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January, 2014

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By analyzing a comprehensive dataset on transport transactions in Japan, we describe a directional imbalance in freight rates by transport mode and examine its potential sources, such as economies of density and directionally imbalanced transport flow. There are certain numbers of observed links which show asymmetric transport costs. Instrumental variable analysis is used to show that economies of density account for deviation from symmetric freight rates between prefectures. Our results show that a 10% increase in outbound transport flow relative to inbound transport flow leads to a 2.1% decrease in outbound freight rate relative to inbound freight rate

Keywords: freight rates, directional imbalance, density economies

JEL classification: F14, L91, R41

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1 Introduction

The recent decade has seen a growing body of literature on analyzing the relationship between transport costs and the spatial structure of economic activity (Fujita, Krugman and Venables (1999)). Remarkable progress on analytically solvable models has been made possible in part by some simple assumptions: that freight rates are exogenously determined, follow the iceberg type, and are directionally symmetric. This symmetry assumption can be justified only if the transport route is identical in both directions and transportation technology is characterized by constant returns to scale in a homogeneous space. However, causal observation reveals that freight rates are often directionally asymmetric, even on the same route. For example, the average freight cost per TEU from Asia to United States is about 1.78-fold that in the opposite direction and the cost from Asia to Europe is about 1.33-fold that in the opposite direction.[1]

Motivated by these observations, recent theoretical studies such as Behrens and Picard (2011) and Takahashi (2011) have re-examined the economic geography models in cases where freight rates are asymmetric due to a directional imbalance in demand for transport services. These theoretical advances improve our understanding of the role of the transport sector in industrial agglomeration, but there has been little systematic empirical analysis of directional imbalance in freight rates. We know little about the actual magnitude of asymmetric freight rates or what factors induce directional imbalance. Thus, there is a lack of empirical evidence on the relevance of theory to actual economic geography in the presence of asymmetric freight rates.

This paper seeks to systematically examine a directional imbalance in freight rates by using a comprehensive survey on transportation transactions in Japan. A novel aspect of our dataset is that freight rates are measured for truck transport of distinct commodity groups among the 47 prefectures. After describing the basic characteristics of freight rates in Japan, we examine the extent to which freight rates differ on the same route depending on direction. The descriptive analysis shows that bilateral freight rates are on average quantitatively close to symmetric, but a statistical test shows that this symmetry is not perfect. Observed deviation from symmetry is large and declines on both tails as density changes. These results provide empirical support for the symmetry assumption and indicate a possible method of relaxing the assumptions of the model.

By drawing upon the literature on transportation technology, we derive an empir-

[1]The data are yearly averages for 2009. During 2009, the maximum and minimum quarterly average freight costs were 2.29 and 1.50 for Asia-USA and 1.55 and 1.20 to Asia-Europe. For details, see Table 4.5 of Review of Maritime Transport 2010.

ical framework for evaluating directional symmetry in freight rates. We formulate an empirical model to account for one-way freight rate by economies of density, imbalances in transport flow, and a variety of other determinants. Then, under a set of reasonable assumptions for truck transport, we show that the ratio between the freight rates in one direction and in the opposite direction depends on the directional difference in transport flow, arising as an effect of economies of density and backhaul problem, and characteristics of the origin and destination prefectures. To estimate a causal impact of the economies of density, we use the variation in communication intensity among prefectures as an instrument for detecting variation in the directional balance of transport flows. We present statistical evidence supporting the validity of our instruments so that we can offer a causal interpretation. Our results show that a 10% increase in outbound transport flow relative to inbound transport flow leads to a 2.1% decrease in outbound freight rate relative to inbound freight rate. Thus, we conclude that economies of density play a crucial role in shaping directional imbalances in freight rates.

Our empirical analysis draws on two strands of prior research. The first branch of studies looks at the role of economies of density in the cost functions of the transport sector. For example, empirical evidence is provided in Caves, Christensen and Tretheway (1984) for air transport and in Braeutigam, Daughety and Turnquist (1982) for rail transport. These studies found that a larger volume of shipments decreases the unit freight rates of a given transport network. The second branch, typified by work such as Jonkeren, Demirel, van Ommeren and Rietveld (2011), investigates the effect of directional imbalance in shipment flows on one-way freight rates. In that study, directional imbalance in transport flows is recognized as a backhaul problem for transport firms, which implies that for a given round trip, a larger quantity of shipments in one direction leads to an insufficient or empty transport in the opposite direction. The analysis of inland marine shipments in northern Europe shows that imbalances in transport flows increase unit shipping prices. Additionally,Clark, Dollar and Micco (2004) and Blonigen and Wilson (2008) provide evidence that imbalance in transport flows positively affects freight rates in international trade conducted by marine shipping.

Although these two strands of research have examined the determinants of one-way freight rates, they have not addressed the question of what factors determine a directional imbalance in freight rates. In this paper, we show that directional imbalance in transport flows has a causal impact on directional imbalance in freight rates via economies of density. This result is robust to an additional control variable, an alternative variable for instruments, and an alternative definition of transport flows.

