An Analysis of Travel Demand in Japan's Inter-city Market: Empirical Estimation and Policy Simulation

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Abstract

Major industry and policy changes are taking place in the Japan's inter-city travel market. This study empirically estimates the air-rail travel demand model with aggregate OD market data. The estimated model is then used to estimate the effects of introducing super high speed rail (HSR), and alternative levels of CO2 emission taxation on the demands for airline and HSR modes. Our key findings are: (a) In Japanese consumers mind there is a substantial product differentiation between air and rail travel modes; (b) Japanese consumers are moderately sensitive to price while being highly sensitive to travel time and frequency of services; (c) The estimated average value of travel time is $42 per hour while the estimated value of airline frequency is about $2 per weekly departure per passenger; (d) The proposed Tokyo-Osaka superconducting maglev HSR services would drive airlines out of business while stimulating substantial new traffic in that market; and (e) CO2 emission taxation would have only a moderate impact on modal shift from air to HSR mode.

Key Words: Intercity travel demand and preference; Japan air-rail competition; nested logit; carbon taxation; maglev super HSR

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1.0 Introduction

The advent of high speed rail (HSR) in 1964, and subsequent improvements in speed of travel brought a new economic era to Japan by making Tokaido corridor, the economic heartland of Japan along the Tokyo – Nagoya – Osaka region, a 'single-day business region'. Despite the dramatic success of the Japanese HSR (Shinkansen) system, partly due to the rapidly expanded network of airports the airlines were able to fill the gap in the extensive markets that HSR cannot fulfill, and thus, in the last two decades air transport services in Japan has achieved even a faster growth than railway services. With a drastic amendment to the Civil Aeronautics Law in 2000, Japanese domestic aviation market has been liberalized, removing regulations on capacity, route license and air fares. These led to an increasing competition among existing airlines, and opened the door for the entry of newly established airlines including low cost carriers (LCCs). This, in turn, led to extensive competition between airlines and HSR services, creating a unique inter-city transport network for Japan (Yamaguchi and Yamasaki, 2009).

On the other hand because of severe capacity constraints at the two primary airports (Haneda and Narita) in Tokyo, airlines had been unable to increase flight frequency in the heavily travelled inter-city routes. However, with completion of the 4th runway and a new terminal in 2010 in Haneda airport and the second runway extension in the Narita airport, the total number of slots at the two Tokyo area airports was increased by more than 20 percent, with further substantial slot increase planned by fiscal year 2014.[1] Other major changes are on the horizon as well. Japan Rail (JR) Central has announced a plan to build a maglev super high speed rail linking

[1] Ministry of Land, Infrastructure, Transport and Tourism (MLITT) plan shows that the combined Narita+Haneda airport slots are to increase from 523,000 in spring 2010 to 640,000 in 2011, and further to 747,000 by 2014.

Tokyo and Nagoya by 2027, which will be further extended to Osaka by 2045. Such a new investment would cut the HSR travel time by more than one half along the most travelled Tokaido corridor, and substantially increase HSR capacity and frequency. Although this project will be privately funded, it has been regarded by the Japanese government as one of the measures for realizing sustainable society, as HSR operations generate much less negative externalities (especially CO2 emission) as compared to other transport modes. A related policy under consideration is the carbon tax, which clearly favors low carbon HSR services to aviation.

With all these major changes taking place and on the horizon, it is important for stake holders to obtain a clear view of the current Japanese inter-city markets. A quantitative analysis of consumer preference and travel demand is an essential starting point. However, most demand studies involving aviation and HSR services have been conducted for markets outside of Asia. Bhat (1997), Koppelman and Wen (2000) estimated the revealed consumer preferences in the intercity market between Toronto and Montreal in Canada. González-Savignat (2004), Román, Espino and Martin (2007), Behrens and Pels (2009) estimated consumer preferences in Europe. Hensher (1997) presented stated preference studies on the proposed HSR service along the Sydney - Canberra corridor. This approach, similar to that used in most HSR feasibility studies, doesn’t capture induced demand due to the introduction of HSR. Hensher (1997) thus suggests that properly addressing this issue would be a major research area in the future. Park and Ha (2006) estimated stated preference for air and HSR mode choice in Korea using a binary logit model with survey data collected 3 months before the Korea’s HSR operation. Yamaguchi and Yamasaki (2009) estimate air vs. HSR mode choice in Japan. They however cautioned that with highly aggregate data, “spatial conditions and speed factors are ignored”, and therefore, “in order to analyze the air-rail relationship in a more comprehensive manner, we need to develop a spatial model that breaks region into zones”.

In summary, although a number of studies have estimated consumer preferences on air vs. HSR choices, few have been conducted for Asia using actual market data (i.e. revealed preference analysis). What is more, except for Román et al. (2007) who estimated willingness to pay, virtually all studies mentioned above estimated conditional elasticities because the ‘outside option’ was not included in their choice set: i.e. the traffic stimulation effects of the changes were ignored. It is difficult to apply the empirical findings from previous studies to the Japanese market directly.[2]

This study estimates consumer demand and preference on travel mode choice in Japan’s domestic inter-city markets using a tri-level Nested-Logit model which includes an ‘Outside Option’ other than rail and air modes. This outside option includes ‘no travel’, car-driving, buses and other modes other than air and rail, and allows us to estimate the stimulated demand in addition to the air-rail substitution effect. The model is estimated on the Origin-Destination market share data using the Generalized Method of Moments (GMM) framework. Our estimation results reveal travelers’ preferences on fares, frequency of services and transit time for rail and air services. Various demand elasticities summarized from estimation results show that there is a strong substitution patterns between rail and air travel modes. The estimated model is used to simulate the impacts of the proposed super HSR services between Tokyo and Osaka (438 kms) and the introduction of CO2 taxation on possible changes in market equilibrium.

