1194 |
| – sensitive | 952 | 458 |
| Adjusted within $R^2$ | 0.26 | 0.31 |

Notes: Estimates for equations (1.4) and (1.5) on a panel of country pairs and industries in period 2000-2006. Dependent variable is the log of the Novy index. Treatment is being an old-new or new-new country pair after 2004. Treatment sensitivity of industries is based on Hummels (2001b). Treatment intensity is the decline in border waiting time between countries (described in Section 1.3.4). Cluster robust standard errors (with country pair clusters) are in brackets. * significant at 10%; ** at 5%; *** at 1%.

$\theta$, the estimated coefficients can directly be interpreted in ad-valorem tariff equivalent terms. It should be kept in mind however that $\theta$ measures only relative (international to domestic) trade costs.

The estimates of equation (1.4) justify that a considerable part of the decline in the trade cost index around EU enlargement can be due to the timeliness gain. The decline is estimated to be 2.4 percentage points for industries that are not time-sensitive (first row). In contrast, the decline in the trade cost index for time-sensitive industries was twice that large. The coefficient on the interaction of the treatment dummy and the time-sensitivity dummy (second row) shows an *additional* 2.6 percentage points decline in trade costs for time-sensitive industries.[29]

When the decline in border waiting time as treatment intensity is included, the significant contribution of the timeliness gain to the overall effect is further strengthened. The estimate is significantly different from zero only for time-sensitive industries, i.e. only for the interaction of the treatment dummy with the treatment sensi-

[29]Estimates without including the GDP per capita regressor are available on request. In short, when the GDP per capita gap variable is not included, the estimates for $\beta_1$ and $\gamma_1$ in equations (1.4) and (1.5), respectively, are significantly larger in absolute value, while the estimates for $\beta_2$ and $\gamma_2$ are not affected.

tivity dummy. The direction of the effect is the expected: a larger decline in border waiting time comes with a larger decline in trade barriers. The coefficient reads as follows: if border waiting time decreases by an additional hour (relative to its average change) for a treatment country pair, then international trade costs (relative to domestic ones) decrease with 0.8 of a percentage point more for time-sensitive than for non-time-sensitive industries. The marginal effect for non-time-sensitive industries is, in fact, zero.

One may find the 0.8 percentage point pretty large for the effect of one hour waiting.[30] Consider however that the estimated effect of an hour may not merely reflect the costs that are directly associated with waiting at the border, such as the deterioration of the product or the rental price of the transport vehicle. More importantly, the estimated effect can also reflect the cost of uncertainty about the timing of deliveries, which can in the longer run lead to otherwise sub-optimal logistics, or even production location, decisions. Moreover, one cannot rule out the possibility that the decline in the border waiting time variable also captures EU enlargement-induced improvements in other types of administrative inefficiencies. It is less clear however why these other inefficiencies should affect only the time-sensitive industries.

As the time path of the trade cost index in Figure 1.2.1 shows, the decline in trade costs around EU enlargement was somewhat stronger for country pairs with two new countries. Table 1.4.2 replicates the estimations separately for the two main treated country pair groups: new with new and old with new. Control country pairs remain the old-old country pairs in both cases. As expected, the estimated effects are larger for the new-new country pair group than for country pairs of an old and a new country for both the time- sensitive and the non-time-sensitive industries. In

[30] Hummels (2001b) estimates the cost of a day to be 0.5% of the product value. Direct comparison of this figure and my estimates however would be misleading due to differences in the research questions and the identification methods.

fact, no significant effect is detected for old-new country pairs in non-time-sensitive industries.

Table 1.4.2: Results by country pair group

| | w/o treatment intensity | | with treatment intensity | |
|---|---|---|---|---|
| | new with new | old with new | new with new | old with new |
| Treatment | -0.058*** | 0.002 | | |
| | [0.012] | [0.008] | | |
| Treatment x Sensitive | -0.063*** | -0.021*** | | |
| | [0.013] | [0.007] | | |
| Treatment intensity | | | 0.008** | -0.003 |
| | | | [0.003] | [0.003] |
| Treatment intensity x Sensitive | | | 0.011*** | 0.007*** |
| | | | [0.003] | [0.003] |
| GDP per capita gap | 0.214*** | 0.322*** | 0.304*** | 0.439*** |
| | [0.072] | [0.034] | [0.063] | [0.050] |
| Country pair - industry effects | yes | yes | yes | yes |
| Industry - year effects | yes | yes | yes | yes |
| Number of observations | 15470 | 26348 | 13916 | 19446 |
| Number of groups, of which: | 2210 | 3764 | 1988 | 2778 |
| - treatment, of which: | 424 | 1978 | 202 | 992 |
| – sensitive | 158 | 794 | 74 | 384 |
| Within $R^2$ | 0.32 | 0.26 | 0.35 | 0.31 |

Notes: Estimates for equations (1.4) and (1.5) on a panel of country pairs and industries in period 2000-2006. Dependent variable is the log of the Novy index. Treatment is either being a new-new or an old-new country pair after 2004. Treatment sensitivity of industries is based on Hummels (2001b). Treatment intensity is the decline in border waiting time between countries (described in Section 1.3.4). Cluster robust standard errors (with country pair clusters) are in brackets. * significant at 10%; ** at 5%; *** at 1%.

A finding that may justify the use of the treatment intensity indicator is that the estimates for $\gamma_2$ are not different from each other statistically across the two country pair groups (1.1 and 0.7 percentage points in Table 1.4.2). In other words, if we take into account the variation in the timeliness improvement by country pair, as it is captured by the decline in border waiting time, the time cost of trade is estimated to be statistically the same for new-new and old-new country pairs. Hence, one possible reason why the trade cost index declined more for new-new than for old-new country pairs can be related to the fact that in new-new trade typically several borders had to be crossed before EU enlargement, while in old-new trade there was only one border in most of the cases.

The growth of bilateral trade relative to domestic trade, induced by the decline in the trade cost index, can be expressed as a simple transformation of the estimated coefficients. Rearranging equation (1.3) and taking the logarithmic time difference

($\Delta \ln$) yields

$$\Delta \ln \left( \frac{X_{ij}^k X_{ji}^k}{X_{ii}^k X_{jj}^k} \right)^{\frac{1}{2}} = -\left(\sigma_k - 1\right) \Delta\theta_{ij}^k, \tag{1.6}$$

where recall that $\theta = \ln \Theta$ and the estimated coefficients can be substituted for $\Delta\theta_{ij}^k$. The elasticity of substitution differs for the time-sensitive and the non-time-sensitive industries: I take the simple average of the industry $\sigma$s from Table 1.A.1 by time-sensitivity, which yields average substitution elasticities of 7.3 and 5.0, respectively, for time-sensitive and non-time-sensitive industries.

The estimated trade cost declines of 2.4 and 2.6 percentage points in Table 1.4.1 translate into 10% and 17% growth rates of bilateral trade flows (relative to domestic trade flows) from the pre-enlargement to the post-enlargement period. Remember that the latter figure is an *additional* growth for time-sensitive industries; altogether trade expanded by around 30% in this segment as a result of EU enlargement. If the two treated country pair groups are looked at separately (Table 1.4.2), 40% and 13% additional trade creation is detected in time-sensitive industries for new-new and old-new groups, respectively. As for the estimates with treatment intensity, the 0.8 percentage point trade costs decline, associated with a one hour decline in the border waiting time, generates 5% more international (relative to domestic) trade in the time-sensitive industries. As pointed out above, this finding is robust to estimating separately for new-new and old-new country pairs.

## 1.5 The role of the transportation mode

The effect of the timeliness gain may vary across the mode of transportation for at least two reasons. First, the abolition of the customs procedure did not take place in intra-EU sea transportation.[31] Trade in goods that are dominantly transported

[31] "Unlike road transport, which has been reaping the benefits of the internal market since 1993, shipments of goods by sea between the ports of the European Union are treated in the same way as shipments to third countries. Consequently, maritime transport between Member States in-

within the EU via sea therefore should be affected less, if at all, than air and land trade. Second, the applied treatment intensity measure (the decline in border waiting time) captures the timeliness gain explicitly for land transportation.

The aim of this section is to check if the estimated results correspond with the above hypotheses. I want to replicate the estimation after controlling for the (typical) transportation mode of each country pair and industry observation. Since there is no data on the mode of transportation for intra-EU trade, I first make projections for transport mode choice probabilities in intra-EU trade, based on extra-EU trade data and Multinomial Logit estimation. Then, on the basis of the projected probabilities, I form transport mode subsamples of the intra-EU sample with observations of relatively high shares in each of the modes.

### 1.5.1 Projection of intra-EU transport shares

Transport mode information is available from Eurostat for exports of EU members to third countries. I project transport mode shares for intra-EU exports based on the observed modal choices in extra-EU exports.[32] Non-EU destination countries may be quite different in several respects than EU countries, including their level of economic development, geographical proximity, or availability of transport modes. Choosing the sample of non-EU importers, the empirical specification and the explanatory variables is crucial to provide valid out-of-sample predictions.

#### Modeling transport mode choice

I model transport mode choice with a random utility model, where the choices are assumed to be mutually exclusive. I differentiate among three types of transport

volves many documentary checks and physical inspections by the customs, health, veterinary, plant health and immigration control officials." European Commission, Directorate-General for Energy and Transport: Memo - Maritime Transport without Barriers, 2007

[32]The recorded mode of transport in the extra-EU trade database is the active mode of transport at the entry or exit to/from the borders of the EU.

modes: land (road + rail + inland waterways), sea and air.[33] Traders choose the mode of transport that yields the highest utility, based on factors, which are either observed or unobserved. Let us take the additive random utility model with the number of alternatives $A = 3$. The random utility of choosing alternative $a$ by individual $n$ is

$$U^*_{na} = \mathbf{x_n}\beta_a + \varepsilon_{na}, \qquad a = \text{air, sea, ground} \tag{1.7}$$

where $U^*_{na}$ is the latent variable for utility, $\mathbf{x_n}\beta_a$ is its deterministic and $\varepsilon_{na}$ is its random component. The $\mathbf{x_n}$ is a vector of observables that influence modal choice; they are assumed to vary with the individual (case-specific) and not with the transport mode (alternative-specific). The $\beta_a$ are unknown parameters that vary with the transport mode. It follows from utility maximization that the probability of the modal choice outcome $u_n$ being alternative $a$ is

$$\begin{aligned} &\mathrm{P}(u_n = a \mid \mathbf{x_n}) = \\ &= \mathrm{P}\left(\varepsilon_{n1} - \varepsilon_{na} \leq \mathbf{x_n}(\beta_a - \beta_1), \varepsilon_{n2} - \varepsilon_{na} \leq \mathbf{x_n}(\beta_a - \beta_2), \varepsilon_{n3} - \varepsilon_{na} \leq \mathbf{x_n}(\beta_a - \beta_3)\right), \end{aligned} \tag{1.8}$$

where $a$ = air, sea, ground. If $\varepsilon_{na}$ is assumed to be i.i.d. following a double exponential distribution, then the choice probabilities for individual $n$ are given by

$$\mathrm{P}(u_n = a \mid \mathbf{x_n}) = \frac{\exp(\mathbf{x_n}\beta_a)}{\sum_{h=1}^{A} \exp(\mathbf{x_n}\beta_h)}, \qquad a = \text{air, sea, ground.} \tag{1.9}$$

[33]Self propulsion of vehicles is included in the group the vehicle belongs to, i.e. road and rail vehicles to land, air vehicles to air, and sea vehicles to sea. I do not consider other modes of transportation: post because of its marginal importance, or fixed mechanism, which is important mainly for energy products that are excluded from this analysis.

The corresponding econometric model is the Multinomial Logit (NNL). It assures that the probabilities always fall between 0 and 1 and their sum across the alternatives is 1. The MNL can be applied only if the regressors are all case-specific. Though ruling out alternative-specific regressors precludes the use of e.g. transport prices as regressors, such data is not available anyway. Estimation is done by Maximum Likelihood.

### MNL specification

Applying the MNL to predict out-of-sample modal shares for intra-EU trade brings up a couple of important considerations. How to reconcile the structure of trade data with individual choice? What is the most appropriate set of non-EU importers? Given data limitations, what estimation strategy and regressors serve the best?

In principle, the individual that makes the transport mode choice is the firm. In contrast, trade statistics observe the exporter and importer countries and the traded product per each transport mode. Whether a unit of observation in trade statistics corresponds to the choice of one firm or several firms is unknown. Hence, it is important to bear in mind that applying a discrete choice model in these circumstances implicitly allows for compressing repeated actions of individual choice within one observation.[34]

The product dimension is very deep, covering more than 4000 different 6-digit HS product codes. Such as in the timeliness regressions, only non-food, non-energy manufactures are considered. The unit of observation is a cell of the exporter, importer and product dimensions, but the projection is ultimately made for a more aggregate

[34] To overcome the lack of micro data in discrete choice modeling, Berry (1994) suggests a method that needs information only on the number of purchases of each alternative per market (market share). However, the method is not applicable in the current case, since international trade data do not contain information on the number of transport mode purchases. Market shares in terms of trade value or weight are endogenous to the modal choice (larger cargos are sent via sea than air, etc.).

unit with products grouped into the 19 manufacturing industries.[35] Projected modal shares for each exporter, importer and industry are calculated as weighted averages of the product-level probabilities, using trade value weights. The estimation and projection is done on a cross-section of the average of the two pre-enlargement years 2002 and 2003.

The 22 EU countries are taken as exporters. The choice of an appropriate set of non-EU importing countries, which ensures that out-of-sample predictions be valid for intra-EU trade, is not straightforward. EU countries form a more or less distinct block in both geographical and economic terms. I opt for taking a set of importers that corresponds to most of the useful variation in transport mode choice. This means taking trade partnerships, where more or less the same transport mode options are present as in intra-EU trade. Practically, this makes me exclude far-distanced importers. A group of 33 importing countries is chosen, which involves EFTA, Balkan and East European countries, Turkey, as well as some countries of the Middle East, Central Asia and North Africa.[36] The sensitivity of the results is checked by replicating the estimation and projection with only the 14 non-EU European importers.

Separate MNLs are estimated for each of the 19 industries (2-digit NACE). An advantage of the industry-by-industry estimation is that it allows for identifying industry-specific effects of the regressors. Each industry MNL contains the same set of regressors, as it is listed in Table 1.5.1. The choice of regressors is supported by Bayesian Information Criteria (BIC), i.e. a specification is preferred if it yields lower BICs for most of the industry MNLs.

The exporter countries (the 22 EU members) are accounted for by exporter dummies. Given that I aim to project their modal choices, this is the most powerful way

[35] Although trade is zero in many exporter-importer-product cells, possible selection effects are not handled here.

[36] Iceland, Norway, Switzerland, Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Macedonia, Romania, Belarus, Moldova, Russia, Ukraine, Turkey, United Arab Emirates, Israel, Iran, Jordan, Kuwait, Lebanon, Oman, Saudi Arabia, Syria, Yemen, Tunisia, Armenia, Azerbaijan, Georgia, Kazakhstan, Uzbekistan, Algeria, Egypt, Morocco.

Table 1.5.1: List of regressors in the transport mode MNL

| **Dimension** | **Regressor** |
|---|---|
| Exporter | dummies |
| Importer | Landlocked, Days from Port, Africa, Asia, Log GDP Per Capita, Log GDP |
| Exporter-Importer Pair | Log Distance, Common Border |
| 6-digit HS Product | Log Weight-to-Value Ratio |
| 4-digit NACE Industry | dummies |
| *Interactions:* | |
| Importer * Product | Landlocked, Days from Port, Africa, Asia * Log Weight-to-Value Ratio |
| Exp.-Imp. Pair * Product | Log Distance, Common Border * Log Weight-to-Value Ratio |

to capture their general transport mode preferences. Importers (and the exporter-importer country pairs) are captured by their geographical characteristics that explain the relative efficiency and availability of the different transport modes. I include a dummy for being landlocked, a variable from the World Bank's *Doing Business* survey on the number of days to transport a shipment from the nearest seaport to the importer's main city[37], dummies for being an African or Asian importer (Europe is the benchmark), as well as the geographical distance between the exporter and importer and a dummy for sharing a border.[38]

GDP per capita and GDP of the importer are also included. The GDP per capita controls for the differences in the level of economic development between the EU and the non-EU sample of importers. Though the inclusion of the GDP is less intuitive, GDP per capita and GDP were found to be *jointly* important explanatory variables based on the BICs.

Products are captured by their weight-to-value ratios, which is trade quantity in kilograms over trade value in euros. How heavy a product is relative to its value is probably one of the most important determinants in choosing between high-price



[37]The days to transport from the nearest seaport is an indicator from the World Bank's *Doing Business* survey. It refers to the number of days needed to transport a standardized container cargo from the nearest seaport to the destination country's main city. Data is from the survey conducted in 2009, since earlier figures for this indicator are not publicly available.

[38]The inclusion of other typical gravity variables (common language, colonial ties, free trade agreements) were not supported by the BICs. The source of the gravity variables (distance, landlocked, common border) is CEPII.

small-capacity versus low-price large-capacity modes (air versus land/sea). The dramatical improvement in the BIC after including this variable also suggests its importance.

Further transport-specificities of industries are accounted for by the inclusion of sub-industry dummies (4-digit NACE). Their inclusion in the regression is supported by the BICs in 16 out of the 19 industry MNLs. Altogether the 4-digit sub-industry dummies control for 175 sub-industries. Table 1.A.4 shows the number of sub-industry dummies per industry MNL.

Finally, interactions of the country-specific geographical variables with the product-specific weight-to-value variable are included. These interactions can handle some product-specificities of the effects of geography on modal choice. The inclusion of interactions of the weight-to-value with the GDP variables are however not supported by the BICs in 15 out of the 19 industry MNLs.

### Estimation and in-sample prediction results

Basic regression statistics and a summary of the estimated coefficients of the industry MNLs are presented in Table 1.A.4 and Table 1.A.5. The Pseudo $R^2$ statistics, ranging between 0.2 and 0.4, suggest a satisfactory explanatory power for a cross-section regression.

The reported coefficient estimates and p-values are the median values across the 19 industry regressions. They are reported for the air and sea transport modes, and can be interpreted relative to land transport (base category). A positive coefficient indicates that, as the value of the regressor increases, it is more likely that air/sea is chosen than land. Be aware however that the interpretation of the interaction term effects are not straightforward; the reported coefficients are not the marginal effects (cross-derivatives).

What one can assess from the coefficient estimates on the single variables is fairly intuitive. Air and sea transport is more likely to be chosen than land if bilateral distance is large, the exporter and importer do not share a border, the importer has good access to a seaport, the importer is in Africa or Asia, and GDP per capita of the importer is relatively high. And air is less likely to be chosen than land if the weight-to-value ratio of the product is high.

Table 1.A.6 compares the in-sample predicted and the true transport mode choice probabilities. MNL by construction restricts the means of the predicted and the true probabilities to be equal. Standard errors of the predicted probabilities are however only half of the true ones. At the product level, the true modal choice probabilities are either 0 or 1, while the prediction often assigns nonzero probabilities for all the three transport modes. Nevertheless, the range is basically the same for the true and the predicted, with 0 as minimum and 1 as maximum, which suggests a considerably good predictive power of the model.

Simple pairwise correlations of the predicted and true modal probabilities are presented in Table 1.A.7 for three different levels of aggregation (product, sub-industry, industry). Subindustry and industry modal shares are weighted averages of product modal probabilities with trade value weights. The correlation coefficients strictly increase with the level of aggregation due to the common weights. Product level correlations are slightly above 0.5, industry level correlations are close to 0.8 for all the three transport modes. Land transport is somewhat better predicted (the correlation coefficients are higher) than the other two modes.

As a robustness check, the estimation and projection exercise is replicated for a restricted set of 14 non-EU European importers (around 50% of the original sample size). For these importers the modal choice is presumed to fall closer to the intra-EU modal choice. In fact, as one would expect, the share of land transportation for this subset of importers is larger than for the full set of importers at the expense of both air and sea. The in-sample predictive power in the restricted case is however somewhat worse than in the full sample case, while the out-of-sample predictions for intra-EU modal choices differ only marginally.[39]

### Out-of-sample prediction

The estimated industry MNLs form the basis of the out-of-sample projections for intra-EU modal choices. The aim is to provide projected transport mode probabilities for all intra-EU country pairs and 2-digit industries. These projections then provide the basis for creating subsamples of country pairs and industries, where either of the three transport modes are predicted to be used relatively frequently.

Having the same regressors as listed in Table 1.5.1 also for intra-EU country pairs and products, it is straightforward to make out-of-sample projections of transport shares.[40] The predicted product modal choice probabilities are then aggregated to the industry level with the use of the corresponding trade value shares as weights. There are country pairs, for which trade is zero for all products belonging to an industry. For these observations, which account for 2% of all intra-EU country pair and industry cells, no projection can be made.

Tables 1.A.8 and 1.A.9 report the out-of-sample predicted transport mode shares for intra-EU trade as averages by industry and by country. The variation of shares across industries and countries seem to be quite intuitive. In general, land transport is projected to have the highest probability (0.65) in intra-EU trade, reflecting the geographical closeness and contiguity of these countries. Air and sea transport are, in general, projected to be of secondary importance.[41] More specifically, air is projected

[39]Results of the MNLs on the restricted sample of importers are available from the author on request.

[40]Trade data for intra-EU exports of Poland and Slovakia is from years 2004 and 2005 (as opposed to 2002-2003), because Eurostat provides no data for these countries for the pre-2004 years at the 6-digit product level.

[41]Note that the relative shares of air versus sea would change considerably in favor of sea transport, if the product-level predicted probabilities had been weighted by trade quantities and not by trade value, since high (low) weight-to-value products are more likely to be shipped via sea (air).

to be relatively important in the low weight-to-value industries like communication equipment or medical, precision and optical instruments, while sea is projected to be more frequent in the transport of heavy wood and basic metal products.

The country variation of out-of-sample predicted transport mode shares supports the general view that landlocked countries use land transport the most frequently. The projected land shares for the Czech Republic, Hungary, Luxembourg, Slovenia, and Slovakia all exceed 0.8, while their projected sea shares are practically zero. In contrast, island countries (Ireland, UK) show higher propensities to use air or sea, and the Northern countries with sea access (Denmark, Estonia, Finland, Sweden), sea transportation. Although the patterns are more or less similar by countries as importers, the relatively small variation of the projected transport mode shares along this dimension reflects the weaker explanatory power of the model on the importer side.

### 1.5.2 Results by mode of transport

I define subsamples on the intra-EU country pairs and industries for the three transport modes as follows. An observation belongs to the land transport subsample, if its projected probability for land transportation is not smaller than 0.5. The rest of the observations belong to the air (sea) transport subsample, if their projected probability for air (sea) is larger than the projected probability for sea (air). In this way, the subsamples of neither air nor sea transport contain observations with their own probabilities being smaller than 0.25.

The construction of the transport subsamples tries to achieve two goals. It aims to reflect the relative importance of the three modes and it also tries to ensure that a sufficient number of observations fall into each subsample. Nevertheless, it is important to see that the resulting air and sea subsamples do not represent as high propensities for air and sea transport as the probabilities for land transport are in the land subsample. The median probability for land transport in the land subsample is 0.7, while the median probabilities for air and sea transport in the air and sea subsamples, respectively, are both only slightly above 0.4.

I estimate equations (1.4) and (1.5) on the three transport mode subsamples, as well as on a non-land (air+sea) subsample. The estimation results are presented in Table 1.5.2. The first four columns show estimates of (1.4), the last four columns present estimates of (1.5).

The estimates in both specifications confirm that the timeliness effect is significant only for country pairs and industries with a high propensity to use land transport. The coefficients on the interaction terms of the treatment dummy (or treatment intensity variable) with the time-sensitivity dummy are significantly different from zero only in the land subsample. One has to note however that larger coefficient standard errors (smaller subsample sizes) may also be behind the insignificance of non-land subsample estimates.

Estimation results from the specification with treatment intensity (change in border waiting time) are more convincing. The coefficients on the interaction variables in the non-land, air and sea subsample estimations are not only insignificant, but also small in magnitude or even have the opposite sign. This finding suggests that one can more successfully separate the effect of timeliness within a double DID framework with the help of an explicit timeliness variable than with a single dummy variable.

## 1.6 Robustness

I carry out two types of robustness checks for the above results. First, I classify industries along their treatment sensitivity in an alternative way. Second, I experiment with alternative measures for treatment intensity.

Table 1.5.2: Results by transport mode

| | w/o treatment intensity | | | | with treatment intensity | | | |
|---|---|---|---|---|---|---|---|---|
| | land | non-land | air | sea | land | non-land | air | sea |
| Treatment | -0.019** | -0.023 | -0.043* | -0.021 | | | | |
| | [0.010] | [0.016] | [0.024] | [0.021] | | | | |
| Treatment x Sensitive | -0.016** | -0.025 | 0.004 | -0.019 | | | | |
| | [0.008] | [0.016] | [0.030] | [0.019] | | | | |
| Treatment intensity | | | | | 0.000 | 0.008 | 0.014 | 0.002 |
| | | | | | [0.002] | [0.006] | [0.010] | [0.005] |
| Treatment intensity x Sensitive | | | | | 0.008*** | -0.002 | -0.009 | 0.003 |
| | | | | | [0.002] | [0.008] | [0.013] | [0.008] |
| GDP per capita gap | 0.197*** | 0.242*** | 0.361*** | 0.104 | 0.275*** | 0.389*** | 0.476*** | 0.252** |
| | [0.048] | [0.052] | [0.067] | [0.076] | [0.062] | [0.068] | [0.070] | [0.097] |
| Country pair - industry effects | yes | yes | yes | yes | yes | yes | yes | yes |
| Industry - year effects | yes | yes | yes | yes | yes | yes | yes | yes |
| Number of observations | 19495 | 9821 | 5264 | 4557 | 13531 | 7329 | 3997 | 3332 |
| Number of groups, of which: | 2785 | 1403 | 752 | 651 | 1933 | 1047 | 571 | 476 |
| - treatment, of which: | 1889 | 513 | 300 | 213 | 1037 | 157 | 119 | 38 |
| – sensitive | 652 | 300 | 210 | 90 | 368 | 90 | 79 | 11 |
| Within $R^2$ | 0.29 | 0.21 | 0.17 | 0.29 | 0.34 | 0.26 | 0.18 | 0.40 |

Notes: Estimates for equations (1.4) and (1.5) on subsamples defined on transport mode propensities on a panel of country pairs and industries in period 2000-2006. Dependent variable is the log of the Novy index. Treatment is being an old-new or new-new country pair after 2004. Treatment sensitivity of industries is based on Hummels (2001b). Treatment intensity is the decline in border waiting time between countries (described in Section 1.3.4). Cluster-robust standard errors (with country pair clusters) are in brackets. * significant at 10%; ** at 5%; *** at 1%.