This finding shows a clear difference between our study of truck transport and previous studies of the backhaul problem in maritime transport, where the direction with larger transport flow is more costly. This latter indicates that the backhaul problem does not always dominate economies of density and suggests that the interaction between economies of density and the spatial distribution of economic activities are interrelated, which is crucial to economic geography models. The rest of the paper is organized as follows. In section 2, we explain the data and examine the variation from symmetry in freight rates. Section 3 formulates the model and gives the method of estimation with a discussion of the theoretical precepts. In section 4, we provide the results from the model. Finally, we offer some concluding comments in section 5.

2 Data

2.1 Survey of Net National Freight Circulation

In this section, we explain *the Survey of Net National Freight Circulation* that we use to analyze the characteristics of freight rates in Japan; this is followed by a description of the basic features of actual transport. The data consist of two parts: the survey and the census. The survey includes freight rates, volume, modes of transport, routes, and characteristics of the owner establishment of goods.[2] On the basis of the responses and sampling methodology, the value of transport flows is estimated. The data cover the 47 Japanese prefectures across four sectors (mining, manufacturing, wholesale, and warehousing).[3] The types of goods include agricultural and marine products, wood products, non-metallic 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). Transport modes include rail container, other rail, private truck, delivery-services truck, rental truck, commercial trailer truck, ferry, container ship, roll-on/roll-off ship, other marine, air, and other. From the census of logistics, we also use data on tonnage of transport flows disaggregated by major good and transport mode. We mitigate possible reporting and aggregation errors in the sampling of freight rates by excluding the top and bottom 1% of the distributions.

[2] The sampling strategy differs by sector. For mining (manufacturing), all establishments with more than 20 (100) employee are sampled. Establishments with fewer employees in mining and manufacturing and the other industries are surveyed.

[3] The total number of establishments in the four sectors was 683,230; of these, 67,121 (9.8%) were selected for sample survey. The number of respondents was 21,045 (3.08%).

Using the census of logistics in 2000 and 2005, we created a two-year panel dataset on domestic freight rates by origin and destination. We incorporate a publicly available dataset on transportation at the prefecture level, which is an approximate average of transactions by different establishments in each prefecture.[4] Thus, our analysis is based on a representative samples of business enterprises; for simplicity, we assume that they are all located at the prefectural office.

=Table 1 comes around here.=

Table 1 shows summary statistics of sampled freight rates and time by mode.[5] We can see that the number of observations is the largest for truck shipping, suggesting that truck transport is the most common mode; ship is the least popular mode of interprefectural transport. Although the median freight rate per tonne per 100 km was 24,276 yen for air and 4,831 yen for truck, it was 1,730 yen for rail and 1,135 yen for ship. Consistent with our intuition, air is the most expensive mode of transportation, and railway and ship are the least expensive. To examine the dispersion of freight rates, we computed the coefficient of variation for each mode. The data in Table 1 also suggest that variations in freight rates are the smallest for air, followed by ship, truck, and rail, in order of increasing variation. For instance, the coefficient of variation for ship is more than twice the corresponding figure for air.

2.2 Directional Balance of freight rates

In this section, we examine the extent to which two-way freight rates between prefectures are symmetric; in later sections, we determine whether an observed directional balance (or imbalance) depends on transport technology. Throughout, we measure directional balance in freight rates from prefecture r to s relative to freight rate from s to r. Specifically, the directional balance in freight rate between prefectures r and s is defined as t_{rsi}/t_{sri}, for $r \neq s$, where t is freight rate per tonne and i is the index of a commodity. We normalize the rates by taking the logarithm of the relative freight rates so that perfect symmetry exactly corresponds to a value of zero.[6] For all non-zero values, the freight rates between prefectures are asymmetric.

It should be emphasized that the freight rate is measured on the weight of transport goods, not on an ad valorem basis. This is because the survey data provide the freight

[4]The survey is conducted at the establishment level, but we do not have access to establishment-level data.

[5]We aggregated over four shipping modes: air, rail, ship, and truck.

[6]The conclusions are not qualitatively different when the log of absolute differences is used instead.

rate per tonne only. However, because we are examining relative differences, the basis of freight charges does not affect our analysis so long as equivalent goods are compared. The law of one price is assumed without loss of generality for the regions in Japan: the prices of the commodities already reflect relative freight rates. Thus, we do not need to consider the specific form of freight rates or the consequences of the form because of the Alchian-Allen effect on quality mix (Hummels and Skiba (2004)). Additionally, we do not consider intraprefectural transport because we are not able to observe the two-way freight rates at a level finer than the prefectural level.