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[2] Hensher (2008) reviewed 319 studies on public transport elasticities and concluded that the factors such as data paradigm, fares used, the unit of analysis, country, and specific transport modes have major influences on the estimation of elasticities. He states “our preference would always be to collect primary data as a basis for conclusions regarding effects of policy changes”.

The rest of the paper is organized as follows: Section 2 describes the demand model and estimation methodology. Section 3 reports data sources and variable construction. Empirical findings including some simulation results on policy changes are reported and discussed in Section 4. Section 5 reports the simulation results on the proposed CO2 emission taxation. The last section summarizes and concludes the paper.

2.0 Model Specification and Estimation Methodology

Japanese domestic market is divided into 24 origin-destination (OD) zones due to data compilation needs. Markets are specified as directional OD pairs such that from zone 1 to zone 2 is a different market with from zone 2 to zone 1. Denote $m = 1, 2, \ldots, M$ to index the markets. In a market, travelers can choose a product from a choice set which includes both rail and air travel choices. Air travel choices include multiple products which are unique combinations of airport (there can be multiple airports in a zone), carrier (Japan Airlines, All Nippon Airways, and others), ticket class (first, business, full, premium coach, and discount coach), and connection (non-stop flight and connecting flight). Pels, Nijkamp and Ritveld (2000, 2001) suggest that air travelers may prefer particular airports, or treat airline-airport combinations as a travel choice. Our specification captures these important service attributes of air services. Recent studies such as Li, Hensher and Rose (2010), Hensher, Greene and Li (2011), Hensher and Li (2012), Chorus and Dellaert (2012) point out that it is also important to incorporate travel time reliability / variability in model specification. However, due to lack of such data this improvement is left for future research. In sum, our data consist of 152 directional OD markets and the total number of travel products on the 152 markets is 901.

We use $\Omega_A \equiv (1, 2, \ldots, J_m)$ to denote the air travel choice set and J_m is the total number of air travel products in market m. The choice set faced by a traveler in market m is then

$$\Omega \equiv (0, r, \Omega_A) \tag{1}$$

where alternative 0 represents the outside choice such as driving car or non-travel; r denotes high speed rail travel, whereas $\Omega_T \equiv (r, \Omega_A)$ denotes the travel choice set. The utility of traveler i choosing a product in market m is specified as

$$u_{i0m} = \varepsilon_{i0m} \tag{2a}$$

$$u_{irm} = X_{rm}B - \alpha p_{rm} + \xi_{rm} + \varepsilon_{irm} \tag{2b}$$

$$u_{ijm} = X_{jm}B - \alpha p_{jm} + \xi_{jm} + \varepsilon_{ijm} \tag{2c}$$

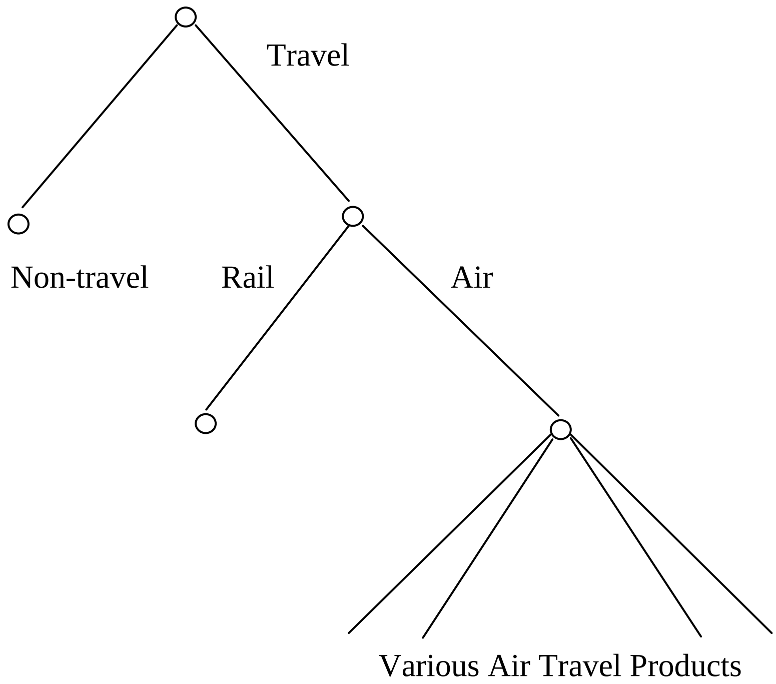
where X is the vector of product attributes; p is the price / fare of a product; ξ is a random component to capture omitted product attributes which can be correlated with price; ε represents measurement error. The joint distribution of $\varepsilon_{im} \equiv (\varepsilon_{i0m}, \varepsilon_{irm}, \varepsilon_{i1m}, \ldots, \varepsilon_{iJ_m m})$ is specified as the following general extreme value (GEV) distribution

$$\exp\left[-\left(e^{-\varepsilon_{i0m}} + \left(e^{-\varepsilon_{irm}/\lambda_T} + \left(\sum_{j\in\Omega_A} e^{-\varepsilon_{ijm}/\lambda_T\lambda_A}\right)^{\lambda_A}\right)^{\lambda_T}\right)\right] \tag{3}$$

