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Transportation Mode Choice and International Fragmentation of Production: Evidence from a Developing Country*

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Abstract: Developments in transportation technologies have facilitated and encouraged the international fragmentation of production by reducing transportation costs and ensuring that parts and components are delivered safely and timely within global production networks. The fact that the stages of the fragmented production processes have been placed in different distance and geographical locations created a demand for alternative modes of transportation. The objective of this study is to analyze the effects of fragmentation of production measured by parts and components trade on the choice of transportation mode including air, sea and road. By doing that, the paper attempts to account for the advantages/disadvantages of alternative transportation modes in short-medium-long distance trade. Using a detailed data set (HS-12 digit product level statistics for the 2000-2014 period and 188 countries) of Turkey's machinery exports, we show that fragmentation of production plays a significant role in the selection of transportation mode. In particular, road transportation with good infrastructure is a significant trade facilitating mode of transportation to nearby trade partners, when trade involves P&C and light products.

Keywords: Mode of transportation, Fragmentation of production, Global production networks, International trade.
JEL Classification: F14, L91, R41

Özet: Ulaştırma teknolojilerindeki gelişmeler, nakliye maliyetlerini azaltarak ve parça ve bileşenlerin küresel üretim ağları içinde güvenli ve zamanında teslim edilmesini sağlayarak uluslararası üretim parçalanmasını kolaylaştırmış ve teşvik etmiştir. Parçalanmış üretim süreçlerinin aşamalarının farklı uzaklık ve coğrafi konumlara yerleştirilmiş olması, alternatif ulaşım yollarına yönelik bir talep yaratmıştır. Bu çalışmanın amacı, parça ve bileşen ticareti ile ölçülen parçalı üretimin hava, deniz ve karayolu dâhil olmak üzere ulaştırma yolu seçimine etkisini incelemektir. Bunu yaparak, çalışma, kısa-orta-uzun mesafeli ticarette alternatif ulaşım yollarının avantajlarını / dezavantajlarını açıklamaya çalışmaktadır. Türkiye'nin makine ihracatına yönelik ayrıntılı bir veri seti (2000-2014 dönemi ve 188 ülke için HS-12 haneli ürün seviyesi istatistikleri) kullanarak, parçalı üretimin ulaşım yolu seçiminde önemli bir rol oynadığı tespit edilmiştir. Özellikle, iyi altyapıya sahip karayolu taşımacılığı, ticaretin parça ve aksam ile hafif ürünleri içerdiği durumlarda, yakındaki ticaret ortaklarına ulaşımı kolaylaştıran önemli bir ulaşım yoludur.

Anahtar Kelimeler: Ulaştırma Yolları, Parçalı üretim, Küresel üretim zincirleri, Uluslararası ticaret.
JEL Kodları: F14, L91, R41

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Non-Technical Summary

Production stages located at different geographical distances and regions have created a demand for alternative transportation modes. Developments in transportation technologies have also supported this process by reducing transportation costs and enabling safe and timely delivery of parts and components (P&C) within the global production networks (GPN). The smooth functioning of the GPN has become contingent to the effectiveness of the transportation system. The objective of this study is to analyze the effects of fragmentation of production on the choice of transportation modes including air, sea, and road.

We use Turkey's exports of machinery products (MP) data set composed of HS-12 digit product level statistics for the 2000-2014 period, with 188 countries in the analysis. In this period, Turkey experienced export growth almost fivefold, thanks to the successful diversification of exports by product and destination market, as well as to the increasing participation in GPNs. Meantime, there had been significant investments in the transportation infrastructure, enabling a qualitative jump in the ranking and competitiveness of air and road transports.

The majority of the Turkish exports were transported by sea, followed by road and air during the analysis period. After the financial crisis in some of the European countries, the shift of Turkish exports to non-European countries, has increased sea and air but reduced road transportation. Meantime, export composition has changed in favor of intermediate goods. It seems that the increase in the share of faraway partners together with the rise in trading of intermediate goods resulted in the use of sea transportation more often.

This paper, after analyzing the current state and some facts related to Turkish MP exports in terms of mode of transportation, formally analyze the transportation mode selection models and apply a gravity-type panel data model for each mode of transportation using ordinary least squares (OLS) and binary probit techniques to quantify the effect of fragmentation on different transport mode choices. The results show that both gravity variables and product-specific variables are significant factors in selecting which transportation mode (air/sea/road) will be used for shipment. For the Turkish MP exports, road transportation with good infrastructure is a significant trade facilitating mode of transportation to nearby trade partners, when trade involves P&C and light products.

1. Introduction

One of the distinguishing features of globalization has been the increase in the international fragmentation of production (i.e. production sharing) in the last few decades. Fragmentation has changed the composition of goods in favor of intermediate inputs and reduced the impact of distance on trade (Borchert and Yotov, 2017). In the meantime, production stages located at different geographical distances and regions have created a demand for alternative transportation modes. Developments in transportation technologies have also supported this process by reducing transportation costs and enabling safe and timely delivery of parts and components (P&C) within the global production networks (GPN). The smooth functioning of the GPN has become contingent to the effectiveness of the transportation system.

Despite the significance of transportation, the number of empirical papers dealing specifically with the impact of fragmentation on the choice of transportation mode in international trade is very limited. Some exceptions are Hayakawa (2008) and Ijiri (2015). They show that air is preferred to sea shipping for P&C in Japan because speedy delivery between the production units is more important than the transport costs. A shortcoming of these papers is that they only focus on air transport versus sea transport. However, as noted in Llano *et. al.* (2017) economic and logistical complexities encourage competition among the alternative modes of transportation. Each mode has advantages and disadvantages depending on the type of products traded, partners and the destination markets. The objective of this study is to analyze the effects of fragmentation of production on the choice of transportation modes including more than two alternatives: air, sea, and road.[3]

Choice of transportation modes depends on several factors including the shipment costs, time cost, type of product, distance to destination, product weight/bulk, etc. Air transport has great advantages in terms of speed and safety, thus it is suitable for medium to long distance transportation, but has the highest cost. Therefore, it is especially preferred for the transport of light-weight valuable materials, P&C, books, medicines, and perishable goods such as fresh vegetables, fruits and flowers (Hummels, 2001). Road transportation is

[3] Llano *et. al*. (2017) investigates the transport competition between road, train, ship and air in inter-provincial deliveries within Spain. In contrast, we use international trade data and focus on P&C trade.

the preferred mode of transportation between countries close to each other. While not as fast as air transportation, it is less expensive and allows flexible and rapid, door to door transport of products in small quantities. Sea transportation has the disadvantage of taking a long time, but is often the preferred mode of transportation because it enables large tonnage products to be transported across long distances at a reasonable cost. Rail transport has the lowest transportation fees and the highest carrying capacity, making it the preferred mode of transportation to nearby countries.

A number of studies in the literature provide evidence that there is a positive linkage between infrastructure and transport costs (See for instance Limao and Venables, 2001; Clarke et al., 2004; Laleman and Van Hove, 2015; and Ijiri, 2015). Quality of infrastructure is important for all types of transportation modes as it improves the efficiency of the transport system or logistics. This system includes all activities from cargo transports (cargo senders, shippers) and warehousing (storage, maintenance and repair) to customs clearance and payment system. Therefore, it affects the choice of transportation mode not only by increasing the transport costs by the amount of the fee paid for using the aforementioned services, but can also extend shipment time depending on how fast and smooth the system works at these centers. The quality and capacity of these centers also determines the quantity of products transported.