From the survey data, we create a dataset on relative freight rates for all pairs of the 47 prefectures in Japan. After excluding several apparent outliers, we are left with $12,855$ observations. Summary statistics show that the mean is 0.03 and the standard deviation is 0.94, suggesting that the log average of relative freight rates is close to zero, but there is a large dispersion from symmetry. To examine whether two-way freight rates are strictly symmetric, we use a $t-$test to check whether the true value might be zero; from the test, the underlying mean is not zero ($p < 0.05$). Thus, we conclude that although two-way freight rates between prefectures are quantitatively similar, they are significantly asymmetric. Because the deviation appears to be small, however, the symmetry assumption on freight rates is not necessarily unjustifiable. Nevertheless, the symmetry assumption cannot be supported unconditionally.

Having verified a deviation from symmetry, we next determine the extent of the deviation by examining the distribution of relative freight rates. Although we do not know the underlying distribution of the individual freight rates, our data form a large set of averages of individual transport transactions aggregated across prefecture, transport mode, and type of goods. From the central limit theorem, the distribution of the prepared data may approximately follow a normal distribution. To test this, we conduct a Shapiro-Francia test for aggregate samples (Shapiro and Francia (1972)).[7] Our null hypothesis is normality; the test gives a p value of 0.21, suggesting that the log of relative freight rates may be normally distributed. Additionally, we present a histogram of the observations in Figure 1, over which we overlay a normal density distribution. The distribution appears to be reasonably symmetric about the mean because it is comparable with the normal density. To summarize: we find that directional symmetry of freight rates does not strictly hold for the overall sample, but deviation from symmetry may be systematic in the sense that it can be approximated by a normal distribution when the sample size is large.

[7] We use the Shapiro-Francia test, which is an alternative to the Shapiro-Wilk test when the sample is very large (Shapiro and Wilk (1965)).

=Figure 1 comes around here.=

It is surprising finding that the log of relative freight rates can be approximated by a normal distribution, but this result may be a result of the central limit theorem. To further examine the data, we disaggregate the samples by transport mode. Figure 2 shows four histograms of the samples for air, railway, and ship. Across transport modes, the majority of observations are concentrated around the value of zero, with the density declining over both tails. Each of the histograms appears to support a convergence tendency of relative freight rates between prefectures towards symmetry. On the other hand, some differences across modes can be observed. In the case of truck, its distribution appears to fit better with a plot of normal density than the distributions for air, railroad, and ship. These transport modes show a slight deviation from a normal density plot, which is likely to stem from the relatively small size of their samples.

=Figure 2 and Table 2 come around here.=

Figure 2 shows four histograms of the samples for air, rail, and ship. Across transport modes, the majority of observations are concentrated around the value of zero, with the density declining over both tails. Each of the histograms appears to converge toward symmetry. However, some differences can be observed between modes of transport. The distribution for truck transport appears more normal than the distributions for air, rail, and ship. These transport modes deviate slightly from the normal curve; this probably occurs because of the relatively small sample sizes.

As is done for the aggregate sample, we statistically examine the directional symmetry of freight rates for each mode. Summary statistics in Table 2 show that the numbers of observations for air, rail, and ship are substantially smaller than that for truck. The average of the relative freight rates is close to zero for rail, ship, and truck, but the mean is 0.10 for air transport. To examine whether these means are statistically different from zero, we conduct a $t-$test on each disaggregated sample. The resulting p values show that the mean is not zero for air transport ($p < .038$) or truck transport ($p < .002$). By contrast, we fail to reject the null for rail and ship transportation, suggesting that relative freight rates are, on average, symmetric for these modes. Possibly, symmetric freight rates are likely to hold for long-distance and large bulk shipments. Additionally, we conduct the Shapiro-Francia test to investigate whether distributions are normal. The results show that the distributions are statistically different from normal, except for truck transport. Because truck transport accounts for the majority of observations in the overall sample, this result would explain why the log of the relative freight rates can be approximated by a normal distribution for the aggregate sample.

Focusing on truck transportation, the differences in freight rates between directions are as follows. 50% of the samples are within the range of 1.45 times, top 95% are 3.98 times and 21 times is the maximum. On the other hand, the difference in transport flow between directions are that 50% of the samples are within the range of 1.85 times, top 95% are 11.6 times and 125.5 times is the maximum.

2.3 Other Data

Here, we use data from other sources. Data on the frequency and duration of interprefectural telephone calls were obtained from the *Telecom Data Book* published by the Japan Telecommunications Carriers Association.[8] These data are used as instruments. For control variables, we use data on prefectural characteristics, including per capita prefectural income (thousand yen), population density (per square kilometer of inhabitable area), and value of manufactured goods per employee (10 thousand yen). These prefectural data were obtained from the website of the Statistical Bureau of the Ministry of Internal Affairs and Communications in Japan.[9] Summary statistics of the variables used in the estimation are listed in Table 3.

3 Empirical Framework

In discussions of transport technology, there are two fundamental concepts: economies of transport density and imbalance in transport flows. To ensure that the model that we construct is testable, we briefly review each concept.

