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Endogenous Transport Costs in International Trade

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Endogenous Transport Costs in International Trade

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Abstract

In this paper we claim that distance alone is a poor proxy for international transport costs in empirical studies. We model a manufacturing and a transport sector and let the level of manufacturing exports determine the demand for transport services. Above a particular trade level, transport service suppliers find it profit-maximizing to invest in an advanced transport technology, which lowers their marginal costs and as a consequence, equilibrium transport prices. Transport costs thus vary with two characteristics: with the distance between two locations and with the endogenous decision to invest in a more efficient technology which is driven, in turn, by the bilateral export level. A simulation exercise reveals that ignoring the effect of the investment decision on transport costs biases empirical results. The empirical estimations rely on newly collected transport price data from United Parcel Service (UPS). We apply an instrumental variable (IV) estimator to account for the endogeneity of the investment decision. Our results confirm that transport prices are influenced by both the distance and the level of exports between two countries. We find that trade partners with 10% more exports enjoy 0.8% lower transport prices.

Keywords: Distance, endogenous transport costs
JEL: F12, F15, R41

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1. Introduction

Falling cross-border transaction costs have stimulated an unprecedented increase in cross-border transactions of all kinds. This rise in international activities has been impressive enough to label the past two decades nothing short of an "era of globalization". The falling costs of cross-border transactions are thereby at the same time the source of the globalization process and its result. Increased cross-border transactions do not only stem from transport cost reductions, they also boost investments in the infrastructure of international trade, which induce further cost cuts. In the light of the importance of this phenomenon, the scarcity of economic studies that address the role of infrastructure investments in lowering transport costs and in stimulating trade, is surprising. In this paper, we put the infrastructure of international trade and the transport sector where the investment decisions are taken in the focus of the analysis.

We start with the observation that the costs of transporting goods between two countries seem to vary not only with respect to the distance between them. While most Asian economies, first and foremost, China, trade high volumes at moderate transport prices with the United States and the European Union (EU), many African economies trade rather moderate volumes at high transport prices – despite of their more favorable geographic location. Hence, there must be more than just distance affecting transport costs. The recent literature has stressed that transport costs differ systematically with the market structure of the transport sector (Hummels et al., 2009), with bilateral trade imbalances (Behrens and Picard, 2011 and Jonkeren et al., 2011), and with port efficiencies (Clark et al., 2004 and Blonigen and Wilson, 2008). Complementing these findings, we argue that bilateral trade levels are an important, yet largely neglected driver of the differences.

To back the argument, we develop a theoretical framework that explicitly models a manufacturing and a transport sector and focuses on the investment decision of transport service suppliers. Transport service suppliers can choose between two route-specific technologies: (i) a low fixed costs / high variable costs technology and (ii) a high fixed costs / low variable costs technology. This choice is motivated by the fact that increasing returns to scale play an important role in transportation.[1]

Since a certain trade level is required to recover the fixed costs, the choice of transport technology depends on the trade level. As a consequence, the high fixed costs / low variable costs technology will be used on routes with high bilateral trade levels and the low fixed costs / high variable costs technology on routes with low bilateral trade levels. Since transport prices depend on the variable costs in transport, routes with high trade levels feature low transport prices, which increase the trade level further. While, according to this explanation, trade levels determine transport prices, trade levels are also determined by transport prices. The interdependency of both variables explains why transport prices differ also after controlling for distance. If the price effect of an investment in a low variable costs technology is strong, investment decisions might be as or even more important than distance in determining transport prices for manufacturing goods. The good news of this insight is that geography is not a destiny. The bad news is that starting from a disadvantageous location might lead to a vicious circle of low trade volumes resulting in low route-specific investments thereby consolidating low trade levels.

We assess the importance of the investment decision in the transport sector on route-specific transport prices letting the theoretical framework guide our empirical analysis. The theory proposes a system with two equations and two endogenous variables: transport prices and trade volumes. We restrict our analysis in this paper to the estimation of the transport price equation, accounting, however, for the endogeneity of the export levels. In bringing this system to the data, we proceed in two steps. First, we use a generic data set and a simulation exercise to establish the empirical strategy. Second, we apply this strategy to trade and transport costs data from 30 exporting and 61 importing countries constituting $30 \times 61 - 30 = 1,800$ country pairs for the year 2010. The sample size is mainly determined by the availability of transport price data which are collected from United Parcel Service (UPS). We find that transport prices are indeed

[1] Clark et al. (2004) for instance report that transport and handling costs per container decrease significantly with the size of the ship and state *"maritime routes with low trade volumes are covered by small vessels and vice versa."* (p. 423).

strongly affected by bilateral trade levels. 10% more exports reduce the transport price *ceteris paribus* by 0.8%. In a multi-country world where each good competes with close substitutes from several countries on the world market, such a transport price advantage might significantly affect trade patterns.

The rest of the paper is as follows: we relate our approach to the literature in Section 2. Based on the insights from earlier research, we develop the theoretical model in Section 3. We illustrate the estimation strategy in Section 4 using generic data. Section 5 reports the empirical results using real data. In Section 6 we discuss the results in a broader context. Section 7 concludes.

2. Related Literature

In spite of the great interest in the globalization process and the important role that economic research and the public alike ascribe to distance in general and transport costs in particular, the number of studies that deals explicitly with transport costs is surprisingly small. Only recently, the determinants of trade cost variations across products and trade routes have gained some interest. Hummels et al. (2009) propose a model of the transport sector to analyze the effect of market power in international shipping on prices in transport and therefore on trade. A theoretical frame of an oligopolistic market with symmetric suppliers guides their empirical specification of prices and mark-ups. Using two micro-level data sets, Hummels et al. (2009) assess the effect of the number of suppliers, the demand elasticity of a particular good, the price-weight ratio, and the tariff rate of a country on transport prices. Transport prices variations across different products and routes can to a significant part be attributed to differences in market power. The impact of market power on shipping prices exceeds the impact of distance. This finding explains why developing countries often show higher costs of transport.

Behrens and Picard (2011) study the effects of the logistics problem of back hauling in a new economic geography framework. They explicitly model a transport sector which accounts for the foregone profits incurred by returning empty containers. The resulting wedge between the transport prices of the two routes of a trade pair increases in the trade imbalance. Firms in the net exporting country face higher, firms in the net importing country face lower transport costs if transport firms optimally set prices for the return journey. This price wedge works against the agglomeration forces. Thus, endogenous transport prices mitigate the separation of countries in an industrial core and an agricultural periphery which is so prominent in the models using iceberg transport costs.

Starting with Clark et al. (2004), a number of empirical studies have identified economies of scale as a determinant of transport costs (see e.g. Wilmsmeier et al., 2006, Martínez-Zarzoso and Wilmsmeier, 2010 and Pomfret and Sourdin, 2010). Clark et al. (2004) find higher transport costs on routes with lower trade volumes. Assuming that any effect of country size on transport costs goes through trade volumes, they use GDP as an instrumental variable (IV) for trade volumes. The negative effect of trade volumes on transport prices becomes more pronounced when exports are instrumented, suggesting that failing to account for the endogeneity of exports understates their impact. Using the gap between c.i.f and f.o.b values of Australian imports as a measure of transport costs, Pomfret and Sourdin (2010) show that country size explains some of the variation in transport costs along with distance, the weight of the product, and the institutional quality of the exporting and/or the importing country. Once imports are used as a regressor instead of GDP to approximate country size, the significantly negative effect on trade costs becomes larger and more robust. Clark et al. (2004) and Blonigen and Wilson (2008) make a reference to technology. They argue that differing port efficiencies explain the country-specific part of transport cost variations whereas variables such as distance, trade imbalances and product weight are introduced to capture the bilateral transport cost determinants.

Closest to the mechanism through which the export level affects transport prices in this paper is a study by Skiba (2007). He assumes a transport price function that rises in the distance between two countries and a good's price-weight ratio and falls in the export level. The transport technology features economies of scale. In contrast to Skiba (2007), we model the transport price as endogenously determined by demand and supply in the transport sector. The decision to supply transport services thereby involves a decision about an investment in a particular transport technology.

