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Comparative Analysis on International Airline Industry

— Cost Approach to Measure an Industrial Inefficiency —

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Abstract

The primary purpose of this paper is to estimate an industrial inefficiency level for several airline firms, and to analyze a difference of the level in international scope. In judging the level of inefficiency, we use time series data for the estimation of a gap between theoretical frontier and real operational level. Using methods based upon the cost functional approach, we find that the managerial cost for Japan's airline firm is relatively higher than the one for other firms, including the United States, Europe, and Asia. We also find a relatively low level of operational cost for Singapore Airline which is marked for quite distinguishing efficient level.

1. Introduction

On the basis of conventional methodology for measuring inefficiency level, numerous studies, including Timmer [1], Aigner & Chu [2], Aigner・Lovel & Schmidt [3], and Cornwell・Schmidt & Sickles [4] have adopted empirical approaches using a frontier production function. Since the application of theoretical context of a duality to economic analysis has fostered rapid development of measurement techniques for modeling the structure of cost, researchers found that general functional representations of the structure of cost could be valid while maintaining classical restrictions on the underlying structure of production. The objective of this paper is to provide new estimates of inefficiency level for internationally well-known firms, including Japan's airline firms. In order to achieve the goal, we adopt a cost approach to estimating theoretical "frontier function". Estimation of frontier models leads us to calculate the gap between the optimal level and the real one. We proceed as follows. In section 2, we set forth the system to be estimated, with emphasis on the technique used to incorporate multi-outputs into the specification. In the third section, we show significant empirical results for various models. Then in section 4, we present calculated inefficiency level for each firm. Finally, we summarize the analysis and interpret the results in order to derive several implications on an industrial policy.

2. Conceptual Issues

2.1 Prior Analysis

Before turning to describe a framework for the estimation, we must draw attention to comparative analysis of data. For the present, it may be useful to look more closely at some of the more important features of respective firms at international market. Fuller discussion will be presented in the next section.

2.2 Functional Forms

The efficient transformation of a vector of inputs X into a vector of outputs Y can be represented by the general function:

$$f(Y_1, Y_2, Y_3, \cdots, Y_m, X_1, X_2, \cdots, X_n) = 0 \tag{1}$$

If f has a strictly convex input structure, then there exists a unique multiproduct cost function:

$$C = g(Y_1, Y_2, \cdots, Y_m, p_1, p_2, \cdots, p_n) \tag{2}$$

which is dual to the transformation function. A convex input structure for (1) is equivalent to (2) being homogeneous of degree one, and concave in the factor prices. Now we will enlarge this argument into a specification of models to be estimated. As to the formulation of specified models, necessary to estimate the frontier function, we face a restriction with respect to data. Since the data, acquired from annual statistics by ICAO, does not cover any input prices p_i, we shall confine our attention to no inputs model allowing multi-outputs. The basic model is now formulated as follows. First of all, 1-0 (one output and no input) model is given by

$$\ln C_t = \alpha + \beta_i \ln Y_{it} + 1/2\gamma(Y_{it})^2 + \epsilon_t \tag{3}$$

Then generalized 2-0 model, allowing multiple outputs, is characterized as

$$\ln C_t = \alpha + \beta_1 \ln Y_{1t} + \beta_2 \ln Y_{2t} + \sum_{i=1}^{2} \gamma_i \ln (Y_{it})^2 + \epsilon_t \tag{4}$$

These two models are adopted to estimate respective frontier model for each firm. Then, as a exception, 2-3 model is tested for Japanese three airline firms (JAL, ANA, and JAS) on the ground that we have data with respect to domestic firms. The model is given by

$$\ln(C_t/p_3) = \alpha + \sum_{i=1}^{2}\beta_i \ln Y_{it} + 1/2\sum_{i=1}^{2}\sum_{j=1}^{2}\gamma_{ij}\ln Y_{it}\ln Y_{jt} + \sum_{h=1}^{2}\delta_h \ln(p_h/p_3) + 1/2\sum_{h=1}^{2}\sum_{g=1}^{2}\theta_{hg}\ln(p_h/p_3)\ln(p_g/p_3) + \sum_{i=1}^{2}\sum_{h=1}^{2}\rho_{ih}\ln Y_{it}\ln(p_h/p_3) + \epsilon_t \quad (5)$$

The third model is to be simultaneously estimated with cost share equations (S_{ij}).

