Preliminary Draft
11/11/2009

Transportation Cost and Distance: Evidence from the Census of Logistics

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First Draft
November 2009

Abstract
Transportation costs play a fundamental role in shaping the pattern of economic activity. Because of the measurement issues of transport costs, the geographic distance is dominantly used as a proxy for the transport costs. However, there have been limited studies on the link between distance and freight cost. To shed further light on this issue, this paper employs the Census of Logistics in Japan that surveys directly the business enterprises over their shipments. The dataset contains extremely detailed characteristics on transportation including transport costs and time across goods, modes, and prefectures. I document that transport costs are more heterogeneous across transportation modes than the type of products shipped. Surprisingly, I find that the transport costs are *negatively*, not positively, correlated with the geographic distance between prefecture pairs after controlling for a wide range of other determinants. To resolve the puzzling results, I discuss the role of just-in-time system, timely delivery, and agglomeration in explaining the unobserved component of modern transportation.

Keywords: Transport Cost, Transport Time, Distance, Logistics

JEL classification: R30, R40, R41

1. Introduction

Transport costs play a central role in shaping the pattern of economic activity. A firm chooses the location of production to minimize the cost of shipping goods to the large market. While increasing returns to scale generates agglomeration forces for industrial location, the cost of moving products produces dispersion forces (Fujita et al., 1999). In the international market, transportation costs create a barrier to an international transaction in various products, which shapes the pattern of international trade (Anderson and van Wincoop, 2003). Exporting costs motivate the firm to locate a production plant offshore for the savings of transport costs, which lead to the formation of multinational firms (Brainard, 1997; Markusen, 2002). Further, transport costs could play an important role in economic growth (Gallup et al. 1999).

Despite the importance of transport costs, the measurement of transport fees has posed a major difficulty for empirically investigating the role of transportation in a wide range of economic activities. Because it is difficult to observe an *ex ante* freight cost faced by agents in making economic decisions, the empirical research has extensively relied on the geographic distance between the origin of a principal agent and the destination of an economic event as a proxy for the transport cost. This approach is justified by the simplifying assumption that the distance increases freight costs over space. As the distance is found to have a large negative effect on international trade flows in almost all studies, it is commonly interpreted that transport costs significantly discourage foreign trade (Disdier and Head, 2008).

However, the geographic distance could capture not only transport costs but also other economic costs, including an acquisition of market information, communication with distant agents, and different preferences over goods (Anderson and van Wincoop, 2004). The question remains as to what extent the geographic distance can explain a variation in transportation costs that differ along many dimensions such as product characteristics, shipping mode, and the origin and destination markets. What are the empirical relationship between transport costs and distance? After sweeping out the distance effects, what factors would explain the residual?

These questions for determinants of transport costs are an empirical basis for making an economic policy to promote industrial development because a barrier to transportation shapes a spatial distribution of industrial activities. To encourage industrial cluster for productivity improvements and growth, an effective policy needs to identify a crucial source of transportation fees.

To address these questions, this paper employs a comprehensive dataset on transport costs in Japan. The *Census of Logistics* published by the Ministry of Land, Infrastructure, Transport and Tourism, Japan, provides rich information on transportation used by enterprises in mining, manufacturing, wholesale, and warehouse industries.[1] These data provide extremely

[1] See Hummels (2007) for data sources on international transportation cost.

detailed characteristics on transportation including freight cost and time, volume of commodity flow, and detailed disaggregation of 8 major product categories, 11 transportation modes, and 47 prefecture pairs.

The richness of the dataset has several advantages for the analysis. As Japan consists of 5 major sub-islands that exhibit distinctive geographic characteristics, transportation modes range widely from railway to commercial truck, marine, and air transportations. Highly disaggregated transport costs would illustrate the extent of heterogeneity on transport costs across products and shipping modes. Additionally, shipping time can be used to isolate the time effect from the distance effect in accounting for transport costs.

In the prior literature, ad-valorem freight rate of trade and distance are the widely used measures of transport costs. Hummels (1999) estimate the relationship between freight cost and distance for imports of the U.S., New Zealand, and Latin American countries in 1994. He finds that the distance elasticity with respect to freight rates is, on average, 0.27. The estimates range from 0.46 for U.S. import by air to 0.22 for ocean shipping. Combes and Lafourcade (2005) report that estimated transport costs for truck shipping increases with distance traveled across regions in France. They find that the distance is highly correlated with freight fees at a point in time, but not over time.

However, these proxy variables suffer from many limitations. In particular, the ad-valorem freight rate is measured between countries by customs officials, i.e., port-to-port shipping costs. The distance is measured between the points of each region. As these conventional measures may not well capture transport costs between producers and consumers, it is difficult to understand the nature of transport costs in the modern manufacturing process characterized by a time-intensive, i.e., just-in-time, form of multi-stage production chains (Hummels, 2001; Deardorff, 2003; Evans and Harrigan, 2003; Harrigan and Venables, 2006). In contrast, the Census of Logistics is distinctive in that transport cost is directly measured from individual shipment fees paid by the business enterprise. This allows me to directly investigate the willingness-to-pay of the enterprises for moving commodities.[2]

Exploiting the rich characteristics of transportation, I illustrate the pattern of transport costs in various categories. As expected, there is a wide dispersion of freight costs across the origin and destination of shipments, commodity groups, and transport modes. In particular, the average cost of air transportation is substantially higher than other transportation modes, pointing to the fact that the freight cost differs most significantly by shipping mode. By computing cumulative density distribution of transport cost and time by mode, I further show a

[2] Limão and Venables (2001) estimate the determinants of transport costs for a standard container shipped from Baltimore in the U.S. While this paper studies transport cost from the demand side, their analysis focuses on the supply side.

trade-off between transportation cost and time; most of railroad and ship transportation is charged with less than 100 yen per ton, but subject to long shipping time. On the other hand, the majority of air shipments is charged with over 250 yen per ton, but delivered within 24 hours. These patterns accord well with our tuition, thereby supporting the soundness of the dataset.

