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"Freight Charges, Time Cost, and Transport Mode Choice: Evidence from Japanese Export"

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Freight Charges, Time Costs, and Transport Mode Choice: Evidence from Japanese Exports

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Abstract

Airfreight is responsible for approximately 30% of the value of Japan's exports in 2011, which is certainly not a small. According to the trade statistics in Japan, 20% of the total exported products are shipped exclusively by air. About 80% of exported products are shipped to large developed countries, such as France, USA, Germany, and UK, by air. Beyond expensive-lightweight products, most of tradable products are shipped by air in Japan.The frequencies of airfreight usage are different among destination countries and products. However, the previous research results have not explain enough such airfreight usage patterns so far. Based on the current situation of air shipping in Japanese export, this study examines how international traders choose a transport mode, either air- or sea- shipping.

Keywords: International trade; Airfreight; Transport mode; Time costs
JEL classification: F14, L93, O18, R41

I. INTRODUCTION: AIRPORT INFRASTRUCTURE DEVELOPMENT

According to the Trade Statistic of Japan published by Japan's Ministry of Finance (hereinafter denoted by MOF), 27% of the total amount of Japan's exports in 2011 was exported by aircraft. Japan being an island nation, the rest of the total amount

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of exports was exported by ocean freighter. According to Hummels (2001) and Ijiri (2008), approximately 30% of America's exports are transported by air; almost exactly the same proportion as Japan. It is believed that this result shows the high importance of airfreight in global trade today. However, until recently most researchers showed little interest in regards to the role of airfreight in global trade.

In other fields than international trade, researchers in transportation engineering and transportation economics are analysing the determinants of international airfreight usage frequency. Previous examples of this sort of analysis can be seen in Matsumoto (2005) and Grosche, Rothlauf and Heinzl (2007), who empirically analysed the determinants of air carriage flows, such as the number of international air passengers, and the amount of air cargo using gravity models. Both studies used gravity models (or other similar models) to analyse the determinants of international trade between two trading partners. In transportation economics, clarifying the deciding mechanisms of the amount of airfreight is vital to the development of appropriate air transportation infrastructure.

At the end of October 2010, the Japanese government reopened Tokyo International Airport[1] (Haneda Airport) to international air routes . With the New Tokyo International Airport (Hereinafter, Narita Airport) nearing the limits of its capacity, an investment was made into transportation infrastructure in order to expand the functionality of the two airports in the Tokyo metropolitan area. Since its opening in 1978, Narita Airport has been the international hub, while Haneda has been the domestic hub. The reopening of Haneda Airport to international flights has greatly changed the division of roles of the two airports in the Tokyo metropolitan area. Unlike Narita Airport which cannot operate around the clock due to noise pollution, Haneda has become a 24-hour international airport since its reopening. Because of this, international flights in the metropolitan area are now available during a wider period of time each day. This is expected to lead to the creation of new air routes, encourage airlines to start servicing the region, and to lower the air transportation costs of international trade. The Chinese government's political reforms and open door policies beginning in the early 1990s have led to the continuous rapid development of China's transportation infrastructure. As shown in Table 1, the length of established air routes have shown vastly more growth in recent years than the transportation routes of other transportation modes. Between 1990 and 2007, the length of China's express-ways grew by a factor of 3.5.

By comparison, its international air routes grew by a factor of 6 over the same period of time. Among the rapid continued economic growth in China,

[1] As part of reopening Haneda to international routes, a new fourth runway was constructed, and the capacity of take-offs and landings was increased from 296,000 to 407,000.

Table 1: *Index of Transport Infrastructure Development in China expressed as the percetage of the value of Year 1990*

Year	Railways	Highways	Waterways	Domestic Aviation	International Aviation
1991	99.8	101.2	100.5	110.3	106.6
1992	100.3	102.8	100.5	165.1	182.1
1993	101.2	105.4	100.9	189.6	167.5
1994	101.9	108.7	101.0	206.3	211.5
1995	107.8	112.5	101.3	222.8	209.3
1996	112.1	115.3	101.5	230.2	232.2
1997	114.0	119.3	100.5	281.2	303.1
1998	114.7	124.3	101.0	297.1	303.1
1999	116.4	131.4	106.7	300.4	314.5
2000	118.7	136.4	109.2	296.5	305.5
2001	121.0	165.1	111.3	306.6	310.6
2002	124.2	171.7	111.4	323.1	345.3
2003	126.1	176.0	113.6	345.2	429.9
2004	128.5	181.9	112.9	404.4	537.4
2005	130.3	325.3	112.9	394.3	514.4
2006	133.1	336.2	113.0	417.0	580.6
2007	134.7	348.5	113.1	462.3	629.5

Source: Statistical Yearbook of China, Various issues

the continuing development of each transportation mode and the extension of transportation routes, air routes are showing the largest growth. In this way, both Japan and China are continuing the development of their domestic air transportation infrastructure. It is surely the result of attempts to keep up with the demand for air transportation.

Incidentally, what does this sort of expansion of air transportation infrastructure development mean for international trade? Until now, Japan has aimed to improve its transportation efficiency with the objective of maintaining the international competitiveness of its industries. It has done by strategically expanding its seaport facilities[2]. However, Japan's airport development policy does not seem to have that same objective. It seems that in Japan the discussion of the link between the expansion of air transportation infrastructure and the maintenance of the international competitiveness of its industries has failed to attract attention. It is the objective of this paper to discuss international trade in Japan, especially the

[2]The MLIT website states Japan's specific policy toward the port facility improvement. http://www.mlit.go.jp/en/kowan/index.html

role of air transportation in exports, while also clarifying its current state. Further, this paper will also analyse how international transport modes for Japan's exports are selected based on the destination and the type of exported product. There have been previous studies, primarily in the field of transportation economics that have analysed the determinants in air shipment flows of the manner mentioned above. However, there are almost no examples of the analysis of the determinants of airfreight usage frequency of exports by product - the air shipment ratio discussed in this paper.

This paper is organised as follows. First, in II, we will confirm the current state of the use of airfreight in Japanese exports using a number of indexes. Then, in III we will consider the selection model for each trader (exporter and importer), in which they either select air or ocean transport. Here we will use an Anderson and van Wincoop gravity model to suggest a theoretical model for analysing the determinants of the air shipment ratio. Finally in IV we will, based on the air shipment ratio determinant analysis model constructed in III, construct an empirical analysis model from Japan's export data, and attempt a quantitative analysis. In V, we will summarise the results of that estimation, and discuss the conclusion of this paper. There, we will see that the results largely support the analysis model constructed in III.

II. The Current State of Airfreight in Japanese International Trade

As shown in Table 2, out of all of Japan's air and ocean trading ports, Narita Airport was the largest trading port, in terms of total transaction value as well as both import and export value in 2011. This explicitly shows the importance of international airport infrastructure to international trade in Japan. Further, as in previous statement, the fact that about 30% of value of exports shipped out of Japan and America are carried on aircraft shows that airfreight is a prominent mode of transportation.