Error term ϵ_{it} is assumed to consist of two components; gap term and standard error term. It is characterized by

$$\epsilon_{it} = u_{it} + \nu_{it}$$

where u_{it} is an inefficiency term, indicating a distance from the frontier, and ν_{it} is a standard stochastic term, satisfying classical assumptions. Term u_{it} is assumed to satisfy following conditions:

$$u_{it} \geq 0, \qquad E(u_{it}) = m_{it}, \qquad E(u_{it}^2) = \sigma_{uit}^2$$

Standard error term ν_{it} is characterized as

$$\nu_{it} \sim IID(0, \sigma_\epsilon^2)$$

as the one satisfying classical assumptions.

2.3 Process for Estimation

Those basic models (3), (4), and (5) are used to acquire frontier models as discussed above. OLS is adopted at first, since OLS residuals are necessary to enable a frontier likelihood function to work. Then residuals are necessary to be checked on the ground that a skewness of the residual tends to diverge[1] likelihood function if its skewness is not neutral. As the third step, specification of stochastic density function must be chosen. Numerous analyses such as Cornwell and Greene [5] proposed several kinds of density functions; half-normal, exponential, and truncated distribution. In this paper, half-normal distribution is applied according to the former attempt of Arai [6]. Now likelihood function for half-normal distribution is given by

$$l = \frac{N}{2}\ln\frac{2}{\pi} - N\ln\sigma + \sum_{k=1}^{K}\ln\left[1 - \Phi(-\frac{\epsilon_i t\lambda}{\sigma})\right] - \frac{1}{2\sigma^2}\sum_{i=1}^{N}\epsilon_{it}^2 \quad (6)$$

where $\mathbf{\Phi}$ indicates a standard normal density function, and following conditions

$$\epsilon_{it} = u_i + v_{it}$$

$$\sigma^2 = \sigma_u^2 + \sigma_v^2 \tag{7}$$

$$\lambda = \frac{\sigma_u}{\sigma_v} \tag{8}$$

are assumed to be satisfied. With these processes above, inefficiency level is finally measured as the final step.

3. Estimation of the Frontier Cost Function

3.1 Prior Analysis

It is desirable to describe a comparative analyses based upon observed data, before moving on to the main issue with respect to the estimation. All diagrams presented in this section have been derived from ICAO statistics published in the fiscal year 2000.

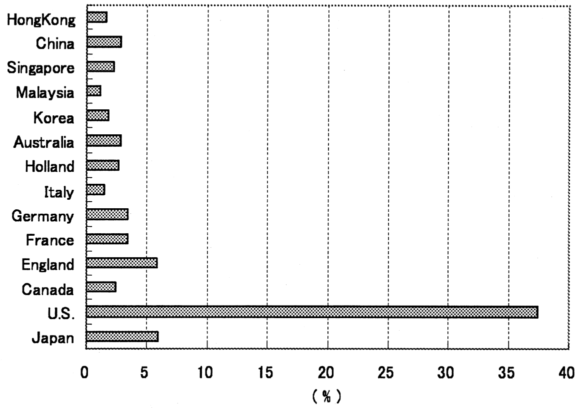

Figure 1. International Market Share in Airline Sector

The figure shown above indicates the market share for the airline industry in the world at the fiscal year 2000. The figure reveals quite high share that the United States occupies, and that the other countries remain at relatively low level.

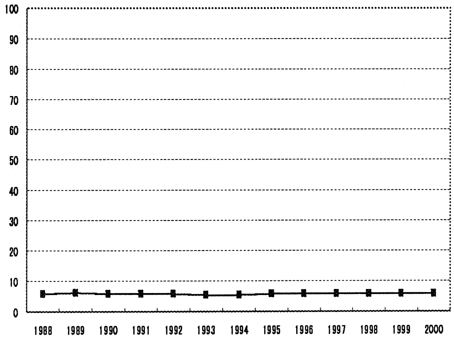

Figure 2. Japan's market share

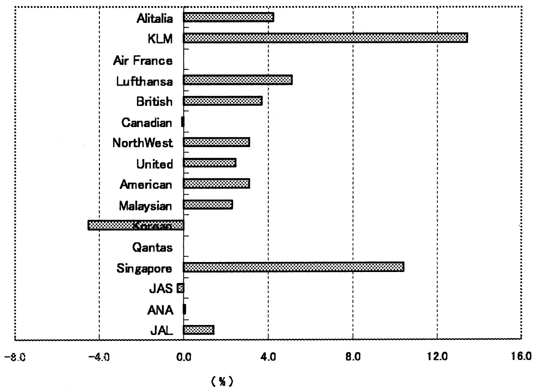

Figure 3. Profit Rate(Fiscal Year 2000)