The specification in (3) models the choice as a tri-level nested logit model in which a traveler first chooses between travel and non-travel (outside choice); within the travel option a traveler chooses then between rail and air; and finally the traveler chooses an air product (unique combinations of airport, carrier, connection, and ticket class) if she chooses air mode. Starting from the bottom level of the tri-level nested logit model, we use $\lambda_A \in (0,1)$ to capture the similarity of air products in a market; because rail travel nest is degenerate, the similarity parameter for the nest is normalized to 1. Moving up to the middle level of the tri-level nested logit, we use $\lambda_T \in (0,1)$ to capture the similarity between the two travel modes – rail and air; again, the similarity parameter for the non-travel nest is normalized to 1 because the nest is degenerate. As discussed in Train (2009), as long as $\lambda_A \in (0,1)$ and $\lambda_T \in (0,1)$, the specified tri-level nested-logit model is consistent with utility maximization for all levels of explanatory variables. Figure 1 describes tri-level nested logit model.

Figure 1

Tri-Level Nested Logit Travel Demand Model Structure



Note that the random component ξ in the demand model accounts for the omitted product attributes which may be correlated with price. Our model follows Berry, Levinsohn and Pakes (BLP 1995) which has three desirable features compared to the discrete choice models estimated from disaggregate (individual) choice data: (1) our model allows us to estimate the discrete choice model with market level data. (2) it takes into account explicitly the omitted product attributes, which are difficult to measure/observe, but are nevertheless influential on consumers' travel decision; and (3) our model specification can handle the case with a large number of choice objects. These features are important to our empirical estimation because it is impossible for us to obtain individual choice data sets for all of the OD pair markets in Japan. Because travelers in our market face a very large number of travel options to choose from (901 products in 152 markets in our case), it is not possible to estimate all of the alternative-specific constants with the aggregate market share data.

The above model specification implies the following market share equations. For market share of air product $j \in \Omega_A$ (market subscript is dropped to simplify notation), it is defined as

$$S_j = \frac{\exp\left(\dfrac{X_j B - \alpha p_j + \xi_j}{\lambda_A \lambda_T}\right)}{\exp(I_A)} \cdot \frac{\exp(\lambda_A I_A)}{\exp(I_T)} \cdot \frac{\exp(\lambda_T I_T)}{1+\exp(\lambda_T I_T)} \tag{4}$$

where

$$I_A = \ln \sum_{j \in \Omega_A} \exp\left(\frac{X_j B - \alpha p_j + \xi_j}{\lambda_A \lambda_T}\right) \tag{5}$$

$$I_T = \ln\left(\exp\left(\frac{X_r B - \alpha p_r + \xi_r}{\lambda_T}\right) + \exp(\lambda_A I_A)\right) \tag{6}$$

The market share of rail is specified as

$$S_r = \frac{\exp\left(\dfrac{X_r B - \alpha p_r + \xi_r}{\lambda_T}\right)}{\exp(I_T)} \cdot \frac{\exp(\lambda_T I_T)}{1+\exp(\lambda_T I_T)} \tag{7}$$

and the market share of outside choice is

$$S_0 = \frac{1}{1+\exp(\lambda_T I_T)} \tag{8}$$

Market share equations specified above describe how market shares in a market are determined. Under the "true" values of demand parameters that we are trying to estimate, the difference between observed and simulated (from the share equations) market shares depends totally on the omitted product attributes ξ. The demand model can then be identified if we can find a set of instruments z such that

$$E[\xi | z] = 0 \tag{9}$$

The identification condition in equation (9) implies that $E[\xi_j \cdot h(z_j)] = 0$, where $h(z_j)$ represents the vector-valued function of instruments. The empirical analog to $E[\xi_j \cdot h(z_j)]$ is $G(\Theta) \equiv M^{-1}\sum_{m=1}^{M}\sum_{j=1}^{J_m}\xi_j(\Theta)\cdot h(z_j)$, where $\xi_j(\Theta)$ express ξ_j as the function of all unknown parameters (Θ). An estimator under the framework of the Generalized Method of Moment (GMM) can then be developed and the estimator solves $\hat{\Theta} = \arg\min_{\Theta} \|G(\Theta)\|$. The intuition behind the GMM estimation is that we search for the values of the unknown parameters in such a way that the distance between the predicted (from the tri-level nested logit model) and observed market shares is minimized. As such, our discrete-choice model can be estimated based on market level data without imposing any distributional assumption about ξ.[3]

Evaluating the GMM objective function requires us to invert the share equations, which are defined in equations (4) – (8), to express ξ_j as the function of unknown

[3] Other classes of estimators can also be developed under additional distributional assumptions. For example, a maximum-likelihood estimator can be developed if we impose a distribution assumption on ξ.

parameters and data. This step can be done by iterating the following system of equations

$$\xi_j^{t+1} = \xi_j^t + \lambda_A \lambda_T \left[\ln S_j^o - \ln S_j\left(\xi^t, \Theta, data\right)\right], \text{ if } j \in \Omega_A \tag{10}$$

and

$$\xi_j^{t+1} = \xi_j^t + \lambda_T \left[\ln S_j^o - \ln S_j\left(\xi^t, \Theta, data\right)\right], \text{ if } j = r \tag{11}$$

where subscript t represents the t-th iteration; S_{jm}^o represents the observed market share.

