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Technical Efficiency, Regulation, and Heterogeneity in Japanese Airports

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Abstract: In this paper, the random stochastic frontier model is used to estimate the technical efficiency of Japanese airports taking into regulation and heterogeneity in the variables. The airports are ranked according to their productivity for the period 1987 to 2005 and homogenous and heterogeneous variables in the cost function are disentangled. Policy implication is derived.

Keywords:
Japan; airports; efficiency; random frontier models; policy implications

1. Introduction

This paper explores the use of random technical efficiency as an instrument for assessing the technical efficiency of Japanese airports, combining operational and financial data. The random frontier model allows for heterogeneity in the data and is considered the most promising state-of-the-art modelling available by which to analyse cost functions (Greene, 2005). The advantages of this method over alternative models are twofold. First, it allows for the error term to combine different statistical distributions. Second, it uses random parameters; i.e., parameters that describe factors not linked to observed features on the cost function. This type of estimation disentangles the explanatory variables to determine which of them must be treated in a homogeneous way and which are heterogeneous and must be managed by segments.

Efficiency has been the focus of much recent research (Fung et al., 2007; Kamp and Niemeier, 2007; Oum et al., 2004). Moreover, the increased competition among Japanese airports resulting from deregulation and liberalisation has placed the airport companies in a much more competitive environment. As a result, airports are now under pressure to upgrade their efficiency relative to their competitors. Benchmarking analysis is one of the ways to drive airports towards the frontier of best practices (Yoshida and Fujimoto, 2004).

Previous research on airports efficiency has employed both either data envelopment analysis (DEA), or the homogeneous stochastic frontier model. However, the later have tended to use homogenous frontier models that assume all units are homogenous. Here, we adopt a modified frontier model to look at the efficiency of Japanese airports.

The paper is organized as follows: In section two the institutional setting and the the background theoretical hypothesis are presented. In section 3, the method is presented. In section 4, data and results are presented. Finally, in section 5 the discussion and conclusion is presented.

2. Background and Hypothesis

2.1. Institutional Setting

Japanese airports have been heavily regulated under Airport Development Act and the airport development special account (Air transport policy in Japan is provided in Appendix). Series of Five-Year Airport Development Plans, funded by a pooled budget of special account, acted as a soft-budget constraint to the government, and resulted in excessive development and an increase in the number of regional airports, however, developments and expansions of major airports such as Narita and Haneda faced difficulties and stayed stagnant. In the background is the fact that regional governments has no incentive to cooperate in the process of major-airport development as they are typically recognized as NIMBY by local residents, where only one exception is Chubu airport: Chubu was developed recently via strong private initiative and received full local support. As a result, unbalanced domestic aviation system has resulted, with excessive capacity in many regional airports while major airports in Tokyo area are facing capacity constraint.

Only in 1996, the seventh Five-Year Airport Development Plan rectified its policy target to emphasizing the development of trunk-route airports in metropolitan areas. This finally gave an end to the history of old-fashioned airport development policy in Japan started in 1970. In 2003, the Airport Development Plans are merged into Social Infrastructure Key Improvement Plan. Thereupon the political environment and its policy targets final changed from the development of regional airports to the better utilization and efficiency improvement of existing airports, as well as more focused capacity investment into the hub airports in Tokyo area. Now, the construction of a new runway at Haneda and expansion of the second runway in Narita are under way, which will slacken the capacity constraint of these airports, though, only to a certain extent.

Research on Japanese airports have emphasised the economic restructuring and political process of decision to construct airports, blaming the political system for excessive construction, Ohta (1999), Feldhoff (2002, 2003). Technical efficiency of the Japanese airports has been analysed by Yoshida (2004) and Yoshida and Fujimoto, (2004). The Japanese airports has undergone regulatory reforms first on 1998 and then in 2000, to de-regulate the entry in the business.