This paper uses statistics from Japan's MOF in its analysis of the importance of airfreight to exports. This trade data[3] in recorded in the HS 9-digit format[4],

[3]The Ministry of Finance's statistics can be downloaded here: http://www.customs.go.jp/toukei/info/tsdl.htm

[4]HS is an abbreviation of the Harmonised Commodity Description and Coding System. It is an internationally-unified statistical product code used in trade statistics that was created by the UN HS treaty. While the first six digits of this statistical product code are unified world-wide between exporters and exporters, the following digits are determined by each country.Japan has expanded the HS product codes into nine-digit codes which, being proprietary to Japan, are not necessarily shared with its trading partners. Further, the United States has an even more detailed 10-digit

Table 2: *The Trading Port Ranking by Transaction Value in 2008, Japan*

(Unit : Million Yen, %)

Rank	Port	Export Value	Share		Port	Import Value	Share
1	Narita Airport	11,208,563	13.8		Narita Airport	11,366,825	14.4
2	Nagoya	11,083,130	13.7		Tokyo	8,009,108	10.1
3	Yokohama	8,695,587	10.7		Nagoya	5,277,042	6.7
4	Kobe	6,107,770	7.5		Chiba	5,158,983	6.5
5	Tokyo	5,369,281	6.6		Yokohama	4,298,882	5.4
6	Kansai Airport	4,634,026	5.7		Osaka	4,131,405	5.2
7	Osaka	3,489,529	4.3		Kawasaki	3,160,907	4.0
8	Mikawa	2,937,482	3.6		Kobe	3,072,621	3.9
9	Shimizu	1,952,719	2.4		Kansai Airport	2,819,930	3.6
10	Chiba	1,693,068	2.1		Mizushima	2,298,340	2.9

Source: Trade Statistics of Japan, Ministry of Finance Japan

and further has the characteristic of being recorded with an indicator of whether airfreight or another mode of transportation was used. According to this data, a total of approximately 150,000 products were exported from Japan in 2007 to all destinations. Of those products, 86,265 products were exported to Japan's trading partners by aircraft. This means that more than half of the products exported by Japan are transported by aircraft. Of course, it also implies that some of the products are difficult or impossible to be transported by air. Generally, aircraft cannot carry heavy or large cargo, so we can expect that products shipped by air may share certain characteristics. For example, there is a report[5] stating that the products primarily carried by air include lightweight products and highly value-added products such as fresh foods, flowers, precious metals, etc. Hummels (2001) and Nordas et al. (2006) discussed the possibility of trade cost differences among traded products, considering the difference in each product's opportunity cost of transit-time. They define products which require the exporter or importer to save transit time as time-sensitive products. In order to apply their idea to international airfreight we will calculate the frequency of airfreight usage for Japanese exports for each HS 9-digit product. We describe it as the air shipping ratio[6] . By analysing this air shipping ratio for each product and for each destination, we can discover the characteristics of each product and each destination.

code system. Japanese trade data for 2007 to 2011 was recorded using the HS2007 edition. The current edition is HS2012, which was applied to trade data beginning in 2012.

[5]For an example, refer to the MLIT Civil Aviation Bureau-published "Suuji de miru kuuko" for each year.

[6]The air shipping ratio (AR) of product k exported to country A is the value of the product k shipped to country A by aircraft divided by the total amount of product k exported to country A.

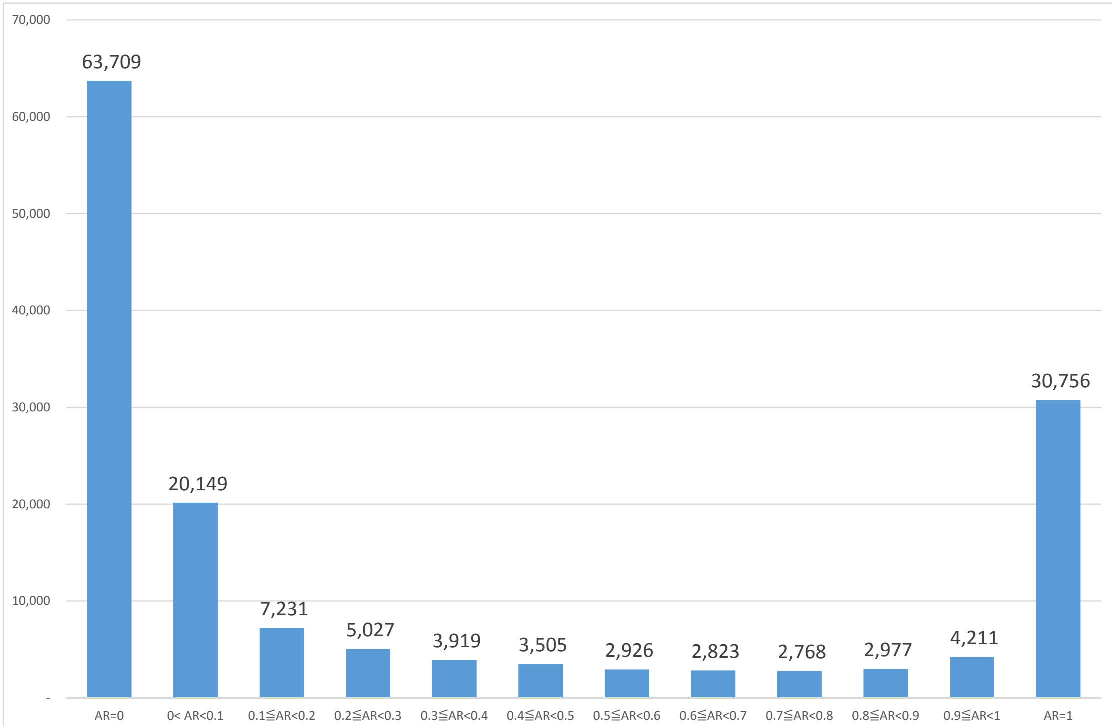

Figure 1: The Histogram of Air Ratio in Japan
Source: Trade Statistics of Japan, Ministry of Finance Japan

The current state of this air shipping ratio is summarised as follows. In case air shipping ratio is equal to 1, it indicates that the product is exported exclusively by aircraft. The number of the products shipped from Japan exclusively by air (hereinafter AR1[7] product(s)) in 2007 was 30,756. This means that about 20% of the total exported products and about 2.2% of total exported value were shipped exclusively by air. In contrast, 63,709 products were shipped exclusively by ocean freight. Figure 1 is a histogram of created with data on Japan's exports that shows the distribution of Air Shipping Ratios in increments of 10%. According to this chart, the exports of both exclusively sea-shipped products (AR=0) and exclusively air-shipped products (AR=1) dominate Japanese exports. This result implies that many export transactions are of products that must be shipped by either aircraft or ship. Further, as shown by the incidences of the levels other than those with Aircraft Shipping Ratios of 0 or 1, many exporters prefer airfreight to ocean freight despite the fact that it is vastly more expensive. It is possible that this may because, as previous studies have indicated, many exporters chose airfreight in order to reduce transit-time.