To explore the role of distance in determining transport cost, I estimate the commonly used specification that transport cost increases loglinearly with respect to distance. To isolate the distance effect from other factors, I control for transport time, the volume of commodity flows, and a wide range of fixed effects in sending and arriving prefectures, commodity groups, transport modes, and year. Robust to a variety of alternative specifications, I find that transport fees are *negatively*, not positively, correlated with the distance. As the result may be driven by heterogeneity in transport mode and sample selection bias, I also employ Heckman two-step estimation across samples disaggregated by railroad, truck, ship, and air. Surprisingly, the distance variable still exhibits a significantly *negative* coefficient across the samples. To resolve the puzzle, I suggest the hypothesis that the time premium for transport and agglomeration play a role in driving the observed link between transport cost and distance.

The rest of this paper is organized as follows. Section 2 gives a detailed description of transportation survey, the Census of Logistics, with an emphasis on the survey design. Section 3 illustrates the characteristics of transportation across goods, shipping mode, and the region. In Section 4, I briefly discuss an empirical framework to estimate the role of distance in explaining transport costs, followed by estimation results. Section 5 presents the hypothesis to explain the negative coefficient of the distance. Section 6 concludes.

2. Data on the Census of Logistics

In this section, I describe the *Census of Logistics* used for analyzing the characteristics of transport costs in Japan. The Ministry of Land, Infrastructure, Transport and Tourism conducts the survey on business enterprises in 47 Japanese prefectures and 4 sectors: mining, manufacturing, wholesale, and warehouse industries. The primary objective of the logistics survey is to examine a comprehensive flow of domestic freight from a demand side of transportation so as to understand the origin and destination of the freight and the relationship between logistics and industrial activity. Starting in 1970, the survey has been conducted every 5 year, but the survey question on transport costs was included from the year-1995 survey. This paper exploits the survey results from the years 2000 and 2005.

The logistics survey defines the freight as materials, manufactures, and commodities that are shipped in and out of the business enterprise for the purpose of production, purchase, and sale. However, the survey excludes the freight that is not directly related to production/sale activities such as business documents, empty container, and industrial wastes. The destination of the freight as defined above ranges from foreign markets, domestic industries, and individual persons. On the other hand, the origin of freight flows does not include industries such as agriculture, forestry and fishery, construction, retail, and services. It also does not cover the freight from imported commodities at domestic marine port and airport.

The sampling scheme of the logistics survey is carefully designed to estimate actual characteristics of domestic transportation flows in the population defined as above. Specifically, the sample size in the survey is determined according to 3 strata: industry, employment, and prefecture. Specifically, the survey first defines the number of business enterprises in each industry of interest from other official statistics, and then decides the number of the enterprises being sampled to meet the minimum sampling rates.[3] Under these sampling designs, 63,417 enterprises were survey in the year 2005 by interview or questionnaire mail. As a result, the actual response was obtained for 21,026 enterprises, with the response rate varying by the interview (78.1%) and mail (31.8%) as well as by mining and warehouse industries (over 40%) and manufacturing and wholesale industries (below 40%). In particular, the survey examines details of all freights being shipped for 3 days in October. The details include information on product, volume and quantity, transport route, and shipping time and cost.

From the census of logistics, I create a 2-years panel on domestic transport costs disaggregated by prefecture-pair, 8 goods categories, and 12 transportation modes. Since there are 47 prefectures in Japan, the number of prefecture pairs is 2,162. The type of goods ranges from agricultural and marine products, wooden products, non-metalic minerals, metals and machinery, chemicals, light industrial products (paper, pulp, food, and beverages), various products (printing, leather, rubber, and plastics), and special goods (fertilizers, containers, and paper boxes). The following transport modes are included: railways by container and others, private truck, delivery-services truck, rental truck, commercial trailer truck, ferryboat, container ship, RORO ship, other marine shipping, air transport, and others.[4]

From the census of logistics, I also use data on the volume of transportation flows disaggregated by major goods, transport modes, and prefecture pairs. At the same disaggregation level of transport costs, freight flows measured in weight can be observed. Finally, the census includes information on transportation time disaggregated by transport modes and prefecture pairs. These data are used in the empirical analysis.

3. The Characteristics of Transportation

This section summarizes the pattern of transport costs that are aggregated over a

[3] See for details at http://www.mlit.go.jp/seisakutokatsu/census/census.html

[4] RORO ship stands for roll-on, roll-off ship. The RORO ship can accommodate commercial vehicles and trailer trucks without lifting them by crane. Thus, ferryboat and RORO ships can be used for marine transportation at the small-scale marine port.

combination of three categories: goods, shipping mode, and region. The Census of Logistics report transport costs measured in Japanese Yen per ton.[5] I denote the per-ton freight fees as τ_{ijmkt} for a departing prefecture i, an arriving prefecture j, a transport mode m, a commodity group k, and year t.

In the original dataset, some observations appear to exhibit implausibly too large or small transport cost. As I find that influential observations affect the average transport fees to a large extent, I exclude the samples in which transportation costs. Further, I drop the sample in which transport time is in the top or bottom 1% tail of the distribution. The remaining sample is used to for the descriptive and econometric analysis.

As Japan consists of 47 prefectures, ranging from Hokkaido in the north to Okinawa in the south, these prefectures can be grouped into 7 regions according to their location: Hokkaido, Tohoku, Kanto, Chubu, Kinki, Chugoku, Shikoku, and Kyushu. The correspondence between the prefectures and regions is provided in the Appendix. Further, transportation can be classified by 4 major modes: air, railroad, ship, and truck.

3.1. The Pattern of Transportation Cost

Grouping transport cost by the region of departing prefectures and freight mode, I compute the (unweighted) average transport cost in yen per ton. Figure 1 illustrates the result of transport fees that aggregated this way. Several patterns are evident. Air transportation cost is the highest, followed by truck transportation. Railroad and ship transportation are less expensive than these modes. As compared to the variation in freight fees by mode, the difference between the departing regions appears to be relatively small. For air shipping, the business enterprises in the middle region of Japan such as Kanto, Chubu, and Kinki tend to pay relatively higher fees.

[Figure 1 around here]

Figure 2 shows the pattern of transport cost by the region of arriving prefectures and shipping mode. Consistent with the previous figure for the home-region grouping, air transportation is substantially more expensive than the other transport modes. While truck shipments are relatively expensive, railroad and ship transport are also less expensive.

[Figure 2 around here]

The previous illustrations have averaged transport costs over commodity groups, which may be widely varying. Instead of grouping freight fees by the location of shipments, Figure 3 shows the pattern of transport fees that are sorted by transportation mode and commodity group. The pattern clearly points to the wide dispersion of freight costs across

[5] I adopt yen-per-ton for the unit of transport costs whereas alternative units of measurement include yen per ton-kilometers, ton-hours, and ton-values. As any of measurement units would be subject to confounding factors that affect shipping costs, it is not clear which unit is the best for the descriptive analysis.

shipping modes. While the cross-product variation is relatively large for air transportation, transport fees do not differ much by commodity for railway, ship, and truck transportation.