We use Turkey's exports of machinery products (MP) data set composed of HS-12 digit product level statistics for the 2000-2014 period, with 188 countries in the analysis. Investigating the Turkish case is important for several reasons. First, Turkey experienced export growth almost fivefold from 27.8 billion US dollars to 157.6 billion US dollars from 2000 to 2014. Second, Turkey's export performance is mainly attributed to the successful diversification of exports by product and destination market, as well as to the increasing participation of Turkish firms in GPN (Saygılı and Saygılı, 2011; Gros and Selçuki, 2013; Aldan and Çulha, 2013; Türkcan, 2014; World Bank, 2014). Indicative of this attachment to the GPN, intermediate goods exports increased about 6.5 times from 11.5 billion US dollars to 75.2 billion US dollars in the same period. Meanwhile, the share of MP in total exports increased from 21% to 28%. Third, Turkey had made significant investments in the transportation infrastructure, enabling a qualitative jump in the ranking and competitiveness of air and road transport, in particular.

The majority of the Turkish exports were transported by sea (period average 50%), followed by road (period average 40%) and air (period average 7.7%) during the analysis period. After the financial crises in some of the European countries, Turkey's major trade partners, with a share of more than 55% of its exports, had shifted towards non-European countries, especially towards Middle East, Africa and Asia. As a result, between 2009 and 2014, there was an increase in sea (54.8% in 2014) and air (8.9% in 2014), but a decrease in road transportation (35.1% in 2014). In the same period, the composition of exports changed and the share of consumption goods decreased from around 50% to 40%, while that of the intermediate goods increased from about 40% to 50%. A smoother decreasing trend was also registered for capital goods trade. It seems that this increase in the share of faraway partners together with the rise in trading of intermediate goods resulted in the use of sea transportation more often.

The purpose of this study is threefold. First, it analyzes the current state and some facts related to Turkish MP exports in terms of mode of transportation. Second, it formally extends the transportation mode selection model of Ijiri (2015) by incorporating more than two transportation modes. It also defines a third trade cost factor, the quality cost of infrastructure in addition to the cargo and time cost of trade. Third, it estimates a gravity-type panel data model for each mode of transportation using ordinary least squares (OLS) and binary probit techniques to quantify the effect of fragmentation on different transport mode choices.

The paper is organized as follows. Section 2 formally analyzes the selection models. Section 3 constructs an empirical analysis and provides some details about Turkish machinery exports. Section 4 summarizes the results of the empirical analysis and section 5 concludes the paper.

2. Modelling Transport Mode Choice

In the following section, we develop a simple transport mode choice model with a number of testable implications. We begin with the examination of the basic gravity model developed by Anderson and van Wincoop (2003), which signifies the importance of relative trade costs (multilateral trade-resistance terms) in explaining bilateral trade. Then, we discuss and extend the Ijiri (2015) model, which allows the role of international fragmentation of production in selecting mode of transportation to be investigated within the Anderson and van Wincoop framework.

2.1. Decision Model

The gravity model of Anderson and van Wincoop (2003) suggests that trade flows between two countries are determined by bilateral trade costs, income shares and relative prices. Formally, it is defined as follows:

$$X_{ij,t} = \frac{Y_{i,t} * Y_{j,t}}{Y_{w,t}} \left(\frac{c_{ij,t}}{P_{i,t} * P_{j,t}}\right)^{1-\sigma} \quad (1)$$

Here, $X_{ij,t}$ is the nominal value of exports from country i to j at time t. $Y_{i,t}$, $Y_{j,t}$ and $Y_{w,t} = Y_{i,t} + Y_{j,t}$ are gross domestic products and total global income, respectively. σ is the elasticity of substitution and assumed to be larger than 1. $P_{i,t}$ and $P_{j,t}$ are consumer price indexes, while $c_{ij,t}$ is the trade cost factor between country i and j. Price indexes are also called "multilateral trade resistance" because they depend on total bilateral resistance ($c_{ij,t}$). The trade cost factor makes the price of goods exported $c_{ij,t}$ times higher than the exporters supply price (net of trade costs): $P_{j,t} = P_{i,t} * c_{ij,t}$. Thus, all else equal, the above gravity equation predicts that countries with larger incomes trade more with each other. In addition, an increase in bilateral trade costs $c_{ij,t}$ relative to the multilateral resistance terms decreases bilateral trade.

Anderson and van Wincoop state that Eq. (1) is a practical way to estimate the gravity equation. It can easily be applicable to the mode of transportation choice models. Assume that there are n types of transportation mode so that $X_{ij,t} = \sum_{m=1}^{n} X_{ij,t}^{m}$. Then, the share of goods transported by type m transportation mode can be computed as follows:

$$SX_{ij,t}^{m} = \frac{X_{ij,t}^{m}}{\sum_{m=1}^{n} X_{ij,t}^{m}} \quad (2)$$

Substituting Eq. (1) in (2), the share of goods transported by type m mode can be reduced to:

$$SX_{ij,t}^{m} = \frac{{c_{ij,t}^{m}}^{1-\sigma}}{\sum_{m=1}^{n} {c_{ij,t}^{m}}^{1-\sigma}} \quad (3)$$

Here $\sum_{m=1}^{n} c_{ij,t}^{m\ 1-\sigma}$ is the total trade cost and Eq. (3) implies that choice of transportation mode is determined by the relative trade costs involved with different transportation types. Since $\sigma > 1$, a relative increase in the trade costs associated with type m mode of transportation reduces the likelihood of supplying goods to partner countries by that mode of transportation, holding everything else constant.

In Anderson and van Wincoop (2003), an unobservable trade cost factor had been modeled as a function of the bilateral distance (d_{ij}) and the existence of borders (b_{ij}) between i and j. Recent studies have emphasized the roles of alternative country and products-specific trade cost factors such as transportation costs, product type, international fragmentation of production, infrastructure quality, etc. in explaining trade. Different cost factors may have different impacts on the selection process. Parallel to this discussion, in the following section, we aim to build a comprehensive transportation mode selection model using Ijiri's (2015) approach.

2.2. Mode Selection Model

Ijiri (2015) extends the Anderson-van Wincoop's (2003) model by decomposing trading costs into two elements: cargo transport cost and transit time cost. It is assumed that there are only two types of transportation modes for exports: air and ocean freight. This study extends the work of Ijiri in two ways. First, it assumes that there are more than two different modes of transportation. Second, there may be another time varying cost element: quality/capacity of transportation infrastructure.

Let $m = s, r, a, o$ indicate modes of transportation where s, r, a and o stand for sea, road, air and other types of transportation modes, respectively. We assume that trading costs consist of three elements: cargo cost of transport (CCT), time cost of transport (TCT) and quality/ capacity cost of transport (QCT).

Cargo cost of transportation

As in Ijiri (2005), we assume that at time *t*, the CCT depends on the distance between countries i and j (d_{ij}), fixed transport fee (α^m) and the weight of the product k (w_k). In addition, we assume that each transportation mode has a different carrying capacity (β^m); thus, fees may change depending on the mode of transportation (m). In sum:

$$CCT_{ij}^{m} = \alpha^m * d_{ij} * w_k^m * \beta^m \quad (4)$$

For the same distance and product, the following relationships are assumed among the cost variables: $\alpha^a > \alpha^r > \alpha^s > \alpha^o$; $\beta^O > \beta^s > \beta^r > \beta^a$. Therefore, air transportation has the highest transportation fee but the lowest carrying capacity, while other transport modes such as rail freight or pipelines have the lowest transportation fee and highest carrying capacity. Sea transportation also provides a cheap and high carrying capacity for exporters. We assume that road transportation has less carrying capacity compared to sea and air but it has the advantage of flexible transportation. In other words, the size of the road transportation vehicles may vary, allowing products to be delivered in flexible amounts.

