The Effect of Governance Forms on North American Airport Efficiency: A Comparative Analysis of Airport Authority vs. Government Branch

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This paper applies a stochastic cost frontier model to a panel of 54 major airports over 2002-2008 to examine how the two dominant governance forms of publicly owned airports in the United States and Canada, namely, operation and governance by a government (city, county, or state) branch, or by an airport authority, affect airport efficiency performance. Our key findings are (a) airports operated by an airport authority achieve higher cost efficiency (on average, 14% higher technical efficiency) than those operated by a government branch; (b) airports operated by a government branch have lower labor share than those operated by an airport authority; and (c) there is no statistically significant difference in the efficiency performance between airports operated by U.S. airport authorities and Canadian airport authorities.

INTRODUCTION

Since the UK government began to privatize its airports in 1987, a great diversity has emerged in the ways in which countries tackle airport ownership and governance issues. In Europe and Australia, many airports have been fully or partially privatized and put under different regulatory regimes. However, in Canada and the United States (henceforth referred to as "North America" for convenience), despite a long tradition of privately owned utilities and transport industries, the majority of commercial airports are still publicly owned and mostly operated either by a government branch (city, county, or state governments) or an airport authority, which is a quasi-governmental organization.

Despite the uniqueness of the North American airport governance structures, few studies have investigated their effects on airport efficiency performance. Many studies, including Barros and Dieke (2007), Oum et al. (2004), Oum et al. (2006), Oum et al. (2008) and Vasigh and Gorjidooz (2006), have focused on the effects of ownership forms and/or regulatory policies on airport efficiency. Indeed, there has been little research about the way in which different governance structures affect airport efficiency or productivity performance. Furthermore, very few studies have focused solely on measuring and comparing the effects of airport governance forms on the efficiency performance of North American airports.

In addition, the literature on airport governance structures provides few concrete, quantitative analyses of how different governance structures affect airport efficiency or productivity. Especially in North America, there has been no consensus so far as to which airport governance structure is better to foster efficiency. Therefore, this paper seeks to find empirical evidence on comparative efficiency performance by the two most widely used airport governance structures in North America: an airport authority vs. a government branch.

To achieve these objectives, we estimate a stochastic cost frontier model using an unbalanced panel data of 54 airports over the 2002-2008 period. Our model will allow us not only to measure the unobserved airport inefficiency, but also allow us to study how much of the inefficiencies are attributable to the different airport governance forms. We employ a parametric method to measure efficiency in order to identify the direction of a potentially non-neutral input-augmenting production structure being employed by the airports operated by the two distinct governance structures.

The structure of this paper is as follows: In the second section, we summarize literature on the effects of ownership and governance forms on airport efficiency. This section also summarizes the fundamental characteristics of airport governance forms adopted in North America. The third section presents the framework of our econometric model for measuring the efficiency and identifying the effects of governance forms. The fourth section describes the data and details on variable construction. The empirical results and a discussion of the findings are given in the fifth section. The last section summarizes the study and considers further research needs.

LITERATURE SURVEY AND GOVERNANCE FORMS OF NORTH AMERICAN AIRPORTS

Literature on Airport Ownership, Governance Structure, and Firm Performance

Since the 1990s, the momentum to privatize airports has been gaining strength around the world. The privatization of airport ownership is usually accompanied by some form of economic regulations, including price regulations. The issue of full and partial privatization and associated economic regulation of airports has attracted a wide range of researchers to measure and analyze airport efficiency performance. There are many studies already on this efficiency measurement: for the UK, Beesley (1999) and Starkie (2001); for Australia, Forsyth (2002) and Hooper et al. (2000), and Air Transport Research Society (2002-2011). Oum et al. (2004), investigate 60 airports worldwide under different ownership forms and provide both theoretical and empirical evidence on the impact of different economic regulations on airport efficiency performance. Their empirical results indicate that privately owned airports do not necessarily achieve higher capital input productivity or total factor productivity than publicly owned airports do.