3.1 Determinants of freight rates

(i) Economies of Transport Density

Several empirical studies confirm the presence of economies of density in the cost function of the transport sector; these studies include Caves et al. (1984), and Braeutigam et al. (1982). Following the definition from Caves et al. (1984) and others, we define economies of density as the proportional increase in output co-occurring with a proportional increase in all inputs, with the network as given and input prices

[8] For details, see the website: http://www.tca.or.jp/english/databook/index.html

[9] For details, see the website: http://www.stat.go.jp/english/data/index.htm

held constant. We assume that product-specific freight rates depend on the density of transport flows, and so we may specify a unit cost function from region r to s of a product i that exhibits economies of transport density as,

$$t_{rsi}\left(Q_{rsi}, \delta\right) = \frac{1}{Q_{rsi}^{\delta}}, \tag{1}$$

where $t(.)$ is the freight rate per unit of goods delivered, Q is the transport density of goods on a given transport link, and δ is a positive indicator of the degree of economies of density. When $\delta = 0$, there are no economies of density. We take the unit of transport as 1 t, which makes the right-hand side variable the freight rate per tonne.

(ii) Transport flow imbalance

As recently discussed by Behrens and Picard (2011), Jonkeren et al. (2011) and Takahashi (2011), freight rates also depend on directional asymmetry in transport flows arising from different levels of demand for transport services by direction. To supply transport services, transport firms jointly produce transport services in two directions because their freight vehicles must be returned to their home region. The physical infrastructure of transport services, such as storage and maintenance facilities for freight vehicles is likely to be located solely in the home region because multiple-location ownership increases the fixed costs of transport services; thus, transport firms face a return constraint. When demand for transport service in one direction is larger than in the opposite direction, carriers may need to return empty. To make profits from round-trip transport, they should charge higher prices for fronthaul shipments than for backhaul shipments. As a result, directional imbalance in transport flows affects freight rates.

Drawing on these discussions, we specify the effect of directional imbalance in transport flow as follows

$$t_{rsi}\left(Q_{rsi}, Q_{sri}, \eta\right) = \left(\frac{Q_{rsi}}{Q_{sri}}\right)^{\frac{\eta}{2}}, \tag{2}$$

where η is an indicator of imbalance in transport flows between prefectures r and s. When $\eta < (>)\, 0$, flow imbalance has a negative (positive) effect on average prices. Holding the aggregate volume of transport flows constant, freight rates depend on the degree of directional trade balance. Clark et al. (2004) adopts a similar specification to examine the impact of directional imbalances in transport flows on shipping freight rates for imports to the United States. A difference in our specification is the absolute difference in the numerator, which allows us to focus on deviation from symmetric trade balance.

3.2 Specification of Deviations from Symmetric Freight Rates

Drawing on prior research, our discussion up to this point suggests that freight rates per unit of goods shipped depend on three factors: economies of density, economies of transport distance, and the directional balance of transport flows. In addition to these factors, it is natural to assume that the price of transport goods also depends on unobserved, fixed, product-level effects, and on characteristics of the origin prefecture.[10] Aggregating these distinct effects, we can specify a unit freight rate function as

$$t_{rsi} = Q_{rsi}^{-\delta} \left(\frac{Q_{rsi}}{Q_{sri}} \right)^{\frac{\eta}{2}} \exp\left(\rho \mathbf{D}' + \beta \mathbf{X}_r' + \gamma \mathbf{W}_r' \right), \tag{3}$$

where $\mathbf{D}$ is a vector of commodity-specific dummy variables introduced to capture the product characteristics such as price, bulk, and other unobserved fixed effects; $\mathbf{X}$ is a vector of regional characteristics; and $\mathbf{W}$ is a vector of input prices, such as labor costs and fuel. Becomes the pairs of regions of interest are within the same country, we assume that common technology and prices prevail among all locations (i.e., $\mathbf{W}_r = \mathbf{W}_s$.) without loss of generality. This means that regardless of the direction, transport technology is identical and input prices are the same.

To investigate the determinants of directional imbalance in freight rates between prefectures, we define the ratio of freight rates for a pair of regions as

$$\frac{t_{rsi}}{t_{sri}} = \frac{Q_{rsi}^{-\delta} \left(\frac{Q_{rsi}}{Q_{sri}} \right)^{\frac{\eta}{2}} \exp\left(\beta \mathbf{X}_r' \right)}{Q_{sri}^{-\delta} \left(\frac{Q_{sri}}{Q_{rsi}} \right)^{\frac{\eta}{2}} \exp\left(\beta \mathbf{X}_s' \right)}. \tag{4}$$

Then, because the commodity-specific dummy variable is identical it can be ignored when we compare the freight rates of the same goods. The input prices can be ignored for the same reason and from previous assumptions. When these variables are removed, we can also consider economies of distance, which suggest that longer shipments are less costly per distance unit. However, because the distance between any pair of prefectures is insensitive to shipping direction (i.e. $d_{rs} = d_{sr}$), this factor is also ignored; our specification suggests no effect from symmetry of freight rates.[11]

Taking the logarithm of both sides and rearranging the result, we obtain the follow-

[10] Transport costs may be related to transport time. From the data, there is no significant difference in transport time by direction, so we excluded transport time from our analysis.