Although we focus on the determinants of transport prices, the analysis naturally relates also to the literature that deals with the correct specification of the gravity equation. Endogeneity problems in gravity equations have provoked lengthy discussions in the trade literature of the past decade. Nearly all of the typically employed variables have been surmised to simultaneously influence trade, and, be influenced by trade. The usual suspects include national incomes (Frankel and Romer, 1999) and Free Trade Agreements (FTAs) (see e.g. Baier and Bergstrand, 2004 and Egger et al., 2010). Mostly approximated by time-invariant distance, transport costs have, by contrast, been perceived as exogenous and even served as an instrumental variable for trade assuming their orthogonality to other gravity variables (Frankel and Romer, 1999).

A notable exception is Rudolph (2009) who argues that scale economies leading to falling average costs arise in the presence of fixed costs in the transport sector. Not accounting for the endogenous impact of trade on transport costs biases the coefficients of traditionally estimated gravity equations. Rudolph (2010) applies a simultaneous equation model to jointly estimate trade and transport costs, the latter being approximated by the trade volume within the respective economies relative to the trade volume between them. He presents two findings: first, trade levels and transport costs are simultaneously determined. Second, ignoring the simultaneity results in overestimating the impact of transport cost proxies on trade. In order to provide a more reliable estimate of the effect of transport costs on trade, researchers should properly account for the interdependency.

In line with this argument and with Hummels (2007), we speculate that the amount of trade has "significant impacts on shipping prices through scale effects" (p. 140) and challenge thereby the orthogonality of transport costs. The existing literature calls for a firm theoretical foundation of the empirical model. For this purpose, we augment a model of international trade with an explicitly set-up transport sector. Clark et al. (2004) forcefully argue in favor of imperfect competition and a globally operating transport sector. We account for the evidence they present by modeling an oligopolistic sector which invests in route-specific instead of country-specific infrastructure. For clarity, we abstract from Hummels et al. (2009)'s finding of different degrees of competition and focus instead on the technology choice.

3. Theoretical Framework

In this section, we develop a two-sector model that formalizes the argument that bilateral trade levels and bilateral transport prices are jointly determined. The model consists of an oligopolistic transport sector, T, (with a fixed number of firms) which produces a homogenous transport service for each route and of a monopolistically competitive manufacturing sector, M, where exporting firms face per-unit transport costs. Prices are determined in equilibrium where the units of offered transport services equal the units of goods from the manufacturing sector that need transportation to a foreign country. To fit the structure of the transport sector, we model the manufacturing sector based on a Melitz and Ottaviano (2008)-framework with a quasi-linear demand structure and additive transport costs. We choose the simplest possible set-up with labor as the only factor of production. There are L_j individuals in economy j, each offering one unit of (homogenous) labor.

3.1. The Manufacturing Sector

The manufacturing sector, M, comprises N heterogenous firms that engage in monopolistic competition. Firms set prices depending on their marginal costs and decide about their export participation. Marginal costs depend on the firm-specific productivity level that is drawn independently at market entry from a common distribution. This firm-specific productivity is the only primary source of firm heterogeneity. The other, secondary source of heterogeneity, is the firm's export status which directly results from the heterogeneity with respect to productivity. In this static framework, consumers spend their complete income on the consumption of the goods produced in the manufacturing sector.

Consumers

Following Melitz and Ottaviano (2008), preferences of a representative individual from country j are described by a quadratic utility function,

$$U_j = q_{ij}^c(0) + \alpha \int_{m\in\Omega_j} q_{ij}^c(m)dm - \frac{1}{2}\gamma \int_{m\in\Omega_j} (q_{ij}^c(m))^2 dm - \frac{1}{2}\eta \left(\int_{m\in\Omega_j} q_{ij}^c(m)dm\right)^2, \quad (1)$$

where $q_{ij}^c(0)$ and $q_{ij}^c(m)$ refer to the individual consumption of the numeraire and the differentiated good, m. The first index, i, refers to the country where the production of the differentiated good, m, takes place. The second index j, refers to the home country of the consumer. α and η indicate the degree of substitutability between the differentiated varieties and the numeraire, γ governs the degree of differentiation between the varieties. The inverse demand function is given by

$$p_{ij}(m) = \alpha - \gamma q_{ij}^c(m) - \eta Q_{ij}^c, \quad (2)$$

where $Q_{ij}^c = \int_{m\in\Omega_j} q_{ij}^c(m)dm$. With $q_{ij} = L_j q_{ij}^c$ and $q_{ij}^c > 0$, we obtain the subset of produced varieties which satisfies

$$p_{ij}(m) \le \frac{1}{\eta N_j + \gamma}\left(\gamma\alpha + \eta N_j \bar{p}_j\right), \quad (3)$$

where N denotes the number of firms and $\bar{p}_j$ the average price in country j with $\bar{p}_j = 1/N\sum_m p_{ij}(m)$. The consumer price, $p_{ij}(m)$, includes the per-unit transport costs, $p_{ij}(m) = p_i(m) + t_{ij}$, if the good is imported ($j \neq i$).

Producers

We assume that product differentiation is costless which guarantees that each good m is produced by only one firm. Firms maximize profits,

$$\pi_{ij}(m) = q_{ij}(m)\left(p_{ij}(m) - c_i(m) - t_{ij}\right) \quad (4)$$

for the foreign market ($i \neq j$) and for the domestic market ($i = j$ and $t_{ii} = 0$) separately. While products enter symmetrically in the consumption bundle, we keep the firm index m because firms differ with respect to their productivity level. Firm-specific productivity levels translate into firm-specific marginal costs $c_i(m)$, firm-specific prices $p_{ij}(m)$ and firm-specific output levels $q_{ij}(m)$. Using the residual demand from (2), firms obtain their output function as

$$q_{ij}(m) = \frac{L_j}{\gamma}\left(p_{ij}(m) - c_i(m) - t_{ij}\right). \tag{5}$$

A firm stays in the domestic and enters a foreign market if its price at least equals its marginal costs, $p_{ij}(m) = c_i(m) + t_{ij}$. We denote the maximum marginal costs for firms from country i to be active in market j as $\hat{c}_{ij}$. These costs equal the price set by the least productive firm from country i in market j, $\hat{p}_{ij}$, which satisfies (3) with equality. Using this equality and the residual demand as given in (2) and (5), the equilibrium price and quantity can be expressed in terms of the marginal costs of firm k and the maximum marginal costs to survive in country j, $\hat{c}_j$:

$$p_{ij}(m) = \frac{1}{2}\left(\hat{c}_{ij} + c_i(m) + t_{ij}\right) = \frac{1}{2}\left(\hat{c}_j + c_i(m)\right) \tag{6a}$$

$$q_{ij}(m) = \frac{L_j}{2\gamma}\left(\hat{c}_{ij} - c_i(m) - t_{ij}\right) = \frac{L_j}{2\gamma}\left(\hat{c}_j - c_i(m) - 2t_{ij}\right). \tag{6b}$$

We aggregate over all $q_{ij}(m)$ which are produced with marginal costs $c_i(m) + 2t_{ij} \leq \hat{c}_j$ to derive the total export volume, Q_{ij}, that firms from country i ship to country j.

$$\begin{aligned} Q_{ij} &= N_i \frac{L_j}{2\gamma}\int_0^{\hat{c}_j - t_{ij}} \left(\hat{c}_j - c_i(m) - 2t_{ij}\right) g(c_i(m))dc_i(m) \\ &= \underbrace{N_i \left(\frac{\hat{c}_j - t_{ij}}{\hat{c}_i}\right)^{\delta}}_{N_{ij}} \frac{L_j}{2\gamma}\left[\frac{1}{\delta+1}\hat{c}_j - \frac{\delta+2}{\delta+1}t_{ij}\right]. \end{aligned} \tag{7}$$

The productivity of the active firms from country i is assumed to follow a Pareto distribution, $G(c_i(m)) = \left(\frac{c_i(m)}{\hat{c}_i}\right)^{\delta}$, with support $[0; \hat{c}_i]$ which we have applied in the second line of equation (7). Using this distribution assumption allows us to express Q_{ij} as a function of the maximum costs in country j, $\hat{c}_j$, and the number of firms from country i, N_i. The number of firms from country i that are active in country j can be expressed as the product of the share of exporters in the number of firms in i, $N_{ij} = \left(\frac{G(\hat{c}_{ij})}{G(\hat{c}_i)}\right) N_i = \left(\frac{\hat{c}_j - t_{ij}}{\hat{c}_i}\right)^{\delta} N_i$.

