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An Analysis of Travel Demand in Japan's Intercity Market

Empirical Estimation and Policy Simulation

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Abstract

This study estimates a travel demand model in Japan's intercity market with aggregate OD data. The estimated model is used to estimate the effects of introducing super high-speed-rail (HSR), and alternative levels of CO_2 emission taxation on the demands for airline and HSR modes. It is found that: (a) there is clear product differentiation between air and rail travel; (b) Japanese consumers are sensitive to travel time and frequency; (c) the proposed Tokyo–Osaka HSR services would drive airlines out of the route while stimulating substantial new traffic; and (d) CO_2 taxation would have a moderate impact on modal shift.

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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 the 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, airlines were able, partly due to the rapidly expanded network of airports, to fill the gap in the extensive markets that HSR cannot fulfil; thus in the last two decades, air transport services in Japan have achieved even faster growth than railway services. With a drastic amendment to the Civil Aeronautics Law in 2000, the Japanese domestic aviation market has been liberalised, removing regulations on capacity, route licences, and air fares. This led to increasing competition among existing airlines, and opened the door for newly established airlines including low-cost carriers (LCCs). This, in turn, led to extensive competition between airlines and HSR services, creating a unique intercity 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 intercity routes. However, with the completion of the fourth runway and a new terminal in 2010 in Haneda airport, and the second runway extension in Narita airport, the total number of slots at the two Tokyo area airports was increased by more than 20 per cent, with a further substantial slot increase planned by the 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 Tokyo and Nagoya by 2027, which will be further extended to Osaka by 2045. Such a new investment would cut HSR travel time by more than 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 realising sustainable society, as HSR operations generate much less negative externalities (especially CO_2 emissions) compared to other transport modes. A related policy under consideration is the carbon tax, which clearly favours low-carbon HSR services over aviation.

With all these major changes taking place and on the horizon, it is important for stakeholders to obtain a clear view of the current Japanese intercity 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 Asia. Bhat (1997) and Koppelman and Wen (2000) estimated the revealed consumer preferences in the intercity market between Toronto and Montreal in Canada. González-Savignat (2004), Román *et al.* (2007), and 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, does not capture induced demand due to the introduction of HSR. Hensher (1997) thus suggests that

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

properly addressing this issue would be a major research area in the future. Park and Ha (2006) estimated a stated preference for air and HSR mode choice in Korea using a binary logit model with survey data collected three months before Korea's HSR operation. Yamaguchi and Yamasaki (2009) estimate air versus HSR mode choice in Japan. However, they cautioned that with highly aggregate data, 'spatial conditions and speed factors are ignored', and therefore, 'in order to analyse 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 versus HSR choices, few have been conducted for Asia using actual market data (that is, 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; that is, 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 intercity 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 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 Generalised Method of Moments (GMM) framework. Our estimation results reveal travellers' preferences on fares, frequency of services, and transit time for rail and air services. Various demand elasticities summarised from estimation results show that there is a strong substitution pattern 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 km), and the introduction of CO_2 taxation on possible changes in market equilibrium.

The rest of the paper is organised 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 provided and discussed in Section 4. Section 5 reports the simulation results on the proposed CO_2 emission taxation. The last section summarises and concludes the paper.

2.0 Model Specification and Estimation Methodology

The Japanese domestic market is divided into twenty-four 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 than from zone 2 to zone 1. Denote $m = 1, 2, \ldots, M$ to index the markets. In a market, travellers can choose a product from

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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'.

a choice set that includes both rail and air travel choices. Air travel choices include multiple products that 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 *et al.* (2000, 2001) suggest that air travellers 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 *et al.* (2010), Hensher *et al.* (2011), Chorus and Dellaert (2012), and Hensher and Li (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 traveller in market m is then:

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

where alternative 0 represents the outside choice such as driving a 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 traveller i choosing a product in market m is specified as:

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

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

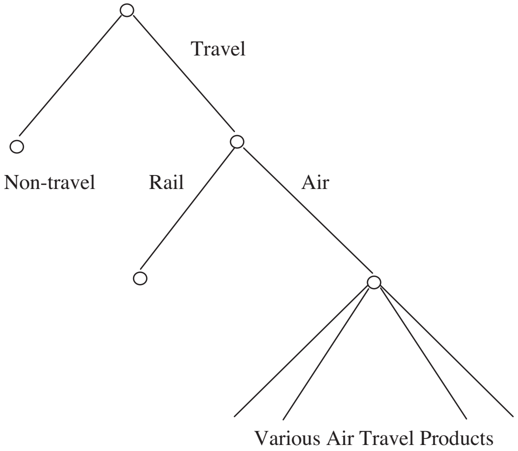
$$u_{ijm} = X_{jm}B - \alpha p_{jm} + \xi_{jm} + \varepsilon_{ijm}, \tag{2c}$$

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, and 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 equation (3) models the choice as a tri-level nested logit model in which a traveller first chooses between travel and non-travel (outside choice); within the travel option the traveller then chooses between rail and air; finally, they choose an air product (unique combinations of airport, carrier, connection, and ticket class) if they choose the 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 normalised 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 normalised 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 maximisation for all levels of explanatory variables. Figure 1 describes the 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 that of Berry *et al.* (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 decisions.
(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 travellers 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:

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

The 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 is:

$$E[\xi_j \cdot h(z_j)] \quad \text{is} \quad G(\Theta) \equiv M^{-1} \sum_{m=1}^{M} \sum_{j=1}^{J_m} \xi_j(\Theta) \cdot h(z_j),$$

where $\xi_j(\Theta)$ express ξ_j as the function of all unknown parameters (Θ). An estimator under the framework of the 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 minimised. 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) to (8), to express ξ_j as the function of unknown parameters and data. This step can be done by iterating the following system of equations:

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

and:

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

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

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[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.

The consistent estimate to the covariance matrix of the estimator is as defined in Berry *et al.* (1995):

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

where:

$$\Psi = \left.\frac{\partial G(\Theta)}{\partial \Theta}\right|_{\Theta=\hat{\Theta}}, \tag{13}$$

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

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

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

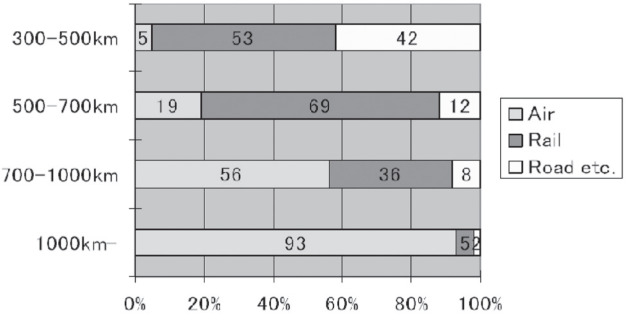
In equation (15), $S_m^o \equiv (S_{1m}^o, S_{2m}^o, \ldots, S_{J_m m}^o)$ is the vector of observed market shares in market *m*.

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 with each other in the distance range of 300 to 1,000 km. As shown in Figure 2, rail market shares are 53 per cent, 69 per cent, and 36 per cent for 300–500 km, 500–700 km, and 700–1,000 km distance ranges, respectively. Airlines' market shares are 5 per cent, 19 per cent, and 56 per cent, respectively for the same distance ranges in intra-Japan markets. Yamaguchi *et al.* (2008) also compare HSR and air fares in some of the representative routes, and confirm that air–HSR competition is most intense in markets within 1,000 km. In particular, airlines often set discount fares significantly lower in the markets where they compete with HSR, while HSR does not

Figure 2

Modal Shares in the Japan Intercity Passenger Market



Source: Yamaguchi *et al.* (2008).

appear to be using discount fares effectively as a competitive tool to compete with airlines.

While we will investigate the intercity transport markets throughout Japan, for the purpose of data compilation we divided the Japanese domestic market into twenty-four 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, the following data sources have been used in the compilation of the variables for the empirical estimation.

