Empirical studies on efficiency in urban railways in Japan: Evaluation of relative performance and the determinants of persistent and transient efficiency

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This research aims to evaluate efficiency of urban rail system in Japan and to provide implications by estimating the model of stochastic production frontier analysis, which disentangles firm effects from persistent and transient inefficiency. In particular, this research identifies the effects influencing the efficiency by focusing on an ownership and system type as well as management strategies. We consider the efficiency as the service effectiveness indicating how the operators deliver produced service to passengers efficiently.
The results show that persistent inefficiency related to the firm's fixed characteristics is likely to dominate the operators technical inefficiency. Mostly, major private operators and overground system tend to perform well comparatively and it might be related to their strong motivation towards the market. In addition, the operator's temporary mistake in decision making or resource allocation barely influence the differences among the operators.

Urban railway SFA Persistent efficiency Transient efficiency

Urban rail systems are in a prime position among other transport modes in terms of sustainability and environmental reason within large metropolitan area of developed countries, as well as Japan. However, operators often have a rather vague perception of how efficient they are in providing transport service. Moreover, their situations are getting worse than before because of decrease in working population due to an aging society and competition with private cars and it urges railway operators to be competitive. Because urban rail systems have been experiencing rapid change of business environment, it is highly necessary that the firm or authority knows how it can deal with inefficiencies by deploying proper strategies in short- or long- term. Decomposing and estimating time invariant and variant inefficiencies in a same model and identifying the factors which influences each inefficiency will provide more precise and appropriate implications to this issue.

Considering all above mentioned, estimating and comparing inefficiency of urban rail firms are largely beneficial to assess and understand their performance in various aspects, thereby leading firms to make proper decision of strategies and authorities to design appropriate regulation. These measures are also advantageous over simple comparison of performance because of providing convincing insights as considering firms' strategic factors such as resource allocation and cost reduction in integrated way.

This research mainly aims to evaluate performance of urban rail system in Japan and to provide implications considering improvement of both technical and cost efficiency, by estimating the model which disentangles firm effects from persistent (time-invariant) and transient (time-varying) inefficiency. This research identifies exogenous factors influencing the efficiency by focusing on an ownership (private, public and quasi-public) and a firm's context (diversification) as well as environmental factors (population density, operating area). This research also analyses the differences on the cost structure of different ownership and system to investigate how it influences on the cost efficiency of the urban railway operators.

This research has been conducted by followings:

  1) Collecting data for quantitative research and literature review
      We mainly compose the dataset which consist of data of urban rail companies in metropolitan area of Japan from 2004 to 2015. As the first step of this research, previous literatures on the efficiency of public transport including passenger railway are reviewed in order to academically explore the factors which influence the technical and cost efficiency of railway companies. We also investigate the effect of historical background of railway development of each operator.