In Appendix A.1, we show that the transport costs affect the trade level negatively, i.e. that the partial derivative $\frac{\partial Q_{ij}}{\partial t_{ij}} < 0$. Considering that exports are declared net of transport costs, we next obtain the total bilateral export value by aggregating each firm's export sales, $r_{ij}^{fob}(m) = p_{ij}^{fob}(m) q_{ij}(m)$, over all exporters from i to j,

$$\begin{aligned} EX_{ij} &= N_i \frac{L_j}{4\gamma} \int_0^{\hat{c}_{ij}} \left(\hat{c}_j^2 - c_i^2(m) + 4t_{ij}^2 - 4\hat{c}_j t_{ij}\right) g(c_i(m)) dc_i(m) \\ &= \frac{1}{4\gamma} N_i L_j \hat{c}_i^{-\delta} \underbrace{\left[\frac{2}{2+\delta} (\hat{c}_j - t_{ij})^{2+\delta} + \left(3t_{ij}^2 - 2\hat{c}_j t_{ij}\right)(\hat{c}_j - t_{ij})^{\delta}\right]}_{\Phi(t)}. \end{aligned} \tag{8}$$

Equation (8) shows that the aggregate bilateral export values are characterized by a gravity-type relation where the two country sizes, N_i and L_j, affect exports positively, while the transport costs, t_{ij}, affect them negatively (since $\hat{c}_j \geq 2t_{ij}$). Furthermore, exports rise in the minimum (and therefore average) productivity of the home country $f(1/\hat{c}_i)$ and fall in the productivity of the partner country $f(1/\hat{c}_j)$. As a result of the additive transport costs, the partner country's productivity, $(1/\hat{c}_j)$, is strongly interlinked with the transport costs between the two countries, t_{ij}.

3.2. The Transport Sector

As the transport sector typically consists of a few, large companies, we impose an oligopolistic market structure. We assume that transport is a homogenous service. Consequently, exporting firms will base their decision for a particular transport service supplier entirely on cost considerations. To keep the model simple and to focus on differences in the aggregate pattern of transport costs between two countries, we model the transport sector as consisting of n^T symmetric firms.[2] In a world with I exporting and J importing countries, $I \times J$ transport routes exist. We assume that each transport firm

[2] Imposing symmetry does not affect our main argument while it simplifies the analysis considerably.

serves each route. The total number of transport firms, n^T, is exogenously given.[3]

Transport firms choose their transport technology when starting to service a particular route. Like Yeaple (2005) and Bustos (2011), we simplify this choice by assuming that there are just two possible cost structures to choose from: technology L with low variable costs, a^L, and high fixed costs, f^L, and technology H with high variable costs, a^H, and low fixed costs, f^H, i.e. $a^L < a^H$ and $f^L > f^H$. Consequently, the marginal costs of shipping one unit of a manufactured good between i and j, a^l_{ij} with $l = L, H$, differ with the chosen technology. This simple cost structure allows to catch the idea of economies of scale in the transport sector. Although we assume constant variable costs, fixed costs degression results in scale effects. We further assume that the investment is specific to a particular route, i.e. to the service between two countries i and j. The variable costs, a^l_{ij}, therefore differ with the bilateral distance and with other characteristics of the two trading countries.[4] The total cost function of a transport firm is given by

$$A_{ij}(t_{ij}) = a_{ij} q^T_{ij}(t_{ij}) + f, \tag{9}$$

where q^T_{ij} denotes the units shipped. The profit function reads

$$\pi_{ij}(t_{ij}) = t_{ij} q^T_{ij}(t_{ij}) - A_{ij}(t_{ij}), \tag{10}$$

where t_{ij} is the price for the homogenous transport service.[5] From (10), we obtain the corresponding supply,

$$q^T_{ij} = \left(\frac{t_{ij} - a_{ij}}{t_{ij}}\right) \varepsilon Q_{ij} = \left(\frac{t_{ij} - a_{ij}}{t_{ij}}\right) \varepsilon n^T q_{ij}, \tag{11}$$

[3]The number of firms could be endogenized by allowing for a fixed cost of market entry in the transport sector, f_T. Deriving the number of transport firms endogenously would not alter our results as long as we keep the assumption that each route is served by every transport firm.

[4]Since all variables except the number of firms in the transport sector, n^T, depend on the chosen technology, we drop l hereafter.

[5]While t_{ij} represents transport costs for the manufacturing sector, it represents transport prices for the transport sector. We use both terms alternatively, depending on whether we refer to the manufacturing or the transport sector.

with $\varepsilon = -\frac{\partial Q_{ij}}{\partial t_{ij}} \frac{t_{ij}}{Q_{ij}}$ as the price elasticity of demand. Output, i.e. the supply of transport services, increases in the transport price, t_{ij}, and the export quantity, Q_{ij}, of the manufacturing sector. With demand (as given in (7)) strictly falling and supply (as given in (11)) strictly rising in the transport price, t_{ij}, there exists exactly one transport price level that clears the market for transport services. Equation (11) also shows that the output of a transport service supplier is negatively affected by the variable costs of supplying the service, a_{ij}.

The second equation in (11) uses the fact that transport firms are symmetric by assumption and that the transport service market must be cleared in equilibrium, hence $Q_{ij}(t) = \sum_1^{n^T} q_{ij}(t_{ij}) = n^T q_{ij}$. Solving the supply equation (11) for the transport price, t_{ij}, yields the price as a function of the firms' costs, a_{ij}, the number of firms, n^T, and the demand elasticity, ε,

$$t_{ij} = \frac{\varepsilon n^T}{\varepsilon n^T - 1} a_{ij}. \tag{12}$$

Knowing that in a symmetric equilibrium every firm serves Q_{ij}/n^T of the demand, we can rewrite the profits from (10) as

$$\pi_{ij} = (t_{ij} - a_{ij}) q_{ij} - f = \underbrace{(t_{ij} - a_{ij})}_{\mu_{ij}} \frac{Q_{ij}}{n^T} - f, \tag{13}$$

where we define the mark-up μ_{ij} as $t_{ij} - a_{ij}$. With this outline, we can now study the incentive to invest in a variable costs saving transport technology for the route between country i and j. Equation (14) uses (12) to show that the variable profits, π_{ij}^{var}, generated on route ij increase as the marginal costs of shipping between these two countries fall,

$$\begin{aligned} \frac{d\pi_{ij}^{var}}{da_{ij}} &= \frac{\partial \mu_{ij}}{\partial a_{ij}} \frac{Q_{ij}}{n^T} + \frac{\partial Q_{ij}}{\partial a_{ij}} \frac{\mu_{ij}}{n^T} \\ &= B \frac{Q_{ij}}{n^T} \frac{1}{\varepsilon n^T - 1} < 0, \end{aligned} \tag{14}$$

where $B \equiv 1 - \left(\frac{(1+\delta)[2\hat{c}_j - (2+\delta)t_{ij}]}{(\hat{c}_j - t_{ij})[\hat{c}_j - (2+\delta)t_{ij}]} \right) \frac{\varepsilon n^T}{\varepsilon n^T - 1} = 1 - \frac{\varepsilon}{a_{ij}} < 0$ if the price elasticity of demand ε is not to low, i.e. if $\varepsilon > a_{ij}$. This holds if the transport costs are not too low, since the price elasticity of demand rises with transport costs.[6] In the following, we assume that the price elasticity of demand for shipping is sufficiently high to ensure the negative relationship. Note, that there is a trade-off between lower mark-ups and larger demand following the cost reduction. Since the second effect outweighs the first, profits increase with falling costs. For our argument most important, equation (14) states that the profit-rising effect of investing in advanced technologies increases in the export volume, Q_{ij}, from the manufacturing sector of country i. Thus, routes on which large volumes of goods are traded generate more additional profits if the variable costs of transportation, a_{ij}, fall.