[11] As is suggested by the following derivation, distance does not appear in the model. However, for robustness, we introduce distance in an ad hoc manner. However, we found no statistically significant effect from distance. The full details of this result will be provided by the authors upon request.

ing equation:

$$\ln \frac{t_{rsi}}{t_{sri}} = (\eta - \delta) \ln \frac{Q_{rsi}}{Q_{sri}} + \sum_{j} \beta_j \ln \left(\frac{X_{rj}}{Xsj} \right). \tag{5}$$

Notably, we can express the effect of trade imbalance by two parameters, η and δ. Additionally, eq. (5) allows us to identify a parameter that shows the net effect of economies of density and imbalance in transport flows.

These results imply something interesting: directional imbalance in freight rates is related to directional imbalance in transport flows expressed as a parameter of economies of density. Prior research, such as Jonkeren et al. (2011), estimated the effect of directional imbalance in transport flows on one-way freight rates for an inland shipping industry and found a direct relationship between imbalance in transport flows and in freight rates. In contrast to those results, our discussion makes clear that the directional trade volume imbalance generates a variable effect from economies of density on freight rates for two directions on the same route. Consistent with the literature, asymmetric freight rates arise in part from directional imbalance in transport flows, but the specific mechanism here is found to be the effect of economies of density on freight rates.

4 Results

Among the several transport modes, trucking can be considered the most competitive. For shipping by air and ship, the nature of the transport technology means that large-scale infrastructure is needed (e.g., airports and seaports). For shipping by rail, both stations and connecting railroads are necessary. Such physical infrastructure creates natural monopolies and entails regulations: regions without appropriate infrastructure cannot be serviced. In contrast to the other modes, investments in roads are made for reasons apart from truck transport and trucking firms can easily change routes.

The Japanese trucking sector was deregulated in 1990, which substantially lowered barriers to market entry. Subsequently, the number of firms has grown from 40,072 in 1990 to 56,871 in 2001 and to 62,712 in 2009. However, the total amount transported has been declining: from 6,113 million tonnes in 1990 to 5,578 million tonnes in 2001 and to 4,965 million tonnes in 2005. This suggests a competitive environment in the truck transport market. To mitigate the influence of market regulations on analysis of freight rates, we focus on truck transport in the following analysis.

4.1 Estimation Strategy

To estimate the parameter of interest, we include an intercept and a stochastic error term in the regression equation. To create balanced pairs of provinces, we add 1 to each quantity Q. Because we use two-year panel data from 2000 and 2005, we include a dummy variable for the year to control for aggregate time effects on transport-cost asymmetry. With a subscript t for the year, our regression model is specified as

$$\ln \frac{t_{rsit}}{t_{srit}} = \beta_0 + \beta_\delta \ln \frac{Q_{rsit}+1}{Q_{srit}+1} + \sum_k \beta_k \ln \left(\frac{X_{rjt}}{X_{sjt}} \right) + \beta_Y Year_t + \varepsilon_{rsit}, \tag{6}$$

where $Year$ is a dummy variable that is 1 for 2005 and 0 otherwise. Our aim in defining the model is to estimate the coefficient of relative transport flows, β_δ.

As is emphasized by Jonkeren et al. (2011), a directional imbalance in transport flows is an endogenous factor of directional imbalance in freight rates. Although we aim to investigate the impact of relative transport flows on relative freight rates, the demand for transport services depends on freight rates also, and so we must simultaneously determine of transport flows and prices in both directions. As a result, ordinary least squares (OLS) estimation is likely to yield a biased estimate of the coefficient of relative transport flows.

To address the endogeneity issue, we employ an instrumental variable (IV) estimation. Our candidate for a plausibly exogenous instrument is information flow between prefectures. We believe that directional flows of information between prefectures are a reasonable candidate for instruments of endogenous transport flows for the following reasons. The link between information and transport demand is conceptually reasonable: if information exchanges from prefecture r to prefecture s are frequent, then transport demand between these prefectures should be large. This reasoning supports the first IV condition, that the instrument is sufficiently correlated with an endogenous variable.

Information exchanges by themselves should have little effect on relevant factors that are not controlled in our estimating equation, but they may affect the pricing of transport shipments. There is, however, no reason to believe that information flows determine the level of freight rates. This intuition supports the second IV condition, that the instrument is reasonably excluded from the estimating equation. Intuitively, we assume that information exchanges between prefectures will affect relative freight rates to only the extent that they affect relative transport flows.