The consistent estimate to the covariance matrix of the estimator is as defined in BLP (1995):

$$Var\left(\hat{\Theta}\right) = \left(\Psi'\Psi\right)^{-1} \Psi'\left(\Sigma\right)\Psi\left(\Psi'\Psi\right)^{-1} \tag{12}$$

where

$$\Psi = \frac{\partial G(\Theta)}{\partial \Theta}\Big|_{\Theta=\hat{\Theta}} \tag{13}$$

and $\Sigma = \Sigma_1 + \Sigma_2$ in which

$$\Sigma_1 = \frac{1}{J} \sum_{m=1}^{M} \sum_{j=1}^{J_m} \xi_j\left(\hat{\Theta}\right)^2 h_j(z)\ \ h_j(z)' \tag{14}$$

$$\Sigma_2 = \frac{1}{NJ} \sum_{m=1}^{M} \sum_{j=1}^{J_m} h_j(z)' \left(\frac{\partial S_{jm}\left(\hat{\Theta}\right)}{\partial \xi} \right)^{-1} \left(diag\left(S_m^o\right) - S_m^{o\,\prime} S_m^o \right) \left(\frac{\partial S_{jm}\left(\hat{\Theta}\right)}{\partial \xi} \right)^{-1\,\prime} h_j(z) \tag{15}$$

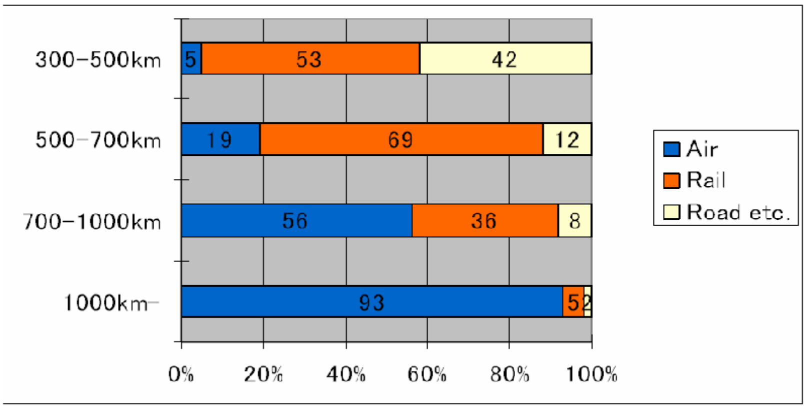
In (15), $S_m^o \equiv \left(S_{1m}^o, S_{2m}^o, \ldots, S_{J_m m}^o\right)$ is the vector of observed market shares in market *m*.

3.0 Data Sources and Variable Construction

Our study investigates consumer preferences for air and HSR services in Japan. Overall, air and HSR modes compete actively each other in the distance range of 300 to 1,000 km. As shown in Figure 2, rail market shares are 53%, 69% and 36% for 300-500 km, 500-700 km, and 700-1000 km distance ranges respectively. Airlines' market shares are 5%, 19% and 56% respectively for the same distance ranges in intra-Japan markets. Yamaguichi, Ohashi and Hihara (2008) also compares HSR and air fares in some of the representative routes, and confirm that Air-HSR competition is most intense in markets within 1000 kms. In particular, airlines often set discount fares significantly lower in the markets where they compete with HSR, while HSR does not appear to be using discount fares effectively as a competitive tool to compete with airlines.

Figure 2

Modal Shares in Japan Inter-city Passenger Market



Source: Yamaguchi, Ohashi and Hihara (2008)

While we will investigate the inter-city transport markets throughout Japan, for the purpose of data compilation we divided the Japanese domestic market into 24 OD zones.[4] With such an aggregation, travel within a zone will not be captured. However, as there is little competition / substitution between air and rail in short-haul markets, such a simplification / limitation is unlikely to have any major impacts to our estimation. In summary, following data sources have been used in the compilation of the variables for the empirical estimation.

Market shares:

- Within air choice, market share for each of the airline products in a market is constructed from the Marketing Information Data Transfer (MIDT) database, which records comprehensive airline booking information.
- Market shares (based on passenger volumes) of rail travel and air travel in a market are obtained from the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) of Japan which are mostly based on the 2005 Japan Transportation Statistical Survey. The data include total passengers by both rail and air between zones in 2005.
- The size of a market is calculated as the geometric mean of populations of the OD zones, a standard approach for demand models which include "outside option" in the specification.

Attributes of Services:

- Attributes of airline products including air fares are constructed from the MIDT booking information.

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[4] The International Transport Policy Unit (ITPU) of Tokyo University has helped create our 24x24 origin-destination data by aggregating the data from the 2005 Japan National Transportation Survey.

- Price of rail travel, travel time of rail and air in a market are obtained from MLIT. Travel time of air or rail between two zones is the sum of average access time, station-to-station (airport-to-airport) time, and terminal time.
- Distance of a route/market (distance between two zones) is obtained from MLIT.
- Number of departures and total seat capacity of an airline in a market are compiled from airline scheduling data, the OAG database.