A committee on the future of airports under the Ministry of Land, Infrastructure, and Transport formed in July 2007 suggested a drastic change in Japanese aviation policy through a major revision of Airport Development Act after a half century. Background of this major revision is a progressed deregulation and liberalization since 1998, during which airlines' reform proceeded much faster and further than that of airports by far, and the need to enhance airports' operational managerial efficiency. The revision, which received a cabinet approval in March 2008, gave itself a new name, "Airport Act," deleting the term "Development." In this new Airport Act, definition of three airport categories were abolished in a way that all airports are divided into major international airports and all others, and surprisingly Osaka International airport (Itami) joined the "all others" among the category-1 airports.

Table 1: Characteristics of the Japanese Airports analysed (2005)

Airport	IATA code	WLU	Number of Employees	Runway Length
Narita International	NRT	53780320	853	6180
Tokyo-International	HND	70028650	304	8500
Osaka International	ITM	20492120	123	4828
Asahikawa	AKJ	1275780	11	2500
Wakkanai	WKJ	245130	6	2000
Kusiro	KUH	1020520	8	2500
Hakodate	HKD	2258570	27	3000
Sendai	SDJ	3412800	23	4200
Akita	AXT	1386080	62	2500
Niigata	KIJ	1274710	41	3814
Kochi	KCZ	1584060	35	2500
Nagasaki	NGS	2803060	325	4200
Kumamoto	KMJ	3407380	36	3000
Oita	OIT	1994810	175	3000
Miyazaki	KMI	3245710	133	2500
Kagoshima	KOJ	6155790	51	3000
-	Mean	10897843	138.31	3638.88
-	Median	2530815	46.00	3000.00
-	Stdev	20677624	215.2725	1692.454

2.2. Literature Survey

Research on airports uses either DEA models or stochastic frontier models. DEA models include Gillen and Lall (1997, 2001) who analyzed USA airports with DEA-BCC model and the Malmquist index. Murillo-Melchor (1999) analyses Spanish airport efficiency with a Malmquist index. Parker (1999) analyses UK airports with DEA-CCR and DEA-BCC model. Sarkis (2000) analyse the technical efficiency of USA airports with several DEA models, including DEA-CCR and DEA-BCC. Adler and Berechman (2001) analyzes European airports with the DEA-BCC model. Pels, Nijkamp and Rietveld (2001) analyses the technical efficiency with a DEA-BCC model. Fernandes and Pacheco (2002) analyses Brazilian airports with a DEA model. Pels, Nijkamp and Rietveld analyze European airports with DEA-BCC model. Sarkis and Talluri (2004) analyze the technical efficiency of USA airports with DEA-CCR and the Doyle and Greene (1994) model. Barros and Sampaio (2004) analyze Portuguese airports disentangling technical and allocative efficiency. Fung, Wang, Hui and Law (2008) analyze China airports with a Malmquist DEA model. Barros and Dieke (2007) analyze Italian airports with several DEA models.

Papers using stochastic frontier models include, Pels, Nijkamp and Rietveld (2001, 2003) who analyse European airports with a homogenous frontier model; Yoshida (2004) and Yoshida and Fujimoto (2004) who analyze on Japanese airports with an endogenous weight method, Barros (2008a) who analyzes Portuguese airports with a homogenous stochastic frontier model and Barros (2008b) who analyze the UK airports with a random frontier model. The present paper contributes to this literature with a random frontier model.

2.3. Economic Regulation

The economic regulation of infrastructure services is desirable and necessary where markets are imperfect and lack a competitive environment, such as the case of the natural monopoly, or where competition takes place, but without fulfilling the required conditions (Crew and Kleindorfer, 1996). When these circumstances exist at airports, they may lead to misuse by the operators who provide an inefficient service with high prices and a poor quality.

Many airports' characteristics call for regulation, particularly their monopolistic features with economies of scale, scope and density which foster the exercise of market power (Czerny, 2006; Basso, 2008). In addition, they have ample asymmetric information (moral hazard and adverse selection), very high and long-lived (sunk) assets and both negative and positive externalities. Nevertheless, airports, in general, always face some type of economic regulation. The issue is to decide the type of regulation to adopt, taking into consideration the possible consequences of the choice, between a cost-based regulation like the American rate-of-return regulation, or a price- based form like the incentive regulation, such as price or revenue cap regulation or yardstick methods. The major difference between them resides in the incentives they offer the regulated industries towards cost minimization. In this case, the latter is superior but, from another perspective, the risk is clearly greater and can lead to underinvestment and to a lower quality of service Littlechild (2003).This paper attempts to test this hypothesis for the yardstick regulation is beneficial for efficiency of the Japanese airports, comparing the period without regulation with the period with regulation.