Figure 2 shows Japan's share in the world market, and it is obvious that domestic three firms (JAL, ANA, JAS) has remained steady at a share of 5 percent so far. Figure 3 indicates respective profit rate for each firm. Airline firms within the United States make profits, and it is clear that both KLM and Singapore airline gain markedly higher benefit.

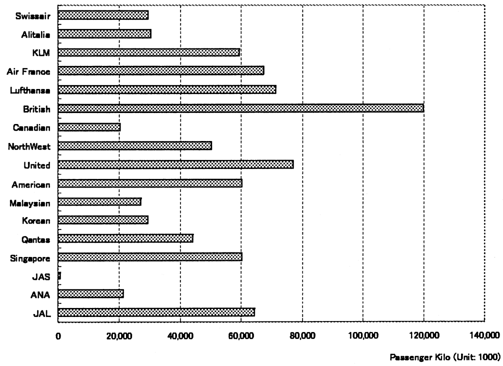

Figure 4. **Output** 1 **(passenger-kilo)**

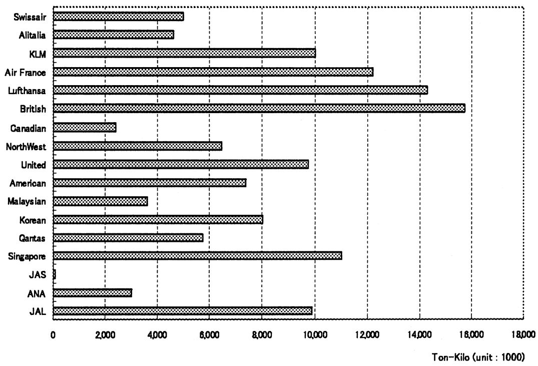

Figure 5. **Output** 2 **(ton-kilo)**

Diagrams shown above indicate two types of outputs that have been produced by airline services. The first output, measured by passenger- kilo, represents higher portion of American capital airlines, European lines, and Japanese firms. Similar feature can be pointed out for other output, ton-kilo, to a greater degree.

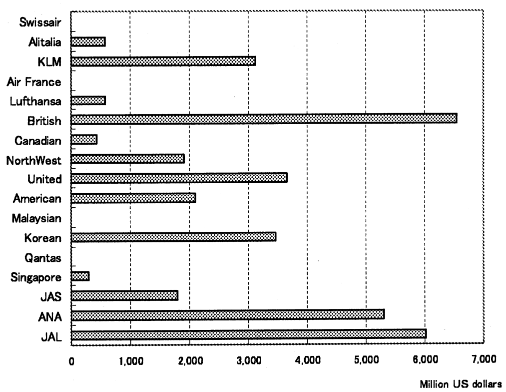

Figure 6. **Long-term Loans**

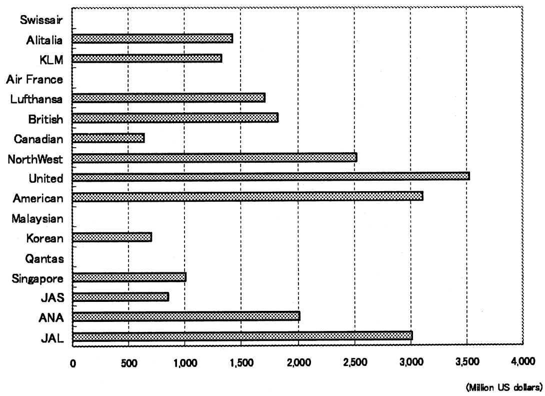

Figure 7. **Labor Cost**

Turning now to the cost structure with respect to production process. Figure 6 indicates a long-term loan, one of the elements that are concerned with investment by firms. As we can see from the diagram, the amount of capital cost (to put it the other way round) owned by both British Air and Japan Airline seems to be quite high. Relatively higher cost structure in Japanese firms may also be found in Figure 7, indicating labor cost.