The comparison of profits guides the firm's decision of investing in one of the two available technologies. Transport suppliers decide to invest in the advanced technology if the lower marginal costs generate sufficiently high variable profits to make up for the higher fixed costs. The discussion above reveals that this is more likely for transport routes with high trade volumes, Q_{ij},

$$d\pi_{ij} > 0 \quad \rightarrow \quad \frac{1}{n^T}\left[(t_{ij}^L - a_{ij}^L)Q_{ij}^L - (t_{ij}^H - a_{ij}^H)Q_{ij}^H\right] > f^L - f^H. \tag{15}$$

Routes that generate more additional variable profits are more likely to jump the additional fixed costs hurdle $f^L - f^H$. As argued above, the large trade volume routes create the largest additional variable profits. Hence, on these routes the introduction of the low variable costs technology is more likely. Since the technology choice depends on the trade volume, we expect lower transport prices on routes with large trade volumes. In turn, the technology choice affects the marginal costs and therefore the transport prices,

$$t_{ij}^l = \begin{cases} \frac{n^T a_{ij}^L}{n^T - 1/\varepsilon^L} & \text{for a high trade volume} \\ \frac{n^T a_{ij}^H}{n^T - 1/\varepsilon^H} & \text{for a low trade volume.} \end{cases} \tag{16}$$

Equation (16) shows that the transport costs for firms from the manufacturing sector

[6] See Appendix A.2 for the derivation of this result.

differ for routes of similar distance and similar other characteristics if the chosen technology differs. This implies that transport prices which are set in the transport sector eventually depend on export volumes decided on in the manufacturing sector, which, in turn, depend on transport prices. The mutual dependance of exports as given by equation (8) and transport prices as given by equation (16) reveals that both variables are, in fact, jointly determined.

4. Estimating Transport Costs: An Illustrative Example

The main insight from the theoretical model is that approximating transport costs by distance and other geography-related variables is not sufficient in the presence of a transport sector with optimizing transport service suppliers. Hummels et al. (2009) point out that omitting the part of equation (16) that is related to market power, $\frac{n^T}{(n^T-1/\varepsilon)}$, affects the estimation of transport cost equations. We complement this finding by adding the role of technology choice which impacts transport prices via the marginal costs, a_{ij}, of supplying transport services between two locations i and j. These costs vary with the distance between the two locations, other marginal cost-related variables, and with the endogenous decision to invest in a more efficient technology for transport services between the two locations.

Unfortunately, we do not have information about route-specific variable costs in the transport sector. In particular, we do not know anything about the technology choice. Nevertheless, we hope to recover this decision from the data. Since setting up an econometric model with an unobserved variable as the main variable of interest is not straight-forward, we proceed in two steps. We start with constructing a data set, which closely resembles the theoretical model from Section 3. We use this generic data to find the most appropriate empirical set-up. In Section 5, we apply this econometric model to real data.

To construct the generic data, we randomly choose latitudes and longitudes for 30 exporting and 61 importing countries[7], from which we calculate a distance matrix between any two of these "countries".[8] We draw an arbitrary size ($GDP_i > 0, GDP_j > 0$) for each of these countries from a uniform distribution with mean 500 and a country-specific marginal cost threshold which corresponds to $\hat{c}_i$ in equation (8) with mean 5. In the following, we call this variable GDP per capita and denote it by gdp_i. Additionally, we draw two error terms, u_t and u_{ex}. With these variables, we can construct export levels and transport costs that are consistent with equations (8) and (16) from the model outlined above. Since the underlying parameters of the exogenous explanatory variables are known, we can assess different regression set-ups in a simple simulation exercise. The descriptive statistics of the constructed sample are given in Table C.1 in Appendix C. All results are obtained by repeating the simulation 10,000 times.

According to (16), we assume that the prices for supplying the transport service depend on route-specific marginal costs, on the technology choice and on an error term. For simplicity we ignore the market power term, since we do not have anything new to add to the analysis of Hummels et al. (2009). To approximate marginal costs, we use the bilateral distance between the two countries and GDP per capita in the export country. GDP per capita is included to account for the wage in the transport sector. Thus, we construct transport prices as

$$t_{ij} = 2 \times dist_{ij}^{0.2} \times gdp_i / I_{ij} \times u_t, \tag{17}$$

where the technology choice, I_{ij}, is set equal to one for all trade pairs. u_t is an error term. The parameter 2 is chosen to generate (jointly with the constant from the trade regression) average export over GDP ratios that are roughly in line with observed export over GDP ratios. The exponent 0.2 reflects the empirical results in Hummels et al. (2009). We use the constructed transport prices to determine the value of country i's exports to country j according to (8). Equation (8) suggests that the exports from

[7]The sample size is chosen to match the real data, we apply the econometric model to in Section 5.

[8]We employ the great circle distance formula which uses the radian values of the latitude and longitudes.

country i to country j are a positive function of the two country sizes, GDP_i and GDP_j, country i's marginal cost threshold, and a negative function of the transport costs, t_{ij}.[9] We capture the marginal cost threshold in country i with country i's GDP per capita, gdp_i. u_{ex} is an error term.

$$EX_{ij} = 0.002 \times GDP_i \times GDP_j \times gdp_i/t_{ij} \times u_{ex}. \quad (18)$$

In equation (17), distance is exogenous, but the investment decision is not. It depends on the export level of manufacturing firms. Equation (15) suggests that the trade level affects the technology choice with higher trade levels favoring investments. To reflect the endogenous investment decision, we rewrite (17) as

$$t_{ij} = 2 \times dist_{ij}^{0.2} \times gdp_i/I_{ij}(EX_{ij}) \times u_t. \quad (19)$$

We account for the technology choice by using two alternative investment functions:

we start with building a discrete variable. In line with Section 3.2, transport service suppliers can recover the higher fixed costs of the investment only if their exports exceed a certain level. Thus, there is an export threshold according to which the investment indicator realizes either a^L or a^H. While modeling the investment decision as a discrete choice variable closely reflects the theoretical set-up, it will probably not match the real world.

Therefore, we assume a continuum of investment opportunities related to a continuum of marginal costs as an alternative. Applying the reasoning from above, higher investment induces lower costs and will consequently pay on routes with high bilateral trade values. The inverse relationship between exports and the marginal costs of supplying the transport service, a_{ij}, is given by $a_{ij}(EX_{ij})$ with $a'_{ij}(.) < 0$.

To test the discrete version of the investment decision, we set $I_{ij} = 3$ for trade pairs with $EX_{ij} > 100$. The chosen export threshold and the parameters discussed

[9] Without loss of validity, the simulation does not reflect all non-linearities from the theoretical model.

above imply that investments into the advanced technology take place on about 15% of all trade routes. In the continuous version of the investment decision, we assume $I_{ij} = 2(EX_{ij}/10)^{0.15}$. The parameters are chosen to match the maxima and minima of the discrete case; the mean in the continuous case is higher (see Table C.1).

Having ruled out the possibilities of heteroskedasticity in the error terms and of zero trade flows between any pair of countries in the simulation exercise, we can log-linearize equation (19) and obtain,

$$\ln(t_{ij}) = \beta_0 + \beta_1 \ln(dist_{ij}) + \beta_2 \ln(gdp_i) - \beta_3 \ln(I_{ij}(EX_{ij})) + \ln(u_t). \tag{20}$$

In the real world, the investment decision, I_{ij}, is unobserved and therefore omitted when estimating equation (20). The resulting bias stems from two sources.

The first problem results from the correlation between the omitted variable, I_{ij}, and the explanatory variable, $dist_{ij}$ (mean correlation coefficient in the discrete case -0.115 and in the continuous case -0.097). Hence, $dist_{ij}$ is not orthogonal to the error term when estimating (20) without a variable capturing the investment decision. Since the coefficient of the investment decision is negative, the sign of the covariance between the omitted variable and the regressor, $dist_{ij}$, determines the direction of the bias. $\beta_3[Cov(dist_{ij}, I_{ij})/Var(dist_{ij})]$ gives the magnitude of the bias of β_1 (Wooldridge, 2002). Thus, the negative covariance of the investment decision with distance indicates the upward bias of β_1 when omitting I_{ij} from (20). In principal, gdp_i is not orthogonal to u_t either leading to a bias of β_2. In our simulation exercise, however, $Cov(gdp_i, I_{ij})$ is very close to zero.

A proxy variable that is strongly correlated with the omitted variable but does not have a direct impact on trade costs could alleviate the bias. In the case with the discrete investment as a marginal cost shifter, a dummy variable indicating the top 150, top 250 or top 350 export routes works well. Such a dummy is closely related to the investment indicator. The cost reduction by cheaper transport services does not change the ranking of bilateral export relationships. The top 150 (top 250, top 350) relationships remain the top 150 (top 250, top 350) bilateral relationships irrespective of whether investment took place on none, on some or on all routes. In the case of the continuous investment function, the direct inclusion of the export level will be more appropriate. This directly brings us to the second source of the bias.