Instruments for price and flight frequency:

In the choice model, both price and airline flight frequency are decisions made by firms and, therefore, are likely to be correlated with omitted product attributes ξ in equations (2b) and (2c). Identification condition of the model requires instrumental variables which are correlated with price and flight frequency but are likely to be exogenous to the firms' price and flight frequency decisions. We use the following variables as instruments for price:

- Variables capturing the impacts of market competition on prices. We use number of products and firms in a market, rail availability in a market, and number of airports in a market for such a purpose.
- Variables affecting costs but not demand. We use average temperature in January in OD zones, and dummies indicating whether a product is served by Tokyo area airports, which are very congested and are subjected to slot control.

In order to get instruments for flight frequency, which is measured by weekly number of scheduled flights between an airport-pair, we regress both the observed flight frequencies and average aircraft size on exogenous market characteristics, including distance, market size as defined previously, mean income, number of runways at departure and arrival airports, and rail availability. The fitted flight frequency and average aircraft size are used as instruments for endogenous flight frequency.

4.0 Empirical Results

The estimation results are summarized in Table 1. Most parameters have the expected signs. In estimation, price coefficients in the two levels were constrained to be the same (rail vs. air choice, and choice among air products); otherwise the price coefficients determining choices among air products would not be identified. The first set of parameters includes air product attributes. 'Price' is the average booking price of each class (business, first class, etc.) offered by an airline between OD airports; 'Connection' dummy takes 1 if the service includes at least one connecting stop; JL and NH dummies indicate whether a product is offered by Japan Airlines and All Nippon Airways, respectively (compared with the base of other airlines); business, first-class and discount dummy variables indicate the class of air service (compared to the base of full fare coach class); number of departures in a market records the daily number of scheduled flights of an airline in a market. Table 1 reports the parameter estimates and summary statistics from the estimation.

Our estimation results indicate the following immediately: (a) The statistically significant difference of the inclusive value for air mode (λ_A) from value of 1.0 indicates that travelers see different air classes as much closer substitutes than air vs. rail choice, and thus, justify the air mode's nest structure in our logit model (i.e. existence of closer substitution among air fare classes than air-rail substitution). (b) On the other hand, the statistical significance of the inclusive value for air-rail choice branch (λ_T) indicates that although Japanese consumers do not regard rail and air services very closely substitutable, air-rail substitution possibility is still stronger than the substitution possibility between air or rail and outside choice (no travel, intercity buses, car driving, etc.) ; (c) Our results show that air travelers exhibit strong aversion to connecting flights and strong preference for flight frequency. Only 11% of domestic air travelers flew connecting flights during our sample period. On average, travelers are willing to pay about $106 to avoid a connection, about $42 for an hour of time-saving[5], about $2 for one additional weekly flight; and (d) Within air-rail travel choice market, as expected the demand for rail and its market share decreases with distance.

Table 1

Estimation Results for the Travel Demand Model

(Standard errors in parentheses)

Variables	Estimate
Generic variables	
Price ($ hundred)	-1.0538 (0.445)
Travel Time (Hour)	-0.4427 (0.046)
Variables affecting product choice within air travel	
Connection dummy (1 if using connecting flight)	-2.2290 (0.168)
JL dummy (1 if a product served by JAL)	1.6267 (0.126)
NH dummy (1 if a product served by ANA)	1.2779 (0.119)
First-class dummy (Economy full as the base)	-2.6327 (0.221)
Business dummy (Economy full as the base)	-1.9179 (0.185)
Discount dummy (Economy full as the base)	-1.0635 (0.141)
Weekly departure frequency (# of scheduled flights by a carrier in a week)	0.0190 (0.006)
Airport dummies included? (there can be multiple airports in a zone)	YES
Variables affecting rail vs. air travel choice	
Rail travel dummy (1 if a product is served by rail)	1.0624 (0.917)
Distance (thousand km) × Rail travel dummy	-6.8273 (3.506)

[5] In 2010 the average hourly wage in the Japanese manufacturing sector was US$31.99 (Bureau of Labor Statistics 2011). Since a significant proportion of travelers in domestic market are business travelers, their average wage is likely to be much higher than $32. Therefore, the value of time-saving is roughly equivalent to hourly wage.

Distance square × Rail travel dummy	4.2771 (2.361)
Variables affecting travel vs. non-travel choice	
Constant	-0.6734 (0.214)
Distance (thousand km)	-1.0139 (0.372)
Other parameters	
λ_A Inclusive value for choices in air mode	0.4550 (0.283)
λ_T Inclusive value for transport (air vs. rail) choice	0.8421 (0.093)
Willingness-to-pay summarized from parameter estimates	
Value of travel time	$42/hour
Value of weekly flight frequency	$2/flight in a week
Number of observations (products)	901
Number of markets	121

In order to explore the empirical results further, below the estimated model is used to simulate the effects on the air and rail demand volumes of changing price or service quality variables one at a time.

Table 2 presents the simulated effects of changing airline price by on average 10% and 50% on its own demand and rail demand. An alternative approach is first to calculate elasticities with the estimated demand parameters, then apply such elasticities to calculate the effects of any price change. However, in our model the elasticity values are specific at given data points and as such it is not accurate when we evaluate changes in traffic volumes in response to a large changes of causal variables such as in our case (10%, 50% changes). Since our model includes the 'outside option', the demand changes reported in this and other tables include the stimulated traffic as well as the traffic shifted to/from other modes.