Harrigan (2010) and Ijiri (2015) show that choice of transportation mode may also vary with respect to the weight of the product: Light-weight or high-value products tend to be delivered by air transport. Road transport may also be preferred for delivering small and light-weight products in flexible amounts over short distances. On the other hand, transportation by sea or railway could be more suitable for carrying cheap and bulky products. Eq. (4) also accounts for the impact of the product's weight on trade costs.

Time cost of transportation

The second type of cost is the amount of time spent on delivering a product from host to importer country. There are three important factors in the determination of transportation time: speed (γ^m), distance and product type (k^m). Formally:

$$TCT_{ij}^{m} = \gamma^m * d_{ij} * k^m \quad (5)$$

For the same distance and product, we assume that: $\gamma^a > \gamma^r > \gamma^o > \gamma^s$. Thus, air transportation is the fastest, while sea transportation is the slowest transportation mode. Road transport is faster than sea or rail transport but slower compared to air transport (Hayakawa et al., 2013). Here we also consider that product type is a significant cost factor in the choice of transportation mode. Transit time cost does not matter much for relatively simple and bulky products (Hummels, 2007). However, it is expected to be higher for perishable goods such as agricultural products; goods exchanged within the production networks such as P&C; products that are not preferred to be stocked such as apparel. Hummels (2001) argues that time costs will be magnified in the presence of fragmentation because ability to deliver P&C on time is a critical requirement for companies within the GPN. For such products, air transportation may be preferred for medium-to-long distances, while road transportation may be preferred for short-to-medium distances. Hayakawa (2008), for instance, reports the significance of international fragmentation measured by vertical intra-industry trade on the choice of transportation mode, namely air transport. Ijiri (2015) also shows that the choice of transport mode may vary depending on the type of product (P&C, processed goods, capital goods and consumer goods) and confirms that airfreight is preferred to ocean freight for intermediate goods.

Quality/capacity cost of transport

The quality and capacity of the transportation system or logistic centers are other significant trade cost factors in facilitating trade between two countries (Nordas and Piermartini, 2004; Laleman and Van Hove, 2015; Ijiri, 2015). These are the physical locations where all logistic activities are carried out together. Logistics is significant for international trade, since it encompasses freight transportation, warehousing, border clearance, payment systems and many other functions. Therefore, we assume that there are three factors important for determining the infrastructure of transport: distance, fixed fees paid for the use of the services provided by the logistics center (θ^m) and the quality of the services or infrastructure (inf_{ij}^m).

$$QCT_{ij}^m = \theta^m * d_{ij} * inf_{ij}^m \qquad (6)$$

Given the same distance and infrastructure quality, we assume that $\theta^a > \theta^s > \theta^r > \theta^o$. The cost of using airports is relatively more expensive than other transportation centers. An improvement in infrastructure quality has a decreasing impact on trade cost, therefore increasing the likelihood of choosing transportation mode *m*, given distance and fees.

Total trade costs

Eventually, total trade cost factor for transportation mode m can be expressed as follows:

$$C_{ij}^m = CCT_{ij}^m + TCT_{ij}^m + QCT_{ij}^m \qquad (7)$$

Using Eq. (4), (5) and (6), we get:

$$C_{ij}^{m}=d_{\ ij}[\ \alpha^{m} * w_{k}^{m} * \beta^{m} + \gamma^{m} * k^{m} + \theta^{m} * inf_{ij}^{m}] \quad (8)$$

Thus, a decrease in α^{m} and θ^{m} but an increase in γ^{m} for the same distance, product type and infrastructure are likely to increase exports using transportation mode *m*. The choice of transportation mode m also depends on distance, type of goods, value of goods, capacity of the transportation mode and infrastructure.

3. Empirical Model, Data and Some Patterns

3.1. Empirical Model

This paper uses a gravity-type panel data model to quantify the effect of fragmentation on the choice of transport mode (sea, road, or air). The methodology closely follows Hayakawa (2008), Harrigan (2010), Ijiri (2015) and Laleman and Van Hove (2015). The basic empirical formulation of the gravity model within the framework in Section 2, where all variables are in natural logarithms, is:

$$ln(M_{ijt}^{k}) = \beta_0 + \beta_1 PC_{ij}^{k} + \beta_2 Y_{jt} + \beta_3 D_{ij} + \beta_4 CB_{ij} + \beta_5 LL_j + UV_{ijt}^{k} + \beta_7 INF_{jt} + \varepsilon_{ijt} \quad (9)$$

here k represents the exports of HS 12-digit products from country i to country j, and ε_{ijt}^{k} is the white noise disturbance term distributed randomly and independently.

In the estimation of Eq. (9), we consider two different specifications for the dependent variable (M_{ijt}^{k}). In the first specification, we estimate a standard gravity model, using a log of the share of each transport mode in total exports for which we employ the OLS method (Hayakawa, 2008; Ijiri, 2015). Because the mode shares take values from 0 to 1, the OLS estimation of a linear or log-linear function may have predicted values for the dependent variables that lie outside the theoretically feasible range. Accordingly, a logit transformation of the dependent variable, defined as $ln\left(\frac{M_{ijt}^{k}}{1-M_{ijt}^{k}}\right)$, was performed to eliminate the possibility of obtaining theoretical values of mode shares beyond the acceptable interval [0,1] (Hayakawa, 2008; Ijiri, 2015). In addition, when the share is either 0 or 1, the choice may not be clear cut between different transport modes. To overcome this problem, these observations have been removed from the analysis, as in Ijiri (2015).

In the second specification, as in Harrigan (2010), the dependent variable is defined as a binary mode indicator that takes the value of one if the share of exports of product *k* supplied by mode *m* by country *i* to *j* is greater than 0.9 and zero if the share is less than 0.1. Note that in this case, the sample size is considerably reduced, because observations where the share of products that are shipped by a specific mode of transport is between 0.1 and 0.9 are dropped from the analysis. Since our second dependent variable is binary, we estimate a binary probit model for each mode.

In terms of the explanatory variables, several product-specific and country-specific variables suggested by the trade literature are considered. The first product-specific explanatory variable included in the gravity model in Eq. (9) is related to the nature or type of product traded, (PC_{ij}^{k}). Here, we would like to use an indicator that also represents the fragmented nature of the GPN. In line with the mode selection model, an increase in fragmentation is expected to be positively associated with the choice of air and road transport, but negatively with sea transport.

The second product-specific explanatory variable widely used in explaining the type of transportation mode to destination markets concerns the value and weight characteristics of a product (Harrigan, 2010; İjiri, 2015; Çoşar and Demir, 2016). The value-to-weight ratio, UV_{ijt}^{k}, defined as the dollar value of exports per physical unit is expected to have a positive effect on the choice of air and road transport, but a negative effect on the choice of sea transport, as implied by the model in Section 2.