The second problem results from the fact that the investment indicator is not merely a function of the partner countries' GDPs, the distance between them and the GDP per capita of country i. Instead, it reflects an endogenous decision of transport service suppliers, which affects the level of their marginal costs. Therefore, as much as the investment decision depends on transport costs, transport costs depend on the chosen technology. In equilibrium, both variables are jointly determined. A single equation framework as in equation (20) therefore requires the investment indicator (or its proxy variable, the export level) to be appropriately instrumented. Both GDPs, the bilateral distance and the GDP per capita are by definition exogenous in equation (18) and serve therefore as valid instruments.

With the constructed data, we estimate six versions of equation (20) and report the results in the Tables 1 and 2. Table 1 shows the results for the discrete case, Table 2 shows the results for the continuous case. We repeat the exercise of constructing the data and running the regressions 10,000 times to ensure that the results are not driven by drawing outliers of the random variables. Thus, Tables 1 and 2 report average results generated by 10,000 repetitions.

Column 1 of both tables presents the results when omitting I_{ij} from equation (17). For both the discrete and the continuous case, the distance effect is too large. We address the omitted variable bias with proxies for the top 150, top 250 and top 350 export routes in Columns 2-4 and the endogeneity bias with IV regressions in Columns 5 and 6 of both tables. Column 5 (in bold) thereby presents the results with an instrumented investment indicator, assuming the investment indicator to be an observable variable. Since this specification addresses the omitted variable and the endogeneity bias, we refer to it as the "true model".

In the discrete case, the coefficients of the proxies for the top 150, top 250 and top

Table 1: Addressing the Omitted Variable Bias in the Transport Cost Estimation: the Discrete Case

	Omitting I_{ij}	Proxy top 150	Proxy top 250	Proxy top 350	**IV** I_{ij}	IV EX_{ij}
Dependent variable: Bilateral transport costs t_{ij}						
$dist_{ij}$	0.275	0.209	0.206	0.214	**0.200**	0.229
	(0.0148)	(0.0101)	(0.00813)	(0.00898)	**(0.00453)**	(0.0116)
gdp_i	1.000	1.000	1.000	1.000	**1.000**	1.000
	(0.0105)	(0.00707)	(0.00571)	(0.00633)	**(0.00312)**	(0.00817)
top 150		-1.054				
		(0.0232)				
top 250			-0.961			
			(0.0150)			
top 350				-0.788		
				(0.0145)		
I_{ij}					**-1.000**	
					(0.0176)	
EX_{ij}						-0.165
						(0.00474)
R^2	0.84	0.92	0.95	0.94	**0.99**	0.90

Table 2: Addressing the Omitted Variable Bias in the Transport Cost Estimation: the Continuous Case

	Omitting I_{ij}	Proxy top 150	Proxy top 250	Proxy top 350	**IV** I_{ij}	IV EX_{ij}
Dependent variable: Bilateral transport costs t_{ij}						
$dist_{ij}$	0.230	0.209	0.208	0.207	**0.200**	0.198
	(0.00906)	(0.00852)	(0.00821)	(0.00793)	**(0.00435)**	(0.00434)
gdp_i	1.000	1.000	1.000	1.000	**1.000**	1.000
	(0.00640)	(0.00597)	(0.00577)	(0.00558)	**(0.00309)**	(0.00308)
top 150		-0.328				
		(0.0196)				
top 250			-0.315			
			(0.0151)			
top 350				-0.309		
				(0.0128)		
I_{ij}					**-1.000**	
					(0.0141)	
EX_{ij}						-0.138
						(0.00182)
R^2	0.93	0.94	0.94	0.95	**0.98**	0.98

Note: Standard errors in parentheses.

Source: Own calculations.

350 export routes come close to the coefficients of the true model. In the continuous case, using the instrumented export level, however, works better. The overidentification test

rejects the validity of the instruments in less than 10% of the repetitions with the continuous investment indicator, while it rejects the validity of the instruments for nearly 50% of the repetitions with the discrete investment indicator. Because the instruments are exogenous by construction, this result demonstrates how sensitive the overidentification test reacts to the nature of the omitted investment variable, i.e. whether it is a discrete or a continuous variable. This is important to keep in mind for the estimations with real data in Section 5, where the nature of the investment function is unknown.

We check the goodness of fit of the different models by comparing the R^2s. Unsurprisingly, for the discrete case, we obtain the highest R^2 on average for the regression with the dummy variable which comes closest to the true average number of investments (250.13 for our parameter choices) – the top 250 proxy. The top 250 dummy beats the top 150 proxy in 7,187, the top 350 proxy in 7,260 and the IV estimation that instruments the continuous exports variable in 9,679 of all 10,000 repetitions. By contrast, for the continuous case, the IV regressions explain most of the variation of the transport prices. Instrumenting exports always gives a higher R^2 than using any of the discrete proxy variables.[10]

When applying the empirical model to real data, we face an unkown shape of the investment function. We expect it to be in between the discrete and the continuous case. Given the results of the simulation exercise, we will let the adjusted R^2 guide the search for the preferred specification also in the empirical application in Section 5.

5. Estimating Transport Costs: The Empirical Test

After having laid out a strategy on how to approach the omitted variable and the endogeneity problem, we expose it to real data. For this purpose, we have collected UPS transport price data. We present two kinds of results in this section: results based on OLS regressions and on poisson regressions. Following Silva and Tenreyro (2006), we use the poisson estimator (i) because we cannot rule out heteroskedastic error terms when

[10] In addition to the higher R^2, both preferred specifications yield distance coefficients that are closer to the true model than any alternative specification.

working with real data and (ii) because poisson regressions allow for a correct treatment of zero trade flows. Even though the number of zeros is very low in this OECD countries-centered sample, the poisson estimations provide an important robustness check.

5.1. Data

Bilateral transport costs are difficult to measure.[11] We have built a new data set by collecting information from UPS on the costs of shipping a *10kg package per express delivery* between two countries. Transport prices for 2010 are available for 61 countries. In cases where different prices apply to different regions of one country, we take the prices of the region to which the most populated city belongs.

We analyze the transport prices charged on different routes together with bilateral trade data. The OECD ICTS database provides bilateral trade data in US$ for 30 OECD countries (all member states as of 2009) with partner countries worldwide. The latest available year for which the data is complete, is currently 2009. We select the 61 trade partners for which we were also able to gather information on transport prices. If we had full information, we would have a data set containing $30 \times 61 - 30 = 1,800$ observations.[12] in Due to a few missings in either the trade or the transport price data, the sample reduces to 1,740 observations.

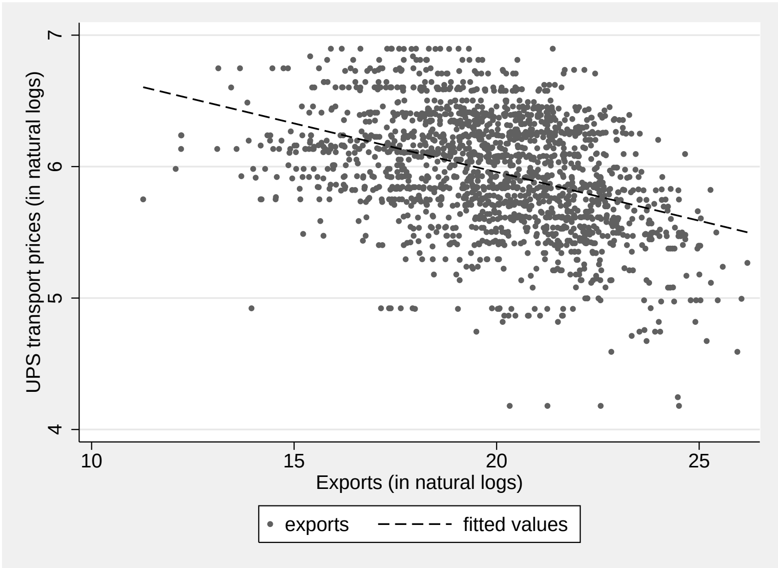
GDPs and per-capita GDPs in current US$ are obtained from the World Development Indicators (WDI). The geodesic distances between the most populated cities of two countries are calculated using the great circle formula and taken from CEPII.