However, it is not only ownership and its associated regulations that determine performance, but also airport governance structures themselves can have significant effects on performance. Gillen (2011) adopts a descriptive approach to examine the evolution of airport governance, and proposes that researchers consider the issue of airport governance in a two-sided framework (airports and airlines).[1] Despite the importance of governance structure on the performance of airports, few studies purposely measured and analyzed the effects of governance forms on efficiency performance of North American airports, in particular comparing airports governed/operated by an airport authority vs. those governed/operated by a government branch. Although most empirical evidence, including Oum et al. (2008), suggests that airports operated by a port authority are less efficient than those run by either a government branch or an airport authority, it has not yet been clearly determined how the airports operated by the latter two governance forms differ in their efficiency performances.

Some studies argue that the difference in efficiency between airports operated by the two governance forms (an airport authority vs. a government branch) is negligible in North America. For example, Oum et al. (2006) examined the impact of six different ownership/governance forms on the variable input productivity performance of 116 airports worldwide and found, among other findings, there is no significant difference in efficiency performance of airports operated by an airport authority from those operated by a government branch. On the other hand, other studies such as Craig et al. (2005) and Oum et al. (2008) detect a better efficiency performance of airports operated by an airport authority. Oum et al. (2008) compare the efficiency of airports owned/operated by seven different governance forms based on a panel data of 109 airports worldwide.[2] Based solely on U.S. airport data, Craig et al. (2005) find results consistent with Oum et al. (2008) that, in term of technical efficiency, the airports operated by airport authorities outperform those operated by government branches. However, given that Craig et al. (2005) did not include non-aeronautical services, it is not clear whether or not their results would have changed if they included the non-aeronautical revenue activities as a part of outputs in view of the fact that the majority of U.S. airports generate 40%-70% of their total revenues from non-aeronautical service activities. Although Zhuo et al. (2013) investigated the effects of U.S. airport governance forms, their analysis focused on the relative performances of the three alternative measurement methods: productivity index approach, DEA (Data Envelopment Method) approach, and stochastic frontier method approach.

Governance Forms in North American Airports

In Canada, in order to promote commercialization and efficiency into the airport sector, the (Canadian) Airport Authority form of governance was introduced beginning in 1992, transferring the responsibility for capacity planning, operation, and management of airports from the federal government (in fact, Transport Canada) to locally based not-for-profit corporations on long-term leases. These airport authorities are self-financing, not-for-profit, non-share-capital corporations incorporated under Canada Business Corporations Act, but do not pay income tax. Their leases are for 60 years with an option to renew for an additional 20 years. Although some business practices are controlled through the lease document, they are not subject to any special economic regulation through legislation. Furthermore, the airport authorities enjoy the freedom to set the prices for various airport activities (e.g., parking, rent, landing aircraft, and terminal use) and determine service levels within the safety regulatory framework. In addition, unlike the airport authorities in the United States, Canada's airport authorities operate airports with virtually no federal assistance or subsidy. In fact, since they are required to make annual ground lease payments, Canadian airport authorities have become a source of significant general treasury revenues for the federal government.

On the other hand, governance and ownership of airports in the United States is actually quite complicated as it can differ for each state. Therefore, we can only describe the general pattern that has emerged in the types of airport governance in the United States. It has long been the tradition that airports in the United States are operated by local or regional government branches (i.e., a division or department of aviation). Such an aviation department is usually separated from other departments, but often uses some functions of local government such as accounting services, purchasing decisions, and fire fighting services. Within an aviation department, the board of directors is appointed by the chief executive officer of the local government and is ultimately responsible to the (city) council. Generally speaking, the board of directors in an aviation department cannot enter into contracts without the approval of the council, which literally owns the airport. Moreover, the annual budget, bond sales, and other similar measures of an aviation department also need to be approved by the council.

As an alternative to direct control by local/regional government, airport authorities were first established to assume control over public airports during the 1950s and 1960s. Unlike those in Canada, U.S. airport authorities are considered public agencies since they are created by the local/regional governments that own airports. Although few airport authorities, such as the Great Orlando Aviation Authority and the Metropolitan Washington Airports Authority, lease the airport from the government, the majority of local/regional governments directly transferred and delegated all airport managerial responsibilities to an airport authority at virtually no cost or lease payment. At large, an airport authority resembles an autonomous corporation with its own functional departments, such as finance and procurement department. While airport authorities are structured as independent and self-supporting institutions, the board members of an airport authority are always elected by the local/regional government. The board members are authorized to appoint the chief executive officer of an airport authority, and the board has the right to veto the authority's decision. Therefore, the local government, to a greater or lesser degree, can exercise varying levels of oversight and control the authority via the makeup and structure of the board. In some states, such as Florida, the elected public officials are allowed to serve as board members, while in other states, such as Michigan, state legislatures have ruled out the elected public officials from the boards of airport authorities. For instance, the mayor of Orlando and other public officials are serving as the board members of the Great Orlando Aviation Authority, whereas the board of the Cincinnati/Northern Kentucky International Airport only consists of civic and business leaders.