Table 2

Demand Response with respect to Airfare
(Elasticity Values in Parentheses)

Air Own Demand Response with respect to Airfare Changes		
Reduce the price of all air services by	% change of air travel demand in short-haul (distance <= 500km)	% change of air travel demand in long-haul (distance > 500km)
10%	13.01 (-1.30)	16.34 (-1.63)
50%	141.93 (-2.84)	126.30 (-2.53)
Rail Demand (cross) Response with respect to Airfare Changes		
Reduce the price of all air products by	% change of rail demand in short-haul (distance <= 500km)	% change of rail demand in long-haul (distance > 500km)
10%	-13.12 (+1.31)	-22.41 (+2.22)
50%	-50.99 (+1.02)	-71.37 (+1.43)
Total Travel Demand (air + rail) Response with Respect to Airfare Changes		
Reduce the price of all air products by	% change of air+rail demand in short-haul (distance <= 500km)	% change of air+rail demand in long-haul (distance > 500km)
10%	0.89 (+0.09)	5.77 (+0.58)
50%	15.15 (+0.30)	58.24 (+1.16)

The simulated results provide useful information for the assessment of possible LCC entry in Japan. If LCCs enter with moderately reduced fares, as existing low cost players do, there will be limited impacts to airlines and the HSR operator (e.g. when airfares decrease by an average of 10%, air mode’s own demand increase by 13% and 16.3% in the short-haul and long-haul markets respectively). The effects on overall travel volume in inter-city markets will be negligible. However, if new entrant LCCs are as aggressive as their European and American peers such as Southwest and Ryanair, major cuts in airfares will generate large stimulated demands as well as inducing a major modal shift between air and rail. The stimulation effect will be very substantial in long distance routes.

Table 3 presents the effects of increasing air flight frequency by 10% and 50% on its own demand and rail demand. These results imply the following elasticity results: (a) own frequency elasticity of air travel demand is 0.39 (0.36) and 0.42 (0.38) in short-distance and long-distance markets, respectively, when air flight frequencies were to increase by 10% (50%); (b) cross flight frequency elasticities of the rail travel demand are -0.13 (-0.13) and -0.20 (-0.20), respectively, in short- and long-distance markets. Overall, flight frequency has significant effects on air travel demand, but moderate effects on rail and overall inter-city markets probably because these latter modes are already providing high frequency services.

Table 3

Demand Response with respect to Air Flight Frequency Changes

(Elasticity Values in Parentheses)

Air Demand (own) Response wrt Flight Frequency Change		
Increase weekly air departures frequency by	% change of air travel demand in short-haul (distance <= 500km)	% change of air travel demand in long-haul (distance > 500km)
10%	3.91 (+0.39)	4.23 (+0.42)
50%	18.01 (+0.36)	18.93 (+0.38)
Rail Demand (cross) Response wrt Flight Frequency Change		
Increase weekly air departure frequency by	% change of rail travel demand in short-haul (distance <= 500km)	% change of rail travel demand in long-haul (distance > 500km)
10%	-1.32 (-0.13)	-2.04 (-0.20)
50%	-6.46 (-0.13)	-10.03 (-0.20)
Total Travel Demand Response with Respect to Flight Frequency Changes		
Increase weekly air departure frequency by	% change of air+rail travel demand in short-haul (distance <= 500km)	% change of air+rail travel demand in long-haul (distance > 500km)
10%	1.91 (+0.19)	3.43 (+0.03)
50%	8.83 (+0.18)	15.23 (+0.30)

Table 4 presents the effects of reducing rail mode's travel time by 10% and 50% on the demands for air and rail travel modes.

Table 4

Demand Response with respect to Rail Travel Time Change

(Elasticity Values in Parentheses)Air (Cross) Demand Response with respect to Rail Travel Time Change		
Reduce the rail travel time by	% change of air travel demand in short-haul (distance <= 500km)	% change of air travel demand in long-haul (distance > 500km)
10%	-7.04 (-0.70)	-2.18 (-0.22)
50%	-27.33 (-0.55)	-14.92 (-0.30)
Rail (Own) Demand response with respect to Rail Travel Time Change		
Reduce the rail travel time by	% change of rail travel demand in short-haul (distance <= 500km)	% change of rail travel demand in long-haul (distance > 500km)
10%	25.45 (+2.55)	54.95 (+5.50)
50%	230.32 (+4.61)	1028.99 (+20.58)
Total Travel Demand Response with Respect to Rail Travel Time Change		
Reduce the rail travel time by	% change of air+rail travel demand in short-haul (distance <= 500km)	% change of air+rail travel demand in long-haul (distance > 500km)
10%	7.21 (+0.72)	9.44 (+0.94)
50%	51.95 (+1.04)	158.04 (+3.16)

When rail travel time is reduced by 10% (50%), air travel demand decreases by 7.04% (27.33%) and 2.18% (14.92%) in the short-haul and the long-haul markets, respectively. In response to the same 10% reduction (50% reduction) of rail travel time the rail mode's own demand would increase by 25.45% (230%) and 55% (1029%), respectively, in the short and long haul markets.[6] Overall, the 10% (50%)