### 1.6.1 Production fragmentation as indicator of treatment sensitivity

So far I used the grouping of industries into time-sensitive and non-time-sensitive industries as a treatment sensitivity indicator. An alternative way to capture treatment sensitivity is to consider that geographical production fragmentation is probably the most important factor behind the increasing demand for timeliness. Hence, industries, where production fragmentation is relatively more prevalent, are expected to be more strongly affected by the trade-creating effect of EU enlargement.

I proxy the extent of production fragmentation in the pre-enlargement years with two industry-specific indicators: one is the share of parts and accessories within an industry in the total trade among the 22 EU countries (henceforth, intra-EU trade), the other is the industry-specific FDI intensity (FDI stock over value added) in the eight new member states. Both indicators are based on data from the average of the two pre-enlargement years, 2002-2003.

The parts and accessories share is calculated as the euro value trade share of parts and accessories (codes 42 and 53 under the Broad Economic Categories, BEC, classification) within each 2-digit NACE industry.[42] Formally, $\text{SHPA}^k = \sum_{p' \epsilon k} X^{p'} / \sum_{p \epsilon k} X^p$, where the numerator is total intra-EU exports in products classified as parts and accessories (indexed by $p'$) belonging to industry $k$ and the denominator is total intra-EU exports in all products (indexed by $p$) belonging to the same industry.

The other indicator is the pre-enlargement industry FDI intensity in the new member states. Outsourcing of production in the eight new EU members both by the EU-15 and other countries has become a widespread phenomena already in the pre-enlargement years. A significant part of this activity takes the form of direct investments of multinational companies and potentially initiates a large amount of

[42] I start from 6-digit HS product-level trade data and use the concordance table that links the HS to the BEC classification.

international trade. Industry FDI intensity is defined as $\text{FDIVA}^k = \text{FDI}^k/\text{VA}^k$, where the numerator is total inward FDI stock in industry $k$ and the denominator is total value added in the same industry in the eight new countries.[43]

The index values and the corresponding groupings of industries are presented in Table 1.A.10 in the Appendix. An industry is classified to have relatively high (low) treatment sensitivity, if the index takes higher (lower) values than the median index value. The median industry is put in the treatment sensitive group in both cases. It is the textile industry for the parts and accessories trade share and rubber and plastic manufacturing for the FDI intensity.[44] An advantage of the alternative classifications is that, as opposed to the baseline case, they avoid the loss of observations, since now all industries are classified.

The grouping of industries according to the parts and accessories index is surprisingly close to the time- sensitivity classification in Table 1.3.1; only the borderline textile industry switched status. The grouping according to the FDI intensity is however considerably different, although most of the high-tech industries are still classified as treatment sensitive.

Estimations of equations (1.4) and (1.5) are carried out with the treatment sensitivity dummy variable based either on the parts and accessories share index or on the FDI intensity index. The corresponding estimation results are presented in Tables 1.A.11 and 1.A.12, respectively, in the Appendix. Both tables contain estimates for the two specifications (with and without treatment intensity) and also for land and non-land subsamples separately.

The qualitative assessment of the results is similar to the baseline case. Significant timeliness effects are detected from both specifications, and these effects come entirely

[43] The FDI stock data is from the FDI database of the Vienna Institute for International Economic Studies (wiiw). The source of value added data is OECD STAN and, for non-OECD countries, Eurostat.

[44] Changing the status of these borderline industries leaves the estimation results qualitatively unaltered.

from the part of the sample with relatively high projected probabilities of land transportation. The magnitude of the estimates is however mitigated, as compared with the baseline case. The estimated effects of an additional hour decline in the border waiting time on the trade cost of treatment sensitive industries are basically halved to 0.4 of a percentage point for both treatment sensitivity indicators.

### 1.6.2 Other indicators of treatment intensity

As another robustness check, I experiment with three alternative treatment intensity measures. One is the change in the number of borders on the route from the exporter to the importer country. The second is the (approximate) change in the days to complete a trade transaction, which I derive from the *Doing Business* survey of the World Bank. The third is a survey-based measure of the change in the customs-related burden of trading.

The alternative treatment intensity measures also make it possible to check whether the missing observations in the border waiting time variable significantly influence the results. The coverage of country pairs by the alternative measures is almost complete.[45]

**Change in the number of borders** The change in the number of borders is the negative of the number of abolished borders variable that was created as a first step in the calculation of the border waiting time variable. The reader is directed to Section 1.3.4 for a description. Similar to the change in the border waiting time variable, this variable also refers to land transportation only. However, it is not specific to waiting time and potentially captures other than time-related elements of border crossings (e.g. financial costs of crossing the border) as well.

[45]The second measure does not cover country pairs with Luxembourg.

**Change in the days to trade** Information on the pre-enlargement days to export and days to import is from the *Doing Business* survey database that is used in Djankov, Freund and Pham (2010).[46] Raw data by country is presented in Table 1.A.13 in the Appendix. This wave of the survey was the first that incorporated questions to large freight forwarding companies on the time needed for a foreign trade transaction by country. Though it is from year 2005, I believe it is a good measure of the pre-enlargement situation, because the survey question explicitly refers to sea transport, where border control and customs inspection remained in place even after 2004.

For exactly the same reason, the subsequent surveys cannot be used to get information on the post-enlargement time to trade. More recent surveys however contain information on the breakdown of the days to trade into four procedures, one of which is the customs clearance and inspection.[47] The time for the customs procedure is on average around 15% of the total time to trade.[48]

Using the above information and assuming that the time for the other three procedures did not change, I simply approximate the change in the days to trade that arose from the abolition of the customs procedure as 0.15 times the negative of the sum of the exporter's day to export ($\text{dayex}_i$) and the importer's day to import ($\text{dayim}_j$), i.e. $\Delta\text{day}_{ij} = -0.15 \cdot \left(\text{dayex}_i + \text{dayim}_j\right)$. The indicator is set to zero for the control country pairs.

**Change in the customs burden** The third alternative measure for treatment intensity captures the change in the burden firms face related to the customs procedure. The idea is that the level of the customs-related burden shortly before May 2004 is

[46] The database of Djankov, Freund and Pham (2010) is downloadable from http://www.doingbusiness.org/methodology.

[47] The four procedures are document preparation, customs clearance and inspection, port and terminal handling, and land transport to/from the nearest seaport.

[48] It is true both for the whole survey sample and for the EU sample only.

proportional to the subsequent improvement in timeliness that happened with the abolition of the customs procedure after EU enlargement.

I derive the customs burden measure from two survey variables from the Global Competitiveness Report 2004/2005 of the World Economic Forum (WEF). The WEF conducts its Executive Opinion Survey each year among top management business leaders from several countries. The two variables are the business impact of the customs procedure and the efficiency of the customs procedure to import.[49] They take values between 1 and 7, a larger score meaning a larger burden. Since the survey was conducted in early-2004, it exactly captures the pre-enlargement situation. Survey scores by country are presented in Table 1.A.13 in the Appendix.

I construct a bilateral variable for the treatment country pairs by taking the average of the exporter's and the importer's scores as $\Delta \text{customs}_{ij} = -(0.5 \cdot \text{ci}_i + 0.25 \cdot \text{ci}_j + 0.25 \cdot \text{ce}_j)$. The weights take into account that the import customs efficiency variable (ce) explicitly refers to importing, while the customs business impact variable (ci) is independent of the direction of trade. I take the negative of the average to capture the change in the burden. Again, the indicator is set to zero for the control country pairs.

**Results** Estimates of equation (1.5) with the treatment intensity being either of the three alternative indicators are presented in Table 1.A.14 in the Appendix. Notice that the industry treatment sensitivity dummy is again defined along the baseline time-sensitivity dimension.

The treatment effect on the time-sensitive industries (second row) is significantly larger than the treatment effect on the non-time-sensitive industries (first row) for the days to trade and the customs burden indicators. The same is not true for the

[49]The exact survey questions are: "What is the impact of your country's customs procedures on your business? 1=damaging, 7=beneficial,"and "For imports, inbound customs activities in your country are 1=slow and inefficient, 7=among the world's most efficient." I reversed the original ranking of the scores to make the interpretation similar to the other treatment intensity variables.

number of borders indicator, which possibly also captures many other factors that are not associated with timeliness.

The pattern of estimates for the decline in days to trade is quite similar to the baseline estimates. The time- sensitive industries are significantly affected, while the effect on the non-time-sensitive industries is statistically zero. This finding justifies that a purely timeliness-related treatment intensity indicator is indeed effective only in the time-sensitive part of the sample. In contrast, the estimate from the regression with the customs burden indicator is significantly different from zero also for non-time-sensitive industries. Again, the customs burden indicator can possibly also capture factors other than timeliness.

A surprising result is that the magnitude of the estimates from the regression with the days to trade indicator and the magnitude of the baseline estimates are similar, although the unit of the treatment intensity indicator is days in the current and hours in the baseline case. This suggests that strictly interpreting the estimates in terms of time units is probably over-ambitious and may be misleading. The main advantage of the treatment intensity variable rather lies in the fact that it helps narrowing down the focus of the specification to the phenomenon of interest.

Finally, Table 1.A.15 in the Appendix presents the corresponding estimates separately for the land and non-land subsamples. Unlike the border waiting time and the number of borders, the days to trade and the customs burden indicators are not restricted to land transport but could also have a strong impact on trade costs related to air shipments. Accordingly, the timeliness estimates (second row of Table 1.A.15) for the latter two indicators are also significant or at least large in magnitude in the non-land subsample.

## 1.7 Conclusion

This paper used the episode of EU enlargement in 2004 to infer the importance of timeliness in international trade. It applied a double DID econometric strategy that compared the changes in trade barriers of treatment, relative to control, country pairs in time-sensitive versus non-time-sensitive industries. The identification was supported by the use of a novel treatment intensity indicator. The improvement in timeliness is shown to have significantly contributed to the EU's trade cost-reducing effect. The main findings seem to be robust to cross-check estimations on projected transport mode subsamples, to changes in the definition of treatment sensitivity, and to alternative treatment intensity indicators.

# 1.A Appendix: Figures and Tables

Table 1.A.1: Industry-level descriptive statistics

| NACE industry | % share in total bilateral exports[1] | % share in total gross output[1] | $\sigma$ | $\theta$ average[2] | No. of obs in balanced panel |
|---|---|---|---|---|---|
| 17 Textiles | 3.2 | 2.5 | 7.3 | 1.8 | 1862 |
| 18 Wearing apparel | 2.1 | 1.5 | 5.7 | 2.7 | 1232 |
| 19 Leather, luggage, footwear, etc. | 1.1 | 0.8 | 7.2 | 2.0 | 1022 |
| 20 Wood, excl. furniture | 2.2 | 3.3 | 3.7 | 7.6 | 2898 |
| 21 Pulp, paper products | 4.6 | 4.4 | 4.4 | 4.6 | 2744 |
| 22 Publishing, printing | 1.3 | 7.4 | 5.1 | 6.9 | 3024 |
| 24 Chemical products | 15.0 | 11.6 | 7.1 | 1.9 | 1876 |
| 25 Rubber and plastic products | 1.0 | 0.8 | 5.2 | 2.6 | 280 |
| 26 Other non-metallic mineral prods | 3.1 | 6.1 | 3.0 | 22.5 | 3024 |
| 27 Basic metals | 8.0 | 4.8 | 3.5 | 5.8 | 1260 |
| 28 Fabricated metal products | 4.8 | 12.1 | 4.9 | 4.9 | 3066 |
| 29 Machinery and equipment | 13.9 | 14.7 | 7.2 | 2.0 | 2856 |
| 30 Office machinery and computers | 0.9 | 0.4 | 10.9 | 1.5 | 350 |
| 31 Electrical machinery and apparatus | 7.0 | 6.7 | 6.0 | 2.3 | 2814 |
| 32 Radio, tv and communication equip. | 5.4 | 3.1 | 5.9 | 2.3 | 1456 |
| 33 Medical, precision and optical instr. | 2.6 | 2.8 | 6.6 | 2.3 | 1974 |
| 34 Motor, vehicles, trailers | 16.7 | 10.8 | 7.3 | 1.8 | 1274 |
| 35 Other transport equipment | 4.2 | 3.3 | 7.5 | 2.3 | 1526 |
| 36 Furniture, manufacturing n.e.c. | 2.9 | 3.0 | 4.1 | 5.1 | 1652 |

Notes: Own calculations based on Eurostat and OECD data. $\sigma$ is based on estimates from Hummels (2001a). Statistics refer to the database of 19 industries (2-digit NACE), country pairs formed by 22 EU countries and 7 years between 2000-2006. Detailed description of the database is in Section 1.2.2. [1] Total is the sum of the 22 EU countries in the database. [2] Simple averages across country pairs.

Table 1.A.2: Country-level descriptive statistics

| exporter | % share in total bilateral exports[1] | % share in total gross output[1] | $\theta$ average[2] | No. of observations in balanced panel |
|---|---|---|---|---|
| Austria | 3.8 | 2.4 | 4.9 | 1722 |
| Belgium | 4.1 | 1.8 | 4.6 | 1281 |
| Czech Republic | 2.5 | 1.6 | 4.7 | 1883 |
| Germany | 27.2 | 27.3 | 2.8 | 2065 |
| Denmark | 1.5 | 1.3 | 4.9 | 1701 |
| Estonia | 0.2 | 0.1 | 5.8 | 1379 |
| Spain | 6.6 | 7.9 | 5.0 | 2058 |
| Finland | 2.0 | 2.2 | 5.4 | 1988 |
| France | 14.0 | 14.2 | 4.1 | 2002 |
| Hungary | 1.8 | 1.0 | 5.7 | 1736 |
| Ireland | 0.7 | 0.9 | 9.6 | 1015 |
| Italy | 11.4 | 17.2 | 4.3 | 2086 |
| Lithuania | 0.2 | 0.1 | 7.0 | 1512 |
| Luxembourg | 0.1 | 0.1 | 11.6 | 672 |
| Latvia | 0.1 | 0.1 | 7.5 | 1176 |
| Netherlands | 6.8 | 3.5 | 4.0 | 1799 |
| Poland | 3.3 | 2.2 | 4.2 | 1995 |
| Portugal | 1.6 | 1.2 | 7.7 | 1820 |
| Sweden | 3.6 | 3.5 | 4.5 | 1841 |
| Slovenia | 0.4 | 0.3 | 6.2 | 1505 |
| Slovakia | 0.7 | 0.3 | 7.4 | 1190 |
| United Kingdom | 7.5 | 11.1 | 4.5 | 1764 |

Notes: Own calculations based on Eurostat and OECD data. Statistics refer to the database of 19 industries (2-digit NACE), country pairs formed by 22 EU countries and 7 years between 2000-2006. Detailed description of the database is in Section 1.2.2. [1] Total is the sum of the 22 EU countries in the database. [2] Simple averages across industries and importers.

Table 1.A.3: Waiting hours at borders raw data by border

| origin country | destination country | number of crossing points[1] | average hours (2000-2002)[2] |
|---|---|---|---|
| Lithuania | Poland | 1 | 5.6 |
| Czech Republic | Poland | 3 | 5.2 |
| Poland | Germany | 8 | 5.0 |
| Poland | Czech Republic | 3 | 4.4 |
| Poland | Slovakia | 2 | 4.2 |
| Slovakia | Poland | 2 | 3.9 |
| Germany | Poland | 8 | 3.6 |
| Poland | Lithuania | 1 | 3.4 |
| Czech Republic | Germany | 7 | 3.3 |
| Germany | Czech Republic | 7 | 2.8 |
| Hungary | Austria | 3 | 2.3 |
| Austria | Hungary | 3 | 2.0 |
| Czech Republic | Slovakia | 6 | 1.9 |
| Slovakia | Austria | 1 | 1.8 |
| Slovakia | Czech Republic | 6 | 1.8 |
| Hungary | Slovakia | 4 | 1.7 |
| Hungary | Slovenia | 1 | 1.6 |
| Slovakia | Hungary | 4 | 1.4 |
| Slovenia | Hungary | 1 | 1.3 |
| Austria | Slovakia | 1 | 1.1 |
| Czech Republic | Austria | 3 | 1.1 |
| Austria | Czech Republic | 3 | 0.9 |

Source: International Road Union (IRU). [1] Number of crossing points with waiting time data per border. [2] Simple averages across years and crossing points.

Table 1.A.4: Regression statistics of transport mode choice MNLs

| NACE industry | Number of observations | Number of sub-industries | Pseudo $R^2$ |
|---|---|---|---|
| 17 Textiles | 72,738 | 9 | 0.27 |
| 18 Wearing apparel | 27,125 | 6 | 0.29 |
| 19 Leather, luggage, footwear, etc. | 11,807 | 3 | 0.28 |
| 20 Wood, excl. furniture | 13,500 | 6 | 0.28 |
| 21 Pulp, paper products | 24,598 | 7 | 0.26 |
| 22 Publishing, printing | 8,892 | 7 | 0.18 |
| 24 Chemical prods | 106,523 | 20 | 0.27 |
| 25 Rubber and plastic prods | 77,732 | 7 | 0.23 |
| 26 Other non-metallic mineral prods | 21,567 | 25 | 0.40 |
| 27 Basic metals | 42,721 | 12 | 0.30 |
| 28 Fabricated metal prods | 48,939 | 13 | 0.25 |
| 29 Machinery and equipment | 105,807 | 20 | 0.25 |
| 30 Office machinery and computers | 9,914 | 2 | 0.22 |
| 31 Electrical machinery and apparatus | 38,887 | 7 | 0.22 |
| 32 Radio, tv and communication equip. | 15,660 | 3 | 0.20 |
| 33 Medical, precision and optical instr. | 30,342 | 4 | 0.22 |
| 34 Motor vehicles, trailers, semi-trailers | 12,749 | 3 | 0.22 |
| 35 Other transport equipment | 4,834 | 8 | 0.27 |
| 36 Furniture, manufacturing n.e.c. | 34,434 | 13 | 0.23 |

Notes: Maximum Likelihood estimation summary statistics for the industry-specific transport mode choice Multinomial Logits. Modal choice alternatives are land (base category), air and sea. The regression specification is described in Section 1.5.1. Unit of observation is country pair (EU exporter, non-EU importer) and 6-digit product. Sub-industries are 4-digit NACE industries.

Table 1.A.5: Median values of estimates from transport mode choice MNLs

| | mode=air | | mode=sea | |
|---|---|---|---|---|
| Regressor | median coefficient | median p-value | median coefficient | median p-value |
| Log Distance | 1.285 | 0.000 | 0.127 | 0.269 |
| Common Border | -1.029 | 0.005 | -1.640 | 0.003 |
| Landlocked | 0.701 | 0.116 | -0.499 | 0.083 |
| Days from Seaport | -0.137 | 0.001 | -0.176 | 0.000 |
| Africa | 1.225 | 0.001 | 2.758 | 0.000 |
| Asia | 1.396 | 0.000 | 2.401 | 0.000 |
| Log GDP Per Capita | 0.185 | 0.000 | 0.251 | 0.000 |
| Log GDP | -0.071 | 0.000 | -0.137 | 0.000 |
| Log Weight-to-Value | -1.100 | 0.000 | 0.334 | 0.147 |
| Log Weight-to-Value x Log Distance | 0.062 | 0.004 | -0.026 | 0.238 |
| Log Weight-to-Value x Common Border | -0.127 | 0.008 | -0.150 | 0.116 |
| Log Weight-to-Value x Landlocked | 0.104 | 0.185 | 0.014 | 0.351 |
| Log Weight-to-Value x Days from Seaport | -0.009 | 0.079 | -0.018 | 0.005 |
| Log Weight-to-Value x Africa | -0.002 | 0.162 | 0.128 | 0.007 |
| Log Weight-to-Value x Asia | 0.097 | 0.081 | 0.193 | 0.000 |
| Exporter dummies | yes | | yes | |
| Industry dummies (4-digit) | yes | | yes | |

Notes: Median values of the coefficient estimates and median value of the corresponding p-values from the industry-specific transport mode choice Multinomial Logit estimations. The base category is land transport. Regressors are described in Section 1.5.1. Unit of observation is a country pair (EU exporter, non-EU importer) and 6-digit product.

Table 1.A.6: Summary statistics of the in-sample predicted and true modal choice probabilities

| Variable | Number of observations | Mean | St.dev. | Min | Max |
|---|---|---|---|---|---|
| Projected share | | | | | |
| air | 708,769 | 0.21842 | 0.21587 | 0.00000 | 1.00000 |
| land | 708,769 | 0.47214 | 0.27772 | 0.00000 | 1.00000 |
| sea | 708,769 | 0.30945 | 0.23787 | 0.00000 | 0.99312 |
| True share | | | | | |
| air | 708,769 | 0.21842 | 0.41317 | 0.00000 | 1.00000 |
| land | 708,769 | 0.47214 | 0.49922 | 0.00000 | 1.00000 |
| sea | 708,769 | 0.30945 | 0.46227 | 0.00000 | 1.00000 |

Notes: Predicted choice probabilities for country pairs (EU exporter, non-EU importer) and 6-digit products are based on the transport mode choice Multinomial Logit estimations, as described in Section 1.5.1.

Table 1.A.7: Correlation coefficients of predicted and true modal shares

| Level of aggregation | Statistic | Mode of Transport | | | No. of obs. |
|---|---|---|---|---|---|
| | | air | land | sea | |
| 6-digit product | correlation coef. | 0.519 | 0.558 | 0.521 | 708,769 |
| | p-value | 0.000 | 0.000 | 0.000 | |
| 4-digit industry | correlation coef. | 0.679 | 0.768 | 0.748 | 67,243 |
| | p-value | 0.000 | 0.000 | 0.000 | |
| 2-digit industry | correlation coef. | 0.744 | 0.796 | 0.790 | 11,645 |
| | p-value | 0.000 | 0.000 | 0.000 | |

Notes: Predicted choice probabilities for country pairs (EU exporter, non-EU importer) and 6-digit products are based on the transport mode choice Multinomial Logit estimations, as described in Section 1.5.1. 4-digit and 2-digit industry (true and predicted) modal shares are weighted averages of product-level (true and predicted, respectively) modal choice probabilities with trade value weights.

Table 1.A.8: Out-of-sample projections of intra-EU modal shares by industry

| NACE industry | air | land | sea |
|---|---|---|---|
| 17 Textiles | 0.10 | 0.72 | 0.17 |
| 18 Wearing apparel | 0.19 | 0.79 | 0.02 |
| 19 Leather, luggage, footwear, etc. | 0.19 | 0.69 | 0.12 |
| 20 Wood, excl. furniture | 0.04 | 0.67 | 0.29 |
| 21 Pulp, paper products | 0.05 | 0.67 | 0.27 |
| 22 Publishing, printing | 0.24 | 0.58 | 0.18 |
| 24 Chemical prods | 0.18 | 0.60 | 0.21 |
| 25 Rubber and plastic prods | 0.15 | 0.63 | 0.22 |
| 26 Other non-metallic mineral prods | 0.12 | 0.85 | 0.03 |
| 27 Basic metals | 0.05 | 0.66 | 0.29 |
| 28 Fabricated metal prods | 0.10 | 0.67 | 0.24 |
| 29 Machinery and equipment | 0.10 | 0.68 | 0.22 |
| 30 Office machinery and computers | 0.31 | 0.54 | 0.15 |
| 31 Electrical machinery and apparatus | 0.21 | 0.60 | 0.18 |
| 32 Radio, tv and communication equip. | 0.35 | 0.52 | 0.13 |
| 33 Medical, precision and optical instr. | 0.33 | 0.54 | 0.13 |
| 34 Motor vehicles, trailers, semi-trailers | 0.07 | 0.65 | 0.27 |
| 35 Other transport equipment | 0.20 | 0.59 | 0.21 |
| 36 Furniture, manufacturing n.e.c. | 0.11 | 0.66 | 0.23 |
| Mean | 0.16 | 0.65 | 0.19 |

Notes: Out of sample projections are based on the transport mode choice Multinomial Logit estimations, described in Section 1.5.1. Out-of-sample projections are made for intra-EU country pairs and 6-digit products. Industry-level modal share projections are weighted averages of product-level projected choice probabilities with trade value weights. Reported modal shares are averages across country pairs.

Table 1.A.9: Out-of-sample projections of intra-EU modal shares by country

| country | if exporter | | | if importer | | |
|---|---|---|---|---|---|---|
| | air | land | sea | air | land | sea |
| Austria | 0.17 | 0.75 | 0.08 | 0.16 | 0.69 | 0.14 |
| Belgium | 0.12 | 0.76 | 0.12 | 0.15 | 0.64 | 0.21 |
| Czech Republic | 0.10 | 0.90 | 0.00 | 0.13 | 0.74 | 0.12 |
| Germany | 0.14 | 0.62 | 0.23 | 0.14 | 0.70 | 0.16 |
| Denmark | 0.15 | 0.57 | 0.29 | 0.17 | 0.61 | 0.22 |
| Estonia | 0.14 | 0.58 | 0.28 | 0.17 | 0.61 | 0.22 |
| Spain | 0.19 | 0.53 | 0.28 | 0.18 | 0.63 | 0.19 |
| Finland | 0.17 | 0.49 | 0.33 | 0.19 | 0.59 | 0.21 |
| France | 0.19 | 0.66 | 0.15 | 0.16 | 0.67 | 0.17 |
| Hungary | 0.11 | 0.89 | 0.00 | 0.15 | 0.71 | 0.14 |
| Ireland | 0.42 | 0.10 | 0.48 | 0.20 | 0.60 | 0.20 |
| Italy | 0.17 | 0.58 | 0.25 | 0.17 | 0.65 | 0.18 |
| Lithuania | 0.12 | 0.73 | 0.15 | 0.16 | 0.64 | 0.21 |
| Luxembourg | 0.12 | 0.82 | 0.06 | 0.20 | 0.62 | 0.19 |
| Latvia | 0.14 | 0.74 | 0.12 | 0.15 | 0.64 | 0.21 |
| Netherlands | 0.16 | 0.70 | 0.14 | 0.15 | 0.64 | 0.21 |
| Poland | 0.10 | 0.80 | 0.10 | 0.13 | 0.69 | 0.18 |
| Portugal | 0.21 | 0.58 | 0.21 | 0.22 | 0.57 | 0.22 |
| Sweden | 0.23 | 0.45 | 0.33 | 0.18 | 0.61 | 0.21 |
| Slovenia | 0.08 | 0.88 | 0.03 | 0.15 | 0.61 | 0.23 |
| Slovakia | 0.05 | 0.95 | 0.00 | 0.12 | 0.75 | 0.13 |
| United Kingdom | 0.32 | 0.20 | 0.48 | 0.17 | 0.66 | 0.18 |
| Mean | 0.16 | 0.65 | 0.19 | 0.16 | 0.65 | 0.19 |

Notes: Out of sample projections are based on the transport mode choice Multinomial Logit estimations, described in Section 1.5.1. Out-of-sample projections are made for intra-EU country pairs and 6-digit products. Industry-level modal share projections are weighted averages of product-level projected choice probabilities with trade value weights. Reported modal shares are averages across industries and trade partners.

