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Factor substitution and complementarity in the Asia airport industry

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Abstract

This paper measures and analyzes how the substitutability between various factors in Asia airports has changed over the years. Production factors are decomposed into capital and labor to examine the role of outsourcing in the recent years. The results reveal that outsourcing has emerged from being a substitute for labor and a complementary factor to capital in the late 1990s to become a substitute for both labor and capital. Increases in price elasticities and substitutability of labor and capital indicate that airports in Asia have become more adept at reacting to price changes.

Keywords: Elasticities of factor substitutions; Airport operations efficiency; Outsourcing

1. Introduction

Competition between Asia airports has put pressure on their operators to improve economic efficiency. In response, airports have continuously enhanced their levels of automation not only to speed up passengers and cargo freight processing procedures but also to alleviate financial pressure associated with rising labor cost. Whilst it is important to analyze the nature of the substitution process between capital and labor, this study proceeds on the basis that the substitutability between these factors cannot be treated in isolation from the impact of outsourcing[1] as part of a range of inputs into the production process.

Much of the recent analysis of airport efficiency has made use of either programming methods, especially data envelopment analysis (DEA), or econometric techniques, many of which embody a total factor productivity (TFP) measure.[2] Both DEA and TFP approaches focus on the amount of inputs required to produce a specified level of output, or on the output that can be produced by a certain amount of inputs. While these studies differ in their selections of input and output variables, some (Pels et al., 2001) have explored the use of some subtle variations of these methods such as stochastic frontier analysis (SFA) to allow for stochastic deviation in the distance to the production frontier. The common focus of all these studies is on airport technical operations efficiency based on the notion that the more efficient the airports the lower cost per output unit. As such, there has been no attempt to incorporate information on factor prices or cost of production.

Nevertheless, the importance of incorporating factor prices in the calculation of efficiency cannot be understated since the efficiency of an airport depends on both the amounts of inputs used and prices of these inputs. Simply put, other than technical efficiency, allocative efficiency also contributes to cost efficiency. An airport is said to be technically efficient if it uses a minimum physical amount of inputs required in producing a certain level of output, but is said to be allocative efficient if it selects an optimal input mix in view of the price ratios of inputs.[3] Since most airports are price takers and have relatively little influence on factor prices, allocative efficiency can be as important as technical efficiency to an airport. Coupled with the fact that the attainment of technical efficiency is bounded by

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[1]The Air Transport Research Society (ATRS) in its annual airport benchmarking project has consistently found that airports that outsource their non-core operations generally experience higher labor productivity.

[2]For examples, Gillen and Lall (1997), Martin and Roman (2001), Vasigh and Hamzaee (2000), Parker (1999), and Sarkis (2000) deployed DEA while Hooper and Hensher (1997), Nyshadham and Rao (2000), Oum et al. (2003) and Abbott and Wu (2002) used the TFP method.

[3]This ignores any notions of *X*-inefficiency.

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many exogenous factors such as available technology and work culture, it may be easier for airports to exploit allocative efficiency to achieve cost competitiveness in comparison to competitors.

One possible way of assessing the inherent potential of allocative efficiency present in an industry is through an explicit computation of the elasticities of substitution (ES); a measure of the degree of factor substitutability in airports' operations with high ESs indicating flexible use of resources.[4] By flexibility, we refer to the ease by which an airport can vary its proportion of input usage so as to take advantage of relative price differences between factors and reap higher allocative efficiency. Comparison of ES is also meaningful because it allows the analysis of how factor substitutions have changed over the past years.

Here we treat the aggregate Asia airport industry as if it were a cost-minimizing homogenous economic unit and model the cost structure of the industry using a translog cost function. Alternatively, we could specify a flexible functional form to provide a second-order approximation to the true production structure as in Khalil (2005). However, we have chosen to estimate the cost function on grounds that input prices are exogenous but input quantities are endogenous to airports. Recognizing the existence of duality between the cost and production functions, we are unlikely to lose any useful information or precision by using the cost function instead of the production function.

The model is estimated by means of multivariate regressions[5] using data from a group of representative airports over the period 1999–2003. From the estimated equations, we calculate AES between aggregate inputs of capital, labor and outsourcing, and evaluate the extent of substitutability among these factors. Using the same model, we determine the own- and cross-price elasticities of factor inputs to measure the responsiveness in the change in quantities of factors use corresponding to changes in prices.