[6] Although at a first glance the 1029% increase in rail mode's travel volume in the long-distance routes in response to 50% reduction of rail travel time appears too large a number, this result is reasonable if one takes into account that the current rail market share on the routes with 1000 km or longer

reduction of rail travel time would increase the total air+rail demand 7.21% (51.95%) and 9.44% (158%) in the short and long distance markets, respectively. In summary, very high speed HSR service will cause substantial modal shift from air to HSR. However, the most significant effect is due to large volume of stimulated rail traffic, particularly in the long distance routes. Since the proposed Tokyo-Osaka super HSR project is expected to reduce the total rail travel time by more than 50%, our total net traffic stimulation effect reported in this table indicates that the Tokyo-Osaka traffic would be stimulated by 52%.[7]

5.0 Effects of CO2 Taxation on Air-HSR Competition

Global warming and climate change effect is at the forefront of all transport infrastructure planning in recent years. It is well known that life-cycle CO2 costing literature indicates that rail mode is far more CO2 friendly than air transport. In this context, the EU Commission has announced its plan to require all international flights to land and/or take off at any European airport to purchase the CO_2 certificates by putting them under the ETS scheme from 2012. The Japanese government is also advocating pricing mechanisms to deal with the climate change externality.

Using the estimated travel demand model (Table 1), it is possible to calculate how market shares of air and HSR modes would change in Tokyo-Osaka market as the amount of carbon tax on CO2 emission is varied. Kato and Shinbahara (2006), and Hayashi (2007) found that Japanese High Speed Rail had a significantly lower

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(700-1000km distance) is only about 5% (36%) while airline share is 93% (56%) (see Figure 2). Introduction of maglev super HSR would induce virtually all travelers over 500-1000kms range to switch from air to the super high speed mode.

[7] Tokyo-Osaka air distance is about 401km and the planned Super HSR distance is 420km while the current HSR Shinkansen distance is 515kms. The Maglev service is expected to end the air services in this route.

average CO_2 emission per passenger-km (average 18.2 grams per PKM) than aviation (117.25grams per PKM), buses (70 gram per PKM) and private cars (140.65gram per PKM).

Table 5

CO_2 Emissions by Transport Mode in Japan

CO_2 Emission (g/pkm)	**Airline**	Rail	**Shinkansen**	Maglev	Bus	Private Car
Hayashi (2007)	**110**	18	**22**	50	70	165
Kato & Shinbahara (2006)	**124.5**	18.3	**14.2**	43	n.a	116.3
Average	**117.3**	**18.2**	**18.1**	**46.5**	**70**	**140.7**

We apply this average CO_2 emission statistics for air and Shinkansen HSR modes, and simulate how traffic volumes and market shares for air and HSR modes would change in Tokyo-Osaka markets as the level of CO_2 taxation is varied from €0 through to €140 per metric tonne.[8] The Tokyo-Osaka market is the top intercity travel market certainly in Japan and one of the most heavily traveled intercity markets in the world. Furthermore, these two cities are the two end points of the route for which Japanese government recently approved the JR-Central's application to construct the superconducting maglev high speed rail with a maximum speed of 580km per hour. In 2005, the latest year for which the Japan national transportation survey data were available at the time of our data collection, Shinkansen (HSR) transported 37,653,000 one-way passengers (81.31%) while airlines carried 8,655,000 one-way passengers (totaling 46,311,000 air+HSR passengers) on Tokyo-Osaka OD market.

It is assumed in our simulations that CO_2 taxation will be 100% passed on to passengers. We are forced to make such a simplification because we don't have

[8] ETS carbon trading price was €29.33 (US$34.14) per tonne in July 2008, but the price crashed to €18.25 by Nov 10, 2008 due to the severe global recession.

reliable cost data for airlines and HSR operators, which are needed for the modeling of stake-holders' strategic response to taxation[9]. Therefore, our estimate on traffic volume reduction due to CO2 tax is likely to be an upper bound. The counter-factual simulation results are summarized in Table 6 and Figure 3.

Table 6

Simulated Rail market shares in Tokyo – Osaka market at different CO2 Taxation Level (Air share = 100% - Rail Share)

CO2 taxation level per metric tonne	Simulated Rail market share
€0	**81.31%**
€20	81.77
€40	82.22
€60	82.66
€80	83.09
€100	**83.52**
€120	83.93
€140	84.33