The first country–specific explanatory variable is the transportation infrastructure. From Section 2, we may infer that improvements in any of the air, road or sea infrastructure will positively affect the likelihood of choosing that transportation mode. In addition to the transportation infrastructure INF_{jt}, several other country-specific variables are included in the analysis to control for unobservable economic and geographical characteristics: a log of the importing countries gross domestic products Y_{jt}, a log of bilateral distance D_{ij}, a common border dummy CB_{ij} and a landlocked dummy LL_j. Harrigan (2010) notes that imports from high-income countries to the US are more likely to be shipped by air rather than by surface (road, sea and train). The reason is that the price of imports from those countries tends to have higher unit values than goods shipped from low-income countries, which in turn implies that using air transportation gives a higher pay off when exporting high-value and time-sensitive products to high-income countries rather than low-income countries. As a result, exports to high-income countries are expected to be realized by air and road transportation, while exports to low-income countries are transported by sea. Accordingly, as in Harrigan (2010) and Laleman and Van Hove (2015) the log of the importing countries' GDP is added to the regressions to account for any unobserved economic characteristics of an importing country that are likely to affect transport mode choice. Section 2 also suggests that distance influences the choice of mode because of its impact on transportation costs, time costs and infrastructure costs. The distance should have a positive impact on the use of air transport and sea transport, but a negative impact on the use of road transport.

The other two country-specific dummies included are: CB_{ij}, which is unity if exporter i and importer j have a border and zero otherwise, and LL_j, which is also unity if the importer j is landlocked (i.e. countries without direct coastal access to the sea) and zero otherwise. Hummels (2007) points out that a large proportion of trade between the US and neighboring countries occurs via land (mainly road transport), while trade with distant countries occurs mainly via sea or air transport. Accordingly, we expect that the presence of a common border will have a positive impact on the use of road transport and a negative impact on the use of sea and air transport. Finally, we expect that for the transportation of products to landlocked countries, the preferred mode of transport should be either air or road, due to the fact that these countries have no direct access to the sea (Ijiri, 2015).

3.1 Data

Turkey's MP trade data is taken from the Turkish Statistical Institute (TURKSTAT). This unique database provides information on trade flows broken down by modes of transportation, destination country and a 12-digit HS product code.[4] The database contains detailed information on both value (in thousands of US dollars) and quantity of the bilateral trade flows. Most of the quantity data are in kilograms, although for some products different units of measure are reported (e.g. liters, meters, square meters, m^3, etc.). The database covers the period from 2000 to 2014.

Different types of transportation modes exist in the database and the types vary from year to year. In early editions of the database, a 1-digit code system was used to identify the

[4] The 12-digit code used in Turkish Tariff Nomenclature is called "Customs Tariff Statistics Positions (GTIP)".

mode of transportation. New 2-digit codes replaced 1-digit codes in 2002. In order to form a consistent set of data, transportation modes are grouped into four main categories: Sea, Road, Air and Other.[5]

Although the theoretical model developed in Section 2 provides a clear relationship between mode choice and fragmentation-based export flows, a well-defined measure for the international fragmentation of production at product level is not straightforward and empirical studies need to be conducted using proxy measures for the trade-related GPN activities. Studies aiming to measure the degree of fragmentation or production sharing can be divided into four groups based on their methodology and data sources. The first group, e.g. Feenstra and Hanson, 1996; Campa and Goldberg, 1997; Hummels et al., 2001, computes fragmentation indicators using input–output tables. The second group, such as Görg (2000), Egger and Egger (2005) and Clark (2006), employs outward and inward processing trade statistics. The third group (e.g. Andersson and Fredriksson, 2000; Kimura and Ando, 2005) utilizes intra-firm trade statistics. Finally, the fourth group suggests using international trade, in other words using either the volume of trade in P&C (Yeats, 2001; Kimura et al., 2007) or the vertical intra-industry trade (IIT) index in intermediate goods (Ando, 2006).

More recently, the availability and utilization of global input-output tables has provided significant methodological contributions to measure the degree of production sharing in a given industry. The global input-output tables have been a dominant means of exploring international production linkages. For example, Johnson and Noguera (2012) generalized the vertical specialization concept of Hummels et al. (2001) by combining input-output and bilateral trade data provided by the Global Trade Analysis Project (GTAP) and computed the value added content of bilateral trade as a measure of cross-border production linkages. Currently, the Value Added Trade (TiVA) database, which is based on the OECD / WTO national input-output tables (released in 2013), and the World Input-Output Database (WIOD), (released in 2012), are the most frequently used resources that enable researchers to map and measure global trade in value added. However, one of the major limitations of using these data sources in this study is the provision of data at the country-industry level in great detail. What is needed for this study is the data at the country-product-mode level. Because of

[5] Railways are not considered as a separate transportation mode, because of their low share (around 1% in 2014).

these limitations, we follow Obashi (2010) and Corcoles et al. (2015) and define a binary variable PC_{ij} to capture the effects of the fragmentation on the choice of transport mode. [6]

The dummy variable PC_{ij} equals one if the HS 12-digit level MP exports are P&C type and zero otherwise. During the period under consideration, a total of 27,098 product items were exported to more than 215 countries and the MP constituted about 22% (5987) of the total. MP are registered within the range of HS 84-92 and cover general machinery (HS 84), electric machinery (HS 85), transport equipment (HS 86-89) and precision machinery (HS 90-92). Following Kimura and Obashi (2010) and Obashi (2010), these items can further be grouped as finished products (FP) and P&C. Accordingly, out of 5987 MP, 2438 are recorded as P&C, while 3549 are listed as FP. Several countries, including free trade zones, have to be removed from the analysis, due to either the lack of trade data or the changes in political boundaries.[7] As a result, the number of countries in the analysis declines to 188, which accounts for more than 90 percent of Turkey's MP exports. The list of countries included in the analysis is reported in Appendix Table A1.

The export unit values are constructed by dividing the export values of the products by the corresponding quantities. Harrigan (2010) argues that there is an endogeneity problem between unit value and transportation mode. To overcome the endogeneity problem, we construct the export unit values of each mode (sea, road and air) using only observations where products are shipped by other modes of transport. For instance, observations where goods are shipped by road and air have been used to calculate the unit values for sea. These instruments capture product characteristics that are exogenous to transport decisions in Turkish exports.[8]

The infrastructure data is taken from the World Economic Forum (WEF)'s (2016) Global Competitiveness Index (GCI) database. The WEF has been annually publishing GCI to compare the competitiveness of nations worldwide since 2006. The GCI consists of 12 pillars of competitiveness, one of which is infrastructure. The infrastructure pillar itself comprises different sub-indicators, including the quality of port, road and airport

[6] It would be ideal to use intra-firm trade statistics to measure the degree of fragmentation. Unfortunately, such data are not available with the necessary detail.

[7] Due to data availability, Belgium and Luxemburg are treated as single country.

[8] There may be another endogeneity issue between the transport modes and trade. The availability / intensity of trade in an area may increase investments in various transport modes. The cost of transportation may be determined by the density of each transport mode. Thanks for the anonymous referee for noting the network externality issue.

infrastructures on a scale of 1 to 7 (with 7 as the best performance). Following Laleman et al. (2015), this study uses these three sub-indicators to measure and assess how the quality of the transportation infrastructure of the importing countries impacts on the mode choice. These sub-indicators are available for 138 countries in the period from 2006 to 2014.

Lastly, GDP data in current dollars has been retrieved from the World Bank's World Development Indicators (WDI) database, while data on geographical variables was taken from the CEPII database. The definition, source and summary statistics of the variables are given in Appendix Table A2 and A3.