Table 1.A.10: Alternative classifications for treatment sensitivity

| Industry | SHPA | sensitive=1 | FDIVA | sensitive=1 |
|---|---|---|---|---|
| 17 Textiles | 0.023 | 1 | 0.382 | 0 |
| 18 Wearing apparel | 0.000 | 0 | 0.170 | 0 |
| 19 Leather, luggage, footwear, etc. | 0.000 | 0 | 0.305 | 0 |
| 20 Wood, excl. furniture | 0.000 | 0 | 0.764 | 1 |
| 21 Pulp, paper products | 0.000 | 0 | 0.674 | 1 |
| 22 Publishing, printing | 0.017 | 0 | 0.165 | 0 |
| 24 Chemical products | 0.000 | 0 | 1.060 | 1 |
| 25 Rubber and plastic prods | 0.697 | 1 | 0.670 | 1 |
| 26 Other non-metallic mineral prods | 0.004 | 0 | 0.593 | 0 |
| 27 Basic metals | 0.000 | 0 | 0.878 | 1 |
| 28 Fabricated metal prods | 0.147 | 1 | 0.297 | 0 |
| 29 Machinery and equipment | 0.191 | 1 | 0.438 | 0 |
| 30 Office machinery and computers | 0.321 | 1 | 1.923 | 1 |
| 31 Electrical machinery and apparatus | 0.479 | 1 | 0.482 | 0 |
| 32 Radio, tv and communication equip. | 0.410 | 1 | 0.800 | 1 |
| 33 Medical, precision and optical instr. | 0.034 | 1 | 0.695 | 1 |
| 34 Motor vehicles, trailers, semi-trailers | 0.141 | 1 | 1.140 | 1 |
| 35 Other transport equipment | 0.201 | 1 | 2.262 | 1 |
| 36 Furniture, manufacturing n.e.c. | 0.019 | 0 | 0.105 | 0 |

Notes: Own calculation, based on Eurostat, OECD and wiiw data. SHPA is the share of parts and accessories in intra-EU trade within the industry. FDIVA is the ratio of inward FDI stock to value added in the new countries by industry.

Table 1.A.11: Results with parts and accessories share as treatment sensitivity

| | w/o treatment intensity | | | with treatment intensity | | |
|---|---|---|---|---|---|---|
| | whole sample | land | non-land | whole sample | land | non-land |
| Treatment | -0.029*** | -0.021** | -0.031** | | | |
| | [0.007] | [0.008] | [0.014] | | | |
| Treatment x Sensitive | -0.011* | -0.011 | -0.003 | | | |
| | [0.006] | [0.007] | [0.014] | | | |
| Treatment intensity | | | | 0.002 | 0.001 | 0.008 |
| | | | | [0.002] | [0.002] | [0.005] |
| Treatment intensity x Sensitive | | | | 0.004** | 0.005** | -0.002 |
| | | | | [0.002] | [0.002] | [0.006] |
| GDP per capita gap | 0.195*** | 0.184*** | 0.211*** | 0.360*** | 0.301*** | 0.336*** |
| | [0.031] | [0.039] | [0.043] | [0.050] | [0.062] | [0.061] |
| Country pair - industry effects | yes | yes | yes | yes | yes | yes |
| Industry - year effects | yes | yes | yes | yes | yes | yes |
| Number of observations | 36190 | 23856 | 12334 | 25578 | 16408 | 9170 |
| Number of groups, of which: | 5170 | 3408 | 1762 | 3654 | 2344 | 1310 |
| - treatment, of which: | 2998 | 2360 | 638 | 1482 | 1296 | 186 |
| – sensitive | 1400 | 1019 | 381 | 676 | 566 | 110 |
| Within $R^2$ | 0.26 | 0.29 | 0.21 | 0.31 | 0.35 | 0.26 |

Notes: Estimates for equations (1.4) and (1.5) on a panel of country pairs and industries in period 2000-2006. Land and non-land refer to subsamples defined on transport mode propensities, described in Section 1.5. Dependent variable is the log of the Novy index. Industry treatment sensitivity is based on the share of parts and accessories within the industry in intra-EU trade. Treatment is being an old-new or new-new country pair after 2004. Treatment intensity is the decline in border waiting time between countries (described in Section 1.3.4). Cluster-robust standard errors (with country pair clusters) are in brackets. * significant at 10%; ** at 5%; *** at 1%.

Table 1.A.12: Results with FDI intensity as treatment sensitivity

| | w/o treatment intensity | | | with treatment intensity | | |
|---|---|---|---|---|---|---|
| | whole sample | land | non-land | whole sample | land | non-land |
| Treatment | -0.028*** | -0.016** | -0.041*** | | | |
| | [0.007] | [0.008] | [0.012] | | | |
| Treatment x Sensitive | -0.015** | -0.024*** | 0.018 | | | |
| | [0.007] | [0.008] | [0.014] | | | |
| Treatment intensity | | | | 0.003 | 0.002 | 0.009** |
| | | | | [0.002] | [0.002] | [0.004] |
| Treatment intensity x Sensitive | | | | 0.003 | 0.004** | -0.005 |
| | | | | [0.002] | [0.002] | [0.004] |
| GDP per capita gap | 0.196*** | 0.186*** | 0.210*** | 0.360*** | 0.301*** | 0.338*** |
| | [0.031] | [0.039] | [0.044] | [0.050] | [0.062] | [0.061] |
| Country pair - industry effects | yes | yes | yes | yes | yes | yes |
| Industry - year effects | yes | yes | yes | yes | yes | yes |
| Number of observations | 36190 | 23856 | 12334 | 25578 | 16408 | 9170 |
| Number of groups, of which: | 5170 | 3408 | 1762 | 3654 | 2344 | 1310 |
| - treatment, of which: | 2998 | 2360 | 638 | 1482 | 1296 | 186 |
| – sensitive | 1256 | 945 | 311 | 652 | 551 | 101 |
| Within $R^2$ | 0.26 | 0.29 | 0.21 | 0.31 | 0.35 | 0.26 |

Notes: Estimates for equations (1.4) and (1.5) on a panel of country pairs and industries in period 2000-2006. Land and non-land refer to subsamples defined on transport mode propensities, described in Section 1.5. Dependent variable is the log of the Novy index. Industry treatment sensitivity is based on the ratio of inward FDI stock to value added in new countries within the industry. Treatment is being an old-new or new-new country pair after 2004. Treatment intensity is the decline in border waiting time between countries (described in Section 1.3.4). Cluster-robust standard errors (with country pair clusters) are in brackets. * significant at 10%; ** at 5%; *** at 1%.

Table 1.A.13: Days to trade and customs quality raw data

| country | Doing Business Survey | | Executive Opinion Survey | |
|---|---|---|---|---|
| | days to export | days to import | customs business impact[1] | import customs efficiency[1] |
| Austria | 8 | 9 | 3.3 | 3.2 |
| Belgium | 7 | 9 | 3.2 | 3.3 |
| Czech Republic | 20 | 22 | 4.1 | 4.3 |
| Denmark | 5 | 5 | 2.7 | 2.4 |
| Estonia | 12 | 14 | 3.4 | 3.2 |
| Finland | 7 | 7 | 2.7 | 2.4 |
| France | 22 | 23 | 4.0 | 4.0 |
| Germany | 6 | 6 | 2.8 | 2.9 |
| Hungary | 23 | 24 | 4.2 | 4.7 |
| Ireland | 14 | 15 | 2.8 | 3.0 |
| Italy | 28 | 38 | 4.3 | 4.4 |
| Latvia | 25 | 26 | 4.3 | 4.5 |
| Lithuania | 6 | 17 | 4.2 | 4.9 |
| Luxembourg | n.a. | n.a. | 3.2 | 2.7 |
| Netherlands | 7 | 8 | 2.6 | 2.6 |
| Poland | 19 | 26 | 4.8 | 5.3 |
| Portugal | 18 | 18 | 3.3 | 3.7 |
| Slovakia | 30 | 31 | 3.4 | 4.0 |
| Slovenia | 20 | 24 | 4.1 | 3.8 |
| Spain | 9 | 10 | 3.9 | 3.9 |
| Sweden | 6 | 6 | 2.5 | 2.3 |
| United Kingdom | 16 | 16 | 2.5 | 2.9 |

Notes: Source of Doing Business data is Djankov, Freund and Pham (2010). Year of the survey is 2005. Source of the Executive Opinion Survey scores is the Global Competitiveness Report 2004/2005 of the World Economic Forum (WEF). [1] Scores range between 1 and 7. Original scores reversed, here larger reflects worse evaluation.

Table 1.A.14: Estimates with alternative treatment intensities

| Variable | Number of borders | Days to trade | Customs burden |
|---|---|---|---|
| Treatment intensity | 0.016*** | 0.002 | 0.007*** |
| | [0.005] | [0.001] | [0.002] |
| Treatment intensity x Sensitive | 0.010 | 0.006*** | 0.007*** |
| | [0.006] | [0.001] | [0.002] |
| GDP per capita gap | 0.235*** | 0.239*** | 0.215*** |
| | [0.032] | [0.037] | [0.036] |
| Country pair - industry effects | yes | yes | yes |
| Industry - year effects | yes | yes | yes |
| Number of observations | 29316 | 28210 | 29316 |
| Number of groups, of which: | 4188 | 4030 | 4188 |
| - treatment, of which: | 2402 | 2362 | 2402 |
| – sensitive | 952 | 938 | 952 |
| Within $R^2$ | 0.26 | 0.28 | 0.26 |

Notes: Estimates for equations (1.4) and (1.5) on a panel of country pairs and industries in period 2000-2006. Dependent variable is the log of the Novy index. Treatment is being an old-new or new-new country pair after 2004. Industry treatment sensitivity is based on Hummels (2001b). Treatment intensity is either the change in the number of borders between countries (described in Section 1.3.4), the approximate change in the days to export/import in the two countries or a survey-based measure on the change in the burden related to the customs procedure in the two countries (the latter two described in Section 1.6.2). Cluster-robust standard errors (with country pair clusters) are in brackets. * significant at 10%; ** at 5%; *** at 1%.

Table 1.A.15: Estimates with alternative treatment intensities, land vs. non-land transport

| Variable | Number of borders | | Days to trade | | Customs burden | |
|---|---|---|---|---|---|---|
| | land | non-land | land | non-land | land | non-land |
| Treatment intensity | 0.013** | 0.026** | 0.001 | 0.000 | 0.005** | 0.008* |
| | [0.006] | [0.010] | [0.002] | [0.003] | [0.002] | [0.005] |
| Treatment intensity x Sensitive | 0.009 | -0.002 | 0.003** | 0.007** | 0.004** | 0.007 |
| | [0.006] | [0.011] | [0.001] | [0.003] | [0.002] | [0.005] |
| GDP per capita gap | 0.201*** | 0.252*** | 0.207*** | 0.280*** | 0.199*** | 0.229*** |
| | [0.040] | [0.047] | [0.045] | [0.053] | [0.046] | [0.052] |
| Country pair - industry effects | yes | yes | yes | yes | yes | yes |
| Industry - year effects | yes | yes | yes | yes | yes | yes |
| Number of observations | 19495 | 9821 | 18725 | 9485 | 19495 | 9821 |
| Number of groups, of which: | 2785 | 1403 | 2675 | 1355 | 2785 | 1403 |
| - treatment, of which: | 1889 | 513 | 1852 | 510 | 1889 | 513 |
| – sensitive | 652 | 300 | 640 | 298 | 652 | 300 |
| Within $R^2$ | 0.29 | 0.21 | 0.32 | 0.22 | 0.29 | 0.21 |

Notes: Estimates for equations (1.4) and (1.5) on a panel of country pairs and industries in period 2000-2006. Land and non-land refer to subsamples defined on transport mode propensities, described in Section 1.5. Dependent variable is the log of the Novy index. Treatment is being an old-new or new-new country pair after 2004. Industry treatment sensitivity is based on Hummels (2001b). Treatment intensity is either the change in the number of borders between countries (described in Section 1.3.4), the approximate change in the days to export/import in the two countries or a survey-based measure on the change in the burden related to the customs procedure in the two countries (the latter two described in Section 1.6.2). Cluster-robust standard errors (with country pair clusters) are in brackets. * significant at 10%; ** at 5%; *** at 1%.

Figure 1.A.1: Trade costs by industry (in log, normalized to year 2000)

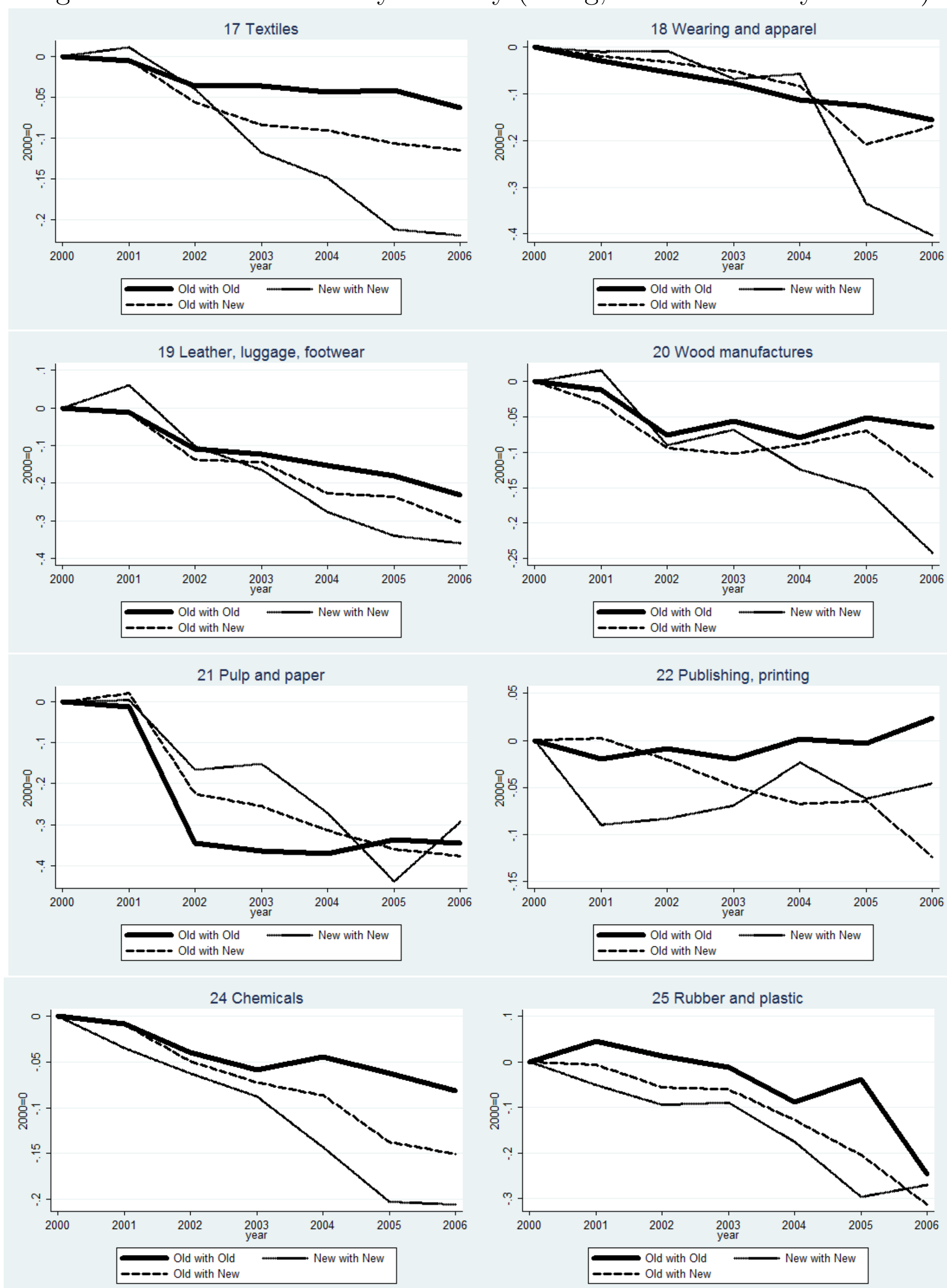


Figure 1.A.2: Trade costs by industry (continued)

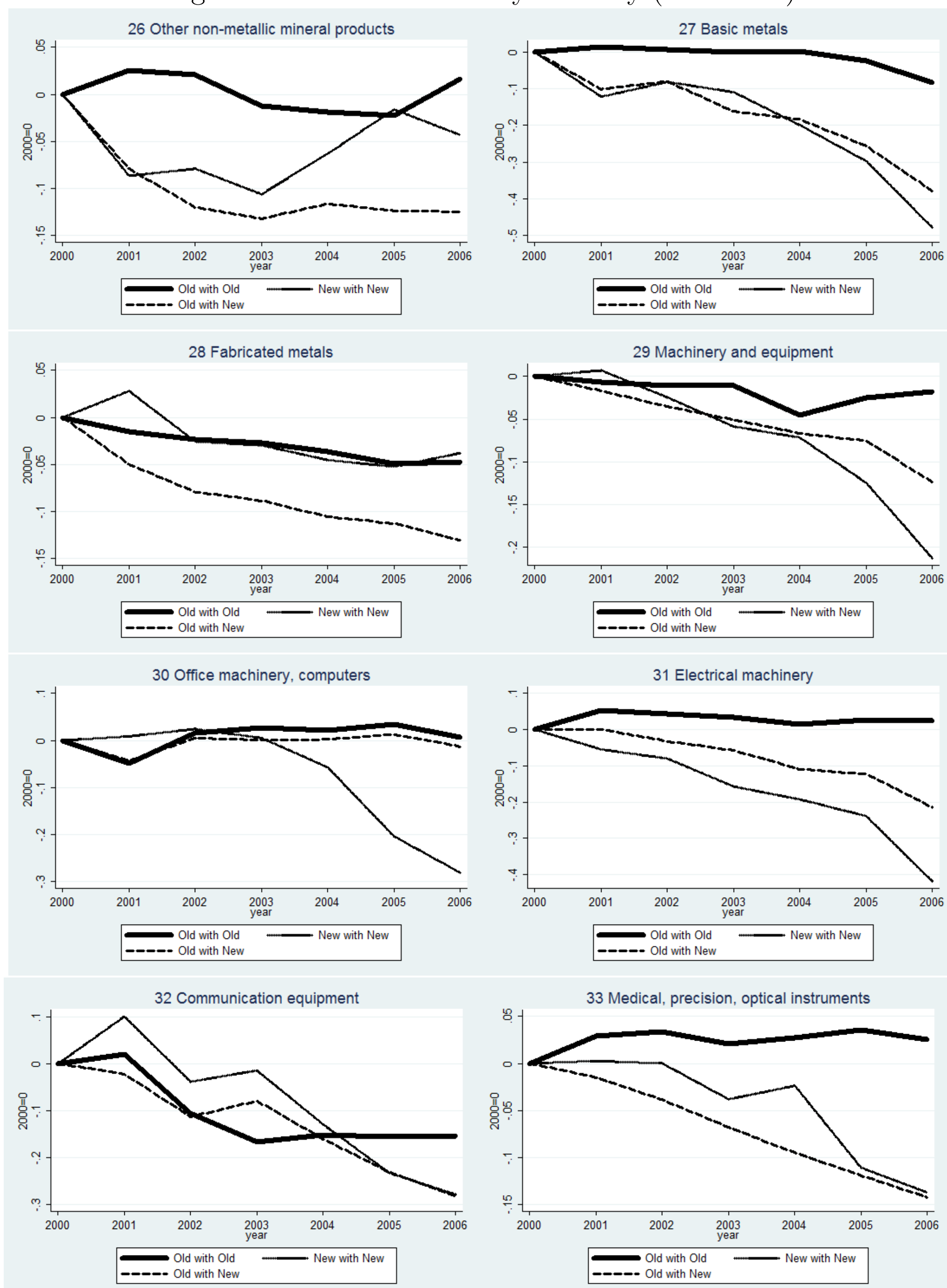
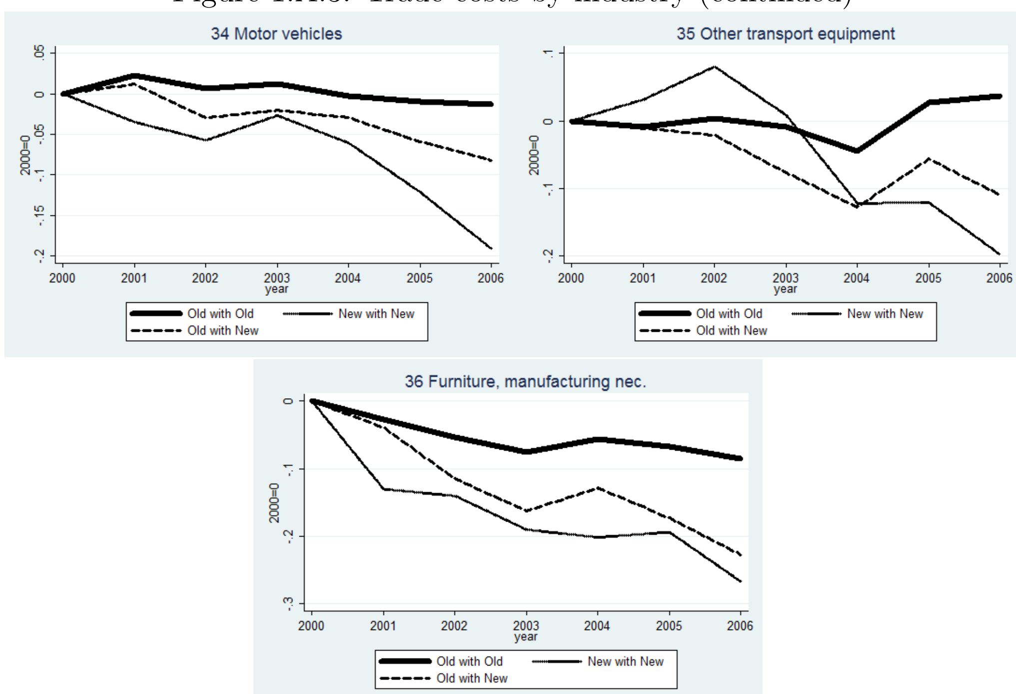


Figure 1.A.3: Trade costs by industry (continued)



# Chapter 2

# Administrative Barriers and the Lumpiness of Trade

**Joint with Miklós Koren**[1]

## 2.1 Introduction

With the diminishing use of tariff-type trade restrictions, the focus of trade policy makers has been increasingly shifted towards less standard sorts of trade barriers, including administrative barriers to trade. We define administrative trade barriers as bureaucratic procedures ("red tape") that a trading firm has to get through when shipping the product from one country to the other. Note that this definition does not involve administrative regulations as product standards, technical or health regulation per se. As an example, administrative barrier is the task of preparing health certificates, but not that of making the product itself comply with the health requirements.

We argue that administrative barriers to trade, as defined above, are typically trade costs of a "per shipment" nature. They are not an iceberg type, for they are

[1] Central European University, IEHAS and CEPR.

not proportional to the value of the product. Nor are they per unit costs. The tasks of trade documentation, cargo inspection, or customs clearance have to be performed for each shipment, and shipments may contain varying quantities of the product.

Administrative costs are not negligible in magnitude. Documentation and customs procedures in a typical export transaction of the United States take 18 working days and cost 4.6% of the shipment value (most of it occurring in the importing country, see Table 2.1.1). The same figures for a typical Spanish export transaction are 20 days and 7.2%. There is large variation in the magnitude of the administrative burden by country. Completing the documentation and customs procedures of an import transaction in Singapore takes only 2 days, in Venezuela 2 months.

Table 2.1.1: Costs of trade documentation and the customs procedure

| | Cost in US | Cost in Spain | Cost in importer country median | min | max |
|---|---|---|---|---|---|
| Time cost in days | 3 | 5 | 15 | 2 | 61 |
| Financial cost in USD | 250 | 400 | 450 | 92 | 1830 |
| as % of the median shipment value | | | | | |
| - in US exports | 1.6% | | 3.0% | 0.6% | 12.0% |
| - in Spanish exports | | 3.4% | 3.8% | 0.8% | 15.5% |

Notes: Cost data is from the *Doing Business* survey 2009 for 170 countries. Shipment size is based on "almost" shipment-level US and shipment-level Spanish export data from 2005. Trade in raw materials and low-value shipments excluded.

Exporters who can sell their products in fewer and larger shipments bear less of these costs. Bunching goods into fewer and larger shipments, involves tradeoffs, however. An exporter waiting to fill a container before sending it off or choosing a slower transport mode to accommodate a larger shipment sacrifices timely delivery of goods and risks losing orders to other, more flexible (e.g., local) suppliers. Similarly, holding large inventories between shipment arrivals incurs substantial costs and prevents fast and flexible adjustment of product attributes to changing consumer tastes. Moreover, certain products are storable only to a limited extent or not at all. With infrequent shipments a supplier of such products can compete only for a fraction of consumers in a foreign market.

This paper focuses on the trade-off of sending larger shipments less frequently versus serving more of the demand in a timely fashion in the foreign market. We abstract from the possibility of inventory holdings and simply assume that the product is non-storable. We build a "circular city" discrete choice model in the spirit of Salop (1979) on the timing of shipments and with per shipment costs. Consumers have preferred dates of consumption and are distributed uniformly along a circle that represents the time points in a year. They suffer utility loss from consuming in dates other than the preferred one. Firms - that for simplicity are assumed to send only one shipment each - decide on entering the market and choose the timing of their shipment. Per shipment administrative costs make firms send larger-sized shipments less frequently and increase the product price.

We also provide empirical evidence on US and Spanish export transactions data with 170 and 143 destination countries, respectively. We run both product-level and aggregate country cross section regressions on a decomposition of export flows into several margins, including shipment frequency, size and price margins. In the aggregate analysis we are able to see adjustments in the shipment size also via changing the transport mode or the exported product mix. Administrative trade barriers are captured by the World Bank's *Doing Business* data on the cost of trade documentation and customs procedure in the importing country. We find convincing evidence that both the US and Spain exports less and larger-sized shipments to countries with larger administrative costs of importing. We find however no evidence on a positive price effect or adjustments in the transport mode or the exported product mix.

Our emphasis on shipments as a fundamental unit of trade follows Armenter and Koren (2010), who discuss the implications of the relatively low number of shipments on empirical models of the extensive margin of trade. The importance of per shipment trade costs or, in other words, fixed transaction costs has recently been emphasized by Alessandria, Kaboski and Midrigan (2010). They argue that per shipment costs lead to the lumpiness of trade transactions: firms economize on these costs by shipping products infrequently and in large shipments and maintaining large inventory holdings. Per shipment costs cause frictions of a substantial magnitude (20% tariff equivalent) mostly due to inventory carrying expenses. We consider our paper complementary to Alessandria, Kaboski and Midrigan (2010). Our paper exploits the cross-country variation in administrative barriers to show that shippers indeed respond by increasing the lumpiness of trade. On the theory side, we focus on the utility loss consumers face when consumption does not occur at the preferred date. Moreover, our framework also applies to trade of non-storable products.