2.4. Heterogeneity

Unobserved heterogeneity has been a subject of concern and analysis in many recent works such as Chesher (1984) and Chesher and Santos Silva (2002). Neglecting this is likely to lead to inconsistent parameter estimates or, more importantly, inconsistent fitted parameters. From an econometric perspective, there are two types of heterogeneity: First, it is related to observed variables of airports, which is described as observed heterogeneity, and second it cannot be related to the observed variables, which is known as unobserved heterogeneity. The former is captured by entering the relevant variable into the model, while the latter is captured by entering random parameters into the model. Thus, the aim of this research is twofold: first, to analyze technical efficiency of Japanese airports and take into account the nature of the unobserved heterogeneity in the variables of the airports analyzed; second, to analyze regulation and their relationship with the estimated technical efficiency scores.

3. Method

The methodological approach adopted here is the stochastic production econometric frontier. The frontier measures the difference between inefficient units and the efficiency frontier by looking at the residuals that are assumed to have two components: noise and inefficiency. The general frontier cost function:

$$Y_{it} = f(X_{it}) \cdot e^{v_{it} - u_{it}} \; ; \forall \ \mathrm{i} = 1,2,\ldots N; \forall \ \mathrm{t} = 1,2,\ldots T \tag{1}$$

where Y_{it} is a scalar production of the decision-unit i under analysis in the t-th period; X_{it} is a vector of input variables present in the production function. The error term v_{it} is assumed to be independent and identically distributed and represents the effect of random shocks (noise). It is independent of u_{it}, which represents technical inefficiencies and is assumed to be positive and to follow a $N(0, s_u^2)$ distribution. The disturbance u_{it} is reflected in a half-normal independent distribution truncated at zero, signifying that the production of each airport company must lie on or above its cost frontier, implying that deviations from the frontier are caused by factors controlled by the airport company management. The variance of u_{it} is $\sigma_u^2 (\pi-2)/\pi$.

The parameterization.of the different elements to the total variation is given by: $\sigma_v^2 = \sigma^2 / (1+\lambda^2)$ and $\sigma_u^2 = \sigma^2 \lambda^2 / (1+\lambda^2)$; where $\lambda = \sigma_u / \sigma_v$, which provides an indication of the relative contribution of u and v to $\varepsilon = u - v$. because estimation of equation 1 yields merely the residualε, rather than u, the latter must be calculated indirectly (Greene, 2003). For panel data analysis, Battese and Coelli (1988) used the expectation of u_{it} conditioned on the realised value of $\varepsilon_{\mathrm{it}} = u_{\mathrm{it}} - v_{\mathrm{it}}$, as an estimator of u_{it}. In other words, $E[u_{it}|\varepsilon_i]$ is the mean productive inefficiency for airport company i at time t. But the inefficiency can also be due to the airport companies' heterogeneity, which implies the use of a random effects model:

$$Y_{it} = (\alpha_0 + w_i) + \boldsymbol{\beta}'\mathbf{x}_{it} + v_{it} - Su_{it} \tag{2}$$

where the variables are in logs and w_i is a time-invariant specific random term that captures individual heterogeneity. u is the time varying inefficiency. The sign of the inefficiency term, S, depends on whether the frontier describes production or cost. Any heterogeneity is either absent or contained in the production function absorbed in two parameters, first, the time invariant w_i, which is interpreted as 'producer inefficiency due perhaps to omitted inputs and in the inefficiency time varying term u.