[Figure 3 around here]

In sum, the evidence points to the wider dispersion of average transport costs across freight modes thant regions and commodities; air and truck transportation are relatively expensive to railroad and ship transportation. These patterns seem to be in line with the wide variation of international freight rates within commodities as found in Hummels (2001).

It is in order here to note that these figures illustrate merely the *observed* freight fees, on average, for each category. As is the nature of the descriptive analysis, there a number of factors that vary systematically by these groupings and affect freight fees. For instace, air transportation fees may be, on average, more expensive than others in part because the business enterprises may choose air transportation for long-distant, long-time, and expensive-goods shipments. Regression analysis is empolyed to sort out the role of distance, shipping time, and the price of goods in accounting for measured costs of transportation.

3.2. Distribution of Transport Cost and Time by Mode

As I show the wide variation of transport costs by mode, it is useful to scrutinize the distribution of transport fees and shipping time by the type of transportation. Figure 4 shows the cumulative density distribution of transport costs. The graph indicates that over 80% of shipments by railroad and ship are charged with less than 100 yen per ton. Truck shipments that cost less than 100 yen per ton account for over 60% of the observations. In contrast, air transportation is charged with over 250 yen per ton in almost half of the observations.

[Figure 4 around here]

Figure 5 displays the cumulative distribution of transport time by transport mode. The pattern is in stark contrast with that for transport fees. Over 80% of air shipments takes less than 24 hours. Most of truck shipments are also delivered within 24 hours. On the other hand, over half of railroad and ship transportation spends more than 24 hours. Taken together with the result for transport cost, these graphs point to a trade-off between transport cost and time.

[Figure 5 around here]

In sum, the descriptive analysis confimrs that the business enterprises spend shipment fees that are widely varying across transport modes, with a trade-off between transport cost and time. The data on transportation from the Census of Logistics accord well with the causal empiricism on transportation choices, providing illustrative support for the credibility of the dataset.

4. Estimating the Role of Distance in Transport Costs

The descriptive analysis in the previous section demonstrates the large dispersion of transport costs across various dimensions of the data, with the pronounced distinction by transport mode. The objective in this section is to estimate the contribution of geographic distance to the variation in measured shipping fees. To this end, an empirical model is specified to sort out the distance effect from a number of (unobserved) determinants of freight cost.

4.1. Empirical Framework

To analyze the structure of transport cost, I follow the literature on the gravity model of international trade in which unobservable trade cost between nations is a loglinear function of bilateral distance and other observable variables (Anderson and van Wincoop, 2003). As my focus is on domestic trade barriers, distance is measured between prefectures, not nations. For a sending prefecture i, a receiving prefecture j, a transport mode m, a commodity group k, and year t, transport cost in yen per ton is specified as:

$$\tau_{ijmkt} = d_{ij}^{\beta_1} \cdot X_{ijmkt} \tag{1}$$

where d_{ij} is the distance between the cities of the prefectural governments, and X is a function of other determinants. The geographic distance in kilometer between prefectural offices is measured from the data of the Geographical Survey Institute, Japan.[6]

In the empirical gravity model, X can include a national border, common language, and a variety of other (unobservable) trade barriers between countries. However, it is difficult to isolate the role of distance from other trade impediments such as information cost, which may increase with respect to the distance. Further, available data on explicitly observable trade barriers for estimating the freight-distance relationship tend to be limited to ad-valorem freight rates (Hummels, 1999), and shipping company quotes (Limão and Venables, 2001).

In contrast, my dataset provides extremely detailed characteristics on transportation, which are likely to influence the pattern of shipping fees. This approach allows me to provide a precise estimate of the distance effect on transport expenses paid directly by producers. In particular, there is no need to take into account national barriers such as customs, currency, and regional integration.

To exploit the rich data on transportation, I specify X as follows.

$$X = T_{ijmt}^{\beta_2} \cdot V_{ijmkt}^{\beta_3} \cdot \exp(\gamma_i \cdot \delta_j \cdot \mu_m \cdot \pi_k \cdot \sigma_t \cdot \epsilon_{ijmkt}) \tag{2}$$

- T is transportation time in hours
- V is the volume of commodity flows in ton
- γ is a departure-prefecture fixed effect

[6] Available at http://www.gsi.go.jp/KOKUJYOHO/kenchokan.html

- δ is a destination-prefecture fixed effect
- μ is a transport-mode fixed effect
- π is a commodity-group fixed effect
- σ is a time fixed effect
- ε represents unobservable influences on transport costs.

By inserting equation (2) into equation (1) and taking logs, the estimating equation is defined as:

$$\ln \tau_{ijmkt} = \alpha + \beta_1 \ln d_{ij} + \beta_2 \ln T_{ijmt} + \beta_3 V_{ijmkt} + \gamma_i + \delta_j + \mu_m + \pi_k + \sigma_t + \epsilon_{ijmkt} \qquad (3)$$

I estimate equation (3) to study the hypothesis that transport cost increases loglinearly with respect to distance, after carefully accounting for other influences on shipping fees.

Transportation time is expected to reduce transport costs because producers/consumers are willing to pay a premium for the faster shipment relative to the slow transportation. The volume of commodity flows is included to account for the supply side of transportation. There is a fixed cost for transportation business, which would depend on public infrastructure to transport equipments. As the larger demand for transportation decreases the relative importance of fixed costs to marginal costs of shipments, there is likely to be more suppliers of transport services in the presence of greater volume of commodity flows. Because the price for freight services is driven down by market competition, transport cost would decrease with respect to the size of freight circulation. The remaining independent variables are included to control for a wide range of other determinants, including transport infrastructure in each prefecture, transportation quality by mode, shipping bulkiness by goods, and time-specific effects of the survey.

4.2. Summary Statistics

Table 1 shows the summary statistics of the key variables defined in levels and logs for the sample used in regression. The average transport cost is 97.6 yen per ton, which ranges from 4.03 to 1,479. The mean of shipping distance is 437 kilometers, ranging from 10.5 to 2,224. The average time of shipments is 21.4 hours.