3.2. Trends and Patterns of Transport Mode Choices in Turkish Machinery Exports

Table 1 reports that sea transport was the prominent mode of transportation in exports of Turkey's MP between 2000 and 2014. This is an expected conclusion for Turkey as it is a country surrounded by sea on three sides: by the Black Sea on the north, the Mediterranean on the south and the Aegean Sea on the west. On average, the majority of MP exports (62% in value and 65% in quantity) are transported by sea, followed by road (29% in value and 31% in quantity). At the same time, Table 1 notes that choice of transportation mode differs for FP and P&C. While sea transport is the number one transportation mode for FP (73% in terms of value and 74% in terms of quantity) and P&C trade in quantity (50%), road is the preferred mode of transportation for P&C trade in value (55%). In addition, the shares of P&C in terms of both value and quantity of exports via air is larger than those of FP.

The findings in Table 1 are in line with the literature: bulk products with lower unit values are mainly transported via sea, whereas high value products are shipped via road or air. Turkey's products to Europe are supplied mainly by road. The relatively larger share of road and air mode in Turkey's P&C exports is consistent with the view that firms within GPN tend to select a faster and more reliable transportation mode that can facilitate the timely and efficient exchange of P&C to nearby countries (Hayakawa, 2008; Harrigan, 2010; Ijiri, 2015).

Figures 1 and 2, meanwhile, confirm that sea and road are the main mode of transportation for MP and FP. However, the financial crises in the second half of 2000s in Europe caused trade to shift towards non-European countries in the Middle East, Asia and Africa (Figure A2). As exports were directed to faraway trade partners, sea transportation gained a higher share in exports. As a result, sea transportation displayed a faster increase, especially after 2009 for all types of MP. For P&C trade, road is still a significant mode of transportation, but it can be observed that the share of sea transportation has increased in the last few years of the period examined and has even exceeded the road ratio. Moreover, along with the rise in the share of non-European countries in total exports, there was an increasing trend in the share of P&C exports, which have even exceeded the exports of final goods trade. A smooth increase could be observed in air transportation as of 2009.

Table A2 shows the performance of the transportation infrastructure in Turkey, while Figure A1 presents scores for port, road and air infrastructure from 2006 to 2014. There was a significant improvement in the position of all three sub-indicators, and the improvement was spectacular particularly for air infrastructure: ranking shifted from no.108 in 2006 to no.34 in 2014. Turkey also made a qualitative leap in road infrastructure with 4.88 points and ranked 40th worldwide, compared to 112th in 2006. Although there was no noticeable change in the score of port infrastructure (4.44), Turkey ranks 57th out of 138 countries in 2014 and has moved up from the 104th to the 57th position in the world ranking since 2006.[9]

In sum, four main conclusions can be derived from the analysis of raw data before proceeding to the formal econometric analysis. First, sea transportation is the most frequently used mode for Turkish's MP exports and its dominance is even more prevalent in the case of FP. Second, the average share of Turkey's MP shipped via sea transport is more significant in terms of volume than in value. Third, the shares of road transportation gained a stable pattern after a fall in 2008; instead, sea (to a limited extent air) transportation accelerated as faraway countries increased their share in total exports with more demand for P&C. Thus, both distance, type of product and geography play significant roles in the choice of transportation mode.

4. Empirical Results

The results obtained from the OLS estimation of Eq. (9) for Turkey's machinery exports, where transport mode shares are used as dependent variables, are reported in Table 2. The estimated coefficient of our key variable, P&C is significantly negative (at the 1% level)

[9] The World Bank's Logistics Performance Index (LPI) shows similar improvements in Turkey's transportation infrastructure. Based on the infrastructure component of the LPI index (1-5 scale), which measures the quality of the country's transport and telecommunications infrastructure, Turkey ranked 39th out of 150 countries in 2007, with a score of 2.94, and 27th out of 160 countries in 2014, with a score of 3.53.

for air and sea transportation, but positive for road transportation. Therefore, road transportation is the preferred mode for P&C exports. However, as the share of P&C exports increases, the use of both air and sea transportation tends to decrease. The fact that Turkey still has strong trade and production links with the nearby European countries may explain the significance of road transportation in our results. These results are different from Hayakawa (2008) and Ijiri (2015). They find that Japanese intermediate goods exports are frequently shipped by airfreight, rather than sea freight. Unfortunately, they do not examine road transportation, so we do not have any results to properly compare with.

The estimated coefficients for unit value variable which proxies the lightness and smallness of a product, are significant at the 1% level and positive for both road and air transportation but negative for sea transport. An increase in the unit value implies a decrease in the weight of the product. Then, positive coefficients suggest that as products get lighter they are more likely to be transported by air or road. The results are consistent with prior empirical studies (Harrigan, 2010; Ijiri, 2015) and expectations of the mode selection model.

The results also indicate that the choice of transport mode depends on the quality of the transportation infrastructure. The estimated effects of the quality of the transportation infrastructure on the mode choice are significant at the 1% level for all types of transport mode. The signs of the estimated coefficients are positive for air and road, but negative for sea transportation. The positive coefficients for road and air are expected since P&C dominate the trade with nearby European countries and investments in road and air transportation make trade with these countries more convenient. Two explanations are possible for the negative coefficient of sea transportation. Firstly, as road and air become preferred modes of transportation for supplying goods to nearby countries, demand for sea transportation declines no matter how good its infrastructure is. Secondly, while some of Turkey's biggest trade partners in Europe were in economic crises towards the end of the analysis period, Turkish exporters found new markets in the Near/Middle East, Asia and Africa. An analysis of Figures A1-A2 and Table A1 suggests that the transition between the markets was realized before the desired amount of infrastructural investment in sea transportation was accomplished. [10]

[10] The importance of road infrastructure in Turkish trade has also been documented by Çoşar and Demir (2016), who found that significant improvements in domestic road infrastructure over the last decade significantly

Considering the estimation results of the other country-specific variables, an increase in the importers' income has a decreasing impact on sea and air transportation while accelerating road transportation. These findings, however, contradict the results of Gee et al. (2014), who found that exports to rich markets are more likely to be air shipped. Laleman and Van Hove (2015) also documented the significant positive impact that the importer's GDP has on air and sea transportation. First of all, these studies focus on sea to air transport, but do not study road transport. Our results for Turkey are not surprising given the fact that exports are still heavily concentrated on the high-income European markets, where road transport is the preferred mode of transportation.

As expected, distance is a significant positive factor in the selection of air and sea transportation, but negatively affects the choice of road transportation. Hence, the longer the shipping distance, the more likely it is to choose air or sea transportation. Having a common border has a significant positive effect on the choice of road transport, while negatively affecting the others. Finally, the landlocked dummy is significantly positive for road transport, but significantly negative for sea and air transportation.

We re-estimated Eq. (9), using a binary probit model to verify whether our results are sensitive to the use of alternative dependent variables and alternative methods of estimation. With the exception of the landlocked variable for the air dummy indicator, our results are qualitatively unchanged. In particular, our key variable has the same impact on the mode choice. These findings are consistent with our hypothesis that P&C trade increases the likelihood of choosing road transportation: road transportation provides a safe, cost-effective and timely solution for transporting P&C within the GPN, for short and medium distances.

6. Conclusions

This paper presents an empirical analysis of the effects of production fragmentation on the mode of transportation including air, sea, and road, using Turkey's machinery exports data set composed of HS-12 digit product level statistics for the period covering 2000-2014 and including 188 countries. The effects of the fragmentation of production have been examined with gravity-type panel data models.

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reduced the cost of shipments by about 70 percent on average, thereby increasing the regional exports and imports.