The model is estimated in the following form:

$$
\begin{aligned}
&Y_{it} = \alpha_i + \beta' x_{it} + v_{it} + u_{it} \\
&v_{it} \sim N\left[0, \sigma_v^2\right] \\
&u_{it} = \left|U_{it}\right|, U_{it} \sim N\left[0, \sigma_u^2\right] \\
&\alpha_i = \alpha + w_i \\
&w_i \sim N\left[0, \alpha_w^2\right]
\end{aligned}
\tag{3}
$$

Concerning the stochastic specification of the inefficiency term *u*, the half-normal distribution is assumed to be time variant. For the likelihood function we follow the approach proposed by Greene (2005), where the conditional density is:

$$
f(\varepsilon_{it}) = \frac{\Phi(-\varepsilon_{it}\lambda/\sigma)}{\Phi(0)} \frac{1}{\sigma} \phi(\frac{\varepsilon_{it}}{\sigma}) \tag{4}
$$

where ϕ is the standard normal distribution and Φ is the cumulative distribution function. Conditioned on w_i, the T observations for airport i are independent.
The log likelihood is computed by simulation, Greene (2005, equation 31).

4. Data and Results

A balanced panel is used comprising 16 Japanese airports during 19 years from 1987 to 2005. The variables are presented in Table 2, where monetary magnitudes are expressed in thousand yens, deflated by the GDP deflator and denoted at prices of 2002. WLU is the work load unit, measured as 1WLU = 1 passenger = 100 kg of freight, a common measure in aviation, Graham (2005), Barros and Dieke (2008). Trend is a time variable to capture time effects in the production function. The inputs are the number of employees, runway area and buildings area. A contextual variable is added: Regul, capturing the effects of change in regulation on the throughput variable WLU. The specification of the production function follows microeconomic theory (Varian, 1987), adopting a Cobb-Douglas function. The costs are regressed in input descriptors.

Table 2: Descriptive Statistics of the Data

Variable	Description	Minimum	Maximum	Mean	Standard Deviation
WLU	WLU- work load unit, a common output measure in aviation management (Graham, 2005; Jessop, 2003, Barros and Dieke, 2008). 1 WLU = 1 passenger = 100 kg of freight.	108010	70028650	8941996	15800641
Trend	Trend variable	1	19	10	5.48
Employee	Number of workers	3	1059	185	266.93
Runway	Runway area, length times width in square metres	54000	1530000	279586	327787.5
Buildings	Floorage of buildings in square metres	3070	1160500	116745	217788.7
Regul	Dummy variable which is one for the years after 1998 when the airports restriction where	0	1	0.42	0.49

Table 3 presents the results obtained for the non-random frontier model and the random frontier model estimated using Nlogit and assuming a half-normal distribution specification for the cost function frontier. Regularity conditions require the cost function to be linearly homogeneous, non-decreasing and concave in input prices (Cornes, 1992). Applying the likelihood test, we conclude that the heterogeneous frontier is the most adequate functional form. In addition, we computed the Chi-square statistic for general model specification, which also advocates using the heterogeneous frontier.

Table 3: Stochastic panel cost frontier. Average value 1987/05

(Dependent Variable: Log WLU)

Variables Non-random parameters	**Non-Random Frontier Model** Coefficient (t-ratio)	**Random Frontier Model** Coefficient (t-ratio)
Constant	1.436 (5.238)*	—
Trend	0.038 (4.458)*	0.036 (4.903)*
Trend^2	-0.002 (-4.048)	-0.002 (-4.594)*
Log runway	0.478 (18.201)*	0.477 (27.429)*
Log buildings	0.755 (32.212)*	0.769 (40.915)*
Log employees	-0.00009 (-0.398)	0.00004 (0.539)
Deregulation	0.005 (0.064)	0.0008 (0.011)
Mean for Random Parameters		
Constant	–	0.724 (3.287)*
Scale Parameters for Distribution of Random Parameters		
Constant	–	0.341 (21.839)
Statistics of the model		
$\sigma = (\sigma_V^2 + \sigma_U^2)^{1/2}$	0.746 (2.898)	0.274 (4.285)
$\lambda = \sigma_U / \sigma_V$	2.731 (1.718)	0.04 (3.289)
Log likelihood	-70.821	-72.347
Observations	304	252

(* indicates that the parameter is significant at 1% level).

To differentiate between the frontier model and the production function, we consider the sigma square and the lambda of the production frontier model. They are statistically significant, implying that the traditional cost function is unable to capture adequately all the dimensions of the data. Furthermore, the random production function fits the data well, since both the R^2 and the overall F-statistic (of the initial OLS used to obtain the starting values for the maximum-likelihood estimation) are higher than the standard cost function. Lambda is positive and statistically significant in the stochastic inefficiency effects, and the coefficients have the expected signs.