This paper relates to the recent literature that challenges the dominance of iceberg trade costs in trade theory, such as Hummels and Skiba (2004) and Irarrazabal, Moxnes and Opromolla (2010). These papers argue that a considerable part of trade costs are per unit costs, which has important implications for trade theory. Per unit trade costs do not necessarily leave the within-market relative prices and relative demand unaltered, hence, welfare costs of per unit trade frictions can be larger than those of iceberg costs. Although these authors do not consider per shipment costs, Hummels and Skiba (2004) obtain an interesting side result on a rich panel data set, which is consistent with the presence of per shipment costs. The per unit freight cost depends negatively on total traded quantity. Hence, the larger the size of a shipment in terms of product units, the less the per-unit freight cost is.

Our approach is strongly related to the literature on the time cost of trade. An important message of this literature is that time in trade is far more valuable than what the rate of depreciation of products (either in a physical or a technical sense) or the interest cost of delay would suggest. Hummels (2001b) demonstrates that firms are willing to pay a disproportionately large premium for air (instead of ocean) transportation to get fast delivery. Hornok (2011) finds that eliminating border waiting time and customs clearance significantly contributed to the trade creating effect of

EU enlargement in 2004. A series of papers (Harrigan and Venables (2006), Evans and Harrigan (2005), Harrigan (2010)) look at the implications of the demand for timeliness on production location and transport mode choice. When timeliness is important, industries tend to agglomerate and firms source from nearby producers even at the expense of higher wages and prices. Faraway suppliers, as Harrigan (2010) argues, have comparative advantage in goods that are easily transported by fast air transportation.

More policy-oriented papers give estimates on the effects of time-related and administrative barriers on trade. Using *Doing Business* data, Djankov, Freund and Pham (2010) incorporate the number of days spent with documentation, customs, port handling and inland transit into an augmented gravity equation and find that each additional day delay before the product is shipped reduces trade by more than 1%. Part of the policy literature is centered around the notion of "trade facilitation," i.e., the simplification and harmonization of international trade procedures. This line of literature provides ample evidence through country case studies, gravity estimations and CGE model simulations on the trade-creating effect of reduced administrative burden.[2]

The paper is structured as follows. Section 2.2 presents the model and carries out comparative statics and welfare analysis on per shipment costs. Section 2.3 describes the indicators of administrative trade barriers, Section 2.4 presents the US and Spanish export databases and descriptive statistics on trade lumpiness. Product-level estimations are in Section 2.5. Section 2.6 develops a novel decomposition of aggregate trade flows and presents the country cross section estimations. In this section, we elaborate on a theory-based gravity estimating equation with a non-bilateral trade cost variable. Section 2.7 concludes.

[2] An assessment of estimates shows that trade facilitation can decrease trade costs by at least 2% of the trade value, and this number may get as large as 5-10% for less developed countries. For more see e.g. Engman (2005) or Francois, van Meijl and van Tongeren (2005).

## 2.2 A model of shipping frequency

This section presents a version of the "circular city" discrete choice model of Salop (1979) that determines the number and timing of shipments to be sent to a destination market. Sending shipments more frequently is beneficial, because the specifications of the product can be more in line with the demands of the time.

### 2.2.1 Consumers

There are $L$ consumers in the destination country.[3] Each consumer buys one unit of a good at unit price $p$.[4] Goods are differentiated only by the time of their arrival to the destination market. Consumers are heterogeneous with respect to their preferred date of consumption: some need the good on January 1, some on January 2, etc. The preferred date is indexed by $t \in [0, 1]$, and can be represented by points on a circle.[5] The distribution of $t$ across consumers is uniform, that is, there are no seasonal effects in demand.[6]

Consumers are willing to consume at a date other than their preferred date, but they incur a cost doing so. In the spirit of the trade literature, we model the cost of substitution with an iceberg transaction cost.[7] A consumer with preferred date $t$ who consumes one unit of the good at date $s$ only enjoys $e^{-\tau|t-s|}$ *effective units*. The parameter $\tau > 0$ captures the taste for timeliness. Consumers are more willing to substitute to purchase at dates that are closer to their preferred date and they suffer from early and late purchases symmetrically.

[3]For simplicity, we are omitting the country subscript in notation.

[4]We assume that the consumers' gross valuation is high enough so that all consumers purchase the product.

[5]Note that this puts an upper bound of $\frac{1}{2}$ on the distance between the firm and the consumer.

[6]Seasonality seems an interesting and important extension that we wish to tackle later.

[7]This is different from the tradition of address models that feature linear or quadratic costs, but gives more tractable results.

The utility of a type-$t$ consumer purchasing one type-$s$ good at price $p$ is

$$U(t, s, p) = e^{-\tau|t-s|} - p,$$

where the consumers' gross valuation for the product is normalized to 1.[8] Note that the timing of consumption enters the utility function symmetrically around the preferred date. We believe both early and late delivery have costs (e.g. spoilage versus the cost of waiting), and treat the preference for timely delivery as symmetric to maintain analytical tractability.

### 2.2.2 Suppliers

There is an unbounded pool of potential suppliers to the destination country. Every supplier can send only one shipment.[9] They first decide whether or not to send a shipment to this destination. They then choose a time of shipment, $s$. After all suppliers fixed their time, they simultaneously pick a price $p(s)$, playing Bertrand competition. At that price suppliers serve all the demand they face, which determines the number of goods per shipment, $q(s)$, i.e., shipment size.[10]

There are two types of costs suppliers face: the per unit cost of producing and shipping the good $c$ and a per shipment cost (fixed transaction cost) $f$. All suppliers face the same per unit and per shipment costs. Profits per shipment are

$$\pi(s) = [p(s) - c]q(s) - f.$$

[8] This utility function can be derived from a quasi-linear preference structure where the outside good enters the utility function linearly.

[9] Alternatively, one may allow for multiple shipments per supplier but fix the total number of suppliers. Such an approach is followed by Schipper, Rietveld and Nijkamp (2003) on the choice of flight frequency in the airline market.

[10] We abstract from capacity constraints in shipping. Large adjustments in capacity can be achieved by changing the transport mode. Note however that we assume per unit costs to be invariant to a modal switch.

### 2.2.3 Equilibrium and comparative statics

We focus on symmetric equilibria. In symmetric equilibrium, shipping times will be uniformly distributed throughout the year, i.e., firms locate evenly-spaced on the circle. This follows from the uniform distribution of consumers, symmetry of $c$ and the convexity of the timeliness cost.[11] By backward induction, we first characterize the residual demand facing a supplier at time $s$. This pins down her optimal price. We then study the choice of shipping times. Finally, we use the zero profit condition to pin down the number of suppliers, and hence, shipping dates.

In equilibrium with symmetric location, the firm that ships at $s$ only competes with its two nearest neighbors. Suppose that one neighbor ships at time $s_{-1} < s$, the other at time $s_{+1} > s$. The first has price $p_{-1}$, the second $p_{+1}$. Firms locate at equal distances from their neighbors, taking the location of their neighbors as given. Hence, the time difference between two adjacent suppliers is $\frac{1}{n}$, where $n$ is the number of suppliers that enter the market. The demand function that firm at $s$ faces can be derived using the indifferent consumer both left and right from $s$.

A consumer at a distance $x$ from $s$ on the left is indifferent to buy from the firm at $s$ or his competitor at $s_{-1}$ if $pe^{\tau x} = p_{-1}e^{\tau(\frac{1}{n}-x)}$. Similarly, a consumer $x$ distant from $s$ on the right is indifferent to buy from the firm at $s$ or the firm at $s_{+1}$ if $pe^{\tau x} = p_{+1}e^{\tau(\frac{1}{n}-x)}$. Solving for $x$ in both equalities and summing them over the mass of consumers gives the demand a supplier faces, $q = 2xL$, as a function of the number of shipments, the competitors' and own price,

$$q(n, p, p_{-1}, p_{+1}) = \frac{L}{\tau}\left(\frac{1}{2}\ln p_{-1} + \frac{1}{2}\ln p_{+1} - \ln p\right) + \frac{L}{n}.$$

After substituting the demand equation in the profit function, the first order condition from the profit maximization with respect to $p$ gives the best response

[11] Economides (1986) shows that for convex transportation costs equilibrium exists with maximum differentiation of locations.

function for the price as a function of the competitors' prices.[12] Imposing symmetry, $p_{-1} = p = p_{+1}$, one gets the expression for the mark-up in equilibrium,

$$\frac{p-c}{p} = \frac{\tau}{n}.$$

Firms can charge a higher mark-up, the more the consumers value timeliness and the larger the time distance between two shipments is. Both effects reduce the substitutability between two shipments occurring at adjacent times and increase the market power of sellers.

The zero profit condition with the mark-up equation determines $n$ in equilibrium,

$$n^* = \frac{\tau}{2}\left(1 + \sqrt{1 + \frac{4cL}{\tau f}}\right).$$

More firms will enter the market, the more consumers value timeliness, the larger the market, the higher the marginal cost and the lower the per shipment cost is. The equilibrium shipment size and price can also be expressed as functions of the model parameters via the equilibrium relationships $q^* = \frac{L}{n^*}$ and $p^* = \frac{cn^*}{n^*-\tau}$. (See derivations in Appendix 2.A.1.)

Taking the partial derivatives with respect to the per shipment cost one finds that equilibrium shipment frequency decreases, while both the equilibrium shipment size and price increases with $f$: $\frac{\partial n^*}{\partial f} < 0$, $\frac{\partial q^*}{\partial f} > 0$ and $\frac{\partial p^*}{\partial f} > 0$. (See derivations in Appendix 2.A.1.) Hence, the model implies that facing larger per shipment costs firms send fewer and larger shipments at a higher per unit product price.

[12] The second order condition is satisfied.

### 2.2.4 Welfare

Aggregate welfare is the sum of aggregate consumer surplus and aggregate firm profit. The former is the sum of the individual utilities over $L$ consumers, the latter is the sum of the individual firm profits over $n^*$ firms.

Individual consumer utility depends on the distance, $x$, between the preferred and the actual arrival time of the product. At the lower end, the two dates coincide and $x = 0$. At the higher end, the consumer's preferred date lies at the borderline between the markets of two adjacent competitors and $x = \frac{1}{2n^*}$. Total consumer surplus can be obtained by integrating individual utilities over the $2n^*$ intervals of length $\frac{1}{2n^*}$ on the time circle and multiplying by the mass of consumers $L$,

$$CS = 2n^* \int_{x=0}^{\frac{1}{2n^*}} \left(e^{-\tau x} - p^*\right) L dx.$$

Aggregate profit of $n^*$ firms at equilibrium is

$$\Pi = (p^* - c)L - n^* f,$$

where we already used that $q^* = \frac{L}{n^*}$. Solving the integral in CS and adding the two components, we get aggregate welfare,

$$W = \frac{2n^* L}{\tau} \left(1 - e^{-\frac{\tau}{2n^*}}\right) - Lc - n^* f.$$

The first term captures the consumers' utility net of the cost of time discrepancy between the preferred and the actual consumption dates. This term is always positive and increases with the shipment frequency, because more shipments reduce time discrepancies. Note that the equilibrium price does not affect welfare. This is due to the fact demand is completely inelastic.

In competitive equilibrium, the total effect of per shipment cost $f$ on welfare is the sum of an indirect effect through the equilibrium number of shipments and a direct effect,

$$\frac{\mathrm{d}W}{\mathrm{d}f} = \left.\frac{\partial W}{\partial n}\right|_{n=n^*} \frac{\partial n^*}{\partial f} + \frac{\partial W}{\partial f}.$$

The direct effect is clearly negative: a marginal increase in $f$ decreases welfare in proportion to the number of shipments. The indirect effect of a marginal increase in $f$ works through a decrease in the equilibrium number of shipments, which has two consequences. First, it decreases the consumer surplus, and hence welfare, due to larger distances between preferred and actual consumption dates. Second, it increases welfare by decreasing the total amount of per shipment costs to be paid. Whether the sum of the two counteracting effects is positive or negative depends on the parameter values. The sign of the total effect in the competitive equilibrium is also ambiguous, but for reasonable parameter values it is negative.

The socially optimal number of suppliers, $n^o$, that maximizes welfare is determined by the condition $\frac{\partial W}{\partial n} = 0$, which does not yield a closed form solution.[13] The number of suppliers in the competitive equilibrium, $n^*$, can be smaller or larger than $n^o$, depending on the parameter values. In the social optimum, the total effect of per shipment costs on welfare equals the marginal effect evaluated at $n = n^o$ (envelope theorem), which gives

$$\frac{\mathrm{d}W^o}{\mathrm{d}f} = \left.\frac{\partial W}{\partial f}\right|_{n=n^o} = -n^o.$$

Hence, in the social optimum a marginal increase in $f$ unambiguously decreases welfare.

[13]In the social optimum, $\frac{2L}{\tau} - \left(\frac{2L}{\tau} + \frac{L}{n^o}\right) e^{-\frac{\tau}{2n^o}} - f = 0$. The second derivative is negative, so $n^o$ maximizes welfare.

## 2.3 Indicators of administrative barriers

We capture administrative trade barriers in the importing country with indicators on the the burden of import documentation and customs clearance and inspection. Data is from the *Doing Business* survey of the World Bank, carried out in 2009.[14] The survey includes, among others, questions on the time required to complete a foreign trade transaction and the financial costs associated with it. The data is country-specific and does not vary with the trading partner or across products.

The *Doing Business* survey is carried out among trade facilitators at large freight-forwarding companies. The majority of world trade is done via freight-forwarders and trade facilitators are well informed about the transaction procedures. The survey questions refer to a standardized containerized cargo of goods shipped by sea.[15] Since data is specific to ocean transport, controlling for the transport mode in the regression analysis will be important. The questions refer to all procedures from the vessel's arrival at the port of entry to the cargo's delivery at the warehouse in the importer's largest city.

The importing process is broken down into four procedures: document preparation, customs clearance and inspection, port and terminal handling, and inland transportation and handling from the nearest seaport to the final destination. Both the time and the financial cost are reported for each procedural stage separately. Time is expressed in calendar days, financial cost in US dollars per container. Financial costs of the four procedures are fees for documents and the customs clearance, customs broker fees, terminal handling charges, and the cost of inland transport, and do not include customs tariffs, trade taxes or bribes.

[14] Detailed survey data is unfortunately not available publicly from earlier surveys. Though the trade data is from 2005, we do not see the time mismatch problematic. *Doing Business* figures appear to be strongly persistent over time.

[15] The traded product is assumed to travel in a dry-cargo, 20-foot, full container load via ocean. It weighs 10 tons, is valued at USD 20,000, is not hazardous and does not require special treatment or standards. (http://www.doingbusiness.org/MethodologySurveys/TradingAcrossBorders.aspx)

We take the sum of data on the first two procedures (document preparation + customs clearance and inspection) as our indicator of administrative barriers. The other two procedures are more closely related to moving and storing the goods than to administrative tasks. It appears that administrative barriers are better represented by the amount of time lost than by a financial measure. In particular, document preparation is the most time-consuming out of the four procedures. As Table 2.A.3 in the Appendix shows, document preparation takes 13.7 days and represents half of the total time for the average importer. In terms of financial costs, inland transportation is the most burdensome, taking up almost half of the total cost for the average importer.

The time and the financial cost measures of administrative barriers are not particularly strongly correlated (Table 2.A.4 in Appendix). The correlation coefficient is 0.39. In contrast, the time and financial cost measures for the sum of the other two procedures has a correlation coefficient of 0.68. This, and the fact that administrative tasks are more time-intensive, will make us rely more on our empirical results for the administrative time and less on the administrative financial cost indicator.

The level of administrative barriers is negatively correlated with the economic development of the importer. The latter is often considered as a proxy for the overall institutional quality of a country. The correlation coefficients with the level of GDP per capita in the last row of Table 2.A.4 are significantly negative. The same pattern can be seen in Table 2.A.5, which presents summary statistics of the administrative barrier indicators by continent. Administrative tasks to import take 21 days and cost USD 630 for the median African country. The same import transaction to complete takes only 7 days and costs USD 280 for the median European importer.

## 2.4 Evidence on trade lumpiness

We examine disaggregated data on exports from the US and Spain to a large set of countries in 2005. We want to look at the lumpiness of trade transactions, i.e., how frequently the same good is exported to the same destination country within the year, as well as the typical size of a shipment.

This exercise requires transaction-level (shipment-level) trade data. Customs Bureaus in both the US and Spain record trade flows at the shipment level. The Spanish database is made publicly available at this same level, whereas the US database is somewhat aggregated up. An entry in the publicly available US Foreign Trade statistics reported by the Census Bureau is differentiated by product, country of destination, month of shipment, and shipping Census region. Most importantly, the dataset also reports the number of shipments aggregated in each entry. More than half of the entries contain only one shipment, and the average number of shipments per entry is only four. In both databases, the identity of the exporting firm is omitted for confidentiality reasons. A more detailed data description is in Appendix 2.A.2.

We consider 170 destination countries for the US and 166 (143 non-EU) destinations for Spain. Product classification is very detailed in both cases, covering around 8,000 different product lines (10-digit Schedule B in the US and 8-digit Combined Nomenclature in the Spanish case). In the case of US exports, which is not a shipment-level database, we can calculate the value of a shipment per each cell by dividing the trade value with the number of shipments in that cell. Similarly, physical shipment size is trade quantity divided by the number of shipments.

Tables 2.4.1 and 2.4.2 report descriptive statistics for the US and Spain, respectively. In both cases four-four importers are selected that are relatively important trading partners and are countries with either low or high administrative barriers to import. The selected country sets partially overlap to enable direct comparison of US and Spanish figures.

Table 2.4.1: Lumpiness in US exports

| importer | median shipment value ($) | how many times good shipped in a month | fraction of months in year good shipped | days to complete doc.&customs procedure |
|---|---|---|---|---|
| *Selected low per shipment cost importers* | | | | |
| Canada | 14515 | 14.1 | 1.00 | 5 |
| Germany | 16452 | 2.0 | 0.64 | 4 |
| Israel | 17864 | 1.3 | 0.36 | 6 |
| Singapore | 17275 | 1.6 | 0.55 | 2 |
| *Selected high per shipment cost importers* | | | | |
| Chile | 12422 | 1.3 | 0.36 | 15 |
| China | 24540 | 1.9 | 0.64 | 19 |
| Russia | 21705 | 1.0 | 0.18 | 29 |
| Venezuela | 19405 | 1.4 | 0.36 | 61 |
| All 170 importers | 15200 | 1.2 | 0.27 | 15 |

Notes: U.S. exports to 170 importers in 2005 with 7,917 ten-digit product categories. Shipment size is the frequency-weighted median of data points at the highest-level of disaggregation. $N$=2,993,218. Shipment frequency statistics are for the median product. Trade in raw materials and low-value shipments (< USD 2,500) excluded. Days to complete documentation and customs procedures is from the *Doing Business* database for 2009.

Table 2.4.2: Lumpiness in Spanish exports

| importer | median shipment value ($) | how many times good shipped in a month | fraction of months in year good shipped | days to complete doc.&customs procedure |
|---|---|---|---|---|
| *Selected low per shipment cost importers* | | | | |
| Australia | 8981 | 1.0 | 0.17 | 4 |
| France | 12238 | 1.8 | 0.92 | $0^a$ |
| Germany | 12810 | 1.4 | 0.67 | $0^a$ |
| USA | 14316 | 1.5 | 0.33 | 3 |
| *Selected high per shipment cost importers* | | | | |
| Algeria | 13494 | 1.0 | 0.17 | 16 |
| China | 21848 | 1.0 | 0.17 | 19 |
| Russia | 12308 | 1.3 | 0.25 | 29 |
| South Africa | 13906 | 1.0 | 0.17 | 18 |
| All 166 importers | 11842 | 1.0 | 0.17 | 15 |

Notes: Spanish exports to 143 non-EU and 23 EU importers in 2005 in 8,234 eight-digit product lines. $N$=2,937,335. Shipment value is the median of individual shipments, converted to US dollars with monthly average USD/EUR exchange rates. Shipment frequency statistics are for the median product. Trade in raw materials and low-value shipments (< EUR 2,000) excluded. Days to complete documentation and customs procedures is from the *Doing Business* database for 2009. $^a$ Imposed for intra-EU.

The first column shows the value of the median shipment in US dollars, calculated from the most disaggregated data (the number of entries is almost 3 million for both exporters). US statistics are weighted by the number of shipments per entry. The value of the typical export shipment is USD 15,200 in the US, which is 28% larger than the typical shipment value in Spain.[16] Shipment sizes for selected individual destinations range between USD 9,000 (Spain to Australia) and USD 24,500 (US to China). These differences may depend on several factors, such as the nature of the

[16]We believe, this cannot be an artifact of statistical reporting requirements, because we used the same threshold value to drop low-value shipments in both databases.

exported products and the transport mode, which we will account for in the regression analysis.[17]

The second column reports how many times the median product is shipped to a given destinations in a month, if there was positive trade in that month. The third column shows the fraction of months in the year with positive trade in the median product to a given destination. Apart from the very strong US-Canada trade relationship, the median product is shipped only 1 or 2 times a month and trade is positive in a relatively small fraction of the months (typically 3 months for the US and 2 months for Spain). Both statistics show a somewhat stronger lumpiness in Spanish than in US exports. These figures are comparable to statistics reported by Alessandria, Kaboski and Midrigan (2010) for monthly US imports from six selected exporters during 1990-2005. These authors also demonstrate that lumpiness is not driven by seasonality and that it is pervasive across different types of traded goods.

The last column reports the indicator for the administrative trade barrier: the number of days trade documentation and the customs procedure take in the destination country. For the moment we impose zeros for intra-EU trade, indicating that administrative trade barriers within the EU are very low. Later, in the regression analysis, EU countries will be dropped from the Spanish sample. As far as the selected countries are concerned, shipment sizes are somewhat smaller for those with low barriers, and shipments to these countries show less strong lumpiness features than shipments to high-barrier destinations. Of course, these differences may be due to other factors as well, which we aim to control for in the regression analysis.

[17]Sea and ground transport modes accommodate much larger shipment sizes than air transportation. We report shipment sizes in both value and weight (kilogram) for these three modes in Table 2.A.2 in the Appendix. The differences are larger for the physical shipment size than for the shipment value, reflecting typically high weight-to-value cargos in air transportation.

## 2.5 Product-level estimation

We want to test the predictions of the model in Section 2.2 and see how the frequency, the number, the size of shipments and the price vary with the level of administrative barriers. We create databases of exports by product and transport mode (air, sea, ground) to 170 importers for the US and 143 importers (EU members excluded)[18] for Spain and decompose the value of exports of product $g$ by mode $m$ to country $j$ as

$$X = h\bar{n}v = h\bar{n}pq, \tag{2.1}$$

where we omitted the $jgm$ subscripts. $h$ is the number of months in the year product $g$ is exported by mode $m$ to country $j$, $\bar{n}$ is the average number of shipments per month with positive trade for a given $j$, $g$ and $m$ and $v$ is the corresponding average shipment value, which can be further decomposed into price, $p$, and physical shipment size, $q$.

Our model predicts that administrative barriers decrease shipment frequency and increase the shipment value by both increasing the physical shipment size and the price. Both $h$ and $\bar{n}$ are margins of shipment frequency. Looking at their responses separately tells us whether the concentration of shipments in relatively few months ($h$) is also responsive to administrative barriers. Our model is consistent with a responsive $h$ margin, given its prediction on evenly-spaced shipments on the time circle.

We estimate simple OLS regressions with product-mode fixed effects with either the logarithm of the export value or one of the elements of decomposition (2.1) on the left-hand side. The estimating equation, with the export value on the left-hand

[18] Destination countries in the US and Spanish sample are listed in Table 2.A.1 in the Appendix. We exclude EU members from the Spanish sample, because the administrative barriers indicators are not relevant for intra-EU trade.

side, is

$$\ln X_{jgm} = \beta \cdot \text{admin}_j + \gamma \cdot \text{other regressors}_j + \nu_{gm} + \epsilon_{jgm}, \tag{2.2}$$

where $\text{admin}_j$ is the importer-specific administrative barrier variable with coefficient $\beta$, other importer-specific regressors are also included, $\nu_{gm}$ are product-mode fixed effects and $\epsilon_{jgm}$ is the error term.[19] Other regressors are those typically used in gravity estimations: logarithm of GDP and GDP per capita[20], geographical distance from the US or Spain, dummies for being landlocked or an island, Free Trade Agreement and Preferential Trade Agreement, common language and colonial relationship with the US or Spain, and the sum of the other two *Doing Business* import cost indicators (port handling + inland transport).

We drop observations from the US database, where the transport mode is not uniquely defined (5.8% of observations). To have a unique quantity measure, we restrict the US sample to those observations, where quantity is reported in kilograms. Since weight in kilograms is reported for all air- or ocean-transported shipments of the US, we need to exclude only part of the ground-transported trade, overall 4.5% of the US sample.[21]

For both the US and Spain, we first run regressions on a sample with all transport mode categories, then restrict the sample to sea (ocean) transported trade. The *Doing Business* survey question explicitly refers to an ocean-transported shipment. Nevertheless, estimations with all transport modes can be relevant too, since the documentation and customs burden (unlike port handling and inland transport) is probably similar across transport modes.

[19]We do not account for zeros in trade and, hence, adjustment at the product extensive margin. The aggregate specification in Section 2.6 accounts for zeros.

[20]GDP per capita also serves as a proxy for the overall institutional quality of the importer. This way we can ensure that the administrative burden variable does not pick up effects from other elements of institutional quality, with which it may be highly correlated.

[21]Ground-transported trade is mostly with Canada and Mexico. We check how excluding these two importers alters the results. Estimation results without Canada and Mexico (available on request) are qualitatively the same as the reported ones.

Table 2.5.1: Product-level estimates for US, Time cost

| Dependent variable | $\beta$ estimate | Robust s.e. | Adj.$R^2$ |
|---|---|---|---|
| | *all modes* | | |
| log export | -0.003 | [0.002] | 0.41 |
| log number of months | -0.003** | [0.001] | 0.38 |
| log shipment per month | -0.002*** | [0.001] | 0.38 |
| log value shipment size | 0.002*** | [0.000] | 0.38 |
| log physical shipment size | 0.001 | [0.001] | 0.68 |
| log price | 0.001** | [0.001] | 0.73 |
| Number of observations | 400096 | | |
| Number of clusters | 10934 | | |
| Number of product-mode effects | 18060 | | |
| | *only sea* | | |
| log export | 0.004* | [0.002] | 0.33 |
| log number of months | 0.001 | [0.001] | 0.30 |
| log shipment per month | 0.001 | [0.001] | 0.26 |
| log value shipment size | 0.003*** | [0.001] | 0.33 |
| log physical shipment size | 0.002** | [0.001] | 0.49 |
| log price | 0.001 | [0.001] | 0.59 |
| Number of observations | 195228 | | |
| Number of clusters | 9599 | | |
| Number of product effects | 7658 | | |

Notes: OLS estimation of (2.2) separately for each margin in (2.1) on a sample of US exports to 170 countries in 10-digit HS products in 2005. If transport mode is not restricted to sea, it is air, sea, or ground. Product-mode fixed effects included. Other regressors: log GDP, log GDP per capita, log distance, dummies for island, landlocked, Free Trade Agreement, Preferential Trade Agreement, colonial relationship, common language, and time to complete port/terminal handling and transport from nearest seaport. Only trade with quantity measured in kilograms included. Clustered robust standard errors with country and 2-digit product clusters. * sign. at 10%, ** 5%; *** 1%.