[Table 1 around here]

Table 2 presents the list of correlation coefficients. Transport fees are negatively correlated with distance, time, and the volume of commodity flows for the variables in both levels and logs. While the negative association is not intuitive, there is possible influence of confounding factors on the correlation coefficients. As expected, the distance and shipping time are highly and positively correlated, suggesting the long-distance shipments take longer.

[Table 2 around here]

4.3. Benchmark Results

Table 3 shows the results of equation (3) estimated by Ordinary Least Squares (OLS) with robust standard errors. In column (1), I include only distance in the model. Surprisingly, the distance variable has the significantly “negative” coefficient. The size of the coefficient implies that a 1% increase in the distance shipped is predicted to *reduce* total transport cost in Yen per ton by 0.35%.

[Table 3 around here]

As omitted variables may drive the surprising results, column (2) includes transport time and commodity flows. The result is even more surprising; holding shipping time constant, the distance reduces transport cost. On the other hand, keeping the distance constant, the transport time increases freight cost. There suggest that the business enterprises pay higher prices for the short-distance and long-time shipments.

As unobserved heterogeneity in a variety of transportation characteristics may play a role, column (3) includes a number of dummy variables. The distance still shows the significantly negative coefficient. An econometric interpretation of the coefficient of -0.87 is that a 1% increase in the distance reduces transport costs in Yen per ton by almost 0.9%. To understand the magnitude of this effect, consider that the distance from Tokyo to Aichi and Osaka is about 260 and 400 kilometers, respectively. If a firm changes a destination from Aichi to Osaka, freight costs paid by the firm would decrease by (54*0.9 =) 48.6%.

Finally, I explore the explanatory power of the distance relative to transport time, commodity flows, and other determinants. To get a crude gauge of the contribution, I estimate the model by restricting the coefficient of the distance to 0 in column (4) and evaluating the change in the fit of the model. Consequently, the R-squared value drops from 0.49 to 0.30. As the R-square value declines only to 0.41 in column (2) by restricting the coefficient of all the dummy variables to 0, the distance appears to play a large -- quite puzzling though -- role in explaining transport costs.

4.4. Sample Selection Correction by Transport Mode

Up to this point, the regression analysis has assumed that distance has the identical influence on transport cost across shipping modes. This may mask a link between the distance and freight cost that may depend on transportation mode. This is likely to be important as producers select transport modes based on their shipping distance, cost, and time. As there would be an upper bound on transport costs that are increasing in distance but may differ by freight mode, the sample on shipments is likely to be only partially observed. This could produce varying truncation on transport costs by mode. These problems suggest that the surprising results may occur from possible bias in the OLS estimates.

To address heterogeneity in transport modes and sample selection bias, I employ the sample selection model by Heckman (1979). As a first step, I specify a selection equation that determines whether the business enterprises pay transport fees for shipments. To distinguish the transport-cost equation from the selection equation, I assume that the volume of commodity flows affects the selection, but does not have a partial effect on the price of shipments. This assumption can be justified by the fact that individual freight costs are not determined by the whole weight of shipment flows.

Table 4 presents the results by Heckman's two-step estimation. The significant coefficient of the inverse Mills ratio points to sample selection bias in rail, truck, and air transportation. This suggests that OLS estimates in the previous regression are subject to selection bias in transport-mode choices. However, the coefficient of distance variables is still significantly negative across transport modes. In particular, he distance exhibits the larger negative coefficient for the truck sample. The interpretation is that, conditional on choosing specific transport modes, the business enterprises pay higher freight fees for the short-distance shipments. From there results, I conclude that the puzzling negative link between distance and transport cost is not driven merely by the heterogeneity in transport modes and selection bias.

[Table 4 around here]

5. Possible Explanations for the Negative Distance Effect

The previous analysis shows that an observed pattern of transportation cost and time accords well with the common idea that transport costs are larger for faster shipping by air and differ by various dimensions of shipments. In the econometric analysis, however, transport costs are negatively correlated with distance, after carefully accounting for a number of other determinants. While the description of transport supports soundness of the Census of Logistics, the negative distance effect is surprising, puzzling, and counter-intuitive. Why does transport cost fall with respect to distance? What factors play a crucial role in driving the negative distance effect?

To discuss possible explanations, I start from the two conjectures. First, the pattern of transport cost is evidence of reasonable surveys. Second, the distance variable is not likely to be subject to measurement errors and simultaneity bias. Thus, I assume that the results reflect some unexplained factors of transportation. While there are a number of unobserved factors, I focus on the role of logistics in modern manufacturing production. My argument is that firms may pay substantially high premiums on timely transportation. This is more likely to be important for shipments in proximity to the firm because of industrial agglomeration. The link between timely-delivery premiums and industrial clusters may explain the result that transport cost declines over distance.

The starting point for this argument is the nature of modern manufacturing production. Toyota Motors invented a just-in-time system in their production line for the 1950s to reduce a cost of inventory holdings. To cut down stocks, manufacturers receive only necessary components and parts from suppliers only in the necessary timing. For this reason, the delivery of the components should be timely, frequent, and small in the JIT system. The flexible logistics in the production system allow for a quick response to defective components and customer orders.

The importance of the JIT system implies that the characteristics of shipments should reflect the demand for transportation services. The report on the Census of Logistics (2005) presents some evidence of the importance of a small batch of shipments and timely delivery. The average volume per unit of shipment is 2.43 ton for the year 1990, which is followed by 2.13 in 1995, 1.73 in 2000, and 1.27 in 2005. Further, less-than 0.1 ton shipments account for almost 70% of 2 millions of total shipping transactions surveyed in 2005. These patterns also apply to such industries as manufacturing, wholesale, and warehouse. For instance, the per-unit volume of shipments in wholesale sector declines from 0.72 in 1990 to 0.36 in 2005. The manufacturing sector shows a decline from 3.16 in 1990 to 2.06 in 2005.

Another important characteristic of transportation is timeliness, which need to be clearly distinguished from shipping time. As the JIT system is organized to coordinate production lines by delivering components on the designated timeline, the timing of transportation would matter much more importantly than the length of shipping time. The shipping time can be saved at dispense of costly transportation, but late delivery with short shipping time is likely to create possibly large cost of idle operation. To understand the role of timeliness, the survey has information on a proportion of shipments whose arrival time is designated by hour, morning or afternoon, day, and none. In 2005, for instance, almost 80% of shipments sent from the manufacturing sector are specified on the arrival time on the basis of aggregate freight weight; arrival time by hour is 35%, by morning or afternoon is 14.5%, and by day is 31.4%. At the aggregate industry level, these shares are 27.7%, 14.6%, and 31.4%, respectively. These figures suggest that timeliness is critical for modern transportation for which firms would have the high willingness-to-pay for timely delivery.