First, we modify the Ijiri (2015) models within the Anderson and van Wincoop (2003) framework to formally derive a relationship between trade cost and trade flows among the trade partners. Trade costs in Ijiri (2015) consist of two different types: shipping costs and transit time cost. We extended the analysis in two ways: by generalizing the trade costs function so that the model could be applicable over more than two types of transportation mode; and by adding a third element to the trade cost, i.e. infrastructure quality cost.

Second, in line with the formal analysis, in the empirical section we examined the effects of both country and product-specific factors that are expected to impact on the choice of transportation mode in MP exports in Turkey. Both gravity variables and product-specific variables are significant factors in selecting which transportation mode (air/sea/road) will be used for shipping products to importing countries. We conclude that for the Turkish MP exports, road transportation with good infrastructure is a significant trade facilitating mode of transportation to nearby trade partners, when trade involves P&C and light products, in particular.

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Appendix

Table A1: List of countries

Afghanistan	Djibouti	Kyrgyzstan	Rwanda
Albania	Dominica	Lao PDR	St. Kitts & Nevis
Algeria	Dominican Republic	Latvia	St. Lucia
Andorra	East Timor	Lebanon	St. Vincent & Grenadines
Angola	Ecuador	Liberia	Samoa
Antigua & Barbuda	Egypt	Libya	San Marino
Argentina	El Salvador	Lithuania	Sao Tome & Principe
Armenia	Equatorial Guinea	China, Macau	Saudi Arabia
Aruba	Eritrea	Madagascar	Senegal
Australia	Estonia	Malawi	Serbia
Austria	Ethiopia	Malaysia	Seychelles
Azerbaijan	Fiji	Maldives	Sierra Leone
Bahamas	Finland	Mali	Singapore
Bahrain	France	Malta	Slovakia
Bangladesh	French Polynesia	Marshall Islands	Slovenia
Barbados	Gabon	Mauritania	Solomon Islands
Belarus	Gambia	Mauritius	South Africa
Belgium-Luxembourg	Georgia	Mexico	Spain
Belize	Germany	Micronesia	Sri Lanka
Benin	Ghana	Moldova	Suriname
Bermuda	Greece	Mongolia	Sweden
Bhutan	Greenland	Montenegro	Switzerland
Bolivia	Grenada	Morocco	Syria
Bosnia & Herzegovina	Guatemala	Mozambique	Tajikistan
Brunei Darussalam	Guinea	Myanmar	Tanzania
Bulgaria	Guinea-Bissau	Nepal	Thailand
Burkina Faso	Guyana	Netherlands	TFYR of Macedonia
Burundi	Haiti	New Caledonia	Togo
Cambodia	Honduras	New Zealand	Tonga
Cameroon	China, Hong Kong	Nicaragua	Trinidad & Tobago
Canada	Hungary	Niger	Tunisia
Cape Verde	Iceland	Nigeria	Turkey
Central African Republic	India	Northern Mariana Islands	Turkmenistan
Chad	Indonesia	Norway	Tuvalu
Chile	Iran	Oman	Uganda
China	Iraq	Pakistan	Ukraine
Colombia	Ireland	Palau	United Arab Emirates
Comoros	Israel	Panama	United Kingdom
Congo (Rep.)	Italy	Papua New Guinea	USA
Congo (Dem. Rep.)	Jamaica	Paraguay	Uruguay
Costa Rica	Japan	Peru	Uzbekistan
Côte d'Ivoire	Jordan	Philippines	Vanuatu
Croatia	Kazakhstan	Poland	Venezuela
Cuba	Kenya	Portugal	Viet Nam
Cyprus	Kiribati	Qatar	Yemen
Czech Republic	Korea (Rep.)	Romania	Zambia
Denmark	Kuwait	Russia	Zimbabwe

Table A2: Overview of competitive strength of Turkey's transport infrastructure in world ranking, 2006-2014

Year	Port		Road		Air	
	Value	Rank	Value	Rank	Value	Rank
2006	1.94	104	1.92	112	2.87	108
2007	2.07	127	2.24	114	3.63	102
2008	2.44	124	2.36	114	4.35	76
2009	3.22	105	2.84	99	4.79	63
2010	3.54	100	3.51	81	4.94	58
2011	3.87	85	4.20	58	5.05	56
2012	3.72	96	4.29	59	4.76	66
2013	4.34	63	4.86	44	5.53	33
2014	4.44	57	4.88	40	5.40	34

Notes: Ranks out of 138 economies and scores measured on a 1-to-7 scale. 1 represents the worst, while 7 is the best.
Source: Global Competitiveness Report (GCR) 2016-2017, World Economic Forum.

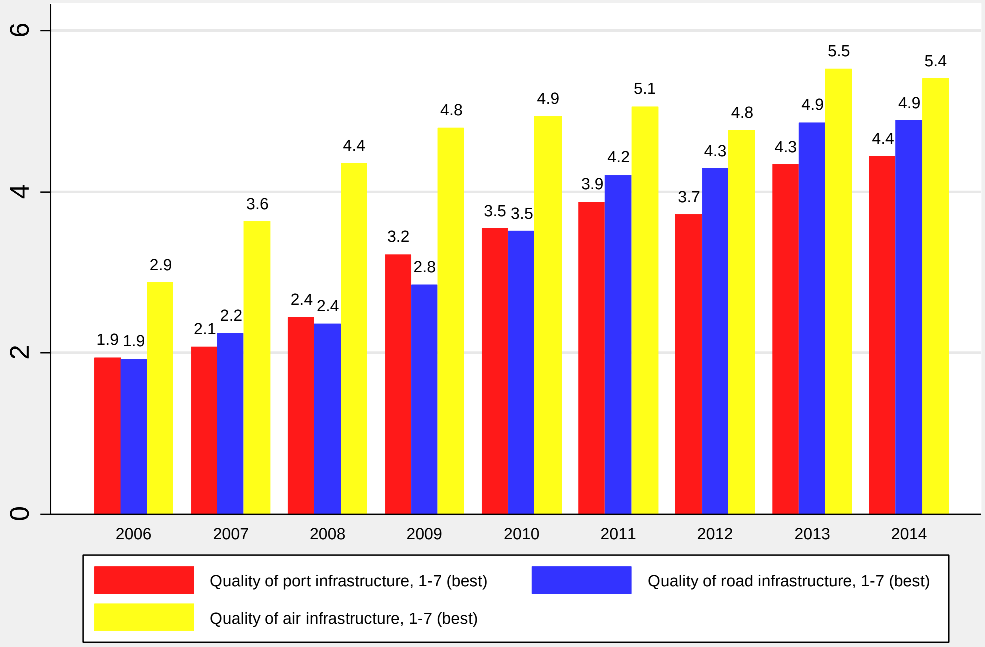
Table A2: Variable definitions and data sources