[7]Hereinafter AR denotes for air shipping ratio.

Table 3 shows the two indexes for the frequency of airfreight usage for each Broad Economic Categories (BEC) classification[8]. This table was also created using data on Japan's 2007 exports. These two indexes are the proportion of AR1 Products out of the total number of products in each BEC classification (Hereinafter, AR1 Ratio), and the average air shipping ratio of each BEC classification. The BEC types of traded products being used here are Parts and Components, Processed goods, Material goods, and Consumer goods. As discussed in Harrigan and Venables (2005), intermediate goods are shipped by faster transportation modes. According to Table 3, Intermediate goods and Consumer goods have relatively high average Air Shipping Ratios of 34.5% and 35.5% respectively. Further, Material goods and Consumer goods have relatively high AR1 Ratios. As discussed in previous studies, there is a high probability that fast transportation modes will be selected for Intermediate goods, which we can infer they are time-sensitive products. We can also infer that they are products with properties similar to those of Consumer goods. Additionally, this also indicates the possibility that a relatively large number of Material goods and Consumer goods can only be transported by aircraft. Further, according to Hummels (2009), for international trade in the United States, the higher a product's trade value per kilogram (Value weight), the more likely it is to be shipped by airfreight.

Table 3: *The Ratio of AR1 Products*

	P&C	Capital goods	Processed goods	Material goods	Consumption goods
# of AR1Products: (1)	4	10	23	17	62
# of Proudcts in the category: (2)	420	601	847	402	1223
AR1 Ratio: (1)/(2)	0.95%	1.66%	2.72%	4.23%	5.07%
Average AR	34.50%	15.98%	16.72%	16.09%	35.51%

Source: Author's calculation using Trade Statistics of Japan,
Ministry of Finance Japan

Next, Tables 4 and 5 show the top 30 export destination countries ranked by frequency of air-shipped products shipped from Japan. The numbers of exported products shown are the number of products shipped to these countries from Japan in 2007. According to the AR1 Ratios on Table 4, Monaco had the highest reliance on airfreight in regard to Japanese imports, with an extremely high 87.10% of products being exclusively imported by airfreight. Additionally, the top 16

[8]The product groups used here is RIETI-TID 2012, which is created by the combination of BEC and System of National Account (SNA) in order to differentiate the traded products by product stages, such as final products, intermediates, materials so on.

countries all had AR1 Ratios higher than 50%. As you can see, airfreight plays a vital role in bringing Japanese imports into more than a few countries. Many of the countries that rank highly on Table 4 are those that both have relatively small economies and are a great distance from Japan. While not all of these countries are landlocked, those that are not landlocked are countries that are not on regular ocean shipping routes. The reason why these countries have so many AR1 Products may because ocean freight is relatively inconvenient.

Table 4: *AR1 Ranking by Destination*

Ranking	Country	# of AR1 Product	# of Export Products	AR1 Ratio
1	Monaco	31	27	87.10%
2	Gibraltar (UK)	42	31	73.81%
3	The West Bank and Gaza Strip	15	11	73.33%
4	Andorra	21	15	71.43%
5	Belarus	125	88	70.40%
6	Moldova	51	32	62.75%
7	Bosnia and Herzegovina	26	16	61.54%
8	Cayman islands (UK)	59	35	59.32%
9	Luxembourg	210	117	55.71%
10	Croatia	235	129	54.89%
11	Serbia	267	146	54.68%
12	Austria	998	533	53.41%
13	US Virgin Islands	27	14	51.85%
14	Lithuania	279	143	51.25%
15	Uzbekistan	190	97	51.05%
16	Armenia	36	18	50.00%
17	Slovenia	325	162	49.85%
18	Zambia	136	67	49.26%
19	Romania	504	245	48.61%
20	Switzerland	1508	720	47.75%
21	Bermuda (UK)	80	37	46.25%
22	Azerbaijan	221	101	45.70%
23	Malta	272	124	45.59%
24	Netherlands Antilles	185	84	45.41%
25	Bulgaria	395	177	44.81%
26	Republic of Macedonia	56	25	44.64%
27	Denmark	963	428	44.44%
28	Ireland	786	347	44.15%
29	Liberia	223	96	43.05%
30	Niue Islands (NZ)	7	3	42.86%
	Average			25.67%

Source: Trade Statistics of Japan, Ministry of Finance Japan

Table 5, by comparison, shows the top 30 countries when ranked by the proportion of air-shipped products out of the total number of exported products in 2007 (Air Shipping Ratio). In this case, "air-shipped products" refers to products

Table 5: *Air Ratio Ranking by Destination*

Ranking	Destination	# of Exported Products	# of Exported Products by Air	AR
1	Monaco	31	27	87.10%
2	France	2,670	2,163	81.01%
3	USA	4,402	3,520	79.96%
4	Austria	1,180	942	79.83%
5	Germany	3,102	2,464	79.43%
6	Luxemburg	210	164	78.10%
7	UK	2,925	2,279	77.91%
8	Switzerland	1,791	1,376	76.83%
9	Andorra	21	16	76.19%
10	Gibraltar(UK)	42	32	76.19%
11	Italy	2,669	2,033	76.17%
12	Hungary	1,079	804	74.51%
13	Palestine	15	11	73.33%
14	Belarus	130	94	72.31%
15	Czech	1,228	887	72.23%
16	Denmark	963	685	71.13%
17	Poland	1,178	831	70.54%
18	Slovakia	458	320	69.87%
19	Sweden	1,370	956	69.78%
20	Israel	1,254	867	69.14%
21	Spain	2,005	1,386	69.13%
22	China	5,048	3,489	69.12%
23	Norway	907	625	68.91%
24	Belgium	2,014	1,374	68.22%
25	South Korea	4,825	3,286	68.10%
26	Ireland	942	641	68.05%
27	Romania	593	400	67.45%
28	Portugal	967	651	67.32%
29	Finland	1,276	858	67.24%
30	Netherland	2,383	1,590	66.72%

Source: Trade Statistics of Japan, Ministry of Finance Japan

that both have a positive export value shipped by airfreight and are at least partially shipped by airfreight. In other words, air-shipped products are products that can be shipped by air and are not exclusively shipped by ocean freight. As in the case with AR1 Ratio, Monaco once again tops the list, having the highest Air Shipping Ratio. However, unlike Table 4, the top-ranking countries on this chart are mostly European and North American countries with large economies. For example, France is ranked #2, with 81.01% of air shipping ratio. The U.S. is ranked #3 with 79.96% of air shipping ratio. These are certainly not countries with small economies or poor access to ocean freight service. In this way, it can be seen that many products are shipped by airfreight despite the viability of ocean freight, and that there is no particular product or country utilising airfreight.