3.2 Estimation of Frontier Cost Function

Having observed raw data and noticed relatively lower cost level of firms located in Asia, one can then go on to consider empirical results that are gained by proposed models described in the previous section.

Table 1. Results of Base Model (3)

	constant	trend	dummy	Q	Q^2
SIA	-1.4332	-	-0.1365	0.9096	0.2712
	(-6.324)	-	(-3.254)	(34.751)	(2.417)
MAS	1.2109	-	0.2654	0.8669	0.3554
	(2.201)	-	(2.784)	(15.412)	(2.107)
NWA	0.8214	-	0.3447	1.0012	0.4354
	(2.569)	-	(3.259)	(7.489)	(2.341)
SWR	-4.0214	-	-0.1654	1.1141	0.4892
	(-3.047)	-	(-2.254)	(8.764)	(1.987)
KLM	-0.5341	-	0.86478	0.9872	0.3179
	(-2.387)	-	(2.546)	(11.527)	(3.357)
QFA	-2.2932	-	-0.2201	1.0124	0.3975
	(-2.897)	-	(-2.188)	(11.934)	(3.451)
JAL	-2.5967	-	0.3184	1.0721	0.6216
	(-4.025)	-	(4.655)	(16.124)	(3.635)
7 Firms	0.0972	-	0.2234	1.0224	0.418
	(1.874)	-	(2.378)	(15.298)	(2.874)

	constant	trend	dummy	Q	Q^2
SIA	-2.1145	-1.2045	-0.2445	0.8835	0.2254
	(-2.001)	(-2.075)	(-3.225)	(19.012)	(2.064)
MAS	0.5412	0.0489	0.2654	0.8669	0.2897
	(3.022)	(1.789)	(2.784)	(15.412)	(2.049)
NWA	0.7115	1.3224	0.4112	0.9987	0.3784
	(2.887)	(2.142)	(2.751)	(6.541)	(2.238)
SWR	-3.211	1.0201	-0.2554	1.0589	0.4217
	(-2.543)	(1.888)	(-3.024)	(4.558)	(1.879)
KLM	-0.742	0.6311	0.7415	0.9779	0.2748
	(-2.114)	(2.454)	(2.234)	(3.569)	(2.981)
QFA	-2.1846	0.4778	-0.2349	1.0054	0.3157
	(-2.413)	(1.588)	(-2.654)	(12.345)	(3.217)
JAL	-2.4167	-0.4687	0.2145	1.0801	0.5741
	(-3.215)	(-2.415)	(3.225)	(7.159)	(2.925)
7 Firms	-1.2167	-0.5281	0.3458	1.0231	0.304
	(1.984)	(-1.764)	(3.012)	(11.379)	(2.424)

Elementary model to be tested at first in order for likelihood function to converge is a one-zero model, presented as equation (3) in the previous section. We have tested two types of one-zero models; no trend model and trend model. The results are described above in Table 1. The model having trend variable has succeeded in converging while no trend model has failed. Estimated parameters with respect to output variables seem to possess some similarities to a certain degree, that is, quite low cost reaction of Singapore Airline to an increase in output.

Table 2. Results of Base Model (4)

	constant	trend	dummy	Q_1	Q_1^2	Q_2	Q_2^2
SIA	-1.045	-1.4104	-0.3457	0.4417	0.2254	0.3927	0.1241
	(-2.540)	(-2.271)	(-4.345)	(12.314)	(2.064)	(2.571)	(1.551)
MAS	0.6714	0.0384	0.3467	0.4657	0.2897	0.4257	0.1954
	(4.241)	(1.541)	(3.217	(8.271)	(2.049)	(2.412)	(1.871)
NWA	0.4512	1.4178	0.3274	0.5417	0.3784	0.4927	0.2078
	(1.127)	(1.971)	(2.457)	(5.347)	(2.238)	(3.541)	(2.137)
SWR	-4.5410	1.3517	-0.3218	0.5749	0.4217	0.5849	0.2147
	(-2.821)	(1.781)	(-3.147)	(4.251)	(1.879)	(2.014)	(1.887)
KLM	-0.5421	0.4276	0.6127	0.4621	0.2748	0.4687	0.1943
	(-2.218)	(2.041)	(1.784)	(2.398)	(1.981)	(1.794)	(1.898)
QFA	-3.4517	0.3871	-0.3217	0.5833	0.3157	0.5412	0.2132
	(-5.319)	(2.489)	(-3.251	(4.241)	(3.217)	(2.017)	(2.216)
JAL	-1.3271	-0.5942	0.3218	0.6217	0.5741	0.4987	0.3041
	(-2.982)	(-3.172)	(3.179)	(3.237)	(2.925)	(2.454)	(1.538)
7 Firms	-2.1341	0.2871	0.3279	0.5631	0.304	0.4971	0.2235
	(-2.983)	(2.012)	(3.148)	(6.117)	(2.424)	(2.791)	(1.997)