The paucity of available data on factors that could plausibly serve as valid instruments is a challenge. This issue has received considerable attention across a broad range of empirical research; we must carefully design an empirical strategy to avoid invalid instruments and compensate for weak instruments (Murray (2006)). In this paper, we use data on interprefectural frequencies of outbound and inbound telephone calls. In using these data on telephone calls, we specify the first-stage equation as

$$\ln \frac{Q_{rsit}+1}{Q_{srit}+1} = \omega_0 + \omega_1 \ln \left(\frac{I_{rst}}{I_{srt}}\right) + \omega_2 \ln \left(I_{rst} + I_{srt}\right) + \Psi Z'_{rsit} + e_{rsit} \qquad (7)$$

where I_{rst} is a measure of the frequency of telephone calls between prefectures, **Z**' a proxy for other exogenous variables, and e is a disturbance term. To check the validity of our instruments,we statistically test whether the excluded instruments are sufficiently correlated with the endogenous variable of relative transport flows.

4.2 Results

Table 4 presents the estimation results from our estimating equation. We some of the OLS results in the column labeled (1). The Breusch-Pagan test gives a p value of 0.113, indicating that heteroskedasticity is not an issue; we report standard errors. Consistent with our prediction, the coefficient of relative transport flows is significantly negative. Since relative freight rates and relative transport flows are defined as logarithms, the magnitude of the coefficient can be interpreted as the elasticity of these two variables. From this, a 10% increase in outbound transport flow relative to inbound transport flow is associated with a 1.8% decrease in outbound freight rate relative to inbound freight rate.

As we discussed when building the estimation framework, the freight rate and the demand for transport services are simultaneously determined. This implies that the OLS coefficient of the relative transport flows contains an endogeneity bias and possibly an omitted-variables bias. To address these potential biases, we report the IV estimation of the same specification in the column labeled (2). As explained in Angrist and Pischke (2008), two conditions of IV estimation must be checked to draw a causal inference from the coefficient of the relative transport flows: the instrument must be relevant and must not be over-identified. We report the first-stage F statistic of excluded instruments; these allow us to strongly reject the null hypothesis that the coefficients of the excluded instruments are jointly zero. We interpret this to mean that our instrument, telephone call frequency between prefectures, is a strong predictor of relative transport flows. The Sargan statistic, used to test for over-identification of the instrument obtained a p value of 0.98, which implies the instrument is not significantly correlated with relative freight rates in the estimating equation.

Having established that our instrument satisfies the two necessary conditions, we can draw a causal inference from the IV estimate. The coefficient of relative transport flows is significantly negative and has a size (0.21) similar to that given by the OLS estimate. Although the OLS estimation might contain some bias, the size of any bias appears to be small. The IV estimate indicates that a 10% increase in outbound transport flow relative to inbound transport flow is associated with a 2.1% decrease in outbound freight rates relative to inbound freight rates.

Although these statistical results are reasonable, we have controlled for only theaggregate time effect and a prefectural difference in income levels. To check the sensitivity of the estimates, we also present the OLS and IV estimations of the specification with relative population density and relative manufacturing production included. As is evident from the results, these regressions provide statistically significant estimates with the expected sign and of the expected magnitude. In the case of IV estimation in the column labeled (4), our instruments pass the two necessary conditions.

4.3 Robustness checks

Having obtained a significant estimate of relative transport flows with the expected sign, we test the robustness of the estimates to enhance the credibility of the instrumental variable estimate. For this purpose, Murray (2006) suggests using alternative instruments and checking whether similar results are obtained. We initially used the frequency of interprefectural telephone calls, and in Table 5, the column labeled (1) presents the IV estimation using the duration of calls between prefectures instead.[12]

The obtained coefficient of relative freight rate is significantly negative with the somewhat large magnitude of 0.33. Because the first-stage F test and the Sargan test support the validity of these alternate instruments, we can draw a causal inference from the IV estimate. This result enhances the credibility of our IV estimation.

We further check whether an additional control variable influences the IV estimate. In Table 5, the column labeled (2) contains the relative volume of average traffic in prefectures; this is included to account for the effects of congestion on freight rates. Traffic congestion is known to influence the cost of truck transport, and a larger difference

[12]Instruments used in Table 5 in the column labeled (1) include the log of relative telephone hours and the log of the sum of telephone hours in prefectures r and s; instruments in the columns labeled (2) and (4) include the log of relative telephone frequencies and the log of the sum of telephone frequencies in prefectures r and s.

in average traffic volume may be associated with a larger difference in outbound and inbound freight rates. Analyzing this, we find that the coefficient of relative transport flows remains significantly negative, which is the predicted sign. Thus, our conclusion is robust to an additional control variable. Finally, we examine whether truck freight rates are related to the aggregate volume of transport flows on a specific route, rather than to the total volume of truck transport shipments. To address this question, we create a variable to model relative transport flows aggregated over commodities and transport modes. Instead of truck-specific transport flows, we include the relative aggregate transport flow in the specification. In Table 5, the column labeled (3) presents the OLS estimation, which indicates that the coefficient is significantly negative; again, this is the expected sign. Additionally, we give the IV estimation in the column labeled (4) to address potential endogeneity bias. The first-stage F test and the Sargan test support the validity of our instruments, and the obtained IV estimate remains is similar, though with a slightly smaller magnitude. We interpret these results as suggesting that economies of density for truck transport are likely to act on the directional volume of transport flows, rather than on the overall volume of transport flows on a given route.