The variables have the expected signs with all production elasticities being positive. Production increase along the trend and decreases with the square trend and, increases significantly with the runway and buildings. Moreover, constant is heterogeneous statistically significant variables. The statistically significant random parameters vary along the sample. The identification of the mean values of random parameters implies taking into account heterogeneity when implementing production control measures.

Based on the new frontier, the rankings are shown in Table 4, which indicates the average production efficiency for each Japanese airports across the sample defined as the ratio between the minimum cost and the actual cost. Hence, the closer to 1 is the ratio, the more efficient the airport. Given that the dependent variable has been transformed in logarithms, we compute:

$$EC = exp(-\hat{u}) \tag{5}$$

where the estimated value of the inefficiency ($\hat{u}$) is separated from the random error term ($\hat{v}$), using Jondrow et al. (1982) formula.

Table 4 demonstrate that each of the frontier specifications produce different scores, with the heterogenous frontier model displaying a higher level of relative efficiency. The average efficiency is 0.650 on the random or heterogeneous frontier but only 0.538 in the homogenous frontier. A comparison of the models reveals that the homogeneous scores present larger variances than those computed from the heterogeneous frontier, indicating that heterogeneity in variables contaminates the scores. Therefore, homogenous frontier models blur efficiency with heterogeneity, resulting in higher levels of efficiency, Greene (2004, 2005). Taking into account heterogeneity, the rankings change and the best practice is achieved by Tokyo airport.

Table 4: Average Cost Efficiency

		Homogeneous Frontier model	Heterogenous or random Frontier model
Observation	Japanese airports	Efficiency Scores	Efficiency Scores
1	Narita International	0.999	0.999
2	Tokyo-International	1.000	1.000
3	Osaka International	0.999	0.998
4	Asahikawa	0.320	0.425
5	Wakkanai	0.289	0.997
6	Kusiro	0.695	0.996
7	Hakodate	0.396	0.458
8	Sendai	0.326	0.349
9	Akita	0.228	0.245
10	Niigata	0.230	0.262
11	Kochi	0.479	0.670
12	Nagasaki	0.257	0.269
13	Kumamoto	0.355	0.395
14	Oita	0.327	0.356
15	Miyazaki	0.725	0.995
16	Kagoshima	0.998	0.998
	Mean	0.538	0.650

5. Discussion and Conclusion

This article has proposed a simple framework for the comparative evaluation of Japanese airports rationalization of their operational activities. The analysis was carried out through implementation of a random or heterogeneous stochastic frontier model, which allows for the incorporation of multiple inputs and outputs in determining the relative efficiencies and the inclusion of heterogeneity in the data.

The main policy implication of our findings is that heterogeneity must be considered a major issue in the Japanese airports. Accordingly, public policies towards these companies should take into account such heterogeneity. Relative to results of the model, the production increases alongside with the trend which signifies that technological improvements are present in the Japanese airports during the period to drive up the production. However, production increases at decreasing rate. Moreover, the production significantly increases homogenously with runways and buildings. It also rises with the constant, but in a random way. The significant random parameter varies along the sample. The identification of the mean values of random parameter implies having into account the heterogeneity when implementing policies for production control. However, employees and deregulation are not statistical significant parameters.

What is the rationality of this result? This is an intuitive result, since these airports are not homogenous. There are small and large and medium sized companies. These visible characteristics translate into different performances obtained in the market, resulting in different clusters within the market. These clusters are distinguished from each other based on the constant, signifying that time invariant heterogeneity is the kind of heterogeneity we find in these airports. This result also signifies that other inputs are relatively homogenous. With regard to runways and buildings, this means that competition over resources drives the market and translates into homogenous dynamics in the inputs.