Table C.2 presents the descriptive statistics of the variables we use. Figure 1 plots bilateral export values and transport prices for each country pair in our sample. The downward sloping fitted line confirms that transport prices are lower the higher the export value.

[11] Attempts to derive transport costs from c.i.f. versus f.o.b. prices are subject to inconsistencies due to discrepancies in trade reporting. Only a limited number of countries (the US, New Zealand, Australia, Argentina, Brazil, Bolivia, Chile, Colombia, Ecuador, Paraguay, Peru and Uruguay) report freight expenditures in import customs declarations.

[12] Please find the list of all included countries in Appendix B.

Figure 1: UPS Transport Prices and Exports



5.2. Main Results

We start with estimating transport prices by using a single equation approach. In order to make our results match the predominant number of empirical studies, we primarily report OLS estimates. Table 3 shows the estimation of transport prices as a function of distance and GDP per capita in Column 1. The results indicate that firms set higher prices on more distant routes. The impact of distance on transport prices is, however, moderate. Transporting goods between countries which are 10% farther away from each other is 1.43% more expensive, on average. This result is in line with Clark et al. (2004) and other empirical estimations of transport cost equations that do not control for route-specific investments. Other marginal costs, captured by per capita GDP, have a similar effect.

Table 3: OLS Estimation of Transport Prices

	Omitting I_{ij}	Proxy top 150	Proxy top 250	Proxy top 350	IV EX_{ij}
Dependent variable: t_{ij}					
$dist_{ij}$	0.143***	0.121***	0.117***	0.112***	0.083***
	(0.018)	(0.017)	(0.016)	(0.017)	(0.017)
gdp_i	0.132***	0.145***	0.150***	0.148***	0.163***
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
top 150		-0.383***			
		(0.049)			
top 250			-0.345***		
			(0.037)		
top 350				-0.293***	
				(0.030)	
EX_{ij}					-0.076***
					(0.008)
N	1,740	1,740	1,740	1,740	1,739
R^2	0.151	0.205	0.220	0.214	0.232
Endog. test					12.585
p-val.					0.000
Hansen J					1.241
p-val.					0.265
Underid. test					57.35
p-val.					0.000
Weak id. test					1730.70
p-val.					0.000

Note: Cluster-robust standard errors in parentheses with significance at the *** $p<0.01$, ** $p<0.05$, * $p<0.1$ level.
Source: Own calculations.

Since we cannot observe investments in the transport sector, we follow the strategy outlined in Section 4 and let the R^2s guide our decision about the most appropriate specification. In Columns 2-4, we include three dummy variables for the top 150, top 250 and top 350 export routes in order to approximate unobservable infrastructure investments. All three proxy variables have a significant negative impact, as expected. In these regressions, we can explain up to 22% of the variation of transport prices. The specification including the top 250 proxy thereby yields the highest R^2 among the dummy variable proxies.[13]

Introducing exports as an explanatory variable raises the R^2 further, indicating that

[13] This result has been used to parameterize the simulation in Section 4 in accordance with the empirical results.

the investment function is rather continuous than discrete. Even though we introduce exports with a one year lag, the vast evidence on the gravity model suggests that endogeneity may still be present. Indeed, the endogeneity test rejects the hypothesis that exports can in fact be treated as exogenous at the 1% significance level. Consequently, a consistent estimation of transport prices requires that exports are appropriately instrumented.

Valid instruments for exports must fulfill two criteria: first, they need to be independent from the residuals of the transport price equation, and second, they need to be sufficiently correlated with the included endogenous regressor. We employ both countries' GDPs, the bilateral distance between them and the per capita GDP of the exporting country as instruments for bilateral exports. Hansen's J overidentification test indicates that the instruments are uncorrelated with the error term and that the validity of the chosen instruments cannot be rejected on this ground. The Kleibergen-Paap statistics further show that the excluded instruments are sufficiently correlated with bilateral exports as the endogenous regressor.

The IV estimation results in Column 5 are close to the single equation estimation results from Columns 1-4. Note, however, that the distance coefficient has dropped considerably compared to the basic estimation in which we omitted the investment decision. Most importantly, we find that two countries with exports 10% above the average for all trade pairs enjoy 0.8% lower transport prices.

These results are in line with Skiba (2007) who employs a very different dataset of maritime transport costs. Skiba (2007) finds an average reduction of 0.6% with a 10% export increase. The results strengthen therefore our argument that it is not sufficient to rely only on distance to approximate bilateral transport costs.

In accordance to the findings of Silva and Tenreyro (2006), we additionally provide Poisson PML results, which are consistent in the presence of heteroskedasticity.

The results reported in Table 3 remain generally robust when applying Poisson PML estimation in Table 4. In line with the findings of Silva and Tenreyro (2006), the coefficients are generally slightly below the OLS estimates. Bilateral distance remains a

Table 4: Poisson Estimation of Transport Prices

	Omitting I_{ij}	Proxy top 150	Proxy top 250	Proxy top 350	IV EX_{ij}
Dependent variable: t_{ij}					
$dist_{ij}$	0.131***	0.113***	0.109***	0.104***	0.088***
	(0.018)	(0.017)	(0.016)	(0.017)	(0.018)
gdp_i	0.132***	0.142***	0.146***	0.145***	0.152***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.006)
top 150		-0.391***			
		(0.046)			
top 250			-0.347***		
			(0.037)		
top 350				-0.289***	
				(0.030)	
EX_{ij}					-0.054***
					(0.007)
N	1,740	1,740	1,740	1,740	1,739
R^2	0.126	0.171	0.185	0.181	0.198

Note: the single equation estimations are reported with cluster-robust standard errors in parentheses with significance at the *** p<0.01, ** p<0.05, * p<0.1 level.

Source: Own calculations.

strong predictor of transport prices, even though there is no "exclusive" relationship as suggested by the gravity literature which often relies entirely on distance to approximate transport costs. Instead, the infrastructure investments, which we approximate by dummy variables for the most frequented export routes and by the bilateral export level are important transport price determinants as well. Including the investment proxies increases the R^2 also in the poisson regressions. Again, it is highest in Column 5, where we include and instrument the bilateral export level. Moreover, the distance coefficient falls which we, based on the theoretical considerations and the simulation, interpret as bias correction.

5.3. Robustness Checks

Transport service suppliers like the UPS do not offer transport for all kinds of goods. Certain raw materials, for example, need a very specific infrastructure, like pipelines, on which cross-border transport crucially hinges. To account for the fact that the collected UPS transport prices may not apply to all goods, we repeat the estimations in Table

3 for two restricted samples. In the large sample, we exclude trade in petroleum, gas, and electric current[14] from total bilateral exports. In the small sample, we additionally exclude goods that might have special transportation requirements, such as animals and perishable foods, chemicals, machinery, and vehicles.[15] Table D.1 in Appendix D shows that the coefficients are, in fact, very close to the main results reported in Section 5.2.

Next, we make use of a new data set on maritime transport costs which was built as part of an OECD project on transport and logistics costs of trading (OECD, 2011). The twelve countries that collect transport cost information as part of their import customs declarations form the basis of this data set. For all other countries in the sample, transport costs are estimated using aggregate indicators. The largest version of the data set includes 43 importing countries in total. Since the EU is treated like one country, the final country coverage overlaps only to a limited extent with the country coverage of our transport price data. Furthermore, the original product-level data is not comprehensive and therefore, any aggregation over products must be treated with caution. Keeping these limitations in mind, the rather low correlation coefficient of 0.32 between UPS transport prices and maritime unit transport costs seems plausible (0.33 with commodity dummies). Nevertheless, our main results hold when we repeat the regressions from Table 3 with the maritime transport costs data set at the two-digit HS level.[16] Table D.2 shows that the investment proxies are significant determinants of transport costs and that the distance coefficient drops with their inclusion. The specification with instrumented exports yields, again, the highest R^2.

Finally, we add the bilateral trade imbalance to our baseline specification in Table 3. Table D.3 shows that imbalances do not drive our results. Due to the lack of data on route-specific competition, we are, unfortunately, unable to control for Hummels et al. (2009)'s market power effect.[17]

[14] This corresponds to Chapters 33-35 of the Standard International Trade Classification (SITC) Rev. 2.

[15] This corresponds to Chapters 00-03, 51-52, 71-74, 78, 94 of the Standard International Trade Classification (SITC) Rev. 2.

[16] We denote product-level variables with the subscript k.