Variable	Definition	Data source
P&C	Takes a value of one if the 12-digit products are considered as machinery parts and components, zero otherwise	TUIK's transportation mode database: www.tuik.gov.tr
Log GDP (importer)	Log of importer's GDP, measured in nominal US dollars	World Bank's World Development Indicators (WDI)
Log distance	Log of the distance in kilometers between Turkey's capital and its trading partner's capital	CEPII's GeoDist database: http://www.cepii.fr
Common border	Takes a value of one if Turkey and its trading partner share a common border, zero otherwise	CEPII's GeoDist database: http://www.cepii.fr
Landlocked	Takes a value of one if the importing country is landlocked and zero otherwise.	CEPII's GeoDist database: http://www.cepii.fr
Log unit values of sea	The log of the unit value is obtained by dividing the value by the quantity exported from Turkey to its trade partner at the 12-digit level of the trade database, excluding exports shipped by sea.	TUIK's transportation mode database: www.tuik.gov.tr
Log unit values of road	The log of the unit value is obtained by dividing the value by the quantity exported from Turkey to its trade partner at the 12-digit level of the trade database, excluding exports shipped by road	TUIK's transportation mode database: www.tuik.gov.tr
Log unit values of air	The log of the unit value is obtained by dividing the value by the quantity exported from Turkey to its trade partner at the 12-digit level of the trade database, excluding exports shipped by air.	TUIK's transportation mode database: www.tuik.gov.tr
Log Q of port infrastructure	Log of quality of port infrastructure, 1-7 (best)	The World Economic Forum Global Competitiveness Index: http://reports.weforum.org/global-competitiveness-report-2015-2016/
Log Q of road infrastructure	Log of quality of roads, 1-7 (best)	The World Economic Forum Global Competitiveness Index: http://reports.weforum.org/global-competitiveness-report-2015-2016/
Log Q of air infrastructure	Log of quality of air transport infrastructure, 1-7 (best)	The World Economic Forum Global Competitiveness Index: http://reports.weforum.org/global-competitiveness-report-2015-2016/

Table A3: Summary statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
Sea share	1,209,760	0.269	0.423	0	1
Road share	1,209,760	0.348	0.458	0	1
Air share	1,209,760	0.131	0.315	0	1
Sea dummy	305,753	0.896	0.305	0	1
Road dummy	395,482	0.934	0.249	0	1
Air dummy	212,381	0.580	0.494	0	1
P&C	1,209,760	0.540	0.498	0	1
Log GDP (importer)	1,197,241	25.677	1.969	18.095	30.485
Log distance	1,209,760	7.757	0.715	6.280	9.772
Common border	1,209,760	0.135	0.341	0	1
Landlocked	1,209,760	0.206	0.404	0	1
Log unit values of sea	979,538	2.799	1.373	-6.226	15.006
Log unit values of road	891,922	2.824	1.424	-7.930	15.006
Log unit values of air	1,096,271	2.410	1.144	-7.930	13.901
Log Q of port infrastructure	758,202	1.424	0.308	0.236	1.921
Log Q of road infrastructure	758,202	1.361	0.361	0.279	1.905
Log Q of air infrastructure	758,202	1.542	0.248	0.690	1.934

Figure A1: Quality of transportation infrastructure in Turkey from 2006 to 2014



Source: The Global Competitiveness Report 2006-2016

Figure A2: Share of Markets and Goods in Exports

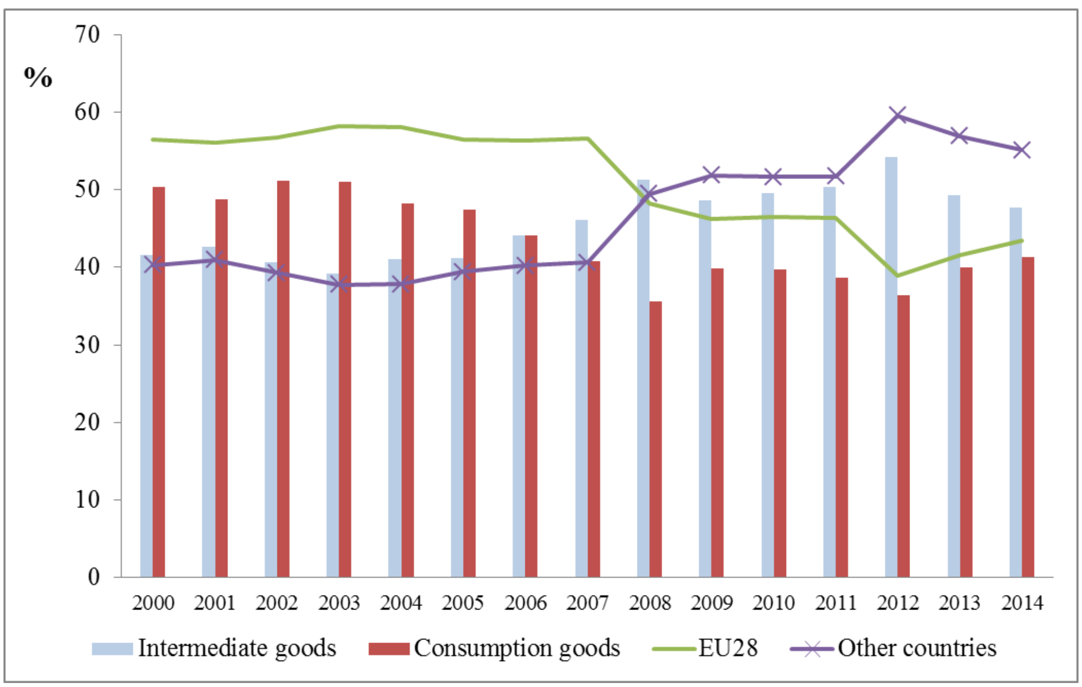


Table 1: Average shares of modes of transportation in Turkey's exports (percentages, 2000-2014)

Sample	Sea		Road		Air		Other	
	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity
MP	61.84	65.46	29.40	31.38	4.75	0.50	4.02	2.66
FP	73.18	73.93	17.91	22.22	3.32	0.25	5.59	3.60
P&C	36.00	50.27	55.36	47.74	8.17	0.95	0.47	1.04

Source: Authors' own calculations based on TUIK's Transportation Mode database

Table 2: Estimates of the OLS model of transport mode choices for exports

	Sea	Road	Air
P&C	-0.263***	0.645***	-0.111***
	(0.026)	(0.026)	(0.027)
Log GDP (importer)	-0.233***	0.039***	-0.175***
	(0.008)	(0.009)	(0.008)
Log distance	0.657***	-1.434***	0.694***
	(0.019)	(0.029)	(0.017)
Common border	-3.133***	1.326***	-0.511***
	(0.069)	(0.045)	(0.043)
Landlocked	-2.011***	1.097***	-0.100***
	(0.037)	(0.033)	(0.032)
Log unit values for sea	-0.284***		
	(0.010)		
Log Q of port infrastructure	-0.622***		
	(0.051)		
Log unit values for road		0.031***	
		(0.009)	
Log Q of road infrastructure		0.133***	
		(0.037)	
Log unit values for air			0.755***
			(0.011)
Log Q of air infrastructure			0.438***
			(0.051)
Observations	123,250	108,752	121,405
R-squared	0.1155	0.1436	0.1220