III. Transportation Mode Selection Model for International Trade

1. Transportation Mode Selection Model

Gravity models have frequently been used to determine the volume of aggregate trade flows between trading partners, considering the scale of supply and demand within each country, as well as trading costs (transport cost, trade barriers, etc.). They are powerful analytical models with high explanatory power[9] Here, we will attempt to apply gravity models to the analysis of the determinants of Air Shipping Ratios. As pointed out in II, the Air Shipping Ratios of Japanese exports are distributed between 0 and 1, and these ratios differ for each product and destination. Even when exporting the same product to the same destination country, the trading costs can differ greatly within that country depending on the trading partner, which indicates the possibility that a different transportation mode may be selected accordingly. In order to analyse the determinants of the amount of airfreight from Japan to each destination country, we need a theoretical model to analyse the amount of airfreight for each product. In this paper, we will apply the microeconomically-refined gravity model developed by Anderson and van Wincoop (2003) in order to suggest a model for analysing the determinants of the Air Shipping Ratios of exports.

The Anderson and van Wincoop model[10], similar to so-called gravity models, explains the size of the aggregate trade flow of two trading partners developed from the consumer utility function discussed below. This new kind of gravity model and gravity equation suggested by Anderson and van Wincoop has been used to great effect in many empirical studies analysing the trade flows between trading partners. Some empirical studies using Anderson and van Wincoop-type analysis models have included non-transport cost trade costs such as tariff barriers, non-tariff barriers, the border effect, etc. They have been used not only to analyse trade volume, but to identify trade barriers and the strength of their influence. In this paper, we will decompose trading costs into two elements, transport cost and transit time cost, in order to analyse the determinants of Air Shipping Ratios. Figure 2 below uses a graph to show the relationship of transport cost and transit

[9] The gravity models have been applied to many empirical researches in international trade for different countries, years, industries so far. One can refer to van Bergeijk and Brakman (2010) as a well-summarised survey for the previous researches on both theoretical and empirical analyses regarding the gravity models.

[10] Eaton and Kortum (2002) has developed an another kind of microeconomically-refined gravity models, which is so-called Ricardian type of gravity model. In addition, Chaney (2008) has introduced a new generation gravity model, which has a firm heterogeneity attribute, in line with new-new international trade theory.

time cost with the transit time to the destination. Figure 2 shows the effect transit time can have on transport cost and transit time cost by coupling four panels, from panel (a) to panel (d). Even for the same given distance, various factors effecting transportation mode and total transit time can influence transit time cost. Below, we will attempt to analyse the selection of transportation modes in exports using Table 2.

First, we assume that there are only two transportation modes for exports: ocean freight and airfreight. The cargo transport costs for any export destination country are given as F^S_{ij} for ocean freight, and F^A_{ij} for airfreight. These cargo transport costs are normally calculated by distance. Since airfreight transport costs are generally higher given the same distance, we assume that $F^A_{ij} > F^S_{ij}$. Next, we assume that each transport cost changes at a fixed rate, α^S or α^A, depending on the distance. Further, when exporting to the same country the cargo transport costs for each transportation mode shall be the same for every product so long as the product's size allows the use of that transportation mode. However, we consider that a product's cargo transport cost increases with the weight of the product. Therefore, cargo transport costs shall increase at a fixed rate. However, as we consider that airfreight transport costs increase at a higher rate than ocean freight transport costs, for the purpose of simplification we shall assume that only airfreight transport costs are affected by weight. This effect shall be given as w_k[11]. The relationship of cargo transport costs and distance for each transportation mode shall be defined with the two following formulas. The transport cost to ship product k from country j to country i for each transportation mode shall be calculated with (1) and (2).

$$F^S_{ij,k} \equiv \alpha^S Distance_{ij} \quad (1)$$

$$F^A_{ij,k} \equiv \alpha^A Distance_{ij} \times w_k \quad (2)$$

Based on our assumptions, α^S is smaller than α^A. Next, we assume the following relationship between transportation mode and transport time. First, total transit time is defined as amount of time it takes for an exported product to arrive at its destination. Generally speaking, ocean freight takes longer than airfreight for the same given destination. Further, when importing or exporting a product, transit time is not the only time required. The best example of other kinds of time required is the time required for customs clearance. Although the amount of time required varies wildly by country, we consider customs clearance

[11] We set $w_k = w^A_k / w^S_k$. w^A_k and w^S_k are an additional freight charge per kilogram to air-and sea-shipments,respectively.

when exporting a product (leaving the country) to require the same amount of time regardless of the transportation mode or the destination country. We label this amount of time as $\bar{C}$.

Another factor that can influence total transit time in the case of ocean freight is transshipment. An example of transshipment would be a ship going from Japan to its destination via Hong Kong or Singapore. Without a direct shipment, the ship would have to transfer its cargo at Hong Kong or Singapore to a regular route heading to the destination. Transshipment normally takes 2 or 3 days[12].Therefore, any time a non-direct ocean freight route is used (for example, a regular route) to ship to a destination country via Hong Kong or Singapore, a significant amount of time will be required for transshipment. In consideration of this the total transit time for ocean freight is customs clearance time $\bar{C}$ plus transship time. However, transship time is not added when the export destination is closer to Japan than Hong Kong or Singapore or when a direct route is used.

In other words, because transshipment becomes necessary over a certain distance, transit time increases at a fixed rate for any destination closer than that distance. This causes a decrease in the average speed to the destination country. This indicates that the average speed of ocean freight can vary even between destination countries of the same distance. Therefore, γ^S, if transshipment occurs (for example, as shown in Figure 2, Panels (a) and (b) after point A), a larger Value γ^* is incurred. Consequently, total transit time is given as $Time_{ij}^S$ for ocean freight and $Time_{ij}^A$ for airfreight, and even when customs clearance time and transshipment time is included, we consider that $Time_{ij}^S > Time_{ij}^A$.

Here we will include transit time cost into our analysis model. Transit time cost is directly proportional to transit time, with lower transit time resulting in a lower transit time cost. The reason is that, for example, in the case of products such as fresh foods, without refrigeration or other special transportation methods, longer transit times reduce the quality (and therefore the value) of the product. Another example is apparel. Apparel retailers use lean inventory because they dislike maintaining large inventories and prefer to restock frequently instead. Yet another example is parts and materials used by manufacturers implementing lean-production methods, who very frequently restock parts in order to minimise their part and material inventories. In order to meet production schedules, parts must be supplied on time. For that reason, transit time costs in this case are relatively high.