In most of the past studies it is conventional to lump together both Canadian and U.S. airport authorities into the same category. However, it is important to note that differences could occur between U.S. airport authorities and their Canadian counterparts. Regardless of the governance form, U.S. airports have developed particular contractual and financial relationships with airlines (their major customers) that distinguish them from airports in Canada. For instance, U.S. airports enter into legally binding contracts known as airport-use agreements which detail the conditions for the use of both airfield and terminal facilities. These contracts are negotiated between the airport and its airline customers. The contracts will specify the fees and rental rates an airline has to pay and the method by which these fees are to be calculated. Regarding sources of capital investment, many U.S. airports are financed partly or largely from the private sector through the bond market. Moreover, U.S. airports are eligible to be funded by the federal government via the Airport Improvement Program (AIP), which is administered by the Federal Aviation Administration (FAA). In addition, while Canadian airports are not directly regulated, U.S. airports are subject to some general pricing rules. For instance, U.S. airports are required to set aeronautical fees so as to collect revenues that reflect the costs of providing services.

U.S. airport authorities are also different from their Canadian counterparts with respect to selection of board members. For U.S. airport authorities, board members have to be appointed by the state or local government that owns the airport, while the board members of an airport authority in Canada are generally appointed by local community organizations. However, it remains a question how such different selection processes affect airport efficiency performance. There is no doubt that politically motivated appointment of board members leaves U.S. airport authorities vulnerable to changes in administration and to the exertion of political influence. It is noticeable, nonetheless, that board members of U.S. airport authorities either serve on a voluntary basis or are paid only a small stipend for attending each official meeting or activity. It is therefore possible that the board members of a U.S. airport authority are more likely to represent the communities that the airport serves and thus have a strong interest in the performance of the airport. On the other hand, the board members of Canadian airport authorities receive compensation for their service on the board and thus may be actually distant from the communities that airports serve.

While the definition of an airport authority varies, it is often noted that airport authorities are likely to be less liable to political interference. To a large extent, airport authorities may be relieved from the pressure to use various services provided by the city or county, and avoid the contract approval process and other constraints imposed on a government branch such as the city's aviation department. Moreover, managers of airport authorities may have greater knowledge and expertise about the aviation industry in general and airport management in particular. In addition, it has been long argued that there is some potential inefficiency in procurement practices of aviation departments. Airports run by a government branch rely on the local government staff to make purchasing decisions, which often make the process longer and less efficient. The political influence from local government, may prevent aviation departments from procuring services from the most cost effective sources.

ECONOMETRIC MODEL

Different methodologies have been proposed to measure and compare airport efficiency performance. These methods can be broadly classified into non-parametric and parametric. Non-parametric methods include the partial and total factors productivity (TFP) indices, data envelopment analysis (DEA), and numerous forms of DEA-derivative methods. Hooper and Hensher (1997), Nyshadham and Rao (2000), Yoshida (2004), and Air Transport Research Society (2002-2011) used regression analysis to decompose a TFP or VFP (Variable Factor Productivity) index and further investigate the productive efficiency of airports from different regions, while Sarkis (2000), Gillen and Lall (2001), and Barros and Dieke (2007), applied a DEA method to evaluate the efficiency performance of airports.

The non-parametric approaches, such as TFP and DEA, readily handle a large number of input and output categories, more easily than they can be accommodated in econometric estimation methods. But econometric estimation methods, if data are available, build on established economic theory relationships and separate out the influences on cost and/or productivity. Barros (2008) and Martin et al. (2009) used the parametric approach to investigate the cost efficiency performance of Spanish airports.[3] In this study, we argue that it is not sufficient to simply describe airport performance but also to be able to assess and understand how different governance structures can affect it. Hence we chose the econometric method as a preferred method to use for accomplishing our key objectives, to isolate the effects of different governance structures from other variable also affecting airport's efficiency.