Table 2 indicates the result of generalized two-zero model that allows multi-outputs process. It has succeeded in making likelihood function to converge when dummies are adopted, and has shown quite similar implication to the point that we have discussed in Table 1.

4. Computation of the Inefficiency Level

As mentioned before, error term ϵ_{it} can be decomposed to inefficiency term u_{it} and standard error term ν_{it}. As a significant feature to be noted, a conditional mean value for u_{it} is given by

$$E\left[u|\nu\right] = \sigma\lambda/\left(1+\lambda^2\right)\left[\phi\left(\nu\lambda/\sigma\right)/\Phi\left(\nu\lambda/\sigma\right) - \nu\lambda/\sigma\right] \quad (9)$$

when half-normal distribution is adopted. $\boldsymbol{\lambda}$ and $\boldsymbol{\sigma}$ are assumed to satisfy following conditions

$$\lambda = \sigma_u/\sigma_\epsilon, \quad \sigma = \left(\sigma_\epsilon^2 + \sigma_u^2\right)^{1/2}$$

at the same time. With the framework described above, we have found respective inefficiency level for each firm; Singapore, Malaysia, NorthWest, Swiss Air, KLM (Dutch Airline), Qantas Airways (Australia), and Japan Airline. The result is presented in Figure 8. In this diagram, the level of inefficiency can be interpreted to be quite high if $|u|$ value gets to be close to 1.

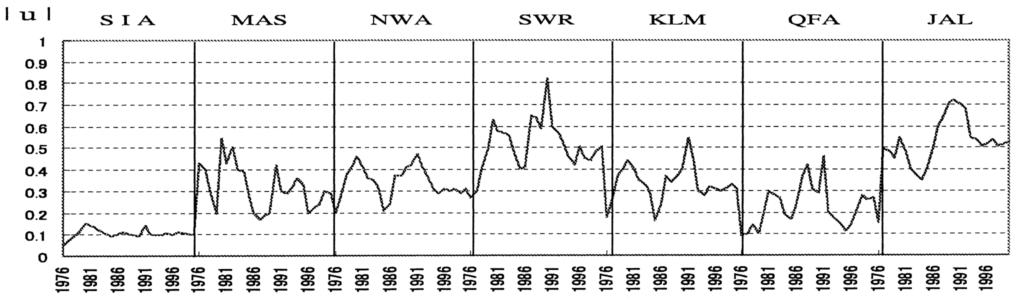

Figure 8. estimated X-inefficiency ··· in case of model (4)

As can be seen from the diagram shown above, we can say with fair certainty following points.

1. markedly lower inefficiency level of Singapore Airline
2. quite high inefficiency level of Japan Airline
3. sharp increase in inefficiency level for all firms during oil shock period ('74 - '75)
4. all firms indicating gradual decline of inefficiency level during mid '80s
5. reverse trend toward higher degree of inefficiency level in the late '80s and the early '90s
6. most of firms showing gradual decrease in inefficiency level after mid '90s except JAL

In comparison with previous analysis using raw data with respect to production process, the results of our experiment in this section are not contrary to those of implications that have been derived from former data analysis. Asian airline firms, including Malaysia and Singapore, have kept lower amount of expenditure to both capital and labor factor. Japan's airline firms, on the other hand, have kept increasing the investment and labor forces so far since early '70s. The difference with respect to the managerial decision making might affect the respective cost structure for each firm, and in case of Japan, it has taken a turn for the worse. The point as we mentioned with respect to Japanese airline operation seems reasonable from our observed results shown in Figure 8.