Table 2.5.2: Product-level estimates for Spain, Time cost

| Dependent variable | $\beta$ estimate | Robust s.e. | Adj.$R^2$ |
|---|---|---|---|
| | *all modes* | | |
| log export | 0.000 | [0.001] | 0.43 |
| log number of months | -0.002*** | [0.000] | 0.36 |
| log shipment per month | -0.001*** | [0.000] | 0.43 |
| log value shipment size | 0.003*** | [0.001] | 0.45 |
| log physical shipment size | 0.002** | [0.001] | 0.74 |
| log price | 0.001** | [0.001] | 0.79 |
| Number of observations | 117544 | | |
| Number of clusters | 7126 | | |
| Number of product-mode effects | 15893 | | |
| | *only sea* | | |
| log export | -0.002 | [0.001] | 0.39 |
| log number of months | -0.004*** | [0.001] | 0.34 |
| log shipment per month | -0.002*** | [0.000] | 0.41 |
| log value shipment size | 0.004*** | [0.001] | 0.40 |
| log physical shipment size | 0.004*** | [0.001] | 0.60 |
| log price | 0.001 | [0.001] | 0.72 |
| Number of observations | 64467 | | |
| Number of clusters | 6010 | | |
| Number of product effects | 6586 | | |

Notes: OLS estimation of (2.2) separately for each margin in (2.1) on a sample of Spanish exports to 143 non-EU countries in 8-digit CN products in 2005. If transport mode is not restricted to sea, it is air, sea, or ground. Product--mode fixed effects included. Other regressors: log GDP, log GDP per capita, log distance, dummies for island, landlocked, Free Trade Agreement, Preferential Trade Agreement, colonial relationship, common language, and time to complete port/terminal handling and transport from nearest seaport. Clustered robust standard errors with country and 2-digit product clusters. * sign. at 10%, ** 5%; *** 1%.

We focus on the estimation results with the time indicator of administrative barriers (Tables 2.5.1 and 2.5.2) and present the results with the financial cost indicator in the Appendix (Tables 2.A.6 and 2.A.7). We report only the $\beta$ estimates. Consistent with the decomposition, the coefficient estimates in the second to fourth rows in all the result tables sum up to the coefficient estimate in the first row, and the estimate in the fourth row (value shipment size) is the sum of the estimates in the fifth and sixth rows (physical shipment size and price). Robust standard errors are clustered by importer and broad product group, where product groups are 2-digit groups of the 10-digit HS and 8-digit CN classifications of the US and Spain, respectively.

The most robust result is that, within product and mode, the value of shipments that are sent to countries with larger administrative barriers tends to be significantly larger (fourth rows). If completing the administrative tasks takes one day longer, the value of a shipment for a given transport mode and product is on average 0.2-0.4% larger. This is mostly the result of a larger physical shipment size (fifth rows) and less of a larger price per kilogram (sixth rows).

We also find evidence on a negative response of the shipment frequency (second and third rows). Larger administrative barriers tend to coincide with more lumpiness of trade for a given product and transport mode. Both the number of months with trade ($h$) and the average number of shipments per month with trade ($\bar{n}$) tend to be lower in destinations with higher administrative time. This effect is however not significant in the US sample with only sea-transported trade.

The (within-product-mode) value of exports does not seem to respond, or responds only modestly, to a change in the administrative barrier (first rows). Administrative barriers make firms send fewer and larger shipments, but they hardly affect the magnitude of export sales. This suggests that simply looking at the effect of administrative barriers on trade flows leaves an important part of the adjustment hidden.[22]

[22] We do not account for adjustments at the product extensive margin, which can also be important.

When we replace the administrative time indicator with the financial cost indicator (Tables 2.A.6 and 2.A.7 in Appendix), the main findings are similar. Evidence on the shipment frequency is however more mixed. A significant negative effect on shipment frequency is found only in the US sample.

## 2.6 Estimation on a country cross section

In this section we present aggregate cross sections estimates. We develop a decomposition of aggregate exports to a country into five margins: the number of shipments, the price, the physical shipment size for a given product and transport mode, the transport mode, and the product composition margins. The five margins separate five possible ways of adjustment. In response to higher administrative barriers firms may reduce the number of shipments, increase the price, pack larger quantities of goods in one shipment, switch to a transport mode that allows larger shipments (sea or ground),[23] or change the export product mix towards products that are typically shipped in large shipments.

The possibility to see adjustments on the last two margins (transport mode and product composition) is an advantage of the country cross section analysis over the product-level regressions in Section 2.5. The disadvantage is that the sample size is reduced to the number of importers (170 for US, 143 for Spain), which can bring up degrees of freedom concerns in the estimation.

### 2.6.1 A decomposition of aggregate exports

Let $g$ index products, $m$ modes of shipment (air, sea, ground), and $j$ importer countries. Let country 0 be the benchmark importer (the average of all of the importers in the sample), for which the share of product-level zeros are the lowest. In fact,

[23]Shipment size statistics by mode of transport are in Table 2.A.2 in Appendix.

we want all products to have nonzero share, so that the share of different modes of transport are well defined for the benchmark country.[24]

Let $n_{jgm}$ denote the number of shipments of good $g$ through mode $m$ going to country $j$. Similarly, $q_{jgm}$ denotes the average shipment size for this trade flow in quantity units, $p_{jgm}$ is the price per quantity unit. We introduce the notation

$$s_{jgm} = \frac{n_{jgm}}{\sum_k n_{jgk}}$$

for the mode composition of good $g$ in country $j$, and

$$s_{jg} = \frac{\sum_k n_{jgk}}{\sum_l \sum_k n_{jlk}}$$

for the product composition of country $j$. We define $s_{0gm}$ and $s_{0g}$ similarly for the benchmark (average) importer.

We decompose the ratio of total trade value ($X$) to country $j$ and the benchmark country,

$$\frac{X_j}{X_0} = \frac{\sum_g \sum_m n_{jgm} p_{jgm} q_{jgm}}{\sum_g \sum_m n_{0gm} p_{0gm} q_{0gm}} = \frac{n_j \sum_g s_{jg} \sum_m s_{jgm} p_{jgm} q_{jgm}}{n_0 \sum_g s_{0g} \sum_m s_{0gm} p_{0gm} q_{0gm}},$$

as follows,

$$\frac{X_j}{X_0} = \frac{n_j}{n_0} \cdot \frac{\sum_g s_{jg} \sum_m s_{jgm} p_{jgm} q_{jgm}}{\sum_g s_{jg} \sum_m s_{jgm} p_{0gm} q_{jgm}} \cdot \frac{\sum_g s_{jg} \sum_m s_{jgm} p_{0gm} q_{jgm}}{\sum_g s_{jg} \sum_m s_{jgm} p_{0gm} q_{0gm}} \cdot \frac{\sum_g s_{jg} \sum_m s_{jgm} p_{0gm} q_{0gm}}{\sum_g s_{jg} \sum_m s_{0gm} p_{0gm} q_{0gm}} \cdot \frac{\sum_g s_{jg} \sum_m s_{0gm} p_{0gm} q_{0gm}}{\sum_g s_{0g} \sum_m s_{0gm} p_{0gm} q_{0gm}}.$$

The first term is the shipment extensive margin. It shows how the number of shipments sent to $j$ differs from the number of shipments sent to the average importer.

[24]Note that the mode of transport will not be well defined for a product/country pair if there are no such shipments. This will not be a problem because this term will carry a zero weight in the index numbers below.

The ratio is greater than 1 if more than average shipments are sent to $j$. The second term is the price margin. It shows how much more expensive is the same product shipped by the same mode to country $j$, relative to the average importer. The third term we call the *within* physical shipment size margin. It tells how physical shipment sizes differ in the two countries for *the same product and mode of transport*. The fourth term is a mode of transportation margin. If it is greater than 1, transport modes that accommodate larger-sized shipments (sea, ground) are overrepresented in $j$ relative to the benchmark. The last term is the product composition effect. It shows to what extent physical shipment sizes differ in the two countries as a result of differences in the product compositions. If bulky items and/or items that typically travel in large shipments are overrepresented in the imports of $j$, the ratio gets larger than 1.

We express the same decomposition identity simply as

$$X_{j,\text{total}} = X_{j,\text{extensive}} \cdot X_{j,\text{price}} \cdot X_{j,\text{within}} \cdot X_{j,\text{transport}} \cdot X_{j,\text{prodcomp}}. \tag{2.3}$$

If administrative trade barriers make firms send less and larger shipments, one should see the shipment *extensive* margin to respond negatively and the *within* physical shipment size margin positively to larger administrative costs. If firms facing per shipment administrative costs choose to switch to a large-shipment transport mode, the transport margin should respond positively. If firms shift the composition of the traded product mix towards typically large shipment products, it should show up as a positive response on the product composition margin.

### 2.6.2 Simple cross section estimation

We run simple cross section regressions with elements of decomposition (2.3) (in logs) on the left-hand side and the administrative barrier and other "gravity" regressors on the right-hand side. The estimating equation is

$$\log X_{j,z} = \beta \cdot \text{admin}_j + \gamma \cdot \text{other regressors}_j + \nu + \eta_j, \tag{2.4}$$

where $z \in$ [total, extensive, price, within, transport, prodcomp] denotes the different margins, $\nu$ is a constant and $\eta_j$ is the error term. Additional regressors are the same as in the product-level estimation less the dummy for island and Preferential Trade Agreement. We drop the latter two regressors to save degrees of freedom and because they are not significant in the total margin equation. We estimate (2.4) with simple OLS and robust standard errors in the case of the total margin. In the case of the five margins, we exploit the correlatedness of the errors and apply Seemingly Unrelated Regressions Estimation (SURE). The Breusch-Pagan test always rejects the independence of errors.

Table 2.6.1: Simple cross section estimation results, Time cost

| Dependent variable | $\beta$ estimate | s.e. | Adj./Pseudo $R^2$ |
|---|---|---|---|
| | *Exporter is US* | | |
| log total export | 0.001 | [0.007] | 0.85 |
| log shipment extensive | -0.007 | [0.008] | 0.85 |
| log price | -0.001 | [0.002] | 0.04 |
| log within physical size | 0.007*** | [0.003] | 0.35 |
| log transport mode | 0.001 | [0.001] | 0.31 |
| log product composition | 0.000 | [0.002] | 0.14 |
| Number of observations | 170 | | |
| Test $\beta_{price}+\beta_{within}$=0 | $\chi^2(1)$=5.41, p-val=0.020 | | |
| Breusch-Pagan test | $\chi^2(10)$=76.95, p-val=0.000 | | |
| | *Exporter is Spain* | | |
| log total export | -0.010 | [0.007] | 0.89 |
| log shipment extensive | -0.015** | [0.006] | 0.91 |
| log price | 0.003 | [0.002] | 0.18 |
| log within physical size | 0.004 | [0.004] | 0.23 |
| log transport mode | -0.001 | [0.001] | 0.06 |
| log product composition | -0.001 | [0.003] | 0.13 |
| Number of observations | 143 | | |
| Test $\beta_{price}+\beta_{within}$=0 | $\chi^2(1)$=4.04, p-val= 0.045 | | |
| Breusch-Pagan test | $\chi^2(10)$=75.68, p-val=0.000 | | |

Notes: OLS estimation of (2.4) with robust standard errors for total exports, SURE for the margins, on a cross section of importers. Pseudo $R^2$ is for SURE. Other regressors: log GDP, log GDP per capita, log distance, dummies for landlocked, Free Trade Agreement, colonial relationship, common language, and time to complete port/terminal handling and transport from nearest seaport. Breusch-Pagan test is for residual independence in SURE. * sign. at 10%, ** 5%; *** 1%.

We report $\beta$ estimates for the administrative time indicator for both the US and Spain in Table 2.6.1. Estimation results for the financial cost administrative barrier indicator are in Table 2.A.8 in the Appendix. By construction, the coefficients on the five margins sum up to the coefficient in the total margin regression. The sum of the price and the within margins is the value shipment size. We report Wald test statistics for the significance of the sum of these two coefficients.

The signs of the coefficient estimates are in most of the cases the expected, though only some of them are statistically significant. The strongest result is a significant positive response on the value shipment size to the administrative time variable: the larger administrative barriers are, the larger the value of the average shipment is. This effect mainly comes from adjustment on the (within) physical shipment size and not from a price effect. There is also evidence of a negative response on the shipment extensive margin, though it is statistically significant only in the Spanish sample. We find no effects on either the transport mode or the product composition margins.

### 2.6.3 Estimating theory-based gravity

So far we have estimated atheoretical gravity equations: we regressed exports (or its components) on variables of economic size and trade costs between the exporter and the importer. In this section we derive and estimate a theory-based reduced form gravity equation that is applicable to a cross section of importers and a multilateral trade cost variable. The administrative barriers are multilateral in nature in that they apply to all trading partners (except domestic trade).

As the seminal paper of Anderson and van Wincoop (2003) has shown, a proper gravity estimation should control for the Multilateral Trade Resistances (MTR) of the exporter and the importer. The MTR of the importer country (inward MTR) is an average measure of trade barriers the suppliers of this country (including trade partners and domestic suppliers) face. Similarly, outward MTR is an average measure of trade barriers that the exporter faces when exporting to the rest of the world. In the theory-based gravity equation trade depends not directly on trade costs between the two partners, but on the ratio of these trade costs to the exporter's and importer's MTRs. The theory links bilateral trade costs and inward and outward MTRs to each other in a complex non-linear way.

We follow the method of Baier and Bergstrand (2009) to control for the MTRs.[25] They propose a first-order log-linear Taylor series approximation of the non-linear MTR expressions around an equilibrium with symmetric trade frictions, i.e. when all bilateral trade costs are equal. This method allows for simple OLS estimation and, under some conditions, comparative static analysis. Moreover, it does not rely on the assumption of bilaterally symmetric trade costs. We can simplify the reduced form gravity equation of Baier and Bergstrand (2009) to the case of a cross section of importers to get

$$\ln\left(\frac{X_{ij}}{Y_j}\right) = \alpha + (1-\sigma)\left[\ln T_{ij} - \sum_{k=1}^{N}\theta_k \ln T_{kj}\right], \tag{2.5}$$

where $X_{ij}$ is export from either the US or Spain to country $j$, $Y_j$ is income of $j$, $T_{ij}$ are trade costs between the US or Spain and $j$, $\alpha$ is a constant, $\sigma$ is the elasticity of substitution between domestic and foreign goods, $\theta_k = \frac{Y_k}{\sum_{l=1}^{N} Y_l}$ is the share of country $k$ in world income and $N$ is the number of countries in the world (also including $j$). The sum of income-weighted trade costs between $j$ and all the countries (second term in the bracket with negative sign) captures the inward MTR of $j$. Note that the sum also includes domestic trade costs, i.e. trade costs of $j$ with itself.

This formula capture the intuition behind Anderson's and van Wincoop's (2003) result: trade flows only depend on relative trade costs. If all trade costs (including domestic trade cost $T_{jj}$) go up by the same amount, then trade does not change,

[25] Most empirical applications use country fixed effects (or country-time fixed effects in panels) to control for the MTRs. In our case fixed-effects estimation is not applicable for two reasons: we have only a country cross section and we want to identify the effect of a trade cost variable that has no bilateral variation. Alternatively, Anderson and van Wincoop (2003) apply structural estimation, but they need to rely on the assumption of bilateral trade cost symmetry.

because $\sum_{k=1}^{N}\theta_k = 1$. To conduct comparative statics with respect to an element of trade costs, we need to check how it affects *relative* trade costs.

We need to take into account that not all the trade cost variables have true bilateral variation. Let us define a log-linear trade cost function that contains two types of costs and an additive error term,

$$\ln T_{ij} = \delta_1 t_{ij} + \delta_2 f_{ij} + u_{ij},$$

where $f_{ij} = f_j$ for all $i \neq j$ and $f_{ij} = 0$ for $i = j$ and the $\delta$'s are parameters. It is easy to see that the term in the bracket in equation (2.5) simplifies to $\theta_j f_j$ for the second type of trade cost. After substituting the trade cost function in (2.5), the gravity equation becomes

$$\ln\left(\frac{X_{ij}}{Y_j}\right) = \alpha + (1-\sigma)\delta_1\left[t_{ij} - \sum_{k=1}^{N}\theta_k t_{kj}\right] + (1-\sigma)\delta_2\theta_j f_j + u_{ij}. \qquad (2.6)$$

In principle, estimating this equation gives consistent estimates of the gravity parameters. In practice, however, there are two issues to consider. First, if we do not restrict income elasticity to unity and put $Y_j$ on the right-hand side, we face a multicollinearity problem between $\theta_j f_j$ and $Y_j$ because $\theta_j$ is the income share of country $j$. Moreover, the inclusion of more than one $\theta_j f_j$ terms can lead to an even more severe multicollinearity problem. Second, the gravity parameter to estimate for the administrative barrier variable will be far larger than the corresponding comparative static effect (Behar, 2009). The gravity parameter is $(1-\sigma)\delta_2$ and the comparative static effect (specific to $j$) is approximately $(1-\sigma)\delta_2\theta_j$. The difference is a factor of the importer's income share, so it is always large.[26]

[26] The difference can get non-negligible for trade costs with bilateral variation too, if at least one of the trade partners has a relatively large income share. Formally, the comparative static effect for the bilateral trade cost is $(1-\sigma)\,\delta_1\,(1-\theta_j-\theta_i+\theta_i\theta_j)$.

We propose a modification of the estimating equation that helps resolve both concerns above. Decompose $\theta_j f_j$ in equation (2.6) as

$$\theta_j f_j = \bar{\theta}\ f_j + (\theta_j - \bar{\theta}) f_j, \tag{2.7}$$

where $\bar{\theta}$ is the mean of the $\theta_j$s across all importers. If instead of $\theta_j f_j$ we include $f_j$ and $(\theta_j - \bar{\theta}) f_j$ separately in the estimating equation, we can consistently estimate the comparative static effect for the average-sized importer, $(1-\sigma)\delta_2\bar{\theta}$, as the coefficient on $f_j$, which is not collinear with $Y_j$.

Table 2.6.2: Estimation results from theory-based gravity, Time cost

| Dependent variable | $\beta$ estimate | s.e. | Adj./Pseudo $R^2$ |
|---|---|---|---|
| | *Exporter is US* | | |
| log total export | -0.006 | [0.007] | 0.86 |
| log shipment extensive | -0.015* | [0.009] | 0.85 |
| log price | -0.001 | [0.002] | 0.06 |
| log within physical size | 0.007** | [0.003] | 0.36 |
| log transport mode | 0.001 | [0.001] | 0.29 |
| log product composition | 0.002 | [0.003] | 0.09 |
| Number of observations | 170 | | |
| Test $\beta_{price}+\beta_{within}$=0 | $\chi^2(1)$=4.21, p-val=0.040 | | |
| Breusch-Pagan test | $\chi^2(10)$=83.59, p-val=0.000 | | |
| | *Exporter is Spain* | | |
| log total export | -0.027*** | [0.008] | 0.87 |
| log shipment extensive | -0.034*** | [0.009] | 0.88 |
| log price | 0.003 | [0.003] | 0.19 |
| log within physical size | 0.005 | [0.005] | 0.24 |
| log transport mode | -0.001 | [0.002] | 0.07 |
| log product composition | 0.000 | [0.003] | 0.08 |
| Number of observations | 143 | | |
| Test $\beta_{price}+\beta_{within}$=0 | $\chi^2(1)$=3.34, p-val= 0.068 | | |
| Breusch-Pagan test | $\chi^2(10)$=81.32, p-val=0.000 | | |

Notes: OLS estimation with robust standard errors for total exports, SURE for the margins, on a cross section of importers. Pseudo $R^2$ is for SURE. Other regressors: log GDP, log GDP per capita, log distance, dummies for landlocked Free Trade Agreement, colonial relationship, common language, and time to complete port/terminal handling and transport from nearest seaport. MTR is controlled for by the method of Baier and Bergstrand (2009). Breusch-Pagan test is for residual independence in SURE. * sign. at 10%, ** 5%; *** 1%.

We calculate the MTR-adjusted trade costs as in the bracket in equation (2.6) for the trade cost variables in the regression (distance, landlocked, FTA, colonial relationship and common language dummies, and the port/terminal handling and inland transport cost).[27] Income shares are based on GDP data, and the world total is the sum of importers plus the exporter in either of the two samples. We apply the

[27]Domestic trade costs are internal distance for distance, 1 for FTA, colony and language dummies, 0 for landlocked and the port/terminal handling and inland transport cost.

solution in (2.7) only to the administrative barrier variable. We estimate (2.4) for each margin with the MTR-adjusted trade cost variables, log GDP and log GDP per capita on the right-hand side.

The results, presented in Table 2.6.2, reinforce the previous findings. The value shipment size is significantly larger for larger administrative barriers, which is primarily due to a larger physical shipment size and not a higher price. Compared to the simple cross section estimates, we find stronger evidence for a negative response on the shipment extensive margin. If administrative barriers are higher, the number of shipments is significantly lower in both US and Spanish exports. Finally, we find qualitatively small and statistically not significant coefficients on the transport mode and product composition margins.

## 2.7 Conclusion

Administrative barriers to trade such as document preparation and the customs process are non-negligible costs to the trading firm. Since such costs typically arise after each shipment, the firm can economize on them by sending fewer but larger shipments to destinations with high administrative costs. Such a firm response can partly explain the lumpiness of trade transactions, which has recently been documented in the literature.

Less frequent shipments cause welfare losses because of the larger discrepancy between the actual and the desired time of consumption. This paper built a simple "circular city" discrete choice model without inventories to study the effect of per shipment costs on shipment frequency, shipment size, price and welfare. The model implies that larger per shipment costs decrease shipment frequency, increase the shipment size and the price, and in the social optimum they unambiguously decrease welfare.

Exploiting the substantial variation in administrative trade costs by destination country, this paper provided empirical evidence on disaggregated US and Spanish export data. A decomposition of exports by destination enables us to identify responses to administrative costs separately on the shipment frequency, the price and the physical shipment size margins. Regarding the latter, we are also able to see adjustments via altering the transport mode or the export product mix. Evidence confirms that firms send larger-sized shipments less frequently to high-cost destinations, while total sales respond only marginally, if at all. We find however no convincing evidence for a positive price effect.

## 2.A Appendix

### 2.A.1 Additional derivations

#### Equilibrium number of shipments

The zero profit condition is

$$(p-c)q = f.$$

After substituting the equilibrium relationships $p = \frac{cn}{n-\tau}$ and $q = \frac{L}{n}$ and some manipulations we get a second degree polynomial equation in $n$

$$fn^2 - f\tau n - c\tau L = 0.$$

The solution that yields $n^* > 0$ is

$$n^* = \frac{\tau}{2}\left(1 + \sqrt{1 + \frac{4cL}{\tau f}}\right).$$

Taking the partial derivative with respect to $f$,

$$\frac{\partial n^*}{\partial f} = -\frac{Lc}{f^2}\left(1 + \frac{4cL}{\tau f}\right)^{-\frac{1}{2}} < 0.$$

#### Equilibrium shipment size

In symmetric equilibrium the shipment size is

$$q^* = \frac{L}{n^*}.$$

Substituting the solution for $n^*$ and collecting terms yields

$$q^* = \frac{2L}{\tau\left(1 + \sqrt{1 + \frac{4cL}{\tau f}}\right)}.$$

Taking the partial derivative with respect to $f$,

$$\frac{\partial q^*}{\partial f} = \frac{4cL^2}{\tau^2 f^2}\left(1 + \sqrt{1 + \frac{4cL}{\tau f}}\right)^{-2}\left(1 + \frac{4cL}{\tau f}\right)^{-\frac{1}{2}} > 0.$$

**Equilibrium price**

In symmetric equilibrium the price is given by

$$p^* = \frac{cn^*}{n^* - \tau}.$$

Substituting for $n^*$ one gets

$$p^* = c\frac{\sqrt{1 + \frac{4cL}{\tau f}} + 1}{\sqrt{1 + \frac{4cL}{\tau f}} - 1}.$$

Taking the partial derivative with respect to $f$ and collecting terms,

$$\frac{\partial p^*}{\partial f} = \frac{4c^2 L}{\tau f^2}\left(1 + \frac{4cL}{\tau f}\right)^{-\frac{1}{2}}\left(\sqrt{1 + \frac{4cL}{\tau f}} - 1\right)^{-2} > 0.$$

### 2.A.2 Data reference

#### US export data

US exports data is from the foreign trade database of the US Census Bureau. We consider only exports in 2005 to 170 destination countries. Monthly trade flows are recorded in 10-digit HS (Harmonized System) product, destination country and US district of origin dimensions. Although it is not a shipment-level database, more than half of the observations represent only one shipment.[28] Information is available on the number of shipments, the value in US dollars and the quantity of trade, as well as the value and weight of trade transported by air or vessel.

If the value of trade by air or vessel does not cover total trade value, we assume ground transportation. We drop those observations, where trade is associated with more than one transport mode (5.8% of observations, 25% of total number of shipments). Hence, one of the three transport modes (air, vessel, ground) is uniquely assigned to each observation.

We drop product lines, which correspond to low-value shipments. In the Census database trade transactions are reported only above a trade value threshold (USD 2,500 for exports). Low value shipment lines are estimates based on historical ratios of low value trade, except for Canada, where true data is available. They are classified under two product codes as aggregates. Hence, they appear erroneously as two large shipments and distort the shipment size distribution.[29]

We also drop product lines that mainly cover raw materials and fuels according to the BEC (Broad Economic Categories) classification. These are the products under

[28]The US Census Bureau defines a shipment accordingly: "Unless as otherwise provided, all goods being sent from one USPPI to one consignee to a single country of destination on a single conveyance and on the same day and the value of the goods is over $2,500 per schedule B or when a license is required.", where USPPI is a U.S. Principal Party in Interest, i.e. "The person or legal entity in the United States that receives the primary benefit, monetary or otherwise, from the export transaction."

[29]Low value shipment lines are 9880002000: "Canadian low value shipments and shipments not identified by kind", 9880004000: "Low value estimate, excluding Canada". In addition, we also drop the product line 9809005000: "Shipments valued USD 20,000 and under, not identified by kind".

the BEC codes 111-112 (primary food and beverages), 21 (primary industrial supplies), 31 (primary fuels and lubricants) and 321-322 (processed fuels and lubricants).

In the database there is no single quantity measure, which would apply to all product categories: product quantities are measured either in kilograms, numbers, square meters, liters, dozens, barrels, etc. In addition, weight in kilograms is recorded as separate variables for trade shipped by air or vessel.

We calculate price as a unit value, i.e. value over quantity. It is an f.o.b. price, since exports are valued at the port of export in the US and include only inland freight charges. It is important to calculate the price at least at the 10-digit product level, where the quantity measure per product is unique. For some products the quantity measure is not defined; here we assume that quantity equals value, i.e. the quantity measure is a unit of US dollar.