Given that firms pay a substantial premium for timely, frequent, and small-batch shipments, the question remains as to why the premium for transport in proximity is particularly large enough to account for the negative distant effect. Possibly, spatial concentration of industrial activity could explain a possible link between a time premium and the short-distance freight. If agglomeration of activity disproportionately increases the importance of timely delivery of components and parts, producers have an incentive to pay a large premium for timely transportation in the proximate location. On the other hand, the timeliness and frequency may not be an important nature of long-distant freight as the JIT approach emphasizes the importance of locating production in proximity to ensure the synchronization of vertical production activities. This interpretation is in line with recent theoretical and empirical studies. For example, Harrigan and Venables (2006) provide the theoretical mechanism that timeliness creates an incentive for clustering of component producers and assembly plants. Further, Evans and Harrigan (2005) show evidence for the model in which demand for timely delivery shifts the location of production in proximity to a home market in the case of U.S. retail sector.

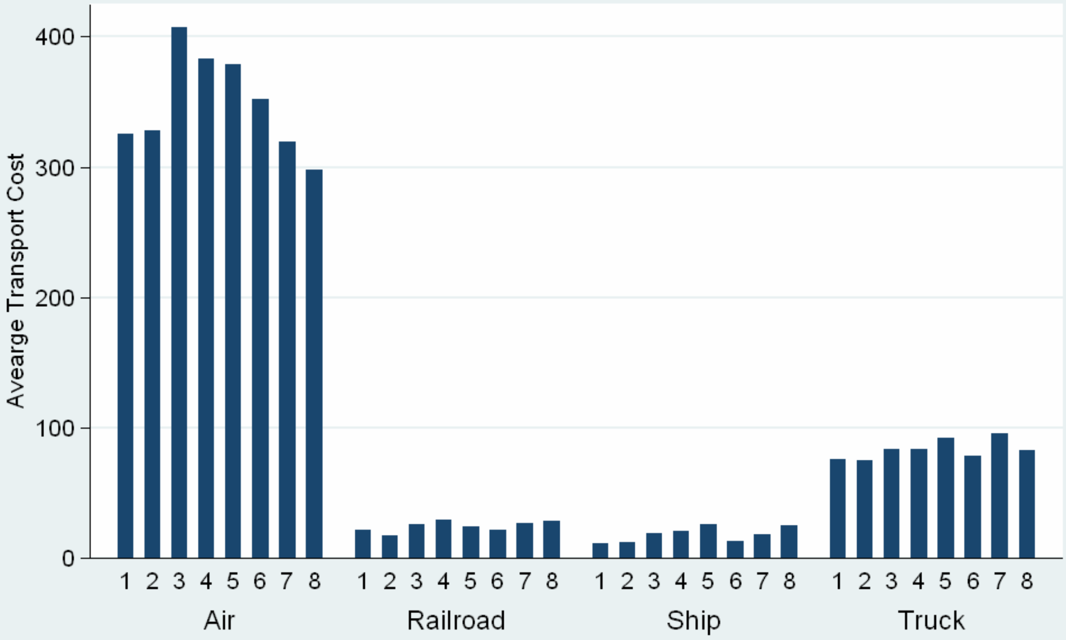
These discussions would be useful for a further investigation on the determinants of transport costs from a demand side of transport services. However, it is not possible to rule out a skeptical view on the negative distance effect; dirty data issues matter. In particular, a possible culprit for the puzzle may be aggregation bias across a wide variety of products that differ in many aspects. The dataset on transportation report transport costs that are measured in weight for the crude category of heterogeneous products. As compared to the distance as a crude measure of transport cost, freight cost per ton disaggregated by many categories is a substantially improved measure. Still, an open question is whether any bias is generated by weight-based measurement of transport cost. In addition, the information on transport cost per ton does not contain the value of shipments. As the relative transport cost, i.e., ad-valorem freight cost, is lower for a more expensive product, firms can accord to pay a premium for the expensive products. To the extent that there patterns are systematically prominent in the short-distant shipments, the missing data on the value of shipments might account for the puzzle.

6. Conclusion

To be concluded.

Figure 1: Transport Cost by Home Region and Transport Mode

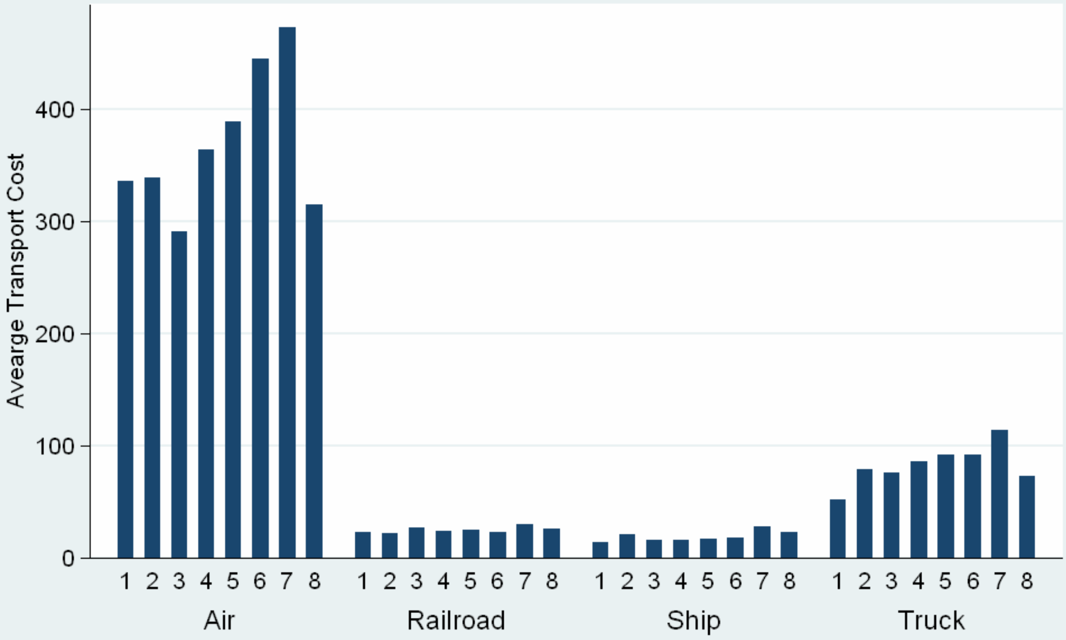
Yen per Ton, Year 2000 and 2005



Source: Census of Logistics
Note: Number 1 to 8 indicates Hokkaido, Tohoku, Kanto, Chubu, Kinki, Chugoku, Shikoku, and Kyushu, respectively