  2) Estimating production and cost function by stochastic frontier analysis
      We estimate both production frontier function and cost frontier function and the functional forms are defined by two ways, Cobb-Douglas and translog function. For estimation, a four-random-component stochastic frontier model and a maximum likelihood estimation method which are introduced by Kumbhakar et al. (2014) is applied and the estimated model allows to take into account simultaneously persistent and transient inefficiencies, unobserved heterogeneity, and random shocks. Finally, the level of each inefficiency is also compared by ownership and system type.
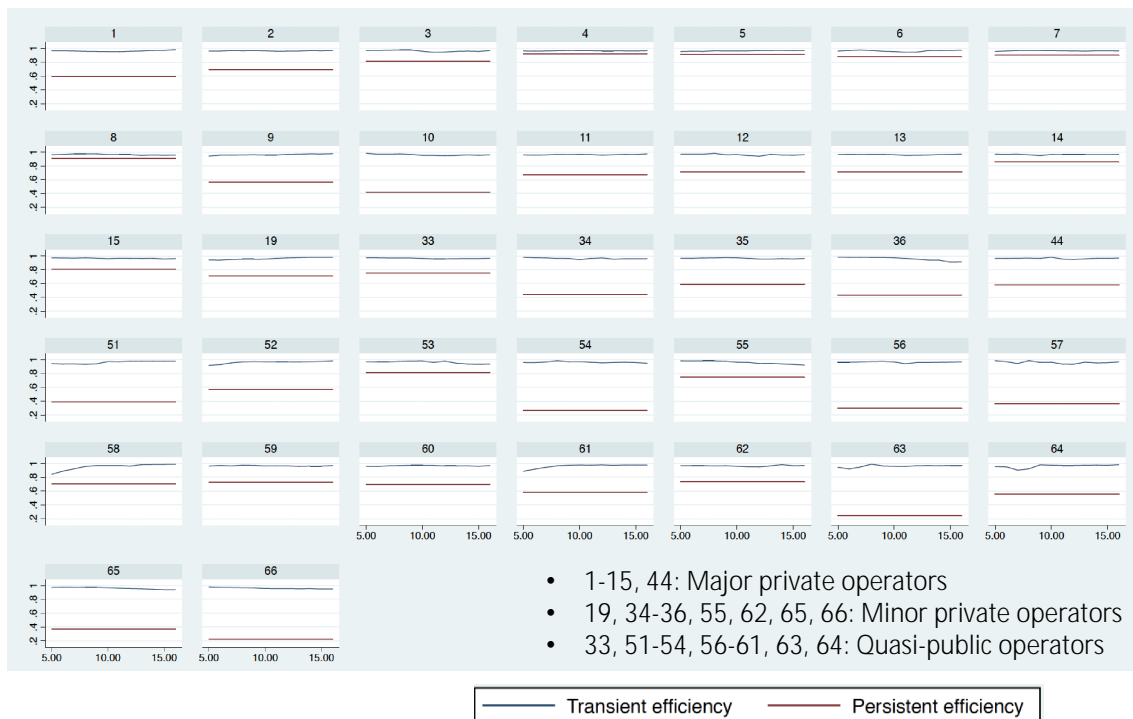

Key findings from this research include followings:

  1) Investigating effects of persistent and transient inefficiency on overall

inefficiency in terms of production technology

According to the estimation result, persistent inefficiency seems to be more important than transient efficiency. Overall efficiency score varies from 0.213 to 0.888 and persistent efficiency score varies between 0.224 and 0.917 having large deviation though transient efficiency score is not likely to vary such as from 0.843 to 0.989. Thus, it can be said that the factors such as temporary mistake in decision making or resource allocation which are amendable in short time do not tend to influence the operators' inefficiency dominantly. It might be also considered that reliability and punctuality due to effective operation scheme which can be decided in short-term comparatively are reflected in generally high transient efficiency scores with small deviation. However, persistent efficiency scores show different variation among ownerships and system types. Picture 1 shows the variation of persistent and transient efficiency scores over time by the operators.

- 1-15, 44: Major private operators
- 19, 34-36, 55, 62, 65, 66: Minor private operators
- 33, 51-54, 56-61, 63, 64: Quasi-public operators

Transient efficiency — Persistent efficiency

Picture 1. Persistent and transient efficiency of sample firms

Major private operators tend to perform well comparing to other ownership types in both overall and long-term. Following factors might be able to support these results: 1) strong motivation towards the market of the major private operators: diversification and competition between areas, 2) simpler decision-making system than minor or quasi-public operators, and 3) historical background of railway development which most of major private operators are not likely to have large capital costs due to their long history of operation. Therefore, we found that persistent aspect such as proper organisation design and regulation are more deserved to be focused to improve overall efficiency under the circumstance where most of operators performs well in short-term.

2) Ownership and system effects on cost structure of urban railway operators

We estimate the cost functions to identify if the cost structure is different among the operators and to consider the ownership and system type effects on the cost inefficiency. We hypothesise that ownership and system type influence the operators cost structure, as well as physical factors like network size. The model composes seven variables: one dependent and six independents. The independent variable is total variable costs while the independent variables are service output, energy price, labour price, material & repair price, network length, and dummies for rail modes. Although it is hardly able to say that the ownership affects

different cost structure of the operators, we could find rail mode (overground, underground and monorail/ATG) are found to be a significant factor on cost as hypothesised. However, we are not able to clarify if the ownership influences the different cost structures of urban railway operators because it could not detach the its effect from system effect significantly according to the result of Chow test.

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