### Spanish export data

Data on Spanish exports in 2005 is from the Spanish Agencia Tributaria. It is a universal shipment-level database that records, among others, the month, the 8-digit CN (Combined Nomenclature) product code, the destination country, the transport mode, the value in euros and the weight in kilograms for each transaction.

In 2005 Spain exported only to 166 out of the 170 destination countries we consider for the US. In the regression analysis, we drop exports within the EU and, hence, the number of destination countries fall to 143. (Malta is not among the 166.)

This database includes low-value transactions. To make it comparable to the US database we drop transactions of value below EUR 2,000 (USD 2,500 converted to euros with the annual average exchange rate in 2005). Similar to the US case, we also drop transactions in raw materials and fuels. When necessary, we convert data in euros to US dollars with monthly average exchange rates.

**Other regressors**

GDP and GDP per capita of the importer countries in current USD for year 2005 is from the World Bank's World Development Indicators database.

Gravity variables (bilateral geographical distance, internal distance, dummies for landlocked, common language, colonial ties) are from CEPII. Bilateral distance is the population-weighted average of bilateral distances between the largest cities in the two countries, common language dummy refers to official language, colonial ties dummy refers to colonial relationship after 1945.[30]

The FTA and PTA dummies indicates free trade agreements and preferential trade agreements, respectively, effective in year 2005. They are based on the Database on Economic Integration Agreements provided by Jeffrey Bergstrand on his home page.[31] We define PTA as categories 1-2, FTA as categories 3-6 in the original database.



[30] Description of variables by CEPII: http://www.cepii.fr/distance/noticedist_en.pdf
[31] http://www.nd.edu/~jbergstr/#Links

### 2.A.3 Tables

Table 2.A.1: Importer countries in the regressions

| US | Spain | importer | US | Spain | importer | US | Spain | importer |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | Afghanistan | 58 | 47 | Gabon | 115 | 95 | Norway |
| 2 | 2 | Albania | 59 | 48 | Gambia | 116 | 96 | Oman |
| 3 | 3 | Algeria | 60 | 49 | Georgia | 117 | 97 | Pakistan |
| 4 | 4 | Angola | 61 | 50 | Ghana | 118 | 98 | Panama |
| 5 | 5 | Antigua and Barbuda | 62 | | Greece | 119 | 99 | Papua New Guinea |
| 6 | 6 | Argentina | 63 | 51 | Grenada | 120 | 100 | Paraguay |
| 7 | 7 | Armenia | 64 | 52 | Guatemala | 121 | 101 | Peru |
| 8 | 8 | Australia | 65 | 53 | Guinea | 122 | 102 | Philippines |
| 9 | | Austria | 66 | 54 | Guinea-Bissau | 123 | | Poland |
| 10 | 9 | Azerbaijan | 67 | 55 | Guyana | 124 | | Portugal |
| 11 | 10 | Bahamas | 68 | 56 | Haiti | 125 | 103 | Qatar |
| 12 | 11 | Bahrain | 69 | 57 | Honduras | 126 | 104 | Republic of Yemen |
| 13 | 12 | Bangladesh | 70 | 58 | Hong Kong | 127 | 105 | Romania |
| 14 | 13 | Belarus | 71 | | Hungary | 128 | 106 | Russia |
| 15 | | Belgium | 72 | 59 | Iceland | 129 | 107 | Rwanda |
| 16 | 14 | Belize | 73 | 60 | India | 130 | 108 | Sao Tome and Principe |
| 17 | 15 | Benin | 74 | 61 | Indonesia | 131 | 109 | Saudi Arabia |
| 18 | | Bhutan | 75 | 62 | Iran | 132 | 110 | Senegal |
| 19 | 16 | Bolivia | 76 | | Ireland | 133 | 111 | Seychelles |
| 20 | 17 | Bosnia-Herzegovina | 77 | 63 | Israel | 134 | 112 | Sierra Leone |
| 21 | 18 | Botswana | 78 | | Italy | 135 | 113 | Singapore |
| 22 | 19 | Brazil | 79 | 64 | Ivory Coast | 136 | | Slovakia |
| 23 | 20 | Brunei | 80 | 65 | Jamaica | 137 | | Slovenia |
| 24 | 21 | Bulgaria | 81 | 66 | Japan | 138 | 114 | Solomon Islands |
| 25 | 22 | Burkina | 82 | 67 | Jordan | 139 | 115 | South Africa |
| 26 | 23 | Burundi | 83 | 68 | Kazakhstan | 140 | | Spain |
| 27 | 24 | Cambodia | 84 | 69 | Kenya | 141 | 116 | Sri Lanka |
| 28 | 25 | Cameroon | 85 | 70 | Korea, South | 142 | 117 | St Kitts and Nevis |
| 29 | 26 | Canada | 86 | 71 | Kuwait | 143 | 118 | St Lucia |
| 30 | 27 | Cape Verde | 87 | 72 | Kyrgyzstan | 144 | 119 | St.Vincent&Grenadines |
| 31 | 28 | Central African Rep. | 88 | 73 | Laos | 145 | 120 | Sudan |
| 32 | 29 | Chad | 89 | | Latvia | 146 | 121 | Suriname |
| 33 | 30 | Chile | 90 | 74 | Lebanon | 147 | 122 | Swaziland |
| 34 | 31 | China | 91 | | Lesotho | 148 | | Sweden |
| 35 | 32 | Colombia | 92 | 75 | Liberia | 149 | 123 | Switzerland |
| 36 | 33 | Comoros | 93 | | Lithuania | 150 | 124 | Syria |
| 37 | 34 | Congo (Brazzaville) | 94 | | Luxembourg | 151 | 125 | Tajikistan |
| 38 | | Congo (Kinshasa) | 95 | 76 | Macedonia (Skopje) | 152 | 126 | Tanzania |
| 39 | 35 | Costa Rica | 96 | 77 | Madagascar | 153 | 127 | Thailand |
| 40 | 36 | Croatia | 97 | 78 | Malawi | 154 | 128 | Togo |
| 41 | | Cyprus | 98 | 79 | Malaysia | 155 | | Tonga |
| 42 | | Czech Republic | 99 | 80 | Maldives | 156 | 129 | Trinidad and Tobago |
| 43 | | Denmark | 100 | 81 | Mali | 157 | 130 | Tunisia |
| 44 | 37 | Djibouti | 101 | 82 | Mauritania | 158 | 131 | Turkey |
| 45 | 38 | Dominica | 102 | 83 | Mauritius | 159 | 132 | Uganda |
| 46 | 39 | Dominican Republic | 103 | 84 | Mexico | 160 | 133 | Ukraine |
| 47 | 40 | Ecuador | 104 | 85 | Moldova | 161 | 134 | United Arab Emirates |
| 48 | 41 | Egypt | 105 | 86 | Mongolia | | 135 | USA |
| 49 | 42 | El Salvador | 106 | 87 | Morocco | 162 | | United Kingdom |
| 50 | 43 | Equatorial Guinea | 107 | 88 | Mozambique | 163 | 136 | Uruguay |
| 51 | 44 | Eritrea | 108 | 89 | Namibia | 164 | 137 | Uzbekistan |
| 52 | | Estonia | 109 | 90 | Nepal | 165 | 138 | Vanuatu |
| 53 | 45 | Ethiopia | 110 | | Netherlands | 166 | 139 | Venezuela |
| 54 | | Germany | 111 | 91 | New Zealand | 167 | 140 | Vietnam |
| 55 | 46 | Fiji | 112 | 92 | Nicaragua | 168 | 141 | Western Samoa |
| 56 | | Finland | 113 | 93 | Niger | 169 | 142 | Zambia |
| 57 | | France | 114 | 94 | Nigeria | 170 | 143 | Zimbabwe |

Table 2.A.2: Shipment size by mode of transport

| Transport mode | Value shipment size ($) mean | median | st.dev | Physical shipment size (kg) mean | median | st.dev |
|---|---|---|---|---|---|---|
| *Exporter is US* | | | | | | |
| air | 37169 | 12757 | 249284 | 318 | 72 | 1264 |
| sea | 62102 | 21424 | 364305 | 51156 | 5368 | 838271 |
| ground | 28838 | 14273 | 681885 | 13870 | 7131 | 45985 |
| all | 35193 | 15200 | 460577 | 15188 | 964 | 389427 |
| *Exporter is Spain* | | | | | | |
| air | 28833 | 6570 | 408154 | 468 | 92 | 10325 |
| sea | 57418 | 14808 | 946887 | 42081 | 5350 | 522298 |
| ground | 69472 | 11947 | 566320 | 21781 | 1540 | 396921 |
| all | 61325 | 11842 | 686071 | 25248 | 1512 | 416202 |

Notes: US exports to 170 importers (most detailed data) and Spanish exports to 166 importers (shipment-level data) in 2005. In the case of US exports, statistics are frequency-weighted and physical shipment size is taken only when quantity is reported in kilograms.

Table 2.A.3: Time and financial costs of four import procedures

| | Time cost (days) | | | Financial cost (US$) | | |
|---|---|---|---|---|---|---|
| Procedure | Mean | % of total | CV | Mean | % of total | CV |
| Document preparation | 13.7 | 51.7 | 0.75 | 306.1 | 19.0 | 0.61 |
| Custom clearance and inspection | 3.7 | 14.0 | 0.74 | 213.7 | 13.2 | 0.97 |
| Port and terminal handling | 4.5 | 16.8 | 0.74 | 317.0 | 19.6 | 0.56 |
| Inland transportation from seaport | 4.7 | 17.5 | 1.56 | 778.0 | 48.2 | 1.08 |
| Total | 26.6 | 100.0 | 0.69 | 1614.8 | 100.0 | 0.63 |

Notes: Own calculations based on *Doing Business* data from 2009. Time and financial cost of the four procedures of an import transaction. Statistics for 170 countries. CV is coefficient of variation (standard deviation over the mean).

Table 2.A.4: Correlation coefficients of the *Doing Business* indicators

| | Admin time | Transit time | Log admin cost | Log transit cost |
|---|---|---|---|---|
| Admin time | 1 | | | |
| Transit time | 0.534 | 1 | | |
| | [0.000] | | | |
| Log admin cost | 0.394 | 0.349 | 1 | |
| | [0.000] | [0.000] | | |
| Log transit cost | 0.551 | 0.684 | 0.341 | 1 |
| | [0.000] | [0.000] | [0.000] | |
| Log GDP per capita | -0.567 | -0.479 | -0.397 | -0.366 |
| | [0.000] | [0.000] | [0.000] | [0.000] |

Notes: Own calculations based on *Doing Business* data from 2009. Admin = documentation + customs, Transit = port handling + inland transport. Time refers to the time cost, cost to the financial cost indicators. Statistics for 170 countries. Significance levels of correlation coefficients in brackets.

Table 2.A.5: Administrative barrier indicators by continent

| Continent | Number of countries | Time cost (days) median | min | max | Financial cost (US$) median | min | max |
|---|---|---|---|---|---|---|---|
| Africa | 51 | 21 | 9 | 57 | 630 | 115 | 1830 |
| America | 32 | 12 | 5 | 61 | 526 | 235 | 1500 |
| Asia | 42 | 16 | 2 | 61 | 386 | 92 | 1100 |
| Europe | 37 | 7 | 2 | 28 | 280 | 175 | 600 |
| Pacific | 8 | 11 | 4 | 23 | 263 | 170 | 389 |
| Total | 170 | 15 | 2 | 61 | 450 | 92 | 1830 |

Notes: Own calculations based on *Doing Business* data from 2009. Time and financial cost of the documentation and customs procedures of an import transaction. Statistics for 170 countries.

Table 2.A.6: Product-level estimates for US, Log Financial Cost

| Dependent variable | $\beta$ estimate | Robust s.e. | Adj.$R^2$ |
|---|---|---|---|
| | *all modes* | | |
| log export | -0.202*** | [0.036] | 0.41 |
| log number of months | -0.127*** | [0.015] | 0.38 |
| log shipment per month | -0.089*** | [0.014] | 0.38 |
| log value shipment size | 0.014 | [0.012] | 0.38 |
| log physical shipment size | 0.020 | [0.016] | 0.68 |
| log price | -0.006 | [0.009] | 0.73 |
| Number of observations | 400096 | | |
| Number of clusters | 10934 | | |
| Nr of product-mode effects | 18060 | | |
| | *only sea* | | |
| log export | -0.152*** | [0.038] | 0.33 |
| log number of months | -0.128*** | [0.018] | 0.30 |
| log shipment per month | -0.056*** | [0.012] | 0.26 |
| log value shipment size | 0.032** | [0.015] | 0.33 |
| log physical shipment size | 0.034* | [0.018] | 0.49 |
| log price | -0.001 | [0.010] | 0.59 |
| Number of observations | 195228 | | |
| Number of clusters | 9599 | | |
| Number of product effects | 7658 | | |

Notes: OLS estimation of (2.2) separately for each margin in (2.1) on a sample of US exports to 170 countries in 10-digit HS products in 2005. If transport mode is not restricted to sea, it is air, sea or ground. Product-mode fixed effects included. Other regressors: log GDP, log GDP per capita, log distance, dummies for island, landlocked, Free Trade Agreement, Preferential Trade Agreement, colonial relationship, common language, and cost to complete port/terminal handling and transport from nearest seaport. Only trade with quantity measured in kilograms included. Clustered robust standard errors with country and 2-digit product clusters. * sign. at 10%, ** 5%; *** 1%.

Table 2.A.7: Product-level estimates for Spain, Log Financial Cost

| Dependent variable | $\beta$ estimate | Robust s.e. | Adj.$R^2$ |
|---|---|---|---|
| | *all modes* | | |
| log export | 0.044** | [0.022] | 0.43 |
| log number of months | 0.004 | [0.012] | 0.36 |
| log shipment per month | 0.021*** | [0.006] | 0.43 |
| log value shipment size | 0.019 | [0.012] | 0.45 |
| log physical shipment size | 0.038** | [0.015] | 0.74 |
| log price | -0.019* | [0.010] | 0.79 |
| Number of observations | 117544 | | |
| Number of clusters | 7126 | | |
| Nr of product-mode effects | 15893 | | |
| | *only sea* | | |
| log export | 0.063** | [0.027] | 0.39 |
| log number of months | 0.008 | [0.015] | 0.34 |
| log shipment per month | 0.019*** | [0.007] | 0.41 |
| log value shipment size | 0.035** | [0.016] | 0.40 |
| log physical shipment size | 0.039** | [0.019] | 0.60 |
| log price | -0.004 | [0.012] | 0.72 |
| Number of observations | 64467 | | |
| Number of clusters | 6010 | | |
| Number of product effects | 6586 | | |

Notes: OLS estimation of (2.2) separately for each margin in (2.1) on a sample of Spanish exports to 143 non-EU countries in 8-digit CN products in 2005. If transport mode is not restricted to sea, it is air, sea, or ground. Product--mode fixed effects included. Other regressors: log GDP, log GDP per capita, log distance, dummies for island, landlocked, Free Trade Agreement, Preferential Trade Agreement, colonial relationship, common language, and cost to complete port/terminal handling and transport from nearest seaport. Clustered robust standard errors with country and 2-digit product clusters. * sign. at 10%, ** 5%; *** 1%.

Table 2.A.8: Simple cross section estimation results, Log Financial Cost

| Dependent variable | $\beta$ estimate | s.e. | Adj./Pseudo $R^2$ |
|---|---|---|---|
| | *Exporter is US* | | |
| log export | 0.021 | [0.176] | 0.86 |
| log number of shipments | -0.053 | [0.143] | 0.86 |
| log price | -0.075** | [0.032] | 0.07 |
| log physical shipment size | 0.107** | [0.050] | 0.33 |
| log mode composition | 0.006 | [0.020] | 0.30 |
| log product composition | 0.035 | [0.047] | 0.15 |
| Test $\beta_{price}$+$\beta_{physicalsize}$=0 | $\chi^2(1)$=0.47, p-val=0.492 | | |
| Breusch-Pagan test | $\chi^2(10)$=72.48, p-val=0.000 | | |
| | *Exporter is Spain* | | |
| log export | -0.008 | [0.155] | 0.89 |
| log number of shipments | -0.019 | [0.120] | 0.91 |
| log price | 0.017 | [0.046] | 0.16 |
| log physical shipment size | 0.055 | [0.083] | 0.23 |
| log mode composition | 0.012 | [0.028] | 0.06 |
| log product composition | -0.073 | [0.051] | 0.14 |
| Number of observations | 143 | | |
| Test $\beta_{price}$+$\beta_{physicalsize}$=0 | $\chi^2(1)$=1.18, p-val= 0.277 | | |
| Breusch-Pagan test | $\chi^2(10)$=72.58, p-val=0.000 | | |

Notes: OLS estimation with robust standard errors for total exports, SURE for the margins, on a cross section of importers. Pseudo $R^2$ is for SURE. Other regressors: log GDP, log GDP per capita, log distance, dummies for landlocked Free Trade Agreement, colonial relationship, common language, and cost to complete port/terminal handling and transport from nearest seaport. Breusch-Pagan test is for residual independence in SURE. * sign. at 10%, ** 5%; *** 1%.

Table 2.A.9: Estimation results from theory-based gravity, Log Financial Cost

| Dependent variable | $\beta$ estimate | s.e. | Adj./Pseudo $R^2$ |
|---|---|---|---|
| | *Exporter is US* | | |
| log export | -0.147 | [0.160] | 0.86 |
| log number of shipments | -0.279* | [0.146] | 0.85 |
| log price | -0.053* | [0.032] | 0.07 |
| log physical shipment size | 0.112** | [0.049] | 0.34 |
| log mode composition | 0.008 | [0.020] | 0.29 |
| log product composition | 0.065 | [0.048] | 0.10 |
| Number of observations | 170 | | |
| Test $\beta_{price}$+$\beta_{physicalsize}$=0 | $\chi^2(1)$=1.61, p-val=0.204 | | |
| Breusch-Pagan test | $\chi^2(10)$=80.32, p-val=0.000 | | |
| | *Exporter is Spain* | | |
| log export | -0.052 | [0.166] | 0.86 |
| log number of shipments | -0.059 | [0.144] | 0.86 |
| log price | 0.032 | [0.044] | 0.19 |
| log physical shipment size | 0.010 | [0.080] | 0.23 |
| log mode composition | 0.011 | [0.027] | 0.06 |
| log product composition | -0.046 | [0.051] | 0.09 |
| Number of observations | 143 | | |
| Test $\beta_{price}$+$\beta_{physicalsize}$=0 | $\chi^2(1)$=0.41, p-val= 0.524 | | |
| Breusch-Pagan test | $\chi^2(10)$=81.72, p-val=0.000 | | |

Notes: OLS estimation with robust standard errors for total exports, SURE for the margins, on a cross section of importers. Pseudo $R^2$ is for SURE. Other regressors: log GDP, log GDP per capita, log distance, dummies for landlocked Free Trade Agreement, colonial relationship, common language, and cost to complete port/terminal handling and transport from nearest seaport. MTR is controlled for by the method of Baier and Bergstrand (2009). Breusch-Pagan test is for residual independence in SURE. * sign. at 10%, ** 5%; *** 1%.

# Chapter 3

# Gravity or Dummies? The Limits of Identification in Gravity Estimations

## 3.1 Introduction

Measuring the effects of trade policy changes on bilateral trade flows has always been a central issue in the empirical trade literature. These effects can be heterogenous across groups of country pairs or asymmetric regarding the direction of trade. Rose (2004) examines differential effects of one-sided and joint WTO membership. Baldwin, Skudelny and Taglioni (2005) and Flam and Nordström (2006) find that the euro increased trade not only among members but, to a lesser extent, also between members and non-members. Learning about such heterogeneous effects is essential to know how trade policies work. In what way such effects can be identified in empirical research is not always clear, however. Since the seminal paper of Anderson and van Wincoop (2003) empirical applications of the gravity equation, the workhorse model of trade, has been challenged by the need to account for the so-called Multilateral

Trade Resistances (henceforth, MTR). The MTRs of the exporter and the importer in the theoretical gravity equation are average measures of trade barriers the exporter faces in, and the importer imposes on, all the countries in the world, and are linked to all bilateral trade costs and to each other non-linearly.

This paper considers one particular empirical specification of the gravity equation, which aims at controlling for the MTRs with dummies, and examines its ability to identify (potentially heterogeneous) effects of trade policy changes. The gravity specification is what I call the "fixed-effects country-time dummies gravity specification" for panel data. It includes fixed effects for all country pairs and a full set of exporter-time and importer-time dummies, the latter controlling for the time-varying MTRs.[1] The same specification was proposed by Baltagi, Egger and Pfaffermayr (2003) and Baldwin and Taglioni (2006) as the theory-consistent fixed effects specification of the gravity equation. In this paper, I argue that the fixed-effects country-time dummies gravity specification severely limits the set of trade policy effects that can be identified from the data. In many applications, identifying heterogeneous effects is not possible at all because of perfect collinearity among the trade policy dummies and the country-time dummies. Moreover, the problem may not be apparent for the first sight, when one uses standard estimation techniques.

Let me consider an example to illustrate the main argument. Take a set of countries that enter a customs union at the same time. A researcher may be interested in using this episode to measure the trade-creating effect of the customs union. She may believe that entering the union has a one-off effect on trade, which can be measured by comparing the growth of trade of the entrants between the pre-entry and the post-entry years, relative to some benchmark. When a country has long been a member (insider), there is no such union effect any more. This enables the researcher to use the growth of trade among insider countries as a comparison group (bench-

[1] This specification has a cross section analogue with exporter and importer dummies. The findings of this paper also apply to the cross section case.

mark). There are three different groups of country pairs with possible trade-creating effect: trade among entrants, trade from entrants to insiders, and trade from insiders to entrants. Suppose that trade growth was 5 per cent in the first and 1-1 per cents in the second and third groups, while there was zero growth in trade among insiders.

The researcher may believe that the entry affected only trade among entrants and she may decide to put trade between entrants and insiders also in the benchmark. This may be justified, if e.g. trade between the union and the entrants was governed by a free trade agreement (FTA) well before the time of entry. FTA and customs union differ only in the trade protection with third countries, which is automatically controlled for by the country-time dummies in the fixed-effects country-time dummies gravity specification. Alternatively, the researcher may think that all the three groups of pairs with at least one entrant are affected by the entry and wants to measure an average effect across the three, compared to trade among insiders. If she uses the fixed effects country-time dummies gravity specification, the estimated trade-creating effect she gets is 3 per cent in the first and -3 per cent in the second case.

I demonstrate in this paper that the astonishing result of getting estimates that are negatives of each other under two ultimately similar research questions is because the fixed-effects country-time dummies gravity specification leaves too little variation in the data. In the above example, there is in fact only one parameter the gravity specification is able to identify. In other words, estimates under different research questions degenerate to simple transformations (like the negative) of a single parameter. A direct consequence of this is that it is not possible to identify more than one effects simultaneously (heterogeneous effects). The above researcher may want to estimate separate effects for trade among entrants and trade between entrants and insiders by including two policy dummies in the estimating equation. I argue that it is not possible in the above setup, because one of the policy dummies will be perfectly collinear with the set of country-time dummies.

Perfect collinearity of the policy dummy with other dummies in the regression is a trivial case for unidentification. Yet, the problem may not be apparent for the first sight, if the researcher uses standard estimation techniques and software. I demonstrate this for Fixed Effects Least Squares Dummy Variables (FE-LSDV) and 'OLS on the demeaned' estimations, using STATA. In the case of FE-LSDV estimation, the software often drops one of the country-time dummies and reports policy effect estimates orderly. If the estimation involves hundreds of country-time dummies, it is likely that the researcher overlooks the problem. OLS on the demeaned reveals the problem and drops the perfectly collinear policy dummy, given that it is properly performed. The demeaning transformation that is used to demean the data before estimation requires a data set that also includes trade of a country with itself (domestic trade). However, if such data is not included, which is usually the case with foreign trade databases, OLS on the demeaned also reports false estimates for the perfectly collinear policy dummy.

A possible solution to the identification problem is to extend the database with countries that are, in none of the trading pairs they form, affected by the policy change. In the above example these may be countries that are outside of the customs union in the whole sample period (so-called third countries). I will show that *at most* four different policy effects can be identified simultaneously in such an extended database. It is crucial, however, that changes in trade barriers with third countries are not correlated with the policy or they are appropriately controlled for by hard data (e.g. data on tariff changes). Entering a customs union involves adopting the union's common external trade policy, i.e. trade protection between entrants and third countries must change. If the researcher does not account for this in the estimation, third countries' trade is not a valid benchmark. If, lacking hard data on trade protection, she wants to control for the third country effects by including additional dummies, the previous identification problem can return.

This paper is a contribution to the literature on the proper econometric specification of the gravity equation. With the development of panel data econometrics, several authors emphasized the importance of country or country pair fixed effects in accounting for the unobserved (time-constant) heterogeneity in the gravity equation (Mátyás (1997), Glick and Rose (2001), Egger and Pfaffermayr (2003), Cheng and Wall (2005)). After the contribution of Anderson and van Wincoop (2003), however, trade economists realized that time-constant fixed effects are insufficient to capture the unobservable time-varying MTR. This lead to the proposition of the fixed-effects country-time dummies gravity specification by Baltagi, Egger and Pfaffermayr (2003) and Baldwin and Taglioni (2006).[2] Estimating gravity with some sets of fixed effects or dummies has been popular among empirical trade researcher, because it can be performed easily and it offers a robust way to control for the unobserved. Alternative solutions to the MTR problem are all imperfect in one way or another. Structural estimation (Anderson and van Wincoop (2003), Bergstrand, Egger and Larch (2010)) is computationally burdensome and requires strict assumptions. Other methods, developed in the recent years, are more data-demanding and/or cannot treat asymmetric trade barriers (Head and Ries (2001), Combes, Lafourcade and Mayer (2005), Novy (2008), Baier and Bergstrand (2009)).

The contribution of this paper is, in general, to show an important drawback of relying on dummies extensively to control for the unobserved heterogeneity in the estimation. Dummies offer a robust control, but they can also absorb too much of the useful variation in the data. In particular, I discourage empirical trade researchers to use the fixed-effects country-time dummies gravity specification, except for some special cases. I demonstrate the above findings with an empirical example: the enlargement of the European Union (EU) in 2004 with eight Central and Eastern European countries and its trade consequences.

[2] Application of this gravity specification, however, has not become widespread. One example is Eicher and Henn (2009) on the effect of WTO membership.

The findings of the paper are more general than the presented examples. They equally apply to cross section gravity estimations, when the estimating equation includes a full set of exporter and importer dummies. Moreover, they apply not only to trade policy dummies, but also to other dummy regressors in the gravity equation (e.g. common language). Finally, these lessons can be useful for empirical researchers in other fields of Economics as well. Multidimensional panel estimations and the tendency to use dummies to control for the unobserved heterogeneity is not confined to the empirical trade research.