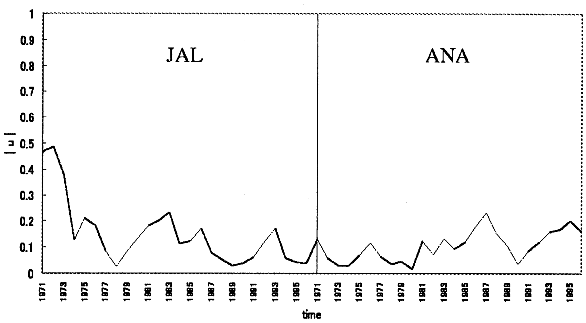

Figure 9. estimated X-inefficiency for Japan's airlines … model (5)

Due to the restriction of data, model specification adopted in this paper have been subject to no input framework. Since managerial data have been sufficient in case of Japan, we would like to present the results of inefficiency measurement with respect to JAL and ANA for reference. It should be noted that estimated ineffciency value of $|u|$ in this case of Figure 9 seems to be lower than the one with respect to previous results in Figure 8; however, it does not lead us to an implication that Japanese cost inefficiency has turned out to be improved in comparison with other international firms. Since trans-log functional form is adopted for computation in this case, there is no relevance to the previous implications. It; however, has shown us quite similar trend of cost structure with respect to domestic airlines.

5. Concluding Remarks

As can be seen from the computated cost inefficiency, we are able to classify seven firms into three groups. First group is marked by lower inefficiency level in terms of cost structure. Singapore airline is obviously a member of the group. Second group is characterized by the middle range of inefficiency level which is close to 0.3. MAS, NWA, KLM, and QFA can be interpreted as factors in this category even though the QFA's level seems to be lower than the one for others in some sense. Third group can be regarded as inefficient group with respect to cost structure. Swiss Air and Japan Airline may belong to the case.

We have found several similarities in transition to all three groups as mentioned in previous section. Exogenous shock of oil crisis has certainly affected the cost structure of all firms. Upward trend in cost efficiency in early '80s, and decline in efficiency level during the late '80s are found in most of the cases. The trend after mid '90s; however, seems to diverge to a certain degree. Singapore airline shows inefficiency level that remains steady, keeping the present level while Japan Airline indicates gradual rise in inefficiency.

There is considerable validity to the trend of Japan Airline since the cost level of both capital and labor seems to be quite high, as can be seen from the data analysis in section 3. It is possible to build up two hypotheses. The first point is a license fee which is well-known as the most expensive rental fee for the usage of airports in Japan, especially Narita and Kansai. Markedly high usage fee can play a role as one significant factor of "X-inefficiency" to push the cost structure exogenously. The second point is an excessive investment into both domestic and international assets during economic boom of 1990.

We have necessary processes that have not yet been tested in this paper. We have not tested multi-inputs model due to the restriction of data. Moreover, we need to rebuild the model specification in order to separate the license fee of airports. These two points are left unsettled in this point.

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Notes

1) In case of divergence, basic models have to be re-arranged within the framework of multi-outputs model.

References

[1] Timmer, C.P., "Using a Probabilistic Frontier Production Function to Measure Technical hspace Efficiency", it *Journal of Political Economy*, July, 1971.
[2] Aigner, D.J., and Chu, S.F., "On estimating the Industry Production Function", it *American hspace Economic Review*, September, 1968.
[3] Aigner, D., Lovell, C. and Schmidt, P., "Formulation and Estimation of Stochastic Frontier hspace Production Function Models", it *Journal of Econometrics*, 6, 1977.
[4] Cornwell, C., Schmidt, P. and Sickles, R.C., "Production Frontiers with Cross-Sectional and hspace Time Series Variation in Efficiency Levels", it *Journal of Econometrics*, 46, 1990.
[5] Greene, W.H., "Maximum Likelihood Estimation of Econometric Frontier Functions", hspace it *Journal of Econometrics*, 13, 1980.
[6] Keita Arai, "Cost Structure of Japanese Transport Industry", it *Osaka Economic Papers*, hspace p. 236, October, 1999.
[7] Caves, D.W., Christensen, L.R. and Swanson, J.A., "Productivity in U.S. Railroads, hspace 1951-1974", it *Bell Journal of Economics*, Spring, 11, 1980.