As in the case of cargo transportation costs, transit time increases at a fixed rate depending on the distance. The relationship between transit time and distance for

[12]For the required days of transshipment, we have referred to the following website. http://www.pref.hiroshima.lg.jp/soshiki_file/kouwan/con_hiro.html

ocean freight and airfreight are defined by the following formulas. This is Panel (B) of Figure 2.

$$Time^{S}_{ij,k} \equiv \beta^{S} \times Distance_{ij} \tag{3}$$
$$Time^{A}_{ij,k} \equiv \beta^{A} \times Distance_{ij} \tag{4}$$

In this case, our previous assumptions mean that $\beta^S > \beta^A$. This β is clearly the average speed from the point of origin to the destination[13]. Expressing the transport time costs mentioned above as distance will give you the following formulas. This is expressed in Panel (a).

$$TC^{S}_{ij,k} \equiv \gamma^{S} \times Distance_{ij} \tag{5}$$
$$TC^{A}_{ij,k} \equiv \gamma^{A} \times Distance_{ij} \tag{6}$$

As with these formulas, we assume that we can express transport time costs for each transportation mode. We consider that while the distance to a certain export destination country is the same regardless of transportation mode, the time required differs, with airfreight requiring a shorter period of time. This is, of course, because the average speed of airfreight is faster than that of ocean freight. This, as expressed by the formula below, means that the higher average speed of airfreight means that shipment requires less time even for the same distance. Thus, the difference of the transit time cost parameters γ^A and γ^S in Formulas (5) and (6) are caused by the difference in transit time required.

In other words, there is a possibility that each export product may have a different transit time cost in every transaction. There is a possibility that, as in the case of fresh foods, each product may have the same transit time cost. Conversely, there is also a possibility that the transit time for each product may differ due to the nature of the transaction (i.e., a transaction within a business group versus outside of a business group). Recognising the different transit time cost for each product and transaction, we label it as μ_k. This μ_k is the transit time cost for every hour of transit time.

As mentioned above, the total transit time is the sum of transit time, customs clearance time, and, in the case of ocean freight, transship time (when required).

[13]This indicates the following relationship.

$Distance_{ij} = \overline{Speed_{Sea}} \times Time_{Sea}$

$Distance_{ij} = \overline{Speed_{Air}} \times Time_{Air}$

From the assumption, we have $\overline{Speed_{Air}} > \overline{Speed_{Sea}}$. Hence, $Time_{Air} < Time_{Sea}$is hold. $\overline{Speed_{Air}}$ and $\overline{Speed_{Sea}}$ are the average speed of air shipping, β^A, and sea shipping, β^S, respectively.

The transit time cost of a given product for each transportation mode is defined as the following.

For Ocean freight,

$$TC^S_{ij,k} \equiv \gamma^S Distance_{ij} = \mu_k(Time_{Sea} + \bar{C} + Trans). \quad (7)$$

For Air freight,

$$TC^A_{ij,k} \equiv \gamma^A Distance_{ij} = \mu_k(Time_{Air} + \bar{C}). \quad (8)$$

Based on our previous assumptions, the transit time costs of airfreight are smaller than ocean freight for the same destination because transit time is shorter. Therefore, $\gamma^A < \gamma^S$. These two trade costs, cargo shipping cost and transit time cost, influence the selection of a transportation mode. As with the previous statement, we consider that trade cost is the sum of cargo shipping cost and transit time cost. In other words, Trade Costs = F + TC. We consider that a trader will select the transportation mode with the lower trade cost as being the most desirable. This means that airfreight is selected when the trade cost is lower than the cost of ocean freight, meaning when $\Delta F < \Delta TC$. Written in another way, $\Delta F/\Delta TC < 1$ is the selection condition for airfreight. As with the transshipment mentioned previously, there are other cases in which transit time cost can increase depending on the transaction. For example, first assume that total transit time t^* in Figure 2 is the upper limit for allowable transit time. If this upper limit was to be exceeded, production could be delayed or inventories could run out, both of which would cause additional costs to be incurred (γ^S grows closer to γ^*). If it is assumed ahead of time that transit time will exceed t^*, the logical choice would be to use airfreight.

2. Air Shipping Ratio Decision Model

Next, we will consider the following in regards to the frequency of airfreight in our model of international trade. First, the Anderson and van Wincoop model considered in recent years to be the standard for analysis of international trade flows between two trading partners is defined with the following formula.

$$EX^k_{ij,t} = \frac{Y_{i,t} \times Y_{j,t}}{Y_{w,t}} \left(\frac{\tau^k_{ij}}{P_{i,t}P_{j,t}} \right)^{1-\sigma}$$

Here, Y_i and $Y_j$are the GDP (or another measure of the size of the economy) for year t of the exporting and the importing nations respectively. Y_w is the total global GDP of year t. P_i and P_j are the multilateral resistance terms of country i and country j, respectively. Further, the elasticity of substitution σ is assumed to be larger than 1 ($\sigma > 1$). By adding the previously mentioned trade costs of each transportation mode to this formula, it becomes equations (9) and (10) respectively. The amount of exports for each transportation mode is determined based on these formulas.

Amount of $Product_k$ exported by airfreight to country j from country i in Year t =

$$AirEX^k_{ij,t} = \frac{Y_{i,t} \times Y_{j,t}}{Y_{w,t}} \left(\frac{\tau^k_{Aij}}{P_{i,t}P_{j,t}} \right)^{1-\sigma} \tag{9}$$

Amount of $Product_k$ exported by ocean freight to country j from country i in Year t =

$$SeaEX^k_{ij,t} = \frac{Y_{i,t} \times Y_{j,t}}{Y_{w,t}} \left(\frac{\tau^k_{Sij}}{P_{i,t}P_{j,t}} \right)^{1-\sigma} \tag{10}$$

Further, in order to analyse the selection of transportation mode, we require the following decision model for the Air Shipping Ratio that utilises equations (9) and (10).

Air Shipping Ratio

$$= AirEX^k_{ij,t}/EX^k_{ij,t} = AirEX^k_{ij,t}/(SeaEX^k_{ij,t} + AirEX^k_{ij,t})$$

$$= \frac{Y_{i,t} \times Y_{j,t}}{Y_{w,t}} \left(\frac{\tau^k_{Aij}}{P_{i,t}P_{j,t}} \right)^{1-\sigma} / \left(\frac{Y_{i,t} \times Y_{j,t}}{Y_{w,t}} \left(\frac{\tau^k_{Sij}}{P_{i,t}P_{j,t}} \right)^{1-\sigma} + \frac{Y_{i,t} \times Y_{j,t}}{Y_{w,t}} \left(\frac{\tau^k_{Aij}}{P_{i,t}P_{j,t}} \right)^{1-\sigma} \right)$$

$$= {\tau^k_{A,ij}}^{1-\sigma} \left({\tau^k_{S,ij}}^{1-\sigma} + {\tau^k_{A,ij}}^{1-\sigma} \right)$$

$$= 1/\left(1 + \frac{{\tau^k_{S,ij}}^{1-\sigma}}{{\tau^k_{A,ij}}^{1-\sigma}} \right)$$

Here, we break down the transactions of product k into individual varieties, ω_n.

In other words,

$$k = \sum_{n=1}^{m} \omega_n$$

, and product k is the sum of ω_n varieties.