The paper is structured as follows. Section 3.2 presents the fixed-effects country-time dummies gravity specification. Section 3.3 describes four research questions on the effect of a trade policy. Section 3.4 examines whether the policy effects under the four research questions are identified and, if they are, what is the estimated effect. Section 3.5 considers the extension of the database with third countries. Section 3.6 presents a summary and discussion.

## 3.2 The fixed-effects country-time dummies gravity

The gravity equation derived from the model of Anderson and van Wincoop (2003) is

$$x_{ij} = \frac{y_i y_j}{y^w} \left( \frac{\tau_{ij}}{\Pi_i P_j} \right)^{1-\sigma}, \tag{3.1}$$

subject to the expressions for $\Pi_i$ and $P_j$,

$$P_j^{1-\sigma} = \sum_i \frac{y_i}{y^w} \left( \frac{\tau_{ij}}{\Pi_i} \right)^{1-\sigma} \tag{3.2}$$

and

$$\Pi_i^{1-\sigma} = \sum_j \frac{y_j}{y^w} \left( \frac{\tau_{ij}}{P_j} \right)^{1-\sigma}, \tag{3.3}$$

where $x_{ij}$ is exports from country $i$ to $j$, $y_i$ and $y_j$ are nominal income of the exporter and the importer, respectively, $y^w$ is world income, $\tau_{ij}$ is the bilateral trade costs between the exporter and the importer, and $\sigma$ is the elasticity of substitution between all goods. $\Pi_i$ and $P_j$ are the Multilateral Trade Resistances (MTR) for the exporter and the importer, respectively. More precisely, $\Pi_i$ is a measure of trade barriers that country $i$'s exports face in the rest of the world and $P_j$ is a measure of trade barriers that country $j$ imposes on imports from the rest of the world.

Let us define the logarithm of income-adjusted exports, $z_{ij} = \ln \left( \frac{x_{ij} y^w}{y_i y_j} \right)$, introduce the time dimension $t$, and express (3.1) in logarithms,

$$z_{ijt} = (1-\sigma) \ln \tau_{ijt} - (1-\sigma) \ln \Pi_{it} - (1-\sigma) \ln P_{jt}. \tag{3.4}$$

Putting income-adjusted exports on the left-hand side implies unit income elasticity, consistent with the theory. Although this assumption is often relaxed in empirical applications, we keep it for the simplicity of the exposition.[3]

Notice that both bilateral trade costs and the MTR terms can vary with time. Let the bilateral trade cost function, $\ln \tau_{ijt}$, be additively separable in its time-varying and time-constant cost components and assume, for simplicity, that the time-varying component can be captured by a policy dummy variable, $T_{ijt}$, with some parameter and an additive error term, $u_{ijt}$, uncorrelated with the policy dummy. Then, the fixed-effects country-time dummies specification for panel data, consistent with (3.4), can be expressed as

$$z_{ijt} = \beta T_{ijt} + \zeta_{ij} + \delta_{it} + \theta_{jt} + u_{ijt}, \tag{3.5}$$

[3]Relaxing the assumption would not change the findings, because the country-time dummies net out all country-time-specific variables, including the income levels.

where $\zeta_{ij}$ are (direction-specific) pair fixed effects and $\delta_{it}$ and $\theta_{jt}$ are a full set of exporter-time and importer-time dummies. The trade effect of the policy is captured by $\beta$, which is the product of $1-\sigma$ and the parameter of the policy dummy in the bilateral trade cost function.

The presence of the exporter-time and importer-time dummies in (3.5) is required, because the MTRs in (3.4) are not observable and potentially vary with time. In contrast, the inclusion of the pair fixed effects ($\zeta_{ij}$) is not directly motivated by the theory. Nevertheless, in panel data applications, when the regressor of interest varies with time, it is customary to control for time-invariant unobservable bilateral trade costs via country pair fixed effects. Many elements of bilateral trade costs, like those related to culture or institutions, cannot be observed and hardly change with time. Researchers tend to choose to avoid omitted variable biases stemming from these unobserved bilateral costs by including pair fixed effects.[4] Some research explicitly follows a difference-in-differences strategy to capture the effect of a policy change (Hornok, 2011). This strategy identifies from the time changes across different groups of country pairs and, hence, requires that time invariant factors are netted out by pair fixed effects.

The panel gravity specification in (3.5) has a cross section equivalent under some conditions. Assume that the trade policy change occurs at one point in time, which defines a two-period panel with $t=1$ pre-policy and $t=2$ post-policy periods. Time-differencing (3.5) on the two-period panel yields

$$dz_{ij} = \beta dT_{ij} + \alpha_i + \eta_j + \epsilon_{ij}, \tag{3.6}$$

where $d$ denotes the time change from $t$=1 to $t$=2, $\alpha_i$ and $\eta_j$ are exporter and importer fixed effects and the error is $\epsilon_{ij} = du_{ijt}$.

[4] Egger and Pfaffermayr (2003) argue for pair fixed effects over separate exporter and importer fixed effects. Baltagi, Egger and Pfaffermayr (2003) and Baldwin and Taglioni (2006) also suggest a gravity specification with pair fixed effects.

In what follows I assume a two-period panel with pre-policy and post-policy periods and derive the analytical results for (3.6). I exploit that the fixed effects and the first-difference panel estimation methods are identical in two-period panels. This can be done without loss of generality. The analytical findings directly extend both to traditional cross section gravity estimations with exporter and importer dummies and to multiple-period panel estimations of the form (3.5), given that the panel has well-defined pre-policy and a post-policy periods (i.e. no sequential policies).

## 3.3 Four research questions

To demonstrate the limits of the fixed-effects country-time dummies gravity specification I consider four research questions on the same data set and trade policy episode. The episode is the enlargement of the EU in 2004 with 8 Central and Eastern European countries.[5] The EU is a customs union, which means tariff-free intra-EU trade and a common external trade protection. Although trade was free for most products due to bilateral FTAs between the pre-2004 EU and the entrants and among the entrants themselves years before the enlargement, evidence shows that the enlargement brought further trade-creation.[6]

Let the sample include two types of countries: entrants and insiders to the customs union. For the moment abstract from outsiders, the third country type. The two types of countries form four groups of country pairs, shown in Figure 3.3.1. Group $G_{11}$ includes pairs, where both the exporter and the importer are entrants, $G_{12}$ are pairs with an entrant exporter and an insider importer, and so on. The number of countries in each type can be arbitrary. If the number is only one, then the within-group trade is trade of a country with itself (domestic trade).

[5] I do not consider Cyprus and Malta, which also joined the EU in May 2004.

[6] See Hornok (2010, 2011).

Figure 3.3.1: Groups of pairs with entrants and insiders

| $i \backslash j$ | entrant | insider |
|---|---|---|
| entrant | $G_{11}$ | $G_{12}$ |
| insider | $G_{21}$ | $G_{22}$ |

When a researcher wants to measure the effect of a trade policy, she needs to define two sets of country pairs: those who are "treated" by the policy (treated) and those who are not (benchmark). Which pairs are treated and which are the benchmark is ultimately an empirical issue. Depending on how this choice is made I define four different research questions:

1. $G_{11}$ is treated, the other three are the benchmark;

2. $G_{11}$, $G_{12}$ and $G_{21}$ are treated and a common effect is estimated for them, $G_{22}$ is the benchmark;

3. $G_{11}$, $G_{12}$ and $G_{21}$ are treated, a separate effect is estimated for $G_{11}$ and a common effect for the other two, $G_{22}$ is the benchmark;

4. $G_{12}$ and $G_{21}$ are the treated and a common effect is estimated for them, $G_{11}$ and $G_{22}$ are the benchmark.

The research question determines the exact formulation of the policy dummy, $T_{ijt}$, in (3.5). In the first case, it is 1 for country pairs in $G_{11}$ in $t$=2 and 0 otherwise. In the second case, it is 1 for pairs in $G_{11}$, $G_{12}$ and $G_{21}$ in $t$=2 and 0 otherwise. In the third case, there are two policy dummies. The first takes value 1 for pairs in $G_{11}$ in the post-policy period and 0 otherwise, the second is 1 for pairs in $G_{12}$ and $G_{21}$ in the post-policy period and 0 otherwise. In the last case, there is one policy dummy that takes 1 for pairs in $G_{12}$ and $G_{21}$ in $t$=2 and 0 otherwise.

Let country pairs in $G_{22}$ be always part of the benchmark. In the EU enlargement example, it relies on the assumption that trade among countries that were already inside the EU in 2004 is not affected by the enlargement. Membership in the EU is likely to have a one-off effect on trade growth, which materializes in the first couple of years after entry and insiders had been already members for one or more decades at the time of enlargement.

In the first research question, the researcher wants to estimate a policy effect for trade among entrants ($G_{11}$), while she puts trade between entrants and insiders ($G_{12}$ and $G_{21}$), together with $G_{22}$, in the benchmark. She may believe that EU enlargement could bring no further trade creation in $G_{12}$ and $G_{21}$, because free trade of most goods was achieved by FTAs ('Europe Agreements') between the pre-2004 EU and the entrants already in the first half of the 1990s.[7] Indeed, trade growth after 2004 was much faster among entrants than between entrants and insiders.

The second research question puts trade between entrants and insiders ($G_{12}$ and $G_{21}$) also in the treated group. The researcher may believe that EU membership decreases some non-tariff trade barriers, which are not eliminated by an FTA, and the fall of these costs affects all trading pairs with at least one entrant equally. Such a non-tariff trade barrier can be e.g. the time cost of trade: trade is faster for country pairs within the EU, because there are no border controls and customs procedures (Hornok, 2011). In this case, the researcher wants to estimate a common effect for the above three groups of country pairs.

The third question is similar to the second, with one difference. It wants to estimate two separate policy effects simultaneously: one effect for $G_{11}$ and a separate (common) effect for $G_{12}$ and $G_{21}$. This research question assumes that a policy has a significantly different effect on a country pair, where both countries are subject to the policy, than on a country pair with only one country, who introduced the policy. It is similar to the approach in Rose (2004, 2005), who examines separate trade effects for joint and unilateral WTO membership. De Benedictis, De Santis, Vicarelli (2005) also take a similar approach on European data, when they compare the pre-2004

[7]Trade among entrants was also subject to FTAs (CEFTA, BAFTA). These were formed somewhat later, in the second half of the 1990s.

regional FTAs among entrants (CEFTA, BAFTA) with the FTAs between entrants and insiders.

The fourth research question asks how trade between entrants and outsiders changed with enlargement, relative to trade among entrants and trade among insiders. Namely, the researcher looks at trade across, relative to within, country types. In the EU enlargement context, this question is not particularly relevant. In other applications, however, it is common. The best example is the so-called 'border effect' literature, which was initiated by the paper of McCallum (1995). This literature looks at how much smaller trade is across nations (international trade), relative to trade within nations (intranational trade). Similarly, research that examines the trade effect of sharing the same language or currency, e.g., is often of this type.[8]

Notice that what the researcher thinks about the evolution of trade costs with third countries is irrelevant as long as the panel estimating equation controls for the MTRs with country-time dummies and the sample does not include trade with third countries. Later in this paper, when I consider samples with third countries, this argument will no longer hold and controlling for trade cost changes with third countries will be an issue.

## 3.4 What is identified and what is not?

I derive the policy effect estimates, $\hat{\beta}$, for the first-differenced panel estimating equation (3.6) under each research question, check whether the effects are identified and, if they are, how the estimates relate to each other. I assume that the sample includes observations for all the country pairs that can be formed with $n_1$ entrant and $n_2$ insider countries ($n_1$ can be different from $n_2$). The sample also includes domestic trade for all the $N = n_1 + n_2$ countries.[9]

[8]See e.g. Rose and van Wincoop (2001) on the effects of currency unions.

[9]Unlike the coefficient estimate, identifiability does not depend on whether domestic trade is included or not.

A simple way to solve for the policy effect estimate analytically is to demean $dz_{ij}$ and $dT_{ij}$ from the exporter and importer dummies in (3.6) and then run OLS regression on the demeaned variables. The $ij$-th element of the demeaned left-hand side variable, $\ddot{dz}$, is

$$\ddot{dz}_{ij} = dz_{ij} - \frac{1}{N}\sum_{i=1}^{N} dz_{ij} - \frac{1}{N}\sum_{j=1}^{N} dz_{ij} + \frac{1}{N^2}\sum_{j=1}^{N}\sum_{i=1}^{N} dz_{ij}, \tag{3.7}$$

and similarly for the demeaned policy dummy, $\ddot{dT}$.[10] Then, the estimate for $\beta$ can be obtained via the OLS formula $\hat{\beta} = \left(\ddot{dT}'\ddot{dT}\right)^{-1}\ddot{dT}'\ddot{dz}$.

To express the demeaned variables in vector form, take the vector of the left-hand side variable as $dz' = \begin{bmatrix} \bar{dz}_{11} & \bar{dz}_{12} & \bar{dz}_{21} & \bar{dz}_{22} \end{bmatrix}$, where the elements are simple averages of the $z_{ij}$'s across the country pairs belonging to the same group. Hence, $\bar{dz}_{11}$ is the simple average of the $n_1^2$ country pair observations belonging to $G_{11}$, $\bar{dz}_{12}$ is the simple average of the $n_1 n_2$ country pair observations belonging to $G_{12}$, and so on. It is straightforward to show that the vector of the demeaned left-hand side variable is $\ddot{dz}' = \triangle N^{-2}\begin{bmatrix} n_2^2 & -n_1n_2 & -n_1n_2 & n_1^2 \end{bmatrix}$, where $\triangle = \bar{dz}_{11} - \bar{dz}_{12} - \bar{dz}_{21} + \bar{dz}_{22}$. The demeaned vectors of policy dummies can be similarly obtained and the policy effect coefficients calculated using the OLS formula. I present the demeaned policy dummies and the $\beta$ estimates for each research question separately in Table 3.4.1.

Table 3.4.1: The demeaned policy dummies and the $\beta$s

| Research question | Demeaned policy dummy ($\ddot{dT}$) | $\hat{\beta}$ |
|---|---|---|
| 1 | $N^{-2}\begin{bmatrix} n_2^2 & -n_1n_2 & -n_1n_2 & n_1^2 \end{bmatrix}$ | $\triangle$ |
| 2 | $-N^{-2}\begin{bmatrix} n_2^2 & -n_1n_2 & -n_1n_2 & n_1^2 \end{bmatrix}$ | $-\triangle$ |
| 3.1 | $N^{-2}\begin{bmatrix} n_2^2 & -n_1n_2 & -n_1n_2 & n_1^2 \end{bmatrix}$ | not identified |
| 3.2 | $-2N^{-2}\begin{bmatrix} n_2^2 & -n_1n_2 & -n_1n_2 & n_1^2 \end{bmatrix}$ | separately |
| 4 | $-2N^{-2}\begin{bmatrix} n_2^2 & -n_1n_2 & -n_1n_2 & n_1^2 \end{bmatrix}$ | $-\frac{\triangle}{2}$ |

Notes: $N = n_1 + n_2$, where $n_1$ is the number of entrants, $n_2$ the number of insiders in the sample. $\triangle = \bar{dz}_{11} - \bar{dz}_{12} - \bar{dz}_{21} + \bar{dz}_{22}$, where the $\bar{dz}$'s are averages of observations of the LHS variable in eq. (3.6) across country pair groups in Figure 3.3.1.

[10] This formula, also called within transformation formula, is present in several Econometrics textbook like e.g. Baltagi (2001). The demeaning formula for the panel equation (3.5) is more complicated. I provide a derivation of it in Appendix 3.A.1.

The answer to the first research question "How much more trade among entrants grew as a result of the policy, relative to the trade of other pairs?" is given by $\hat{\beta} = \triangle = \bar{d}z_{11} - \bar{d}z_{12} - \bar{d}z_{21} + \bar{d}z_{22}$, where $dz$ is the change in the level of (income-adjusted) trade from the pre-policy to the post-policy period in either of the country pair groups. If, like in the Introduction, I assume that (income-adjusted) trade grew by 5% among entrants and by 1% between entrants and insiders, while it did not change among insiders, the estimated policy effect becomes 3%. If I modify the research question and ask "How much more trade of country pairs with at least one entrant grew as a result of the policy, relative to trade among insiders?"(second research question), the estimated coefficient changes sign and becomes $\hat{\beta} = -\triangle$, i.e. -3%. Since the two research questions are not mirror images to each other, such a change in the estimated policy effect does not look reasonable.

The estimate under the fourth research question "How much different trade growth was between entrants and insiders, relative to trade growth among entrants or insiders?" is $\hat{\beta} = -\frac{\triangle}{2}$, yet again a simple transformation of the same parameter, $\triangle$. This suggests that, for the fixed-effects country-time dummies gravity specification, the range of coefficient estimates under different research questions are severely restricted. In fact, for samples with only two types of countries (here entrant and insider), there is only one parameter that can be identified and the coefficient estimates under different research questions are simple transformations of this one parameter.

The two policy effects under the third research question cannot be identified separately. This is another consequence of the fact that the fixed-effects country-time dummies gravity specification on a sample of entrants and insiders cannot identify more than one policy effects. Notice that the two demeaned policy dummies in Table 3.4.1 are clearly perfectly collinear (3.1 stands for the effect on trade among entrants, 3.2 for the effect on trade between entrants and insiders). Another way to see that more than one policy dummies cannot be identified is to write out the matrix of regressors in (3.6) for the third research question,

$$\begin{bmatrix} \alpha & \eta & dT \end{bmatrix} = \begin{bmatrix} 1 & 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 & 1 \\ 0 & 1 & 0 & 0 & 0 \end{bmatrix}, \tag{3.8}$$

where the elements of the matrix are vectors of ones or zeros of dimensions ${n_1}^2$ in the first, $n_1 n_2$ in the second and third and ${n_2}^2$ in the fourth rows of the matrix. The first two columns of the matrix are the exporter dummies, the third column includes the importer dummies for entrants (importer dummies for insiders omitted) and the last two columns are the two policy dummies. Since the number of linearly independent columns should always be equal to the number of linearly independent rows, the five column vectors of this matrix cannot be linearly independent. The exporter and importer dummies already take three out of the maximum four linearly independent column vectors. Hence, there is room left for only one linearly independent policy dummy.[11]

I demonstrate the above findings on the example of EU enlargement by estimating policy effects under all the four research questions on a panel of country pairs formed by 8 entrants and 12 insiders in three years before (2001-2003) and three years after the enlargement (2004-2006).[12,13] I use annual data and not a two-period panel to show

[11] Of course, having only one policy dummy is a necessary but not sufficient condition for linear independence and, hence, identification. Even if there is only a single policy dummy, identification is not possible if the regressor matrix is of deficient rank. This means that the policy dummy is constructed so that it is perfectly collinear with one or more of the country dummies. This would be the case if the researcher wanted to estimate e.g. the effect on $G_{11}$ and $G_{12}$, relative to $G_{21}$ and $G_{22}$. In this case the policy dummy is, by construction, perfectly collinear with the exporter dummies for the entrants (first column of the regressor matrix).

[12] Entrants: Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia. Insiders: Austria, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Portugal, Spain, Sweden, United Kingdom.

[13] The post-policy period starts with 2004, although the date of enlargement was precisely 1 May 2004.

that the analytical findings extend to multiple period panels. I estimate (3.5) with income-adjusted bilateral exports on the left-hand side, where income is captured by nominal GDP levels.[14] I use two estimation methods, FE-LSDV with pair fixed effects and exporter-year and importer-year dummies and OLS on the demeaned variables, both performed in STATA. For the latter method it is important that the database also includes observations for trade of a country with itself (domestic trade). Since such data is not available, I construct it as gross output of all non-services sectors minus total exports of goods.[15] For OLS on the demeaned I demean the left-hand side variable and the policy dummy using the formula derived in Appendix 3.A.1.

Table 3.4.2: Estimates for EU with entrants and insiders

| Research question | FE-LSDV $\hat{\beta}$ | Cluster s.e. | Within $R^2$ | Identified?[1] | OLS on demeaned $\hat{\beta}$ |
|---|---|---|---|---|---|
| 1 | -0.007 | 0.059 | 0.31 | Yes | -0.007 |
| 2 | 0.007 | 0.059 | 0.31 | Yes | 0.007 |
| 3.1 | $0.450^a$ | 0.157 | 0.31 | No (1) | dropped |
| 3.2 | $0.229^a$ | 0.077 | | | 0.003 |
| 4 | 0.003 | 0.029 | 0.31 | Yes | 0.003 |

Notes: Eq. (3.5) is estimated with FE-LSDV and OLS on demeaned. No of obs: 2400. No of groups: 400. The sample includes country pairs of 12 of the EU-15 countries and 8 of the countries that joined the EU in 2004. Dependent variable is log bilateral exports normalized by GDPs. Time dimension is years between 2001 and 2006. Pair fixed effects, exporter-year and importer-year dummies included. [1] Number of extra country-year dummies dropped in bracket. [a] significant at 1%, [b] at 5%. Last column shows coefficient estimates from OLS on demeaned, where significance is not reported.

The estimation results are shown in Table 3.4.2, FE-LSDV in the first four columns, OLS on the demeaned in the last column. The $\beta$ estimates reinforce the analytical findings. The value of the parameter $\triangle$ is -0.007, given that the elements of the $dz'$ vector in this particular sample are, in order, 0.041, 0.072, -0.181, and -0.157. The $\beta$ estimates under the different research questions relate to each other as expected. The estimate for the second question is the negative of the estimate for the first question, and the estimate for the fourth question is half of the estimate for the second question. None of them is statistically different from zero.

[14] All data is from Eurostat and OECD.

[15] Domestic trade is similarly constructed, among others, in Wei (1996), Novy (2008), Jacks, Meissner and Novy (2011) and Hornok (2011).

The policy effects under the third research question cannot be separately identified. Yet, quite misleadingly, the FE-LSDV estimation method reports sizeable and strongly significant estimates. If one checks the number of exporter-year and importer-year dummies that are dropped, it turns out that FE-LSDV drops one of these dummies, instead of the policy dummy, due to the perfect collinearity. In contrast, OLS on the demeaned drops the perfectly collinear policy dummy. It is important to emphasize, however, that OLS on the demeaned reports perfect collinearity only with a database that also includes domestic trade observations. If domestic trade is not part of the database, OLS on the demeaned also reports "false" estimates.[16] In this case, the reported estimates are different from the FE-LSDV estimates.

## 3.5 Third countries: a solution?

I extend the sample with countries that are outside the EU's customs union. I call these countries outsiders or third countries interchangeably. In the extended sample the number of country pair groups increases to nine (Figure 3.5.1). Outsiders export to all the three types of countries ($G_{3\cdot}$ in last row) and the three types of countries export to outsiders ($G_{\cdot 3}$ in last column).

Figure 3.5.1: Groups of pairs with entrants, insiders and outsiders

| $i \backslash j$ | entrant | insider | outsider |
|---|---|---|---|
| entrant | $G_{11}$ | $G_{12}$ | $G_{13}$ |
| insider | $G_{21}$ | $G_{22}$ | $G_{23}$ |
| outsider | $G_{31}$ | $G_{32}$ | $G_{33}$ |

I consider the four research questions as before with unchanged treated pair groups. This implies that the benchmark, relative to which the policy effect is identified, automatically extends with the country pairs of outsiders ($G_{\cdot 3}$, $G_{3\cdot}$). It is by no means an innocuous modification. The choice of the benchmark observations, which

[16]It is because the demeaning (within transformation) formula is derived for a full trade matrix.

is ultimately the researcher's responsibility, is crucial to get a reliable estimate for the policy effect. Outsider country pairs are valid benchmark only if their trade is not affected by the policy change or, if it is affected, the policy-induced change in their trade costs is appropriately controlled for in the estimation.

### 3.5.1 All are benchmark

Let us assume for the moment that country pair groups with outsiders are valid benchmark and check the identifiability of the policy effects under the four research questions. Let the number of outsider countries in the sample be $n_3$. It is straightforward to see that all the four research questions are identifiable on the extended database.[17] In particular, the matrix of regressors in (3.6) for the third research question is now

$$\begin{bmatrix} \alpha & \eta & dT \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 1 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 \end{bmatrix}, \tag{3.9}$$

where the order of observations is $G_{11}$, $G_{12}$, $G_{13}$, $G_{21}$, $G_{22}$, $G_{23}$, $G_{31}$, $G_{32}$, $G_{33}$ and the elements of the matrix are vectors of ones or zeros of the following dimensions: ${n_1}^2$ in the first, $n_1 n_2$ in the second and fourth, $n_1 n_3$ in the third and seventh, ${n_2}^2$ in the fifth, $n_2 n_3$ in the sixth and eighth and ${n_3}^2$ in the ninth rows of the matrix.

[17] With third countries in the sample the $\beta$ estimates cannot be expressed as simply as before. An alternative way to check identifiability is to write out the regressor matrix ($X$) and check whether the determinant of $X'X$ is zero (singular matrix) or approximately zero (near singular matrix). A singular or near singular matrix indicates perfect collinearity.

The first three columns of the matrix are the exporter dummies, the fourth and fifth columns are the importer dummies (importer dummies for outsiders omitted) and the last two columns are the two policy dummies of the third research question. The extension of the database with outsider countries increases the number of rows of the regressor matrix to nine, which also increases the maximum possible number of linearly independent column vectors to nine. Since five columns are reserved for the country dummies, the researcher is able to identify *at most* four policy effects separately.

Does the inclusion of outsider countries also lead to a less restrictive range of estimated effects? The answer is yes. One can solve for the $\beta$ estimates by following the same steps as in the previous section. Again, I assume that the sample includes observations of all the country pairs formed by $n_1$ entrants, $n_2$ insiders and $n_3$ outsiders, also including domestic trade observations. The vector of the left-hand side variable in (3.6) is

$$dz' = \begin{bmatrix} \bar{d}z_{11} & \bar{d}z_{12} & \bar{d}z_{13} & \bar{d}z_{21} & \bar{d}z_{22} & \bar{d}z_{23} & \bar{d}z_{31} & \bar{d}z_{32} & \bar{d}z_{33} \end{bmatrix},$$

where the elements are simple averages of the observations across country pairs belonging to the same group. The estimated $\beta$ coefficients for each research question can be expressed as linear combinations of the elements of $dz$ with some parameter vector. The elements of the parameter vectors are functions of $n_1$, $n_2$ and $n_3$. Details of the analytical solution are shown in Appendix 3.A.2.

I present the parameter vectors for the four research questions under the simplifying assumption that the number of countries by type is equal, i.e. $n_1 = n_2 = n_3$. The elements of the parameter vectors are in the rows of Table 3.5.1. Linear combinations of the elements of $dz$ with these give the $\beta$ estimates for each research question. For instance, the estimated effect under the first research question can be expressed as $\hat{\beta} = \bar{dz}_{11} - 0.5 \cdot \left(\bar{dz}_{12} + \bar{dz}_{13} + \bar{dz}_{21} + \bar{dz}_{31}\right) + 0.25 \cdot \left(\bar{dz}_{22} + \bar{dz}_{23} + \bar{dz}_{32} + \bar{dz}_{33}\right)$.