Figure 2: Transport Cost by Host Region and Transport Mode

Yen per Ton, Year 2000 and 2005



Source: Census of Logistics
Note: Number 1 to 8 indicates Hokkaido, Tohoku, Kanto, Chubu, Kinki, Chugoku, Shikoku, and Kyushu, respectively

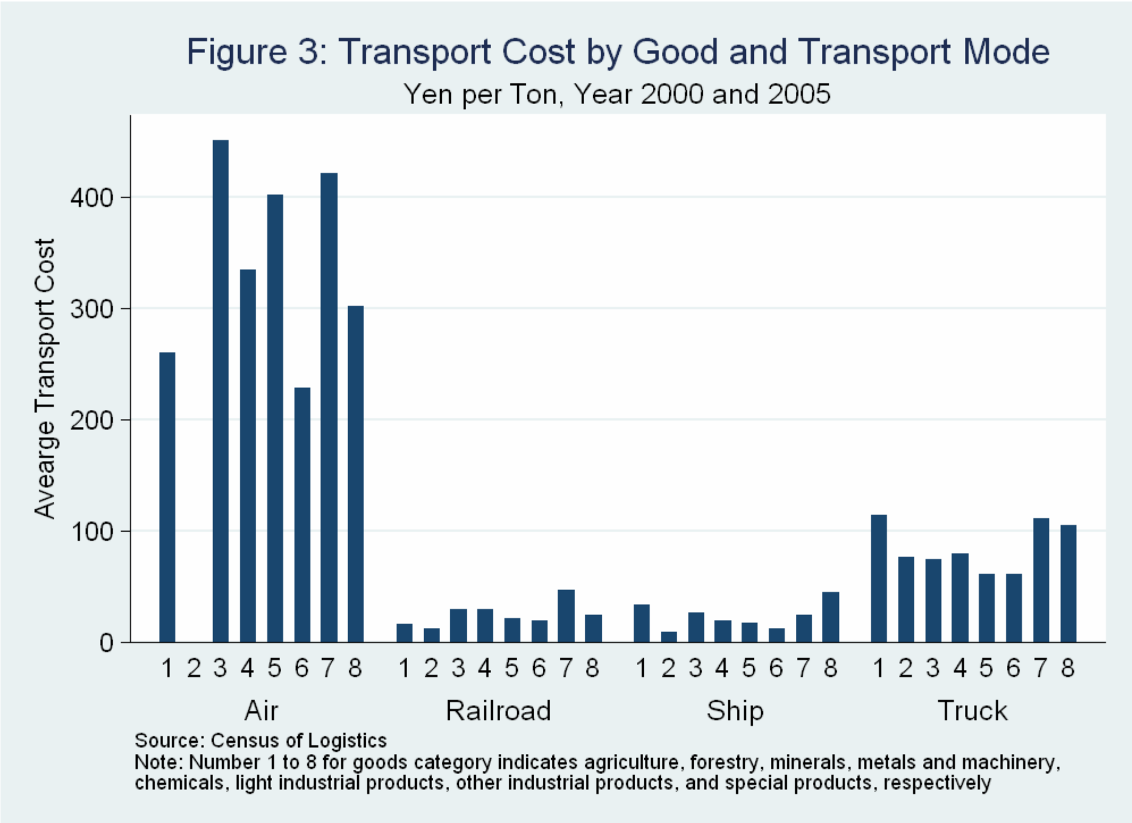


Figure 3: Transport Cost by Good and Transport Mode
Yen per Ton, Year 2000 and 2005
Avearge Transport Cost
0
100
200
300
400
1 2 3 4 5 6 7 8
1 2 3 4 5 6 7 8
1 2 3 4 5 6 7 8
1 2 3 4 5 6 7 8
Air
Railroad
Ship
Truck
Source: Census of Logistics
Note: Number 1 to 8 for goods category indicates agriculture, forestry, minerals, metals and machinery, chemicals, light industrial products, other industrial products, and special products, respectively