3.1 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, and 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 the ‘outside option’ in the specification.

3.2 Attributes of services

- Attributes of airline products including air fares are constructed from the MIDT booking information.
- The price of rail travel and travel time of rail and air in a market are obtained from the 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.
- The distance of a route/market (distance between two zones) is obtained from the MLIT.
- The number of departures and total seat capacity of an airline in a market are compiled from airline scheduling data, the Official Airline Guide (OAG) database.

3.3 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). The 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.

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

- 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 the 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 summarised in Table 1. Most parameters have the expected signs. In estimation, price coefficients in the two levels were constrained to be the same (rail versus 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, and so on) 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); and 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 travellers see different air classes as much closer substitutes than air versus rail choice, and thus justify the air mode's nest structure in our logit model (that is, 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 as very closely substitutable, the possibility of air–rail substitution is still stronger than that of substitution between air or rail and an outside choice (no travel, intercity buses, car driving, and so on).

(c) Our results show that air travellers exhibit a strong aversion to connecting flights and a strong preference for flight frequency. Only 11 per cent of domestic air travellers flew connecting flights during our sample period. On average, travellers are willing to pay about \$106 to avoid a connection, about \$42 for an hour of time-saving,[5] and about \$2 for one additional weekly flight.

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[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 travellers in domestic market are business travellers, their average wage is likely to be much higher than \$32. Therefore, the value of time-saving is roughly equivalent to the hourly wage.

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 (hours)	−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 versus 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)
Distance square × Rail travel dummy	4.2771 (2.361)
Variables affecting travel versus 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 versus rail) choice	0.8421 (0.093)
Willingness-to-pay summarised 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

Note: Standard error in parentheses.

(d) Within the air–rail travel choice market, as expected, the demand for rail and its market share decreases with distance.

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 per cent and 50 per cent 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 change of causal variables such as in our case (10 per cent and 50 per cent 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 ⇐ 500 km)	% change of air travel demand in long-haul (distance > 500 km)
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 ⇐ 500 km)	% change of rail demand in long-haul (distance > 500 km)
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 ⇐ 500 km)	% change of air + rail demand in long-haul (distance > 500 km)
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 (for example, when airfares decrease by an average of 10 per cent, air mode's own demand increases by 13 per cent and 16.3 per cent in the short-haul and long-haul markets, respectively). The effects on overall travel volume in intercity markets will be negligible. However, if new entrant LCCs are as aggressive as their American and European 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 per cent and 50 per cent 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 per cent (50 per cent).

(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 intercity markets. This is probably because these latter modes are already providing high-frequency services. Table 4 presents the effects of reducing rail mode's travel time by 10 per cent and 50 per cent on the demands for air and rail travel modes.

Table 3

Demand Response with Respect to Air Flight Frequency Changes (Elasticity Values in Parentheses)

Air demand (own) response with respect to flight frequency change

Increase weekly air departures frequency by	% change of air travel demand in short-haul (distance ⇐ 500 km)	% change of air travel demand in long-haul (distance > 500 km)
10%	3.91 (+0.39)	4.23 (+0.42)
50%	18.01 (+0.36)	18.93 (+0.38)

Rail demand (cross) response with respect to flight frequency change

Increase weekly air departure frequency by	% change of rail travel demand in short-haul (distance ⇐ 500 km)	% change of rail travel demand in long-haul (distance > 500 km)
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 ⇐ 500 km)	% change of air + rail travel demand in long-haul (distance > 500 km)
10%	1.91 (+0.19)	3.43 (+0.03)
50%	8.83 (+0.18)	15.23 (+0.30)

When rail travel time is reduced by 10 per cent (50 per cent), air travel demand decreases by 7.04 per cent (27.33 per cent) and 2.18 per cent (14.92 per cent) in the short-haul and the long-haul markets, respectively. In response to the same 10 per cent reduction (50 per cent reduction) of rail travel time, the rail mode's own demand would increase by 25.45 per cent (230 per cent) and 55 per cent (1,029 per cent), respectively, in