Table 3.5.1: $\beta$ estimates in panels with outsiders ($n_1 = n_2 = n_3$)

| Research question | Elements of vector of LHS variable | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $\bar{dz}_{11}$ | $\bar{dz}_{12}$ | $\bar{dz}_{13}$ | $\bar{dz}_{21}$ | $\bar{dz}_{22}$ | $\bar{dz}_{23}$ | $\bar{dz}_{31}$ | $\bar{dz}_{32}$ | $\bar{dz}_{33}$ |
| 1 | 1 | -0.5 | -0.5 | -0.5 | 0.25 | 0.25 | -0.5 | 0.25 | 0.25 |
| 2 | 0 | 0.5 | -0.5 | 0.5 | -0.5 | 0 | -0.5 | 0 | 0.5 |
| 3.1 | 1 | 0 | -1 | 0 | -0.25 | 0.25 | -1 | 0.25 | 0.75 |
| 3.2 | 0 | 0.5 | -0.5 | 0.5 | -0.5 | 0 | -0.5 | 0 | 0.5 |
| 4 | -0.4 | 0.5 | -0.1 | 0.5 | -0.4 | -0.1 | -0.1 | -0.1 | 0.2 |

Notes: $\beta$ estimates are linear combinations of the elements of $dz$ with the parameter values in the rows.

Estimation results for the EU enlargement episode confirm that the inclusion of third countries enables identification under all the four research questions. The EU database is augmented with 8 countries outside the EU[18] and, for the ease of interpretation, the number of insiders is also reduced to 8 to satisfy $n_1 = n_2 = n_3$.[19] The 8 entrants are unchanged. The estimating equation and the estimation methods are the same as in the previous section. Table 3.5.2 presents the estimation results for both the FE-LSDV and OLS on the demeaned estimations. Identification is possible under all the four research questions. FE-LSDV does not drop any extra country-time dummies and OLS on the demeaned drops none of the policy dummies. The point estimates given by the two estimation methods are exactly the same.

One can check whether the analytical solutions for the $\beta$ estimates in Table 3.5.1 are correct. In this particular database the elements of the $dz$ vector take the following values:

$$dz' = \begin{bmatrix} 0.041 & 0.085 & 0.283 & -0.171 & -0.146 & -0.071 & 0.272 & 0.014 & -0.014 \end{bmatrix}.$$

The $\beta$ estimate for the first research question, e.g., can be calculated as linear combination of the elements of this vector with the corresponding parameter values in

[18]The choice of outsiders is determined by data availability. They are Switzerland, Israel, Iceland, Japan, South Korea, Mexico, Norway, United States.

[19]Denmark, Greece, Ireland and Portugal are dropped from the original 12 insiders. The choice is arbitrary.

Table 3.5.2: Estimates for EU with entrants, insiders and outsiders

| Research question | FE-LSDV $\hat{\beta}$ | Cluster s.e. | Within $R^2$ | Identified? | OLS on demeaned $\hat{\beta}$ |
|---|---|---|---|---|---|
| 1 | -0.248[a] | 0.074 | 0.20 | Yes | -0.248 |
| 2 | -0.254[a] | 0.060 | 0.21 | Yes | -0.254 |
| 3.1 | -0.502[a] | 0.115 | 0.22 | Yes | -0.502 |
| 3.2 | -0.254[a] | 0.059 | | | -0.254 |
| 4 | -0.053 | 0.034 | 0.20 | Yes | -0.053 |

Notes: Eq. (3.5) is estimated with FE-LSDV and OLS on demeaned. No of obs: 3456. No of groups: 576. The sample includes country pairs of 8 of the EU-15 countries, 8 of the countries that joined the EU in 2004 and 8 non-EU countries. Dependent variable is log bilateral exports normalized by GDPs. Time dimension is years in 2001-2006. Pair fixed effects, exporter-year and importer-year dummies included. [a] significant at 1%, [b] sign. at 5%. Last column shows coefficient estimates from OLS on demeaned, where significance is not reported.

the first row of Table 3.5.1, i.e. $\hat{\beta} = 0.041 - 0.5 \cdot (0.085 + 0.283 - 0.171 + 0.272) + 0.25 \cdot (-0.146 - 0.071 + 0.014 - 0.014) = -0.248$.

The $\beta$ estimates in Table 3.5.2 are strikingly different from the estimates in Table 3.4.2; they are all negative, mostly large in absolute value and statistically significant. The big difference between the two sets of estimates is due to the change in the benchmark observations, which now include all country pairs with outsiders. Income-adjusted trade with outsiders, and especially between entrants and outsiders (3rd and 7th elements of the $dz'$ vector), increased faster than elsewhere, which causes the $\beta$ estimates to be significantly negative.

### 3.5.2 Dummies for third country effects

Are country pairs with outsiders valid benchmark for the estimation of a policy effect? It is ultimately an empirical question. If there are good reasons to believe that changes in trade barriers with outsiders are uncorrelated with the policy, the answer is positive. If they are correlated with the policy, but appropriately controlled for in the estimation (e.g. with hard data on trade costs), the answer is still positive. If however such "third-country effects" are not accounted for properly, country pairs with outsiders are not valid benchmark. If, e.g., the trade policy change involves a decrease in trade costs between entrants and outsiders, which increases their bilateral trade, leaving entrant-outsider country pairs in the benchmark without controlling for this change results in the underestimation of the policy effect.

Getting back to the example of EU enlargement, entering the EU involves entering a customs union and adopting its external trade policy. Available data suggests that tariffs of entrants with outsiders had to change considerably with EU entry (Table 3.5.3). Before enlargement most entrants faced higher tariffs as exporters in, and imposed higher tariffs as importers on, the eight outsiders in the sample, relative to the level of tariffs faced and imposed by the EU member Germany. The difference from the EU's external protection was especially large for import tariffs of some entrants (Poland, Slovenia, Hungary). In contrast, outsiders were only marginally more protective towards the entrants than towards the pre-2004 EU.

Table 3.5.3: Difference in tariffs with 8 outsiders relative to Germany in 2001

| Faced by exporter | diff in tariff (%point) | Imposed by importer | diff in tariff (%point) |
|---|---|---|---|
| Czech Republic | 0.4 | Czech Republic | 4.4 |
| Estonia | 0.4 | Estonia | -2.0 |
| Hungary | 0.8 | Hungary | 7.6 |
| Lithuania | 0.5 | Lithuania | 1.2 |
| Latvia | 0.1 | Latvia | 0.9 |
| Poland | -0.2 | Poland | 14.7 |
| Slovakia | 1.2 | Slovakia | 4.4 |
| Slovenia | -0.1 | Slovenia | 8.8 |

Notes: Manufacturing tariffs, average of 3-digit ISIC industries. Source is CEPII. Outsiders: Switzerland, Israel, Iceland, Japan, South Korea, Norway and the United States.

Controlling for changes in trade barriers with hard data is often problematic. Available data on bilateral tariffs is deficient and often not good quality, let alone data on non-tariff trade barriers. The empirical researcher is tempted to simply include additional dummies to account for the changes in third-country trade costs between the pre- and post-policy periods. Because the decline in third-country tariffs of entrants at EU enlargement was apparently asymmetric, I consider the inclusion of two separate dummies, one for the (smaller) entrant-outsider and another for the (larger) outsider-entrant effects. I demonstrate that with such a modification to the estimating equation the identification problems discussed in Section 3.4 can return.

The panel fixed-effects country-time dummies estimating equation (3.5), augmented with the entrant-outsider and outsider-entrant dummies, is

$$z_{ijt} = \beta T_{ijt} + \gamma_1 D_{13,t} + \gamma_2 D_{31,t} + \zeta_{ij} + \delta_{it} + \theta_{jt} + u_{ijt}, \tag{3.10}$$

where $D_{13,t}$ is a dummy variable taking value 1 for country pairs in $G_{13}$ in $t = 2$ and 0 otherwise, $D_{31,t}$ is a dummy taking value 1 for country pairs in $G_{31}$ in $t = 2$ and 0 otherwise, and $\gamma_1$ and $\gamma_2$ are parameters to estimate. Estimation results for the four research questions in the EU enlargement example are in Table 3.5.4.

Table 3.5.4: Estimates for EU with direction-specific entrant-outsider effects

| Research | | FE-LSDV | | | | OLS on demeaned |
|---|---|---|---|---|---|---|
| question | Coefficient | Estimate | Cluster s.e. | Within $R^2$ | Identified?[1] | Estimate |
| 1 | $\beta$ | 0.006 | 0.068 | 0.22 | Yes | 0.006 |
| | $\gamma_1$ | $0.174^b$ | 0.080 | | | 0.174 |
| | $\gamma_2$ | $0.334^a$ | 0.089 | | | 0.334 |
| 2 | $\beta$ | -0.006 | 0.068 | 0.22 | Yes | -0.006 |
| | $\gamma_1$ | 0.167 | 0.086 | | | 0.167 |
| | $\gamma_2$ | $0.328^a$ | 0.103 | | | 0.328 |
| 3.1 | $\beta$ ($G_{11}$) | 0.695 | 0.379 | 0.22 | No (1) | dropped |
| 3.2 | $\beta$ ($G_{12}$,$G_{21}$) | 0.344 | 0.190 | | | -0.003 |
| | $\gamma_1$ | $0.518^a$ | 0.192 | | | 0.171 |
| | $\gamma_2$ | $0.679^a$ | 0.210 | | | 0.331 |
| 4 | $\beta$ | -0.003 | 0.034 | 0.22 | Yes | -0.003 |
| | $\gamma_1$ | $0.171^b$ | 0.076 | | | 0.171 |
| | $\gamma_2$ | $0.331^a$ | 0.090 | | | 0.331 |

Notes: Eq. (3.10) is estimated with FE-LSDV and OLS on demeaned. No. obs: 3456. No. groups: 576. The sample includes country pairs of 8 of the EU-15 countries, 8 of the countries that joined the EU in 2004 and 8 non-EU countries. Dependent variable is log bilateral exports normalized by GDPs. Time dimension dimension is years between 2001 and 2006. Pair fixed effects, exporter-year and importer-year dummies included. [1] Number of extra country-year dummies dropped in bracket. [a] significant at 1%, [b] sign. at 5%. Last column shows coefficient estimates from OLS on demeaned, where significance is not reported.

Both estimated third-country effects are positive, and $\hat{\gamma}_2$ is larger and more strongly significant than $\hat{\gamma}_1$. That entrants adopted the EU's external trade policy, which is less restrictive than their pre-enlargement trade protection was, seems to have promoted trade between entrants and outsiders in both directions. In contrast, with the inclusion of the two additional dummies, the $\beta$ coefficient estimates become small and not different from zero statistically. Recall that the benchmark now includes outsider country pairs of $G_{23}$, $G_{32}$ and $G_{33}$, but not country pairs of $G_{13}$ and

$G_{31}$. Despite the fact that outsider countries are also in the sample, the relationship among the $\beta$ estimates is like in Section 3.4. The $\beta$ estimate of the second research question is the negative of the $\beta$ estimate of the first one, and the estimate of the fourth research question is half of the second's. Yet again similar to Section 3.4, the two policy effects of the third research question cannot be identified separately.

The identification problem under the third research question is due to a deficient rank regressor matrix. The number of columns in the regressor matrix (nine) equals the number of rows, which would allow identification. However, there is perfect collinearity among the columns. The regressor matrix (3.9), extended with the two third-country dummies becomes

$$\begin{bmatrix} \alpha & \eta & dT & D_{13} & D_{31} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}, \tag{3.11}$$

where $D_{13}$ and $D_{31}$ are the last two columns. Perfect collinearity arises from the linear relationship among the exporter and importer dummies for entrants, the two policy dummies and $D_{31}$ of the form $2\mathbf{v}_6 + \mathbf{v}_7 + \mathbf{v}_8 + \mathbf{v}_9 - \mathbf{v}_1 - \mathbf{v}_4 = \mathbf{0}$, where the $\mathbf{v}$s are the column vectors in order.

All in all, the advantages of adding outsider country observations to the sample are completely lost, when one has to control for (direction-specific) third-country effects via additional dummies. Of course, depending on the empirical application, additional third country dummies may take different forms. In some applications, a common entrant-outsider dummy (i.e. not direction-specific dummies) may be sufficient. In others, insider-outsider effects, or both entrant-outsider and insider-outsider effect, should be controlled for.

Table 3.5.5: Identifiability with additional third country dummies

| | Additional dummies for pair groups in $t=2$ | | | | | |
|---|---|---|---|---|---|---|
| Research | $G_{13}$, $G_{31}$ | | $G_{23}$, $G_{32}$ | | $G_{13}$, $G_{31}$, $G_{23}$, $G_{32}$ | |
| question | common | separate | common | separate | common | separate |
| 1 | yes | yes | yes | yes | yes | no |
| 2 | yes | yes | yes | yes | yes | no |
| 3 | no | no | yes | yes | no | no |
| 4 | yes | yes | yes | yes | yes | no |

Notes: "yes" and "no" refer to identifiability of the policy effect under research questions 1-4, when additional dummies for country pair groups with outsiders in $t=2$ are also included. "Common" stands for a common dummy, "separate" for separate dummies by country pair group.

Table 3.5.5 shows how the different sets of third-country dummies determine the identifiability of the policy effects under the four research questions. There is no identification problem with only insider-outsider dummies. When entrant-outsider dummies are included (common or separate), the policy dummies in the third research question cannot be identified. Finally, none of the policy effects can be identified, when separate dummies are included for both insider-outsider and entrant-outsider groups.

## 3.6 Summary and Discussion

The findings of this paper point to the fact that the country-time dummies in the fixed-effects country-time dummies gravity specification absorb too much of the variation in the data. In most cases the variation left is so narrow that heterogeneous policy effects cannot be identified, because the country-time dummies and the policy dummies are perfectly collinear. Being aware of this limitation is important, because standard estimation techniques do not report the problem clearly. Little variation left is problematic even if the policy effect of interest is identified, because the estimated coefficients may not be meaningful estimates. I demonstrate this problem, when I compare the policy estimates under the first and the second research questions in Table 3.4.2. The estimates are negatives of each other, while the research questions are not mirror images.

The message of this paper is not limited to the presented examples. Cross section gravity estimations are equally subject to the above limitations, given that the estimating equation includes a full set of exporter and importer dummies. The same findings apply to all regressors that are captured by dummies and not only to policy dummies. For instance, looking at the trade effect of a common language (captured by a dummy) in a cross section estimation is similar to the fourth research question of this paper. Finally, these findings can also serve useful in other fields of empirical research, where dummies are extensively used as control variables.

Researchers, who want to estimate a theory-consistent gravity equation, are advised to find other methods to control for the MTRs in a theoretically consistent way. Alternative methods are numerous, though none is perfect. The researcher should choose among them, based on what assumptions are reasonable to make and what data is available. Anderson and van Wincoop (2003) use structural estimation, assuming symmetric trade costs. In their structural estimation, Bergstrand, Egger and Larch (2010) relax the trade cost symmetry assumption. Other authors regress the gravity equation on some ratio of international to intranational trade (Head and Ries (2001), Novy (2008)) to net out the MTRs. Baier and Bergstrand (2009) develop a linear reduced-form gravity equation with first-order log-linear Taylor series approximation of the MTRs.

Needless to say that all the above methods are more data-demanding than the fixed-effects country-time dummies specification. The method of Baier and Bergstrand (2009), e.g., requires comprehensive bilateral trade cost data for all country pairs in the world. A well-designed empirical strategy like a quasi-experimental framework or matching country pairs can help reduce the data requirement. Nevertheless, the need for an improvement in the availability and quality of data on trade barriers remains a central issue in the empirical trade research.

## 3.A Appendix

### 3.A.1 The demeaning formula for the panel specification

I derive the demeaning (within transformation) formula for the error structure of the fixed effects panel estimation (3.5).[20] The derivation is based on the general solution in Davis (2002). The formula, together with a degrees of freedom adjustment, is also given in Mátyás, Harris and Konya (2011).

The fixed effects panel specification for international trade data can be represented with the error structure

$$u_{ijt} = \zeta_{ij} + \delta_{it} + \theta_{jt} + \nu_{ijt}, \tag{3.12}$$

where $i = 1, ..., N$ denote exporters, $j = 1, ..., M$ importers and $t = 1, ..., T$ time, $\zeta_{ij}$, $\delta_{it}$ and $\theta_{jt}$ are the unobservable pair-specific, exporter-year and importer-year effects, respectively. In vector form,

$$u = Z_\zeta \zeta + Z_\delta \delta + Z_\theta \theta + \nu, \tag{3.13}$$

where $\zeta$, $\delta$ and $\theta$ are vectors of parameters to estimate of dimension $NMT \times NM$, $NMT \times NT$ and $NMT \times MT$, respectively, and $Z_\zeta = I_{NM} \otimes \iota_T$, $Z_\delta = I_N \otimes \iota_M \otimes I_T$ and $Z_\theta = \iota_N \otimes I_{MT}$. $I$ is the identity matrix and $\iota$ is the vector of ones of given dimension and $\otimes$ denotes the Kronecker product.[21]

The projection matrix, which projects onto the range of $Z = (Z_\zeta; Z_\delta; Z_\theta)$, is $P_{[Z]} = Z \left(Z'Z\right)^{-1} Z'$. The orthogonal projection matrix is $Q_{[Z]} = I - P_{[Z]}$. $P$ and $Q$ are symmetric and idempotent. Note that $P_{[Z_\zeta]} = I_{NM} \otimes \bar{J}_T$ averages the data over $t$, where $\bar{J}_T = \frac{1}{T} J_T$ with $J_T$ being the matrix of ones of dimension $T$. Similarly,

[20] The formula for the cross section equation (3.6) is widely known and can be found in Econometrics textbooks like Baltagi (2001, p. 32.). The textbook formula is derived for individual and time dimensions, which should be replaced by the exporter and importer dimensions.

[21] A useful property of the Kronecker product (mixed-product property) is that $(A \otimes B) \cdot (C \otimes D) = AC \otimes BD$, given that the dimensions of the matrices are such that taking their product is possible.

$P_{[Z_\delta]} = I_N \otimes \bar{J}_M \otimes I_T$ averages the data over $j$ and $P_{[Z_\theta]} = \bar{J}_N \otimes I_{MT}$ averages the data over $i$. For example, in the last case, $\left(\bar{J}_N \otimes I_{MT}\right) u$ has a typical element $\bar{u}_{.jt} = \frac{1}{N}\sum_{i=1}^{N} u_{ijt}$.

The general solution for the within transformation matrix according to Davis (2002) is

$$Q_{[Z]} = Q_{[A]} - P_{[B]} - P_{[C]}, \tag{3.14}$$

where $A = Z_\theta$, $B = Q_{[A]}Z_\delta = Q_{[Z_\theta]}Z_\delta$ and $C = Q_{[B]}Q_{[A]}Z_\mu = Q_{[Q_{[Z_\theta]}Z_\delta]}Q_{[Z_\theta]}Z_\zeta$.

It is straightforward to show that

$$Q_{[A]} = \left(I_N - \bar{J}_N\right) \otimes I_{MT}.$$

The second term can be expressed as

$$P_{[B]} = \left(I_N - \bar{J}_N\right) \otimes \bar{J}_M \otimes I_T,$$

where I used that $Q_{[A]}Z_\delta = \left(I_N - \bar{J}_N\right) \otimes \iota_M \otimes I_T$. The third them is

$$P_{[C]} = \left(I_N - \bar{J}_N\right) \otimes \left(I_M - \bar{J}_M\right) \otimes \bar{J}_T,$$

where I used that $Q_{[A]}Q_{[B]}Z_\zeta = \left(I_N - \bar{J}_N\right) \otimes \left(I_M - \bar{J}_M\right) \otimes \iota_T$.

Collecting terms,

$$\begin{aligned} Q_{[Z]} &= \left(I_N - \bar{J}_N\right) \otimes \left(I_M - \bar{J}_M\right) \otimes \left(I_T - \bar{J}_T\right) \\ &= I_{NMT} - \bar{J}_N \otimes I_{MT} - I_N \otimes \bar{J}_M \otimes I_T - I_{NM} \otimes \bar{J}_T + \\ &+ I_N \otimes \bar{J}_{MT} + \bar{J}_N \otimes I_M \otimes \bar{J}_T + \bar{J}_{NM} \otimes I_T - \bar{J}_{NMT} \end{aligned}$$

with a typical element

$$\ddot{u} = Q_{[Z]}u = u_{ijt} - \bar{u}_{.jt} - \bar{u}_{i.t} - \bar{u}_{ij.} + \bar{u}_{i..} + \bar{u}_{.j.} + \bar{u}_{..t} - \bar{u}_{...}, \tag{3.15}$$

where $\bar{u}_{.jt} = N^{-1}\sum_i u_{ijt}$, $\bar{u}_{i.t} = M^{-1}\sum_j u_{ijt}$, $\bar{u}_{ij.} = T^{-1}\sum_t u_{ijt}$, $\bar{u}_{i..} = (MT)^{-1}\sum_t\sum_j u_{ijt}$, $\bar{u}_{.j.} = (NT)^{-1}\sum_t\sum_i u_{ijt}$, $\bar{u}_{..t} = (NM)^{-1}\sum_j\sum_i u_{ijt}$ and $\bar{u}_{...} = (NMT)^{-1}\sum_t\sum_j\sum_i u_{ijt}$.

The estimation method 'OLS on the demeaned' is done by demeaning the variables as in (3.15) and estimating the regression equation with the demeaned variables. It is important to add that this formula is derived for a "full" trade matrix. This means that, if some countries are both exporters and importers in the database (which is almost always the case), data on trade of these countries with themselves (domestic trade) should also be included.

### 3.A.2 Deriving the $\hat{\beta}$'s without assuming $n_1 = n_2 = n_3$

If I do not assume $n_1 = n_2 = n_3$, the demeaned left-hand side variable can be expressed as

$$\ddot{dz} = a_1\bar{dz}_{11} + a_2\bar{dz}_{12} + a_3\bar{dz}_{13} + a_4\bar{dz}_{21} + a_5\bar{dz}_{22} + a_6\bar{dz}_{23} + a_7\bar{dz}_{31} + a_8\bar{dz}_{32} + a_9\bar{dz}_{33},$$

where the $a$'s are vectors, whose elements are functions of $n_1$, $n_2$ and $n_3$.

Expressing the $a$'s in terms of the number of countries we get

$$
\begin{aligned}
\begin{bmatrix} \ddot{dz}_{11} \\ \ddot{dz}_{12} \\ \ddot{dz}_{13} \\ \ddot{dz}_{21} \\ \ddot{dz}_{22} \\ \ddot{dz}_{23} \\ \ddot{dz}_{31} \\ \ddot{dz}_{32} \\ \ddot{dz}_{33} \end{bmatrix}
&= \frac{1}{N^2} \begin{bmatrix} (n_2+n_3)^2 \\ -n_1(n_2+n_3) \\ -n_1(n_2+n_3) \\ -n_1(n_2+n_3) \\ n_1^2 \\ n_1^2 \\ -n_1(n_2+n_3) \\ n_1^2 \\ n_1^2 \end{bmatrix} \bar{dz}_{11} + \frac{1}{N^2} \begin{bmatrix} -n_2(n_2+n_3) \\ (n_1+n_3)(n_2+n_3) \\ -n_2(n_2+n_3) \\ n_1 n_2 \\ -n_1(n_1+n_3) \\ n_1 n_2 \\ n_1 n_2 \\ -n_1(n_1+n_3) \\ n_1 n_2 \end{bmatrix} \bar{dz}_{12} + \\
&+ \frac{1}{N^2} \begin{bmatrix} -n_3(n_2+n_3) \\ -n_3(n_2+n_3) \\ (n_1+n_2)(n_2+n_3) \\ n_1 n_3 \\ n_1 n_3 \\ -n_1(n_1+n_2) \\ n_1 n_3 \\ n_1 n_3 \\ -n_1(n_1+n_2) \end{bmatrix} \bar{dz}_{13} + \frac{1}{N^2} \begin{bmatrix} -n_2(n_2+n_3) \\ n_1 n_2 \\ n_1 n_2 \\ (n_1+n_3)(n_2+n_3) \\ -n_1(n_1+n_3) \\ -n_1(n_1+n_3) \\ -n_2(n_2+n_3) \\ n_1 n_2 \\ n_1 n_2 \end{bmatrix} \bar{dz}_{21} + \\
&+ \frac{1}{N^2} \begin{bmatrix} n_2^2 \\ -n_2(n_1+n_3) \\ n_2^2 \\ -n_2(n_1+n_3) \\ (n_1+n_3)^2 \\ -n_2(n_1+n_3) \\ n_2^2 \\ -n_2(n_1+n_3) \\ n_2^2 \end{bmatrix} \bar{dz}_{22} + \frac{1}{N^2} \begin{bmatrix} n_2 n_3 \\ n_2 n_3 \\ -n_2(n_1+n_2) \\ -n_3(n_1+n_3) \\ -n_3(n_1+n_3) \\ (n_1+n_2)(n_1+n_3) \\ n_2 n_3 \\ n_2 n_3 \\ -n_2(n_1+n_2) \end{bmatrix} \bar{dz}_{23} + \\
&+ \frac{1}{N^2} \begin{bmatrix} -n_3(n_2+n_3) \\ n_1 n_3 \\ n_1 n_3 \\ -n_3(n_2+n_3) \\ n_1 n_3 \\ n_1 n_3 \\ (n_1+n_2)(n_2+n_3) \\ -n_1(n_1+n_2) \\ -n_1(n_1+n_2) \end{bmatrix} \bar{dz}_{31} + \frac{1}{N^2} \begin{bmatrix} n_2 n_3 \\ -n_3(n_1+n_3) \\ n_2 n_3 \\ n_2 n_3 \\ -n_3(n_1+n_3) \\ n_2 n_3 \\ -n_2(n_1+n_2) \\ (n_1+n_2)(n_1+n_3) \\ -n_2(n_1+n_2) \end{bmatrix} \bar{dz}_{32} + \frac{1}{N^2} \begin{bmatrix} n_3^2 \\ n_3^2 \\ -n_3(n_1+n_2) \\ n_3^2 \\ n_3^2 \\ -n_3(n_1+n_2) \\ -n_3(n_1+n_2) \\ -n_3(n_1+n_2) \\ (n_1+n_2)^2 \end{bmatrix} \bar{dz}_{33},
\end{aligned}
$$

where $N = n_1 + n_2 + n_3$ is the total number of countries in the sample.

The demeaned policy dummy is $\ddot{dT} = a_1$ for the first research question, $\ddot{dT} = a_1 + a_2 + a_3$ for the second research question and $\ddot{dT} = a_2 + a_3$ for the fourth research question. The matrix of the two demeaned policy dummies under the third research question is $\ddot{dT} = \begin{bmatrix} a_1 & a_2 + a_3 \end{bmatrix}$, where $a_1$ and $a_2 + a_3$ are column vectors of the matrix.

To express the policy effect estimates as functions of the $n$'s and the $\bar{dz}$'s, one needs to solve for the OLS formula $\hat{\beta} = \left(\ddot{dT}'\ddot{dT}\right)^{-1}\ddot{dT}'\ddot{dz}$ for each research question separately.

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