[4]The concept of ES was initially introduced by Sir John Hicks (1932) with the main purpose of determining how factor shares of income would change as the price or quantity ratio changed. Lerner (1933) later defined the elasticity of substitution as the reciprocal of the degree to which the substitutability of two factors (i.e., marginal rate of substitution) varies as the ratio of the two inputs varies while the output is held constant. Hicks and Allen (1934) developed the Hicks–Allen elasticity of substitution (HES) while introducing the concept of elasticity of complementarity. The authors denoted HES between factors i and j to be a measure of the percentage change in the ratio of inputs i and j due to a 1% change in the ratio of their prices. Allen (1938) then defined the Allen partial elasticity of substitution (AES) for the production function. Uzawa (1962) derived the AES for the cost function, which was popularized by Berndt and Wood (1975) in a classic paper. Subsequently, AES has become a common way of classifying inputs as complements or substitutes as apparent in some of the application studies in areas like energy (Westoby and McGuire, 1984), construction and service (Asai, 2004) and manufacturing (Khalil, 2005).

[5]Our approach is similar to Greene (1993) and Martin-Cejas (2002) who have used a regression-based approach to estimate a deterministic cost frontier by ordinary least squares. This involves shifting an estimated line such that the residual is minimum. Other methods of parameter estimation include Zellner-Efficient Iteration, ordinary least squares and maximum-likelihood estimations. For example, Westoby and McGuire (1984) and Khalil (2005) used the Zellner-Efficient Iteration method. Meanwhile, Asai (2004) estimated the values of parameters using maximum likelihood.

2. The model

The cost function for airports is estimated in a way similar to Westoby and McGuire (1984) and Asai (2004). Assuming production is characterized by constant economies of scale[6] and using Hicks' neutral technical change,[7] the translog unit cost function[8] is given by

$$\ln C = \ln \alpha_a + \ln Y + \sum_i \alpha_i \ln P_i + \frac{1}{2}\sum_i \sum_j \gamma_{ij} \ln P_i \ln P_j, \quad i,j = \mathrm{K,L,O}, \tag{1}$$

where C refers to the total cost for an output level Y; P_i is the factor price of input i; γ_{ij} represents the constant elasticities of cost share of factor input i to price of factor input j; α_a is the constant intercept term and α_i is the average cost share of factor i.

Differentiating Eq. (1) with respect to $\ln P_i$, we obtain

$$\frac{\partial \ln C}{\partial \ln P_i} = \frac{\partial C}{\partial P_i}\frac{P_i}{C} = \alpha_i + \sum_i \gamma_{ij} \ln P_i, \quad i,j = \mathrm{K,L,O}, \tag{2}$$

where the factor input K, L and O refers to capital, labor and outsource, respectively. Eq. (2) holds for $\gamma_{ij} = \gamma_{ji}$, which is the symmetry restriction imposed in Westoby and McQuire (1984), Asai (2004) and Khalil (2005).

Shephard's Lemma states that the optimal quantity of factor i to be used at price P_i, X_i is given by

$$X_i = \frac{\partial C}{\partial P_i}, \quad i,j = \mathrm{K,L,O}. \tag{3}$$

It follows from Eqs. (2) and(3) that

$$X_i = \frac{\partial C}{\partial P_i} = \frac{C}{P_i}\left(\alpha_i + \sum_i \gamma_{ij} \ln P_i\right), \quad i,j = \mathrm{K,L,O}, \tag{4}$$

Since the input cost share equation is $S_i = P_i X_i / C$ for factor i, we have

$$S_i = \alpha_i + \sum_j \gamma_{ij} \ln P_j, \quad i,j = \mathrm{K,L,O}. \tag{5}$$

[6]Doganis (1998) found empirical evidence that economies of scale appear to be limited to airports with relatively low passenger numbers. Meanwhile, Jeong (2005) discovered that the effects of airport size levels off between 2.5 and 5 million passengers in his study of US airports.

[7]Hicks' neutral technical change requires that there is no interaction between time and capital, labor and outsourcing for any technical change affecting these variables.

[8]The cost functions are assumed to be monotonic and concave. According to Westoby and McGuire (1984), monotonicity requires that fitted shares are non-negative at all points. Concavity requires that the Hessian matrix of second derivatives of the cost function is negative semi-definite at each point. This will be true if the first $n-1$ estimated principal minors alternate in sign. However, the matrix is not determined if any principal minors are statistically significant, this procedure does not constitute a statistical test of concavity.