5 Conclusion

We have shown that there is significant asymmetry in freight rates between pairs of regions. To statistically verify implication, we constructed a simple model for testing unit freight rates; this was used to show that the economies of density are a key factor in asymmetric freight rates. To address endogeneity issues between trade volume and its costs, we performed IV estimation with interprefectural communication frequency as the instrument. The results of this estimation confirmed that economies of density are a source of asymmetric freight rates. Our main finding is that a 10% increase in relative transport flows decreases freight rates by 2.1%. We may conclude that economies of density, rather than the backhaul problem, dominate the determination of freight rates. This finding confirms previous empirical results the role of economies of density in cost functions of the transport sector and shows a clear difference from studies on trade imbalance in maritime transport, such as Clark et al. (2004), Blonigen and Wilson (2008) and Jonkeren et al. (2011). Because we examined the competitive truck transport, the backhaul problem may be handled by price discrimination on promptness and schedule regularity.

Our results support the fundamental assumptions of Behrens and Gaigne (2006) and

Behrens, Gaigne and Thisse (2009), which introduce symmetric economies of density to the unit freight rate function in economic geography models and examine location equilibria. Those studies show that agglomeration is delayed in comparison to a model without such freight rates. The reason is that transport flow is maximized between symmetric regions, and when agglomeration occurs, transport flow decreases. This means that concentration of economic activities increases freight rates and acts as a dispersive force. Our results imply that the introduction of asymmetry in freight rates may induce agglomeration to regional cores. The combination of these forces shapes the distribution of economic activities. Further analysis on the imbalance of regional and international freight rates for route pairs would enhance the understanding of the determinants of trade flow, freight rates, and spatial distribution of economic activities.

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Appendix I: Data

The logistics survey defines freight as materials, manufactured goods, and commodities that are shipped in and out of the business enterprise for the purpose of production, purchase, or sale. The survey excludes freight that is not directly related to production or sale activities, such as business documents, empty containers, and industrial waste. The destination of freight as defined above includes foreign markets, domestic industries, and individual consumers. The origin of freight flows does not include industries such as agriculture, forestry and fishery, construction, retail, or services.

The sampling scheme of the logistics survey was carefully designed to estimate the actual characteristics of domestic transport flows in the population as defined above. Specifically, the sample was stratified on three criteria: industry, employment, and prefecture. The survey identifies the number of business enterprises in each industry from other official statistics and then decides the number of the enterprises to be sampled to meet the minimum sampling rates. In 2005, 63,417 enterprises were surveyed by interview or through a mailed questionnaire for shipments sent during three days in October. The survey questions included product, volume and quantity, transport route, and shipping time and cost. Responses were received from 21,026 of the surveyed enterprises. The rate of response was significantly higher for interviewed enterprises (78.1%) compared with those surveyed by mailed questionnaire (31.8%). The response from the mining and warehousing sectors was over 40%; the manufacturing and wholesale sectors responded at a rate below 40%.

Table 1: Freight Rates by Mode

	No. of Obs.	Mean	Median	C.V.	Min	Max
Air	1,870	34,772	24,276	0.83	1,356	148,133
Rail	2,041	2,365	1,730	1.29	457	72,710
Ship	1,201	2,114	1,135	1.87	401	99,584
Truck	34,545	10,060	4,831	1.63	402	148,165
All	39,657	10,589	4,684	1.66	401	148,165

Notes: Freight rates are measured in yen per ton per 100km;
C.V: a coefficient of variation.

Table 2: Directional Balance of Freight Rates Between Prefectures by Mode

Mode	No. of Obs.	Mean (n)	S.D.	$t-test$ for Zero Mean	Shapiro-Francia Test for Normality
Air	398	0.1	0.99	0.038	0.02
Railway	266	0.04	0.83	0.432	0.00001
Ship	132	0.007	1.04	0.938	0.05
Truck	12,059	0.02	0.94	0.002	0.183
(All)	12,855	0.03	0.94	0.0005	0.217

Notes: Directional balance is the positive log of freight rates from prefecture r to prefecture s relative to that from s to r; S.D. standard deviation; t-test shows $p-values$ for the null hypothesis of zero mean; Shapiro-Francia test shows $p-values$ for the null hypothesis of normality.