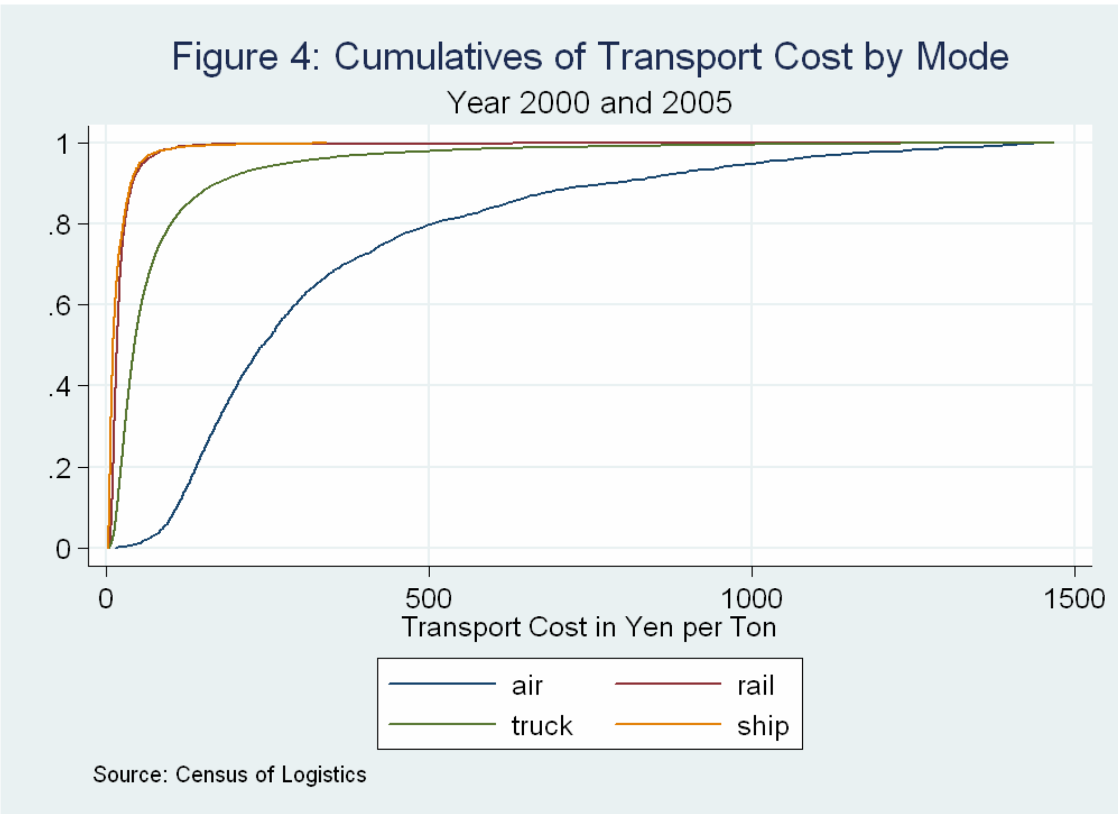


Figure 4: Cumulatives of Transport Cost by Mode
Year 2000 and 2005
0
.2
.4
.6
.8
1
0
500
1000
1500
Transport Cost in Yen per Ton
air
rail
truck
ship
Source: Census of Logistics

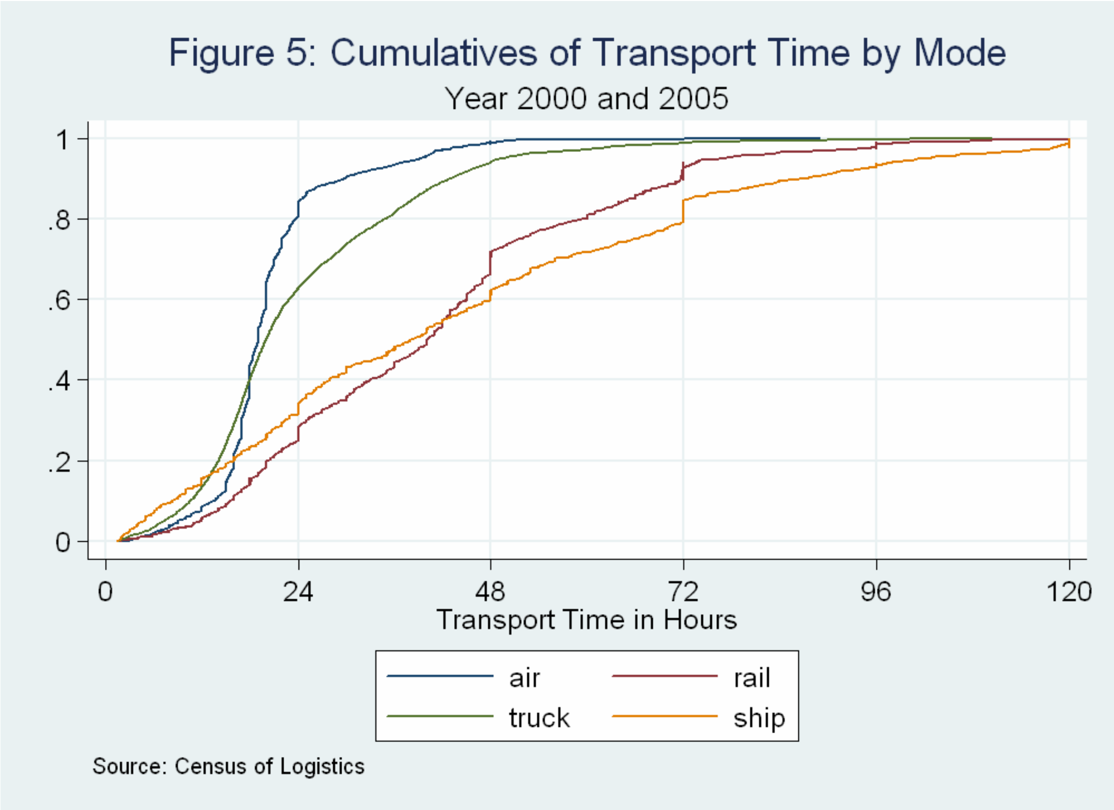


Table 1: Summary Statistics

No. of obs. = 37,186

Variable		Mean	Std. Dev.	Min	Max
τ	yen per ton	97.6	157	4.03	1479
d	km	437	304	10.50	2244
t	hours	21.4	15.2	1.56	120
v	ton	354	1705	0.001	116260
$\ln \tau$	yen per ton	3.93	1.07	1.39	7.30
ln d	km	5.80	0.83	2.35	7.72
ln t	hours	2.83	0.71	0.44	4.79
ln v	ton	3.28	2.68	-6.91	11.7

Table 2: Correlation Coefficients

No. of obs. = 37,186

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
τ	1							
d	-0.09	1						
t	-0.06	0.68	1					
v	-0.05	-0.16	-0.14	1				
ln t	0.78	-0.18	-0.13	-0.08	1			
ln d	-0.18	0.90	0.61	-0.22	-0.27	1		
ln τ	0.01	0.69	0.88	-0.24	-0.04	0.71	1	
ln v	-0.35	-0.39	-0.30	0.36	-0.42	-0.40	-0.41	1

Table 3. Benchmark Results

Dependent variable: log of transport cost in yen per ton

Regressor	(1)	(2)	(3)	(4)
Log of distance	-0.345***	-0.801***	-0.874***	
	(0.007)	(0.008)	(0.008)	
Log of transport time		0.228***	0.198***	-0.355***
		(0.010)	(0.010)	(0.008)
Log of transport flow		-0.240***	-0.272***	-0.219***
		(0.002)	(0.002)	(0.002)
Sending prefecture dummy	No	No	Yes	Yes
Arriving prefecture dummy	No	No	Yes	Yes
Transport mode dummy	No	No	Yes	Yes
Commodity dummy	No	No	Yes	Yes
Year dummy	No	No	Yes	Yes
Observations	37186	37186	37186	37186
R-squared	0.07	0.41	0.49	0.30

Note: Constant is included, but not reported; "Yes" and "No" indicate whether the corresponding dummy variable is included or not.