The Stochastic Frontier Analysis (SFA) was first developed by Aigner, Lovell and Schmidt in 1977. The basic empirical framework for SFA is a regression specification involving a logarithmic transformation that adds a positive (truncated) random error term, along with the traditional symmetric noise term, to capture unexplained inefficiency. We use the framework proposed by Battese and Coelli (1995) to estimate the frontier production (or cost) function and the inefficiency model simultaneously, avoiding the econometric problem of the two-steps procedure.

In the short run, if an airport tries to minimize its production cost (C) given the outputs (Q), variable input prices (W), and capital inputs (K), then the cost minimization frontier in a logarithmic form can be expressed as $lnC^*(Q_{it}, K_{it}, W_{it}, t; \boldsymbol{\beta})$, where i represents airport and t represents time. In reality, airports may deviate from their cost minimization objective for various reasons and such deviations indicate the existence of inefficiency. To reflect this reality, for airport i, a positive random term ξ_{Tit} is denoted as technical inefficiency, which indicates the deviation of airport's actual cost from its efficient cost frontier. Further, since our interest centers on determining whether and/or how governance structures can affect efficiency performance, it is assumed that the technical inefficiency term ξ_{Tit} depends on the variables indicating airport governance form Z_{it}, with the dependence expressed as $\xi_{Tit}(Z_{it}; \varsigma)$. Moreover, it is possible that governance structures can assert influence not only on airport technical inefficiency but also on allocative inefficiency primarily by affecting input (labor vs. non-labor) mix. In order to reduce the complexity in estimation, the impact of governance structures on allocative inefficiency is analyzed by simplifying the functional form of $\xi_{Ait}(Z_{it}, W_{it}; \rho)$ to include only the interaction terms between governance form variable Z_{it} and input price variables (W_{it}). By applying Shephard's lemma, this specification can identify how different governance forms change variable input mix. Taken together, the observed actual production cost of airport i at time t can be expressed as

$$(1)\quad lnC_{it} = lnC^*_{it}(Q_{it}, K_{it}, W_{it}, t; \boldsymbol{\beta}) + \xi_{Ait}(Z_{it}, W_{it}; \rho) + \xi_{Tit}(Z_{it}; \varsigma) + \varepsilon^c_{it}$$

where, $lnC^*_{it}(Q_{it}, K_{it}, W_{it}, t; \boldsymbol{\beta})$ is the deterministic kernel[4] of the stochastic cost frontier, ξ_{Ait} captures the effect of governance structures on airport variable input usage, $\xi_{Tit} \geq 0$ captures the effect of technical inefficiency, $\varepsilon^c_{it} \sim iid\, N(0, \sigma^2_v)$ is the effect of the symmetric random noise term, and the vector $\boldsymbol{\beta}$ and ρ are the parameters to be estimated. In particular, our model includes three outputs in vector Q_{it} (number of passengers q_{1it}; number of aircraft movements q_{2it}; and non-aeronautical output q_{3it}), two variable input prices in vector W_{it} (labour price w_{1it}; and price of the soft cost input[5] w_{2it}), and three quasi-capital inputs in vector K_{it} (number of runways k_{1it}; number of gates k_{2it}; and terminal size).[6]

The translog cost functional form is adopted to estimate the kernel of the stochastic cost frontier model. In addition to governance structures, many other factors, such as location, are important with airports but beyond managerial control. Therefore, we augment the cost frontier to account for observed airport heterogeneity by adding two variables: percentage of international passengers in total passenger traffic (π_{it}) and, Canada dummy variable (D_i). In addition, since economic conditions of the day is the most powerful driver of changes in the air transport industry at large, a set of year dummies (T_t) is included in the cost frontier to reflect the impact of general economic conditions on airport operating cost.