Of all ω varieties, airfreight will be selected for transactions in which $\Delta F < \Delta TC$. For example, the scenario in which airfreight is selected for varieties ω_1 to ω_h can be expressed as $k^A = \sum_{n=1}^{h} \omega_n$, and the varieties for which ocean freight is selected in this scenario can be expressed as $k^S = \sum_{n=h+1}^{m} \omega_n$. Using this, the Air Shipping Ratio can be rewritten as following.

Air Shipping Ratio

$$= \frac{\sum_{n=1}^{h} EX_{ij,k}^{\omega_n}}{\sum_{n=1}^{m} EX_{ij,k}^{\omega_n}} = 1 / \left(1 + \frac{{\tau_{S,ij}^{k}}^{1-\sigma}}{{\tau_{A,ij}^{k}}^{1-\sigma}} \right) \tag{11}$$

This equation (11) has the following meaning: as $\tau_{A,ij}^{k}$ increases, Air Shipping Ratio decreases. Conversely, if $\tau_{S,ij}^{k}$ increases in number, the Air Shipping Ratio increases. Here, we introduce trade costs, including the transit time cost mentioned above. As previously mentioned, trade costs $\tau_{A,ij}^{k}$ and $\tau_{S,ij}^{k}$ are broken down into cargo transportation cost and transit time cost as follows.

$$\tau_{A,ij}^{k} = F_{ij,k}^{A} + TC_{ij,k}^{A}$$
$$\tau_{S,ij}^{k} = F_{ij,k}^{S} + TC_{ij,k}^{S}$$

In this scenario, if $\tau_{A,ij}^{k} / \tau_{S,ij}^{k}$ increases, Air Shipping Ratio of an export of product k from i to j decreases.

Conversely, if it declines the Air Shipping Ratio increases. First, for the Air Shipping Ratio to be positive, $\tau_{A,ij}^{k}$ must be a finite number. If it is infinite, the Air Shipping Ratio will converge with zero. Conversely, if $\tau_{S,ij}^{k}$ is infinite, the Air Shipping Ratio will converge with 1. Therefore, in order for the Air Shipping Ratio to increase, either $\tau_{A,ij}^{k}$ must decrease, or $\tau_{S,ij}^{k}$ must increase. In this case, we consider that $\tau_{A,ij}^{k} / \tau_{S,ij}^{k} < 1$. If $\tau_{A,ij}^{k}$ is smaller than $\tau_{S,ij}^{k}$, the probability that airfreight will be chosen over ocean freight will be high. This can be rewritten as the following formula.

From $\tau_{A,ij}^{k} / \tau_{S,ij}^{k} < 1$, we get

$$\begin{aligned}
& F_{ij,k}^{A} + TC_{ij,k}^{A} < F_{ij,k}^{S} + TC_{ij,k}^{S} \\
= \;& F_{ij,k}^{A} - F_{ij,k}^{S} < TC_{ij,k}^{S} - TC_{ij,k}^{A} \\
= \;& \Delta F < \Delta TC \\
= \;& \Delta F < Distance_{ij} (\gamma^S - \gamma^A) \\
= \;& \Delta F / Distance_{ij} (\gamma^S - \gamma^A) < 1.
\end{aligned} \tag{12}$$

This equation (12) leads to the following. First, the lower the difference in cargo transport costs for each transportation mode, the more often airfreight is selected. In other words, when a destination country or exported product has relatively low airfreight costs or relatively high ocean freight costs for the same distance, the Air Shipping Ratio will increase. One example of this would be an export destination with frequent regular passenger flights, which have a high probability of having low airfreight costs. Further, landlocked countries and those with insufficient port infrastructure have a high probability of relatively high ocean freight costs. Similarly, when there is a large difference in the transit time costs between each transportation mode, airfreight is more likely to be selected. In other words, even for the same distance, products (and/or transactions) with high transit time costs are likely to have high Air Shipping Ratios. Finally, the longer the distance, the more likely that airfreight will be selected. Based on these results, in the next section we will empirically analyse the determinants of Air Shipping Ratios of exports using Japanese export data.

3. Empirical Analysis Model

In this section, we will empirically analyse whether the Air Shipping Ratio of exports is influenced by the factors explained in the previous section. We have designed an estimation model like (13) below based on the discussion in the previous sections. This model uses data from 2007, and adopts the OLS estimation method.

$$\begin{aligned} AR_{ij}^{k} = \beta_0 + \beta_1 Distance_{ij} + \beta_2 D\_TC_k + \beta_3 D\_Landlocked_j + \beta_4 InfraF_j \\ + \beta_5 Port_j + \beta_6 VW_{ij}^{k} + \varepsilon_{ij}^{k} \end{aligned} \tag{13}$$

Firstly, the dependent variable AR is the previously discussed air shipping ratio of exports, and it is calculated for each of Japan's HS 9-digit export products. Because the Air Shipping Ratio takes a value between 0 and 1, we perform a logit transformation on the dependent variable. Further, Air Shipping Ratios of 0 and 1 have been removed from the sample set. As an Air Shipping Ratio of 0 or 1 indicates that the product (transaction) in question cannot be shipped by either ocean freight or airfreight, there is no choice on a transportation mode for these products. Therefore, they are not subject to analysis in this paper.

Secondly, factors that influence transit time on the national level are selected as explanatory variables for the first group. First of these is Distance, which is the great circle distance[14] from Japan to the export destination. As discussed in the previous section 2, a longer distance decreases average speed, pointing out

[14]This distance data is collected from the GeoDist, CEPII. One can download this file from the following URL : http://www.cepii.fr/anglaisgraph/bdd/distance.htm

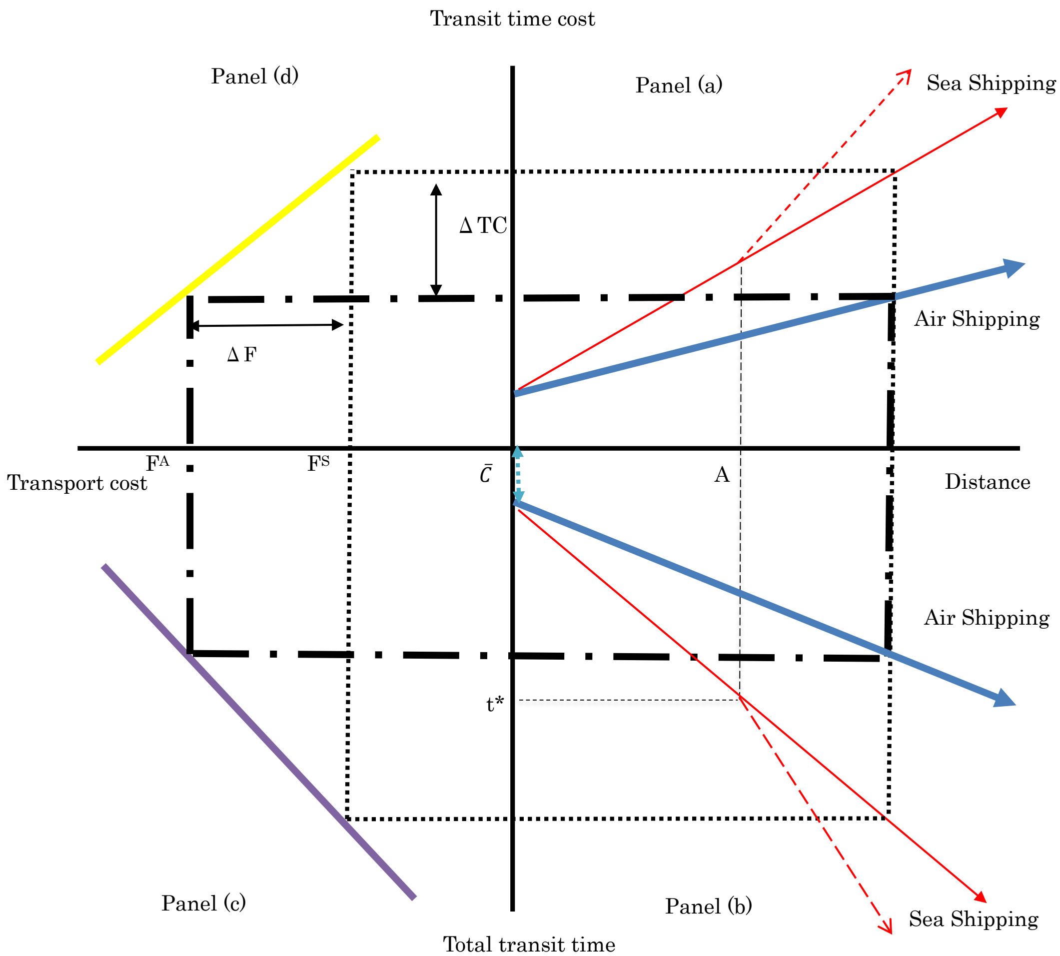

Figure 2: Transport Mode Decision Model

the possibility that transit time costs may become relatively higher. Therefore, we predict that distance has a positive influence on the Air Shipping Ratio.

Thirdly, we consider that landlocked countries without ports require ground transportation, which will cost relatively more than ocean freight costs for an equivalent distance. In other words, we predict that being landlocked will increase the Air Shipping Ratio of a country, thus having a positive effect on the air shipping ratio. For this reason, we add a dummy variable (*D_Landlocked*), with landlocked countries having a value of 1, and all other countries having a value of 0.

Finally, we introduce the explanatory variable of the level of transportation infrastructure development of each country. "Port" represents the quality of the each country's port facilities on a scale from 1 to 7 (with 7 being the best possible

Table 6: *Definition of Dependent and Explanatory Variables*

Dependent Variable	Definition of Variables
Air Shipping Ratio	Air Shipping Ratio of HS 9-digit product: Export value shipped by air freight ÷ Export value of product k from Japan to country j in year t

Explanatory Variables	Definition	Expected Sign Condition
$Distance_j$	Great circle distance from Japan to country j in log	+
	Dummy variables for transit-time cost of product k to country j :	
D_PC	Parts and components product = 1, Others = 0	+
D_PG	Processed goods products = 1, Others = 0	-
D_CG	Capital goods products = 1, Others = 0	-
D_Con	Consumer goods products = 1, Others = 0	+
VW_j^k	Export value ÷ Weight(kg) of product k exported from Japan to country j	+
$D\_Landlocked_j$	Dummy variable for landlocked country j : Landlocked = 1, Coastal = 0	+
$Port_j$	Level of Port Infrastructure development of country j	-
$InfraF_j$	Relative level of domestic airfreight infrastructure development : Air Transport Freight ÷ Road, goods Transported	+

rating)[15]. Landlocked countries do not have port facilities, so this is no data. In order to prevent the loss of sample data on landlocked countries, they are given a 1 for this variable (1 being the worst possible rating). Because the presence of high-quality port facilities is certain to contribute decreasing the transit time of ocean freight, it is expected to be a factor that decreases the Air Shipping Ratio. In the same way, an export destination country having a high level of road and rail infrastructure development is also considered to be a factor that decreases the Air Shipping Ratio. However, the level of land route infrastructure development has a high correlation coefficient with the level of airport infrastructure development, and is therefore not included as an explanatory variable. Therefore, we include the relative level of airport infrastructure development as an explanatory variable,

[15]The data of the quality of port infrastructure used here is taken from the World Development Indicators, The World Bank.

and we consider that the Air Shipping Ratio will increase when the level of airport infrastructure has a relative advantage to those of land routes.

The explanatory variables of the second group are those that take into account the characteristics of each product that we consider to have an effect on the Air Shipping Ratio. These are all dummy variables for transit time cost. Here, based on the UN Broad Economic Categories (BECs) previously mentioned, we try to find the differences in transit time cost that likely exist between each product. For example, intermediate goods within an internationally fragmented production network, global value chains (GVCs), are products that absolutely must be supplied in a reliable manner.

In the case of Japanese companies that use lean production methods in particular, intermediate goods such as parts and components must be delivered on time. Because of this, we consider intermediate products to have relatively higher transit time cost than other products. Therefore, we introduce a transit time cost dummy variable, such as 1 for intermediate products and 0 for other products. In the same way, we introduce a dummy variable for each BECs, namely, consumer goods, materials, processed goods, and capital goods.

Here, the export data of the dependent variable is on the HS 9-digit level, yet BEC classifications are on the HS 6-digit level. Therefore, each 9-digit product is categorised in the HS 6-digit level so as to make to be compatible with BEC classifications. According previous studies, intermediate products and consumer products have high frequency of being shipped by airfreight. In addition to this, we have also included the export value per 1 kg of each product (a proxy variable for lightweight products, VW) as an indication of the effect the characteristics of each product has on its Air Shipping Ratio. Because lightweight products have proportionately lower airfreight transportation costs, we assume that higher Value Weight (VW) is a factor that increases the Air Shipping Ratio. A summary of the definitions and expected sign conditions of these variables can be found in Table 6 below.

In addition, in this paper we are using trade data from before the so-called "Lehman shock". As the world suffered a rapid decline and increase in the amount of trade after the Lehman shock, we found that the extreme fluctuations were not conducive to the purpose of our analysis. Therefore, we have analysed a period of time prior to the Lehman shock in 2008.

4. Results of Estimations

The results of estimations using the estimation model explained in IV are shown on Table 7. Here, we separate the estimation models into two large groups. Namely, the estimation models of the first group include data on exports to landlocked countries (Models (1) through (6), while the estimation models of the second group (Models (7) through (11)) exclude this data. This is in consideration of the fact that the characteristics of landlocked countries have a large effect on Air Shipping Ratios, with the possibility of a large variance from coastal countries.

As shown in Table 7, based on all of the estimation results we can come to the conclusion, that the estimation models are highly significant overall. Virtually all of the explanatory variables are statistically significant, with most of them being significant to the level of 1%. To begin, of the explanatory variables considered to affect the Air Shipping Ratio at the country level, Distance was found to be both positive, and significant in all of the models to the 1% level. As predicted by the previous models, this signifies that the further the shipping distance is, the higher the Air Shipping Ratio will be. Previous studies including shipment weight as an explanatory value have also shown that distance has a positive correlation with the Air Shipping Ratio.

Next, the landlocked dummy is both positive and significant to the 1% level. As we expected, countries without seaport facilities tend to have longer transit times than countries of the same distance with them. Therefore, it is likely that there are merits to cutting down total transit time by air shipping. Further, the relative level of airport infrastructure development was positive as expected, albeit with a slightly low level of significance. On the other hand, Port was statistically significant, but gave us an unexpected result of positive. This may mean that countries with high-quality ports also have sufficiently developed airport infrastructure. It may also be that the quality of port facilities may not have a significant effect on ocean freight shipping costs. Therefore, the quality of port facilities does not have a significant effect on the selection of transportation modes, and there may be a more important factor at work.

The second group of explanatory variables, which consider the characteristics of each product, the dummy variables for intermediate and consumer goods are both significant and positive. As pointed out by previous research, intermediate goods have are frequently shipped by airfreight. In the same way, consumer products, as demonstrated by lean inventory methods, are considered to be products with have relatively high transit time costs. Finally, the Value-Weight variable was also shown to be significant and positive. As expected, we can say for sure that the lighter a product is, the higher its Air Shipping Ratio.

IV. Conclusion

Currently, airfreight is responsible for approximately 30% of the value of Japan's exports, which is certainly not a small amount. As shown in this paper, the Air Shipping Ratio for Japanese exports differs vastly depending on the product

Table 7: *The Estimation Results*

Table 7 Estimation Results.

	Including landlocked countries						Excluding landlocked countries				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	AR	AR	AR	AR	AR	AR	AR	AR	AR	AR	AR
Distance	0.0000386***	0.0000491***	0.0000466***	0.0000715***	0.0000488***	0.0000764***	0.0000368***	0.0000475***	0.0000904***	0.0000497***	0.0000955***
	(13.87)	(17.49)	(16.59)	(17.60)	(17.31)	(19.01)	(13.12)	(16.78)	(20.34)	(17.51)	(21.89)
D_PC	0.595***	0.363***	0.352***	0.394***	0.369***	0.377***	0.603***	0.365***	0.395***	0.382***	0.380***
	(20.57)	(12.61)	(12.24)	(10.10)	(12.83)	(9.66)	(20.35)	(12.40)	(9.73)	(12.97)	(9.37)
D_PG	-0.695***	-0.698***	-0.698***	-0.707***	-0.716***	-0.680***	-0.715***	-0.719***	-0.749***	-0.737***	-0.731***
	(-15.45)	(-16.03)	(-16.06)	(-12.74)	(-16.48)	(-12.25)	(-15.65)	(-16.26)	(-13.16)	(-16.65)	(-12.84)
D_CG	0.0703*	-0.0922**	-0.100**	-0.175***	-0.0975**	-0.181***	0.0637	-0.106**	-0.198***	-0.103**	-0.202***
	(2.16)	(-2.76)	(-3.01)	(-3.92)	(-2.93)	(-4.05)	(1.92)	(-3.09)	(-4.28)	(-3.02)	(-4.38)
D_Con	0.443***	0.416***	0.417***	0.349***	0.387***	0.377***	0.457***	0.428***	0.362***	0.399***	0.382***
	(12.08)	(10.60)	(10.64)	(6.93)	(9.86)	(7.50)	(12.26)	(10.75)	(7.02)	(10.01)	(7.42)
VW		0.00540***	0.00539***	0.00367***	0.00539***	0.00367***		0.00523***	0.00351***	0.00523***	0.00350***
		(30.03)	(30.02)	(19.62)	(30.07)	(19.58)		(29.03)	(18.68)	(29.07)	(18.66)
D_Landlocked			0.616***	0.659***	0.629***	0.629***					
			(10.88)	(10.70)	(11.13)	(10.23)					
Port				0.0974***	0.0732***				0.0753***	0.0715***	
				(7.71)	(9.49)				(5.81)	(9.19)	
InfraF				0.0559		0.0719*			1.440***		1.571***
				(1.79)		(2.31)			(10.62)		(11.73)
_cons	-1.758***	-1.862***	-1.865***	-2.483***	-2.228***	-2.053***	-1.770***	-1.872***	-2.599***	-2.228***	-2.283***
	(-67.02)	(-71.32)	(-71.52)	(-36.97)	(-48.15)	(-54.95)	(-67.10)	(-71.29)	(-37.61)	(-47.64)	(-53.63)
N	49662	44868	44868	25804	44868	25804	47613	43035	24148	43035	24148

t statistics in parentheses
*p<0.05, **p<0.01, ***p<0.001

and the destination. Out of all Japanese exports, the majority of transactions (products or destinations) have an Air Shipping Ratio of either 0 or 1, indicating that they can only be shipped by either ocean freight or airfreight. However, all other transactions had Air Shipping Ratios distributed between 0 and 1, and a given product being shipped to a given destination will not necessarily always be shipped either by ship or aircraft. In other words, a trader exporting a certain product to a specific country will not always exclusively select either airfreight or ocean freight. While it seems that ocean freight is the clear choice when considering shipping costs, in reality the selection of transportation modes is more complex. Therefore in this paper we attempted to analyse the mechanisms which can cause airfreight to become the logical choice by introducing the concept of transit time cost.

First, we applied the Anderson and van Wincoop-type gravity model in order to express the degree to which traders select airfreight in terms of the Air Shipping Ratio. This indicated that the Air Shipping Ratio relied on the relative difference of the trade costs between airfreight and ocean freight. Then, we divided trade costs into shipping costs and transit time costs, and considered the conditions in which airfreight was advantageous based on their correlation to distance and total transit time. There, we saw that products having relatively high transit time costs, factors that decrease the cost of airfreight shipping, factors that increase ocean freight shipping costs, and distant trading partners all increased the frequency of the use of airfreight. Based on the results of this consideration, we constructed the estimation model using the data of Japanese exports in 2007 and performed the quantitative analysis. Based on the results of our estimations, we can state that the factors predicted by the analysis model influenced on the Air Shipping Ratio of Japanese exports. Namely, we saw that intermediate and consumer goods have higher Air Shipping Ratios due to their high transit time costs. This is best represented by transactions involving traders utilising lean production and inventory methods.

Finally, we saw that the greater the distance to the destination, the greater additional transit time due to various factors (landlocked, etc.) for destinations of the same distance, and/or the higher the quality of airport infrastructure development of a destination, the higher the Air Shipping Ratio will be for Japanese exports.

Based on the assumption that time costs would differ for products based on their purpose of use, we introduced a dummy variable for each BEC classification as a proxy variable for time cost. In the future, we wish to consider introducing time cost for each product as a non-dummy quantitative variable.

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