***: significant at 1%

**: significant at 5%

*: significant at 10%

Table 4. Sample Selection Estimation by Transport Mode

Dependent variable: log of transport cost in yen per ton

Transport Mode Regressor	Rail (1)	Truck (2)	Ship (3)	Air (4)
Log of distance	-0.494***	-1.216***	-0.431***	-0.389*
	(0.104)	(0.025)	(0.052)	(0.186)
Log of transport time	0.136	1.494***	0.152**	0.001
	(0.102)	(0.034)	(0.050)	(0.175)
Inverse Mills ratio	1.859***	2.388***	0.0364	2.310***
	(0.342)	(0.0811)	(0.257)	(0.525)
Sending prefecture dummy	Yes	Yes	Yes	Yes
Arriving prefecture dummy	Yes	Yes	Yes	Yes
Commodity dummy	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes
Observations	2532	41142	1554	2091

Note: Log of transport flow is used in the selection model; constant is included, but not reported; "Yes" indicates whether the corresponding dummy variable is included.

***: significant at 1%

**: significant at 5%

*: significant at 10%

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Appendix

Figure A1: The Map of Japan

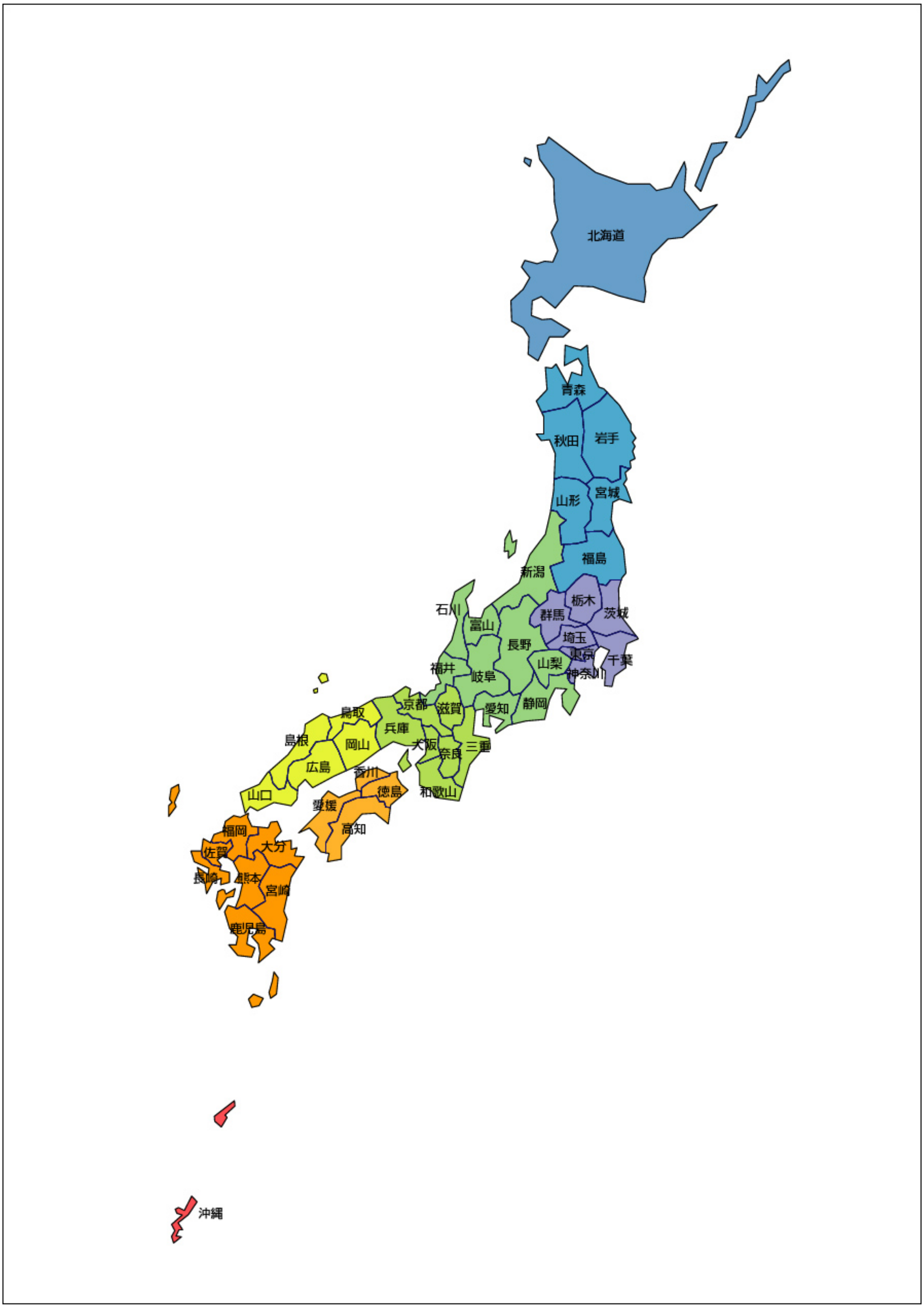

Table A1: Prefecture and its Region

Region	**Prefecture**					
Hokkaido	Hokkaido					
Tohoku	Aomori	Iwate	Miyagi	Akita	Yamagata	Fukushima
Kanto	Ibaragi	Tochigi	Gunma	Saitama	Chiba	Tokyo
	Kanagawa					
Chubu	Niigata	Toyama	Ishikawa	Fukui	Yamanashi	Nagano
	Gifu	Shizuoka	Aichi			
Kinki	Mie	Shiga	Kyoto	Osaka	Hyogo	Nara
	Wakayama					
Chugoku	Tottori	Shimane	Okayama	Hiroshima	Yamaguchi	
Shikoku	Tokushima	Kagawa	Ehime	Kouchi		
Kyushu	Fukuoka	Saga	Nagasaki	Kumamoto	Ohita	Miyazaki
	Kagoshima	Okinawa				

Table A2: Variable Definition and Data Sources

Variable	Definition	Source
τ	Transportation costs measured in yen per ton that vary by prefecture pairs, transport mode, commodity group, and year	Census of Logistics published by the Ministry of Land, Infrastructure, Transport and Tourism, Japan
t	Transportation time measured in hours that differs by prefecture pairs, transport mode, and year	
v	Volume of shipment flows measured in ton that vary by prefecture pairs, transport mode, commodity group, and year	
d	Distance measured in kilometers between the cities of prefectural government offices	Geographical Survey Institute, Japan