[17] As an additional robustness check, we have repeated the estimations in Section 5.2 with country

6. Transport Sector Investments and Globalization

The empirical results reveal that distance affects transport prices positively. Yet, geography is not a destiny although it poses a challenge to policy-makers. Our results point to a strong price reducing effect of bilateral trade values, which we interpret as stemming from investments in the transport sector. These investments in new, often large-scale trade-enhancing transport technologies result in important cost savings. Falling transport costs, i.e. falling costs of trade are the drivers of globalization. Even though the debate on the "distance puzzle" or the "missing globalization puzzle" (Coe et al., 2007) mentions that new technologies in transport bring down the costs of trade, in empirical applications such technology changes do not play a role. Instead, transport costs are modeled as iceberg costs which increase in distance. Consequently, globalization is searched for in the distance coefficient.

We argue that finding the source of falling trade costs requires augmenting international trade models by a transport sector, where the transport prices are actually set. When setting up the transport sector, we explicitly model firms that face a technology choice. Firms choose route-specific technologies to maximize profits on each route. Modeling both the manufacturing goods sector and the transport sector enables us to show that specifying transport costs as a mere function of distance and distance-related variables misses an important point and creates an omitted variable problem in empirical applications. Since actual investments are often unobservable, the regressions require a proxy variable as a regressor.

From a policy perspective, there are at least three arguments that support the inclusion of transport sector investments in the analysis of international trade: it helps understanding (i) the driving force of globalization, (ii) the distance puzzle, and (iii) trade and development.

First, our model has the nice reinforcing feature of increasing trade leading to falling

dummies. We obtain qualitatively the same results with a slightly higher distance and per capita GDP coefficient. These additional results are not reported here but will be made available upon request.

transport prices which again stimulate trade. We think that the globalization process is well explained by such an investment-induced fall in transport prices. Seen like this the driving force of globalization is endogenous and the outcome of a profit-maximizing behavior in the transport sector. The empirical results support this view. Transport prices are driven down by trade levels. Unfortunately, we do not have time series data and take all variation from the cross-section but if the production function of the transport sector did not miss anything important, infrastructure investments are a main source of differences in transport prices on routes with similar distances. And, they are easily included as a regressor in the transport price equation.

Second, the study relates to the distance puzzle in two rather different ways. On the one hand, we observe that the omitted variable biases the distance coefficient in the transport price equation upwards which might contribute to the biased distance coefficient in gravity equations. On the other hand, we argue that if estimated correctly, the distance coefficient should be unaffected anyway by technological changes that do not influence the distance elasticity of transport costs. If this elasticity is systematically reduced, we are probably confronted with an investment function which is not only affected by the trade level but also by distance. That might be the case if the technology choice includes the decision about different modes (air, sea, land, rail, pipeline) of transport which we have abstracted from in this study.

Third, the circular causality of transport prices and trade levels is very important for developing countries. Any change that leads to increasing trade has the potential to reduce transport prices and any transport price reduction increases trade levels. A regional trade agreement for instance might induce more trade and therefore lower transport prices which reinforce trade integration even more. Better investment conditions in the transport sector might induce investments in modern technologies and lower transport prices, thereby increasing the level of trade. One can think of many other policy measures that could help relatively closed economies to start a virtuous circle of lower transport costs and larger trade.

7. Conclusions

Unlike most of the literature that assumes exogenously set, iceberg-type transport costs, this paper proposes marginal costs and prices in the transport sector to be endogenous and affected by the bilateral export levels between two countries. By setting up a theoretical framework which comprises a manufacturing and a transport sector, we show that optimizing transport service suppliers invest in modern transport technology on highly frequented trade routes. The technology choice affects transport prices via the marginal costs of supplying transport services between two locations. If this description of investment in the transport sector is correct, it is not sufficient to approximate transport costs by distance and distance-related variables as done in the vast majority of empirical trade applications.

Using a constructed data set, we illustrate that the bias stemming from the omission of the investment decision in the transport sector, and its endogeneity to bilateral trade levels can be cured by using proxy variables and IV techniques. Employing a new data set which contains information on UPS transport prices, we detect an effect from exports on transport prices. We find that two countries with exports 10% above the average for all trade pairs enjoy 0.8% lower transport prices. This result adds to the discussion of the drivers of globalization, the distance puzzle and the development of economies which are currently lagging behind in terms of trade openness.

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Appendix A. Theoretical Appendix

Appendix A.1. Derivation of the Negative Slope of the Demand Function

Demand is given by (7) which can be written as

$$Q_{ij} = \hat{c}_i^{\delta} \frac{N_i L_j}{2\gamma} \left(\hat{c}_j - t_{ij}\right)^{-\delta} \left(\frac{1}{1+\delta}\hat{c}_j - \frac{\delta+2}{\delta+1} t_{ij} \right) \qquad \text{(Appendix A.1)}$$

The partial derivative with respect to transport costs t_{ij} reads

$$\begin{aligned} \frac{\partial Q_{ij}}{\partial t_{ij}} &= -\delta \left(\hat{c}_j - t_{ij}\right)^{-1} \hat{c}_i^{\delta} \frac{N_i L_j}{2\gamma} \left(\hat{c}_j - t_{ij}\right)^{-\delta} \left(\frac{\hat{c}_j - (2+\delta) t_{ij}}{1+\delta} \right) \\ &- \frac{\delta+2}{\delta+1} \hat{c}_i^{\delta} \frac{N_i L_j}{2\gamma} \left(\hat{c}_j - t_{ij}\right)^{-\delta} \\ &= - \left(\frac{\delta}{\hat{c}_j - t_{ij}} + \frac{2+\delta}{\hat{c}_j - (2+\delta) t_{ij}} \right) Q_{ij} < 0. \end{aligned}$$

Since $\hat{c}_j - (2+\delta)t_{ij}$ is positive, the partial derivative is negative.
We use the partial derivative to derive ε as $\varepsilon = -\frac{\partial Q_{ij}}{\partial t_{ij}} \frac{t_{ij}}{Q_{ij}} = \left(\frac{\delta}{\hat{c}_j - t_{ij}} + \frac{2+\delta}{\hat{c}_j - (2+\delta)t_{ij}} \right) t_{ij}$.
Note that the elasticity of demand increases in t_{ij}, since
$\frac{\partial \varepsilon}{\partial t_{ij}} = \frac{\delta(\hat{c}_j - t_{ij}) + t_{ij}\delta}{[\hat{c}_j - t_{ij}]^2} + \frac{(2+\delta)[\hat{c}_j - (2+\delta)t_{ij}] + (2+\delta)^2 t_{ij}}{[\hat{c}_j - (2+\delta)t_{ij}]^2} > 0$

Appendix A.2. Derivation of the Negative Slope of the Profit Function

The change of the variable profits π_{ij}^{var} in reaction to a cost reduction has two components: (i) the mark-up $\mu_{ij} = t_{ij} - a_{ij}$ decreases and (ii) the demand Q_{ij} increases. Thus, $\frac{\partial \pi_{ij}^{var}}{\partial a_{ij}} = \frac{\partial \mu_{ij}}{\partial a_{ij}} Q_{ij}/n^T + \frac{\partial Q_{ij}}{\partial a_{ij}} \frac{\mu_{ij}}{n^T}$. We derive the two effects in turn. We write the mark-up μ as $\mu_{ij} = \frac{1}{\varepsilon n^T - 1} a_{ij}$.

$$\text{First component:} \quad \frac{\partial \mu_{ij}}{\partial a_{ij}} \frac{Q_{ij}}{n^T} = \frac{1}{\varepsilon n^T - 1} \frac{Q_{ij}}{n^T} > 0$$

The second part involves the partial derivation of demand with respect to costs of supplying transport $\frac{\partial Q_{ij}}{\partial a_{ij}} = \frac{\partial Q_{ij}}{\partial t_{ij}} \frac{\partial t_{ij}}{\partial a_{ij}} = -\left(\frac{\delta}{\hat{c}_j - t_{ij}} + \frac{2+\delta}{\hat{c}_j - (2+\delta)t_{ij}} \right) Q_{ij} \frac{1}{\varepsilon n^T - 1}$.