In comparison with the previous literature in this area, our research overcomes the bias towards DEA models in studies on airport efficiency. The prevalence of DEA models in this research field exhibits the problem of the short data span. The comparison between homogenous and heterogeneous frontier models is undertaken in the present research, concluding that heterogeneity better captures the cost structure of the Japanese airports. Possibly, the main limitation of the present research relates to the number of units analysed, which is, to some extent, short for econometric purposes. Therefore, a larger data set is needed to confirm the validity of the present results. Future extensions of the present research include the analysis of the effects of public-private relationship and the role of competition on the efficiency of Japanese airports.

Appendix: Air Transport Policy in Japan

(1) Formation of Civil Aviation System in Japan: The 45/47 Regime

Soon after the civil aviation resumed its service in 1951, following the enactment of Civil Aeronautics Law in 1952, Japan Airlines (JAL) was established in 1953 as a state-owned enterprise. The government designated JAL to be the only operator in international routes, while it allowed other airlines to be operating in domestic routes.

As the competition became intensive in the domestic markets with rising demand, the government tried to alleviate the competition via regulation. The Transport Policy Council of the Ministry of Transport announced a Recommendation of 1970 which was followed by the Ministerial Order of 1972. These successive policies made clear that air transport markets in Japan are classified into three groups, for each of which only a designated airline is allowed to operate. The first of these three groups is the international and domestic trunk routes, in which only JAL is allowed to operate. The second is the domestic trunk routes and some regional routes, where All Nippon Airways (ANA) is only allowed. The last is the other local routes, and Toa Domestic Airlines (TDA, later called Japan Air System or JAS) is designated to be the operator in these routes. This is the main component of the 45/47 regime, a regulatory framework that strongly governed Japanese aviation industry until it is gradually liberalized in the mid 80's.

(2) Market Access

It was more than ten years later from the formation of 45/47 regime that the government has turned its policy orientation to liberalization, and started to amend the route-based license system with supplydemand adjustment. The first step was to allow more than one airlines operating in the same market with substantial demand volume. For those routes with annual passenger volume of one million or more, triple tracking was allowed; for those with 700 thousand or more, double tracking was allowed.

These threshold values were lowered once in 1992, and then in 1996. It was only in 1997, the standard for double/triple tracking has been finally abolished. In terms of available seats, 47% were in monopoly routes in 1985 while in 1999 this ratio was only 10%. In the mid 80's, ANA was allowed to operate in international routes, and JAL was privatized completely in 1987.

In 1998 entrance regulation was completely lifted, and this deregulation has made new entry to Japanese domestic airline business possible for the first time in the past 35 years. The first of these entrants are Skymark Airlines and AirDo, who entered into Haneda-Fukouka and Haneda-Sapporo routes respectively. After the deregulation, an airline can enter on the permission basis. The permission is rendered on the company basis mainly based on the satisfaction of safety standards, instead of route basis in the old time. As a result, following the first new entry in 1998 by Skymark Airlines and AirDo, the number of airlines has steadily increased and became 25 by the fiscal year of 2003.

Also, the route setting and flight schedule has been liberalized to so-called "advance-submission system" in which operating routes, frequency, and schedule are decided at the discretion of airlines in principle. Yet, approval is still required when using congested airports such as Haneda and Narita airports. Slot allocation of congested airports is reviewed every five years from the viewpoint of both promoting competition and enhancing networks.

(3) Regulation on Airfare

Until the deregulation in the 90's, airfares in Japanese domestic aviation markets were reviewed and required an approval by the Civil Aviation Bureau of the Ministry of Transport. The background idea of this process is the cost-based fare setting so as to equate the total cost (with moderate profit) and the total revenue of airlines, which was common for other public utility industries as well back then.

As the political pressure for the public-utility reform rises in the mid 90's, deregulation of airfare has commenced. Following the partial introduction of submission system in place of approval system in 1994, Zone Approval System was introduced in 1996. Under this system, it was allowed to discount the actual fare up to 25% from the cap, which is the normal fare set as before according to the cost calculation. This system is called the Zone Approval System and first introduced in 1996.

After a drastic amendment of Civil Aeronautics Law in 2000, fare setting system has changed to the advanced submission system, where in principle, fare and charge are set at the discretion of airlines as well. Minister of Land, Infrastructure and Transport intervenes in the event of inappropriate and unfair fares and charges through the Minister's order only.

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