Table 4

Demand Response with Respect to Rail Travel Time Change

Air (cross) demand response with respect to rail travel time change (elasticity values in parentheses)

Reduce the rail travel time by	% change of air travel demand in short-haul (distance ⇐ 500 km)	% change of air travel demand in long-haul (distance > 500 km)
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 ⇐ 500 km)	% change of rail travel demand in long-haul (distance > 500 km)
10%	25.45 (+2.55)	54.95 (+5.50)
50%	230.32 (+4.61)	1,028.99 (+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 ⇐ 500 km)	% change of air + rail travel demand in long-haul (distance > 500 km)
10%	7.21 (+0.72)	9.44 (+0.94)
50%	51.95 (+1.04)	158.04 (+3.16)

the short- and long-haul markets.[6] Overall, the 10 per cent (50 per cent) reduction of rail travel time would increase the total air plus rail demand by 7.21 per cent (51.95 per cent) and 9.44 per cent (158 per cent) in the short- and long-distance markets, respectively. In summary, super HSR services will cause substantial modal shift from air to HSR. However, the most significant effect is due to the 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 per cent, our total net traffic stimulation effect reported in Table 4 indicates that the Tokyo–Osaka traffic would be stimulated by 52 per cent.[7]

5.0 Effects of CO_2 Taxation on Air–HSR Competition

Global warming and climate change effects have been at the forefront of all transport infrastructure planning in recent years. It is well known that life-cycle CO_2-costing literature indicates that rail transport is far more CO_2-friendly than air transport. In this context, the EU Commission has announced its plan to require all international flights landing and/or taking off at any European airport to purchase CO_2 certificates by putting them under the Emissions Trading System (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 the Tokyo–Osaka market as the amount of carbon tax on CO_2 emission is varied (see Table 5). Kato and Shibahara (2006) and Hayashi (2007) found that Japanese HSR had a significantly lower average CO_2 emission per passenger-km (average 18.2 g per PKM) than aviation (117.25 g per PKM), buses (70 g per PKM), and private cars (140.65 g per PKM).

We apply this average CO_2 emission statistic for air and Shinkansen HSR modes, and simulate how traffic volumes and market shares for air and HSR modes would change in the Tokyo–Osaka market, 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 travelled intercity markets in the world. Furthermore, these two cities are the two end points of the route for which the Japanese government recently approved the JR-Central's application to construct the superconducting maglev HSR with a maximum speed of 580 km per hour. In 2005, the latest year for which the Japan national transportation survey data were available at the time of our data

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[6] Although at first glance the 1,029 per cent increase in rail mode's travel volume in the long-distance routes in response to a 50 per cent 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 1,000 km or longer (700–1,000 km distance) is only about 5 per cent (36 per cent), while the airline share is 93 per cent (56 per cent) (see Figure 2). Introduction of the maglev super HSR would induce virtually all travellers over 500–1,000 km to switch from air to the super high-speed mode.

[7] Tokyo–Osaka air distance is about 401 km and the planned super HSR distance is 420 km, while the current HSR Shinkansen distance is 515 km. The maglev service is expected to end the air services on this route.

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

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 and Shibahara (2006)	124.5	18.3	14.2	43	n.a.	116.3
Average	117.3	18.2	18.1	46.5	70	140.7

Table 6
Simulated Rail Market Shares in Tokyo–Osaka Market at Different CO_2 Taxation Level (Air Share = 100% – Rail Share)

CO_2 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

collection, Shinkansen (HSR) transported 37,653,000 one-way passengers (81.31 per cent), while airlines carried 8,655,000 one-way passengers (totalling 46,311,000 air and HSR passengers) on the Tokyo–Osaka OD market.

It is assumed in our simulations that CO_2 taxation will be 100 per cent passed on to passengers. We are forced to make such a simplification because we do not have reliable cost data for airlines and HSR operators, which are needed for the modelling of stakeholders' strategic response to taxation.[9] Therefore, our estimate on traffic volume reduction due to CO_2 tax is likely to be an upper bound. The counter-factual simulation results are summarised in Table 6 and Figure 3.