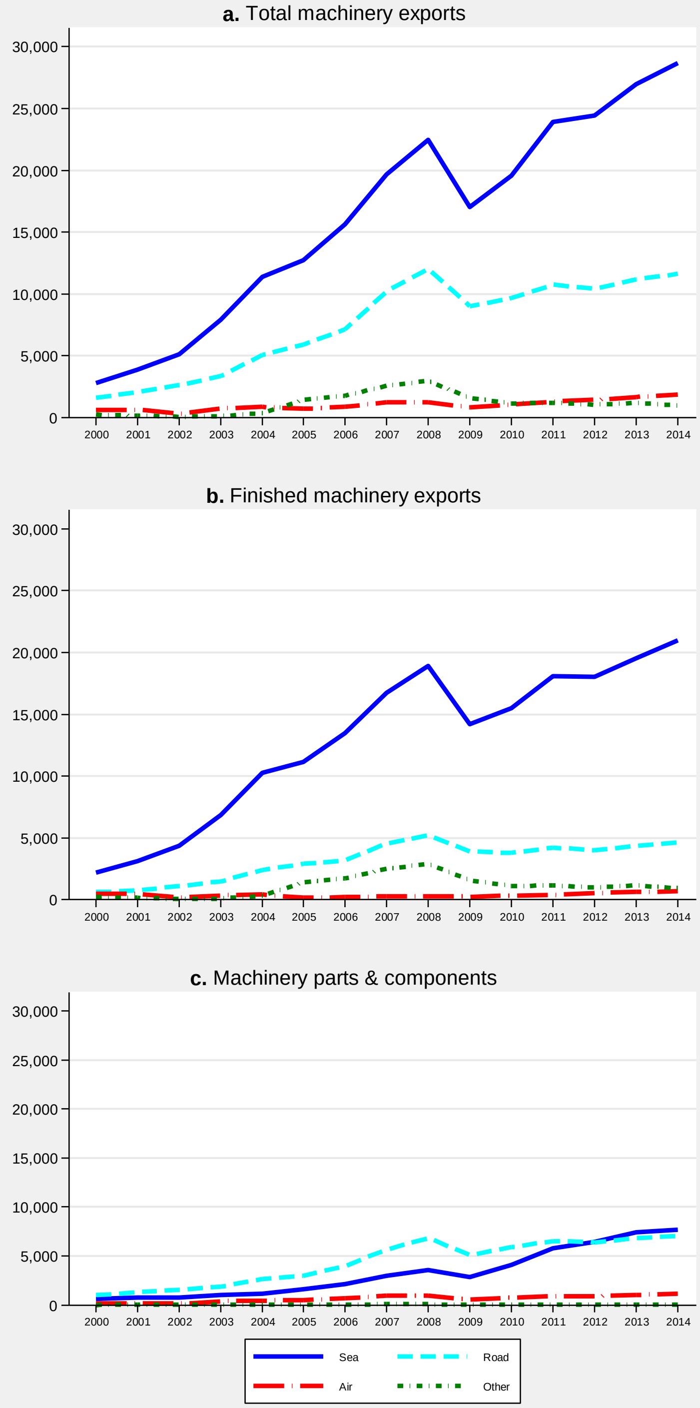
Notes: The dependent variable (mode shares) is a continuous variable that is bounded between 0 and 1. The logit transformation of the dependent variable is used in the estimations. Robust standard errors clustered at the importer-product level appear in parentheses. All regressions include year fixed effects. *, ** and *** indicate statistical significance at 10, 5 and 1% levels, respectively.

Table 3: Estimates of the probit model of transport mode choices for exports

	Sea	**Road**	**Air**
P&C	-0.126***	0.398***	-0.263***
	(0.018)	(0.019)	(0.019)
Log GDP (importer)	-0.176***	0.032***	-0.011*
	(0.006)	(0.006)	(0.006)
Log distance	0.506***	-0.895***	0.246***
	(0.014)	(0.021)	(0.014)
Common border	-1.998***	0.833***	-0.203***
	(0.066)	(0.035)	(0.038)
Landlocked	-1.474***	0.824***	-0.034
	(0.033)	(0.027)	(0.027)
Log unit values for sea	-0.148***		
	(0.006)		
Log Q of port infrastructure	-0.406***		
	(0.037)		
Log unit values for road		0.026***	
		(0.006)	
Log Q of road infrastructure		0.144***	
		(0.027)	
Log unit values for air			0.314***
			(0.008)
Log Q of air infrastructure			0.238***
			(0.041)
Observations	52,350	47,472	66,062

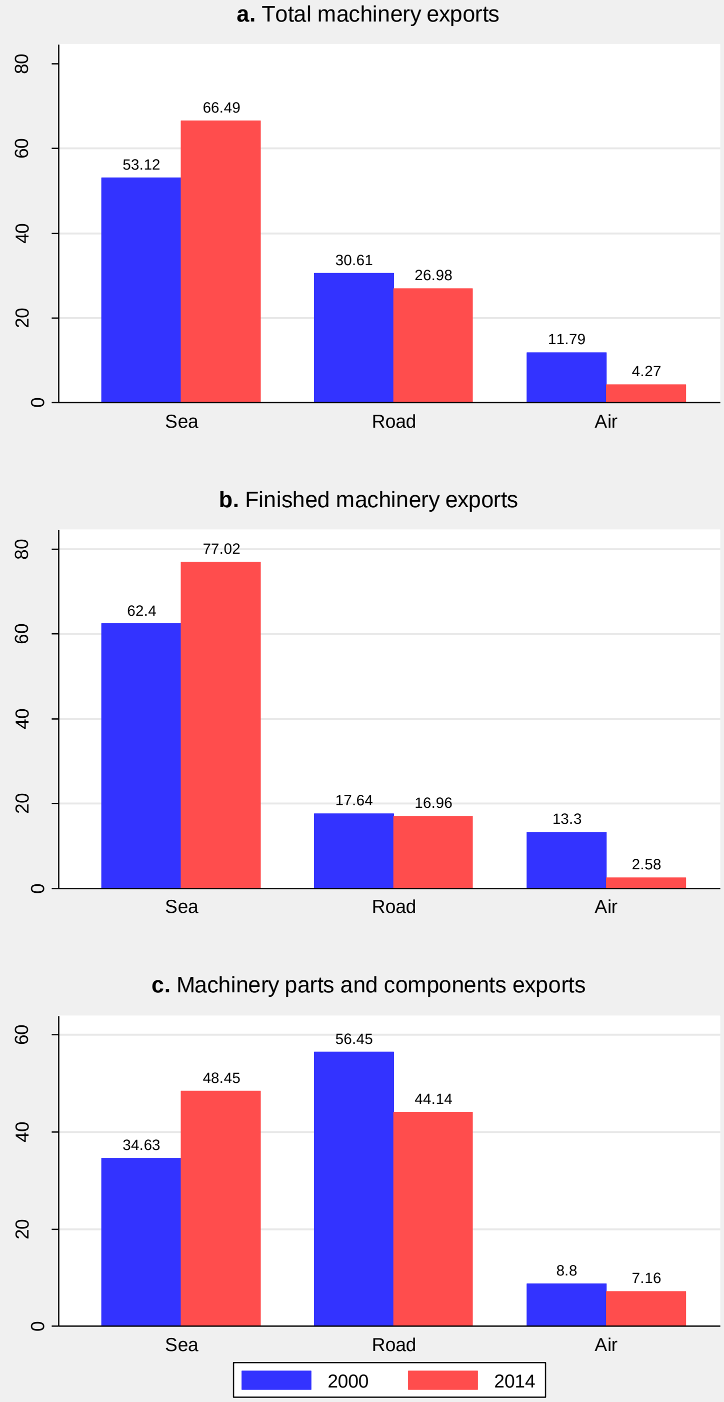
Notes: The dependent variable (binary mode share indicator) is a dummy variable that takes the value of one if the product is transported by its corresponding mode (sea/road/air) and is equal to zero if the share is less than 0.1. Robust standard errors clustered at the importer-product level appear in parentheses. All regressions include year fixed effects. *, ** and *** indicate statistical significance at 10, 5 and 1% levels, respectively.

Figure 1: The value of Turkey's machinery exports by mode of transportation



Source: TURKSTAT

Figure 2: Percentage changes in transport mode shares from 2000 to 2014



Source: TURKSTAT

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