$$\text{Second component:} \quad \frac{\partial Q_{ij}}{\partial a_{ij}} \frac{\mu_{ij}}{n^T} = - \left(\frac{\delta}{\hat{c}_j - t_{ij}} + \frac{2+\delta}{\hat{c}_j - (2+\delta)t_{ij}} \right) \frac{Q_{ij}}{n^T} \frac{1}{\varepsilon n^T - 1} \frac{\varepsilon n^T}{\varepsilon n^T - 1}$$

The effect of *decreasing* marginal costs a_{ij} on variable profits π_{ij}^{var} in the transport sector is therefore positive, if the demand elasticity exceeds ε the marginal costs.

$$\frac{\partial \pi_{ij}^{var}}{\partial a_{ij}} = \frac{Q_{ij}}{n^T} \frac{1}{\varepsilon n^T - 1} \underbrace{\left[1 - \left(\frac{(1+\delta)[2\hat{c}_j - (2+\delta)t_{ij}]}{(\hat{c}_j - t_{ij})[\hat{c}_j - (2+\delta)t_{ij}]} \right) \frac{\varepsilon n^T}{\varepsilon n^T - 1} \right]}_{B = 1 - (\varepsilon / a_{ij})} < 0 \quad \text{if } \varepsilon > a_{ij}$$

Appendix B. Country List

Table B.1: List of Exporting Countries

Australia	Finland	Ireland	New Zealand	Spain
Austria	France	Italy	Norway	Sweden
Belgium	Germany	Japan	Poland	Switzerland
Canada	Greece	Luxembourg	Portugal	Turkey
Czech Republic	Hungary	Mexico	Slovak Republic	United Kingdom
Denmark	Iceland	Netherlands	South Korea	United States

Table B.2: List of Importing Countries

Algeria	Croatia	Iceland	Netherlands	Slovenia
Argentina	Czech Republic	India	New Zealand	South Africa
Australia	Côte d'Ivoire	Indonesia	Nigeria	South Korea
Austria	Denmark	Ireland	Norway	Spain
Belgium	Egypt	Israel	Panama	Sweden
Brazil	Estonia	Italy	Peru	Switzerland
Bulgaria	Finland	Japan	Philippines	Thailand
Canada	France	Lithuania	Poland	Tunisia
Chile	Germany	Luxembourg	Portugal	Turkey
China	Greece	Malaysia	Russia	United Kingdom
Colombia	Hong Kong, China	Mexico	Singapore	United States
Costa Rica	Hungary	Morocco	Slovak Republic	Uruguay
				Venezuela

Appendix C. Descriptive Statistics

Table C.1: Descriptive Statistics: Generic Data Set

Variable	Mean	Std. Dev.	Min	Max
EX_{ij}	48.30101	43.26484	.1637765	262.7748
EX_{ij} (discrete indicator)	85.49509	130.3522	.1637765	788.3245
EX_{ij} (cont. indicator)	130.7079	131.1241	.2043223	859.8897
t_{ij}	53.33445	31.85967	2.09644	139.5377
t_{ij} (discrete indicator)	48.73319	32.69631	1.014088	139.4168
t_{ij} (cont. indicator)	23.84564	15.99659	.7897388	108.1036
GDP_i	500.6226	283.0366	32.58583	968.2606
GDP_j	500.2634	286.0244	16.04828	983.9497
$dist_{ij}$	4834.533	2447.5	0	11669.45
gdp_i	4.991023	2.824063	.3244602	9.670952
I_{ij} (discrete)	1.277914	.6782134	1	3
I_{ij} (continuous)	2.353069	.4319265	.9341526	3.260896
u_t	.9999748	.1154719	.8002172	1.199781
u_{ex}	.9999977	.0288664	.9500549	1.049946

Source: Own calculations.

Table C.2: Descriptive Statistics: Real Data Set

Variable	Mean	Std. Dev.	Min	Max
t_{ij}	426.4566	180.4115	65.35735	989.058
$dist_{ij}$	6444.817	5042.864	59.61723	19629.5
gdp_i	38277.33	18457.15	8720	84640
top 150	.0833333	.2764622	0	1
top 250	.1388889	.3459266	0	1
top 350	.1944444	.3958824	0	1
EX_{ij} (in Tsd. US$)	3760000	13200000	0.439	237000000
GDP_i (in Mrd. US$)	1360	2620	12.1	14100
GDP_j (in Mrd. US$)	879	1990	12.1	14100

Source: Own calculations.

Appendix D. Additional Empirical Results

Table D.1: Robustness: Restricted Samples

	Large Sample				Small Sample			
	Proxy top 150	Proxy top 250	Proxy top 350	IV EX_{ij}	Proxy top 150	Proxy top 250	Proxy top 350	IV EX_{ij}
Dependent variable: t_{ij}								
$dist_{ij}$	0.121***	0.117***	0.112***	0.084***	0.118***	0.116***	0.109***	0.079***
	(0.016)	(0.016)	(0.017)	(0.018)	(0.016)	(0.016)	(0.017)	(0.018)
gdp_i	0.144***	0.147***	0.145***	0.161***	0.145***	0.145***	0.144***	0.160***
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
top 150	-0.397***				-0.428***			
	(0.046)				(0.047)			
top 250		-0.340***				-0.348***		
		(0.037)				(0.035)		
top 350			-0.292***				-0.312***	
			(0.032)				(0.032)	
EX_{ij}				-0.076***				-0.075***
				(0.008)				(0.008)
N	1,740	1,740	1,740	1,739	1,740	1,740	1,740	1,739
R^2	0.210	0.218	0.213	0.231	0.219	0.221	0.222	0.245
Endog. test				13.635				6.330
p-val.				0.000				0.012
Hansen J				1.273				1.618
p-val.				0.256				0.203
Underid. test				57.437				56.979
p-val.				0.000				0.000
Weak id. test				1753.73				1420.70
p-val.				0.000				0.000

Note: Cluster-robust standard errors in parentheses with significance at the *** p<0.01, ** p<0.05, * p<0.1 level.

Source: Own calculations.

Table D.2: Robustness: Maritime Transport Costs

	Omitting I_{ij}	Proxy top 20%	Proxy top 25%	Proxy top 30%	IV EX_{ij}
Dependent variable: $martc_{ijk}$					
$dist_{ij}$	0.361***	0.309***	0.287***	0.308***	0.252***
	(0.033)	(0.033)	(0.033)	(0.031)	(0.034)
gdp_i	-0.046*	0.024	0.035	0.021	0.037
	(0.026)	(0.027)	(0.027)	(0.027)	(0.029)
top 20%		-0.344***			
		(0.067)			
top 25%			-0.385***		
			(0.065)		
top 30%				-0.313***	
				(0.059)	
EX_{ij}					-0.062***
					(0.013)
N	6,754	6,754	6,754	6,754	6,754
R^2	0.039	0.055	0.062	0.056	0.069
Endog. test					3.900
p-val.					0.048
Hansen J					1.605
p-val.					0.205
Underid. test					89.77
p-val.					0.000
Weak id. test					2598.91
p-val.					0.000

Note: Cluster-robust standard errors in parentheses with significance at the *** p<0.01, ** p<0.05, * p<0.1 level.

Source: Own calculations.

Table D.3: Robustness: Trade Imbalances

	Omitting I_{ij}	Proxy top 150	Proxy top 250	Proxy top 350	IV EX_{ij}
Dependent variable: t_{ij}					
$dist_{ij}$	0.115***	0.108***	0.107***	0.105***	0.086***
	(0.016)	(0.016)	(0.016)	(0.016)	(0.019)
gdp_i	0.138***	0.144***	0.147***	0.145***	0.162***
	(0.01)	(0.009)	(0.009)	(0.009)	(0.01)
top 150		-0.213***			
		(0.048)			
top 250			-0.198***		
			(0.037)		
top 350				-0.152***	
				(0.032)	
EX_{ij}					-0.068***
					(0.015)
trade imbalance	-0.063***	-0.051***	-0.047***	-0.049***	-0.01
	(0.006)	(0.006)	(0.007)	(0.007)	(0.012)
N	1,737	1,737	1,737	1,737	1,737
R^2	0.241	0.255	0.258	0.254	0.238
Endog. test					8.703
p-val.					0.003
Hansen J					1.181
p-val.					0.277
Underid. test					42.726
p-val.					0.000
Weak id. test					125.89
p-val.					0.000

Note: Cluster-robust standard errors in parentheses with significance at the *** p<0.01, ** p<0.05, * p<0.1 level.

Source: Own calculations.

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