Table 6 shows that the rail market share on the Tokyo–Osaka route would have increased from 81.31 per cent to 83.52 per cent, an increase of 2.51 percentage points if €100 per tonne carbon tax were imposed. Although this is a relatively small percentage shift, it represents nearly 1 million more rail passengers — not a negligible number. This happens largely because the airfares would have increased on average by 4.23 per cent, while rail fares would have risen by only 0.87 per cent.

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 CO_2 taxation increases from €0 per tonne (no tax) to €150 per metric tonne. For example, a €100 tax per tonne of CO_2 emission would have increased air fares by 4.24 per cent and rail fares by 0.86 per cent, and air traffic would have fallen 14.4 per cent to 7,478,156 passengers while rail traffic would have increased by 2.5 per cent to 38,575,556 passengers.

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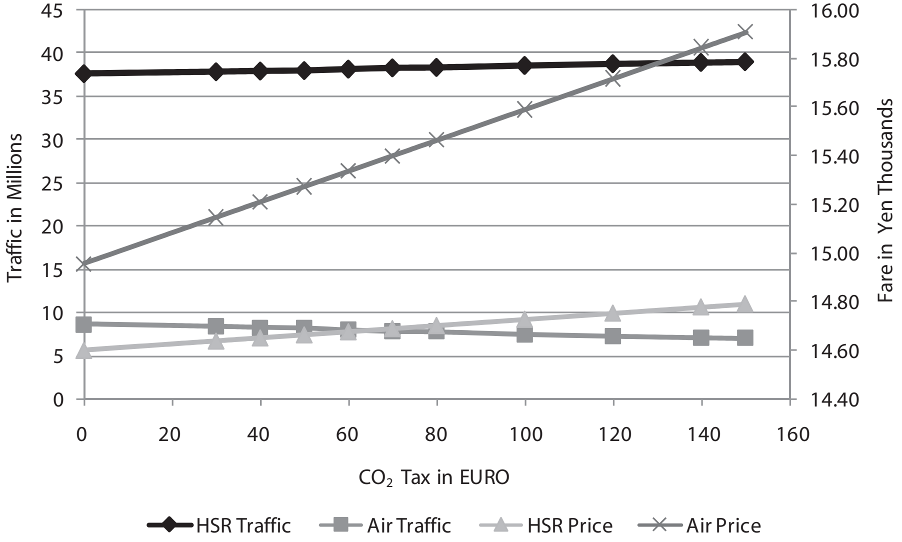
[9] For modelling of strategic/competition effects of taxation, see, for example, Heijnen and Kooreman (2006).

Figure 3

Air and HSR Traffic Growth Versus CO_2 Tax: Tokyo–Osaka Market



In sum, our counterfactual simulation on the effects of the CO_2 externality taxation on the Tokyo–Osaka market shows a moderate effect in terms of percentage change. In terms of traffic volume, however, the CO_2 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 intercity passenger transport market, yet there have been no comprehensive studies investigating consumer preferences about rail and air services using updated market data. This study estimates travellers' preference and choice behaviour via a tri-level nested logit model. By including the choice between 'air–rail travel' versus 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 GMM method.

The statistically significant difference of the inclusive value (from 1.0) for the air–rail choice justifies our treatment of this separately from the 'outside choice' (no travel, car-driving, buses, and so on) in our model, because in Japan's intercity travel market the air–rail substitutability is significantly higher than that between air or rail and the outside choice (car, bus, no travel, and so on). 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 for each other, and, as such, this justifies including a choice branch for airlines and fare classes in our nested logit model. This also implies that there is a 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 travellers 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 sizeable modal switch from rail to airlines.
- Travel time is of great importance to Japanese travellers. For example, a 50 per cent 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 effects 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 travellers' average hourly wage.
- CO_2 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 is a need for further studies on Japan's intercity transport markets, travel choices, 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. The natural extension of our work is to separate out the intercity bus mode and private auto-driving from the '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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