Appendix

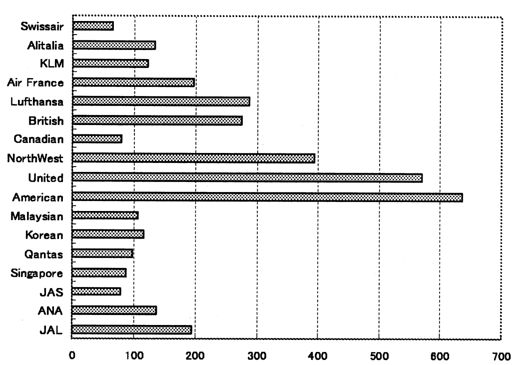

Figure 10. Number of Aircrafts

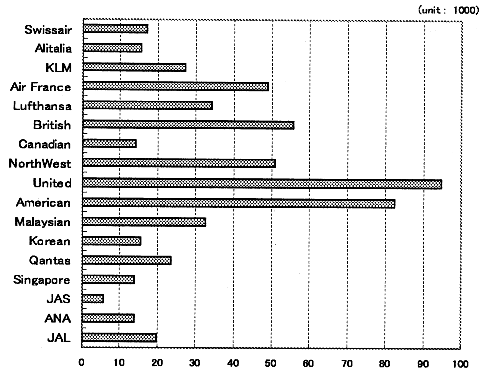

Figure 11. Number of Employees

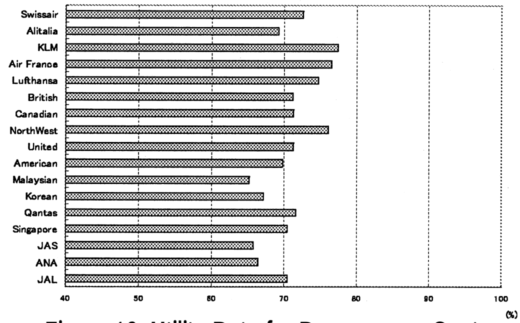

Figure 12. Utility Rate for Passenger's Seat

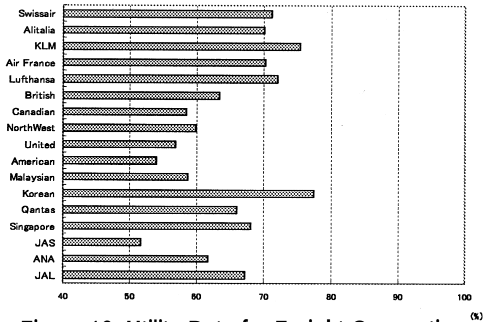

Figure 13. Utility Rate for Freight Occupation

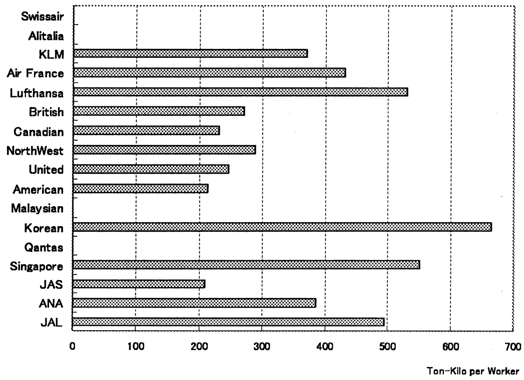

Figure 14. Labor productivity

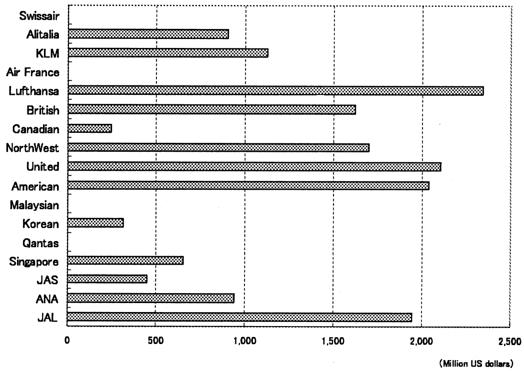

Figure 15. Labor cost & License fee