Table 3: Summary Statistics

Variable	No. of Obs.	Mean	Std. Dev.	Min	Max
Relative freight rates	11824	0.03	0.88	-3.05	3.06
Relative transport flow	11824	-0.004	1.62	-4.83	4.84
Relative aggregate transport Flow	11824	-0.10	1.28	-7.01	5.52
Relative call frequencies	11824	-0.02	0.36	-2.54	2.52
Sum of call frequencies	11824	8.73	1.79	4.09	14.26
Year 2005 dummy	11824	0.48	0.50	0.00	1.00
Relative per capita income	11824	0.04	0.19	-0.78	0.86
Relative population density	11824	-0.05	1.13	-3.56	2.81
Relative manufacturing production	11824	-0.02	0.37	-1.13	1.12

Note: All variables are defined as logarithms except for the year 2005 dummy.

Table 4: Estimation Results for Truck Transportation

Dependent variable: relative freight rates

	(1) OLS	(2) IV	(3) OLS	(4) IV
Relative transport flow	-0.18***	-0.20***	-0.18***	-0.14**
	(0.005)	(0.06)	(0.005)	(0.06)
Year 2005 dummy	-0.05***	-0.05***	-0.05***	-0.05***
	(0.02)	(0.02)	(0.02)	(0.02)
Relative per capita income	0.32***	0.34***	0.16***	0.13*
	(0.04)	(0.06)	(0.06)	(0.08)
Relative population density			0.03***	0.03***
			(0.01)	(0.01)
Relative manufacturing production			0.03	0.02
			(0.02)	(0.03)
No. of observations	11824	11824	11824	11824
R2	0.106		0.107	
P-value of heteroskedasticity Test	0.807		0.641	
First-stage F statistic for		40.88		41.15
excluded instruments $(P - value)$		0.000		0.000
Sargan statistic for overidentification		0.276		1.124
test of all instruments $(P - value)$		0.599		0.289

Notes: Values in parentheses are standard errors; all variables have a logarithmic scale except for year dummy; constants are not reported; instruments used in columns (3) and (4) include the log of relative telephone call frequencies and the log of the sum of telephone call frequencies in prefectures r and s;
*, **, *** indicates significance at the 10%, 5%, and 1% level, respectively.

Table 5: Robustness Check

Dependent variable: relative freight rates	(1) IV	(2) IV	(3) OLS	(4) IV
Relative transport flow	-0.33**	-0.13**		
	-0.14	-0.06		
Relative aggregate transport flow			-0.06***	-0.13**
			-0.01	-0.06
Year 2005 dummy	-0.05***	-0.05***	-0.06***	-0.06***
	-0.02	-0.02	-0.02	-0.02
Relative per aapita income	0.22*	0.05	-0.08	-0.1
	-0.13	-0.08	-0.07	-0.07
Relative population density	0.03**	0.04***	0.03***	0.01
	-0.01	-0.01	-0.01	-0.02
Relative manufacturing production	0.07*	0.02	0.06**	0.13**
	-0.04	-0.03	-0.03	-0.06
Relative traffic volume		0.02		
		-0.01		
No. of observations	12059	12059	12059	12059
R^2			0.01	
P-value of heteroskedasticity Test			0.461	
Instruments for telephone calls	Hours	Freq.		Freq.
First-stage F statistic for	7.785	39.84		94.99
excluded instruments ($P - value$)	0.00	0.00		0.00
Sagan statistic for overidentification	0.184	0.239		0.489
test of all instruments ($P - value$)	0.668	0.625		0.484

Notes: Values in parentheses are standard errors; all variables have a logarithmic scale except for the year dummy; constants are not reported; instruments used in columns (1) include the log of relative telephone hours and the log of the sum of telephone hours in prefectures r and s; instruments in columns (2) and (4) include the log of relative telephone frequencies and the log of the sum of telephone frequencies in prefectures r and s; *, **, and ***,indicates significance at the 10%, 5%, and 1% level, respectively.

Figure 1: Distribution of Relative Transport Costs

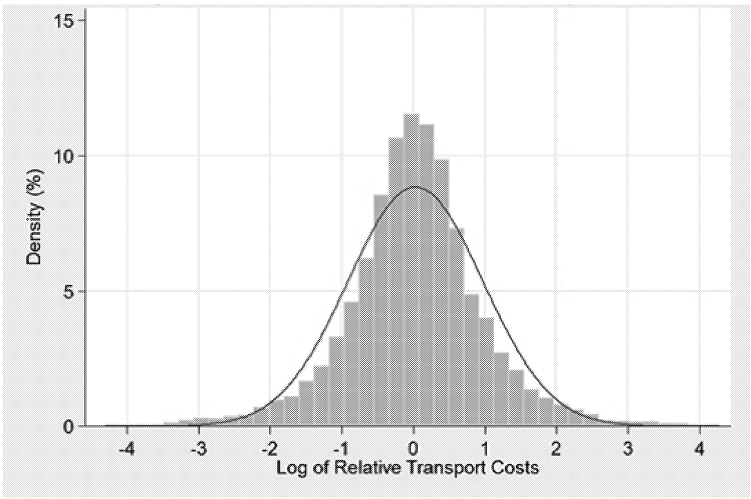

Figure 2: Distribution of Relative Transport Costs by Mode