As mentioned earlier, the physical measure is treated as a fixed input, i.e., the physical measure enters the cost frontier rather than the price of capital. However, in practice, airports may not be able to adjust their capacity as output changes. In order to account for the short-run disequilibrium adjustment in capacity, we estimate the restricted translog cost frontier, which is log-linear in the physical measure of capital inputs. Adjusted to these specifications, the stochastic cost frontier adopted in the study can be written as follows:

$$\begin{aligned} LnC_{it} &= lnC^*_{it}(Q_{it}, K_{it}, W_{it}, t;\ \beta) + \xi_{Tit}(Z_{it}; \varsigma) + \xi_{Ait}(Z_{it}, W_{it}; \rho) + \varepsilon^c{}_{it} \\ &= \alpha + \gamma\pi_{it} + \varphi D_i + \sum_{t=1}^{6} \omega_t T_t + \sum_{j=1}^{3} \beta_j\, lnq_{jit} + \sum_{j=1}^{3} \lambda_j\, lnk_{jit} + \sum_{j=1}^{2} \delta_j\, lnw_{jit} \\ &\quad + \frac{1}{2}\sum_{j=1}^{3}\sum_{n=1}^{3} \phi_{jn}\, lnq_{jit} lnq_{nit} + \frac{1}{2}\sum_{j=1}^{2}\sum_{n=1}^{3} \tau_{jn}\, lnw_{jit} lnw_{nit} \\ &\quad + \sum_{j=1}^{3}\sum_{n=1}^{2} \vartheta_{jn}\, lnq_{jit} lnw_{nit} + \sum_{j=1}^{2} \rho_j Z_{jit}\, lnw_{jit} + \xi_{Tit} + \varepsilon^c{}_{it} \end{aligned} \tag{2}$$

where ξ_{Tit} is the technical inefficiency model, which is assumed to have a non-negative half normal distribution as follow:

$$\xi_{Tit} = \varsigma_0 + \varsigma_1 Z_{1it} + \varsigma_2 Z_{2it} + \mu_{Tit}$$
$$\mu_{Tit} \sim N(0, \sigma_z^2)$$

and $\varepsilon^c{}_{it}$ is white noise error

$$\varepsilon^c{}_{it} \sim N(0, \sigma^2)$$

As the cost function must be linearly homogeneous in input prices, the following restrictions are imposed in the estimation of the above model:

$\delta_1 + \delta_2 = 1, \vartheta_{11} + \vartheta_{12} = 0, \vartheta_{21} + \vartheta_{22} = 0, \vartheta_{31} + \vartheta_{32} = 0, \tau_{11} + \tau_{12} = 0,$
$\tau_{12} + \tau_{22} = 0, \frac{1}{2} * \tau_{11} + \tau_{12} + \frac{1}{2} * \tau_{22} = 0, \rho_1 + \rho_2 = 0$

In addition, we also impose the following symmetric conditions in the estimation:

$\phi_{12} = \phi_{21},\ \ \phi_{13} = \phi_{31},\ \ \phi_{23} = \phi_{32},\ \ \tau_{12} = \tau_{21}$

AIRPORT SAMPLE AND VARIABLE CONSTRUCTION

Our sample consists of an unbalanced panel of 54 airports in the United States and Canada for the 2002-2008 period. These airports are governed/operated by either an airport authority or a government branch (see the list in Appendix A). The data re compiled from various sources, including the U.S. FAA (Federal Aviation Authority) and airports' annual reports. Some data were obtained directly from airports. For more details on the data, the reader is referred to any annual issue of the ATRS Global Airport Performance Benchmarking Reports (2002-2011).

The airport outputs commonly used in economic analysis are the number of passengers enplaned and deplaned, the tonnages of air cargo handled, and the number of aircraft movements (ATM or Air Transport Movements). The number of passengers handled is obviously the most important output measure for most airports. The air cargo services are generally handled by airlines, third-party cargo handling companies or other firms who lease spaces and/or facilities from the airports. As a result, the airports' rental incomes from such space/facility leases are included in the airport's non-aeronautical revenue. Since most of cargo services are not operated directly by airports, we do not include air cargo services as a separate output for airports. Some may also argue ATM should not be included as an airport's output because aircraft movements (landings and takeoffs) are the means by which passengers and air cargo are carried. ATM may be considered as an intermediate activity required to handle passengers and cargos, given that almost all airport activities are related to the movement of aircraft, like most other studies, we decided to include the number of ATM as an output.