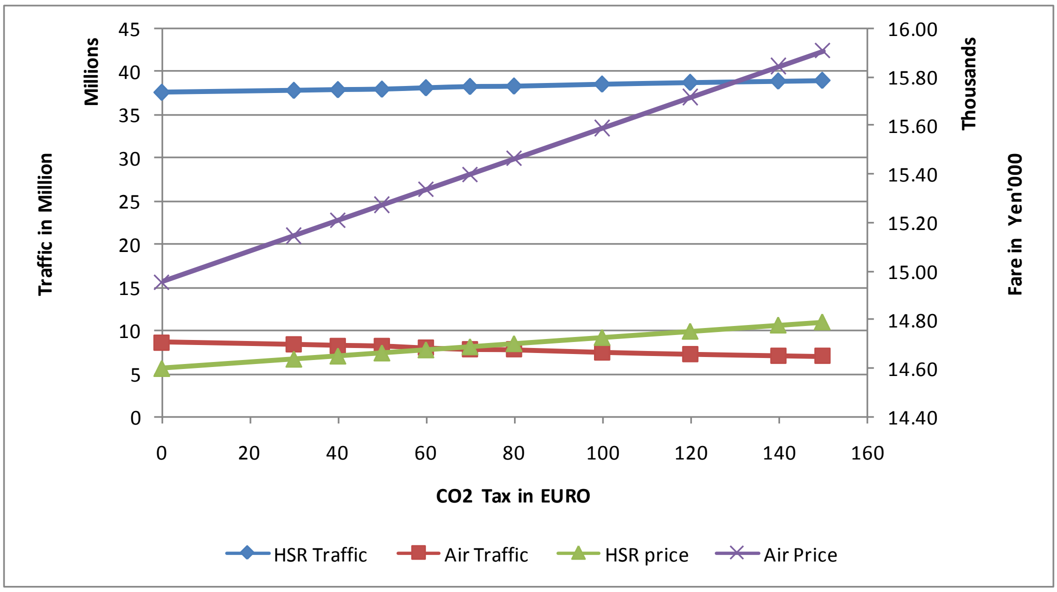
Table 6 shows that the rail market share on Tokyo-Osaka route would have increased from 81.31% to 83.52%, an increase of 2.51 percentage point if €100 per tonne carbon tax were imposed. Although this is a relatively small percentage shift, it represents nearly one million more rail passengers, not a negligible number. This happens largely because the airfares would have increased on average by 4.23% while rail fares would have risen only by 0.87%.

[9] For modeling of strategic / competition effects of taxation, see for example Heijnen and Kooreman (2006).

Figure 3 gives a more comprehensive picture by showing relative increases in airfares and HSR prices and passenger volume changes for air and HSR as CO2 taxation increases from €0 per tonne (no tax) to €150 per metric tonne. For example, a €100 tax per tonne of CO2 emission would have increased air fare by 4.24% and rail fare by 0.86%, and air traffic would have fallen 14.4% to 7,478,156 passengers while rail traffic would have increased by 2.5% to 38,575,556 passengers.

Figure 3

Air and HSR Traffic Growth versus CO2 Tax: Tokyo-Osaka Market



In sum, our counterfactual simulation on the effects of the CO2 externality taxation on Tokyo-Osaka market shows a moderate effect in terms of percentage change. In terms of traffic volume, however, the CO2 taxation could reduce air passenger traffic, and increase HSR passenger traffic in large numbers.

6.0 Summary and Conclusion

Major industry and policy changes are taking place in Japan's inter-city passenger transport market, yet there has been no comprehensive studies investigating consumer preferences over rail and air services using updated market data. This study estimates travelers' preference and choice behavior via a tri-level Nested-Logit model. By including the choice between 'air-rail travel' vs. an 'outside option' (includes no travel or travel by other modes such as car and intercity buses) our model allows us to estimate the Marshalian market demand, not just the mode choice with fixed market size. In addition, we also controlled for the unobservable (unknown) product/service attributes in the estimation. Further, our model is estimated using market-level data via a Generalized Method of Moments (GMM) method.

The statistically significant difference of the inclusive value (from 1.0) for the air-rail choice justifies our treatment of the air-rail choice separately from 'outside choice' (No travel, car-driving, buses etc.) in our model, because in Japan's intercity travel market the air-rail substitutability is significantly higher than the substitutability between air or rail and the outside choice (car, bus, no travel, etc). Furthermore, the statistical significance of the inclusive value for air product choice indicates that Japanese consumers do not regard rail and air services as close substitutes to each other, and as such, this justifies for including choice branch for airlines and fare-classes in our nested logit model. This also implies that there is strong market segmentation between air and rail services in Japan.

Simulation results obtained using the estimated model led us to conclude the following about the Japan's intercity air and rail market:

- Only major reduction of airfare is likely to generate substantial stimulated demands as well as inducing a significant modal shift from rail to air. That is, only a wholesale introduction of true Low Cost Carrier (LCC) services in

Japan's domestic market is likely to stimulate domestic air travel in a major way as well as shifting rail market share to air mode.

- Japan's air travelers value flight frequency highly. With an aggressive frequency increase, airlines would be able to expand their markets substantially mostly because of stimulated traffic especially in the long haul markets, although there would also be a sizable modal switch from rail to airlines.
- Travel time is of great importance to Japanese travelers. For example, a 50% travel time reduction by the proposed superconduct maglev HSR in the Tokyo-Osaka market is expected to wipe out airline travel in this route. Although the traffic diversion effects from airlines to HSR would not be very large in long haul, market expansion via traffic stimulation effect would be significant. This implies that the introduction of the maglev service would greatly expand Japan's intercity travel market. The average value of time estimated by our model is $42 per hour of travel time saving, roughly equivalent to travelers' average hourly wage.
- CO2 externality taxation would have a small effect in terms of percentage change but in terms of absolute volume it could reduce air passenger traffic, and increase HSR passenger traffic in large numbers.

Although we are confident with our model and empirical results, there are needs for further studies on Japan's intercity transport markets, travel choice and consumer preferences. In our study, we lumped together other intercity modes (other than air and rail) along with 'non-travel' in our 'outside option' primarily because of the limitations on our research budget and data. Natural extension of our work is to separate out the intercity bus mode and private auto-driving from 'non-travel' option. In addition, external costs associated with these competing intercity modes should also be considered. Further investigation on those issues would provide a more comprehensive evaluation.

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