In addition to the outputs discussed above, airports also derive revenues from concessions, car parking, land and office rentals, and other numerous non-aeronautical services they provide. These services are not directly related to aeronautical activities in a traditional sense, but they are important and becoming increasingly more important source of revenues for airports. In fact, as shown in Figure 1, the non-aeronautical revenues account for anywhere between 30% and 85% of the total revenue of North American airports. Since many of the airport inputs are not separable between the aeronautical and the non-aeronautical activities of an airport, any productivity or efficiency measure that excludes the non-aeronautical services as an output would bias empirical results seriously against the airports generating a larger portion of their revenues from commercial and other non-aeronautical activities than their peers. For this reason, we decided to include the non-aeronautical services output as the third output. Since non-aeronautical services include numerous items and activities, it is difficult to construct an "exact" price index consistent across all airports in different regions and over time. Therefore, we construct the non-aeronautical output quantity index by deflating the total non-aeronautical revenues of an airport by the cost of living index (COLI) of the census metropolitan region in which the airport is located.

On the input side, we initially considered four general categories: (1) labor, which is measured by the number of full-time equivalent employees who work for and are paid for by an airport operator; (2) purchased goods and materials; (3) purchased services, including those contracted out to external parties; and (4) capital, which consists of various facilities and infrastructure. In practice, however, few airports provide separate expense accounts for input categories (2) and (3). We therefore combine them to form a single input category (henceforth referred to as "the soft cost input"). Since airports' operating expenses are measured in different currencies and are subject to very different price levels depending on location of the airport, again we adopt the COLI as the proxy for the soft cost input price index, and create the soft cost input quantity index by deflating the soft cost input expenses by the COLI. Moreover, as the proxies for capital input, we consider three physical measures of capacity: the number of runways, the number of gates, and the terminal size (measured in square meters).

Table 1 reports the summary statistics of our data on the airports operated by a government branch and by an airport authority for selected years. The table shows: (a) all of the outputs and proxy capital measures show that, overall, the airports operated by airport authorities are smaller than the airports operated by the government branches; (b) on average, the labor cost shares of the airports operated by airport authorities are higher than the airports operated by government branches; and (c) the airports operated by airport authorities have higher shares of international passengers in their total passengers and also generate a higher share of total revenues from non-aeronautical revenue as compared with airports operated by government branches.

Table 1: Summary Data for Comparing Between Two Groups of Airports
(The numbers in parentheses are standard errors)

	Airports Operated by Government Branch			Airports Operated by Airport Authority		
	2002	2005	2008	2002	2005	2008
Output Measures						
Number of Passengers (million)	23 (19)	27 (22)	28 (23)	14(12)	15(14)	15(12)
Number of Aircraft Movements(000's)	328 (221)	347 (251)	349(245)	245(162)	242(160)	222(134)
Non-Aeronautical Revenue						
(million COLI deflated $)	74(51)	79 (56)	91 (69)	52(39)	61(46)	75(75)
Proxy Capital Measures						
Number of Runways	3.4(1.2)	3.5 (1.3)	3.6 (1.2)	3.2(1.1)	3.3(1.2)	3.3(1.2)
Number of Gates	73 (46)	79(47)	79(48)	59(42)	58(39)	64(41)
Terminal Size (000's Squared Meter)	200 (183)	224 (195)	212(159)	121(102)	126(100)	133(10)
Variable Inputs' Prices						
Wage (000's US$)	58 (16)	69(21)	86(27)	55(12)	67(13)	84(19)
Soft Cost Input Price Index) (COLI: cost of living index)	1.04(0.2)	1.14(0.2)	1.26(0.3)	0.99(0.1)	1.08(0.2)	1.18(0.2)
Variable Inputs' Share						
Labour Cost Share (%)	39%(10)	40%(11)	38%(11)	46%(10)	42%(10)	43%(9)
Other Characteristics						
Percentage of International Passengers (%)	8%(11)	8%(11)	7%(12)	10%(14)	10%(15)	11%(15)
Share of Non-Aeronautical Revenue (%)	49%(11)	49%(12)	50%(11)	52%(13)	54%(12)	56%(13)
Percentage						
Canadian Airports (%)				26%	26%	25%
US Airports (%)				74	74	75
Number of Airports in the sample	26	25	24	27	27	28

EMPIRICAL RESULTS AND DISCUSSIONS

Table 2 presents two alternative stochastic cost frontier models estimated by the Gauss maximum-likelihood computer program. In Model I, we postulate there is no difference between Canadian and U.S. airport authorities; i.e., the two countries' airport authorities perform identically. Therefore, in Model I, all sample airports are classified into two categories: (1) airports operated by a government branch and (2) airports operated by an airport authority. In Model II, we separate Canadian and U.S. airport authorities: i.e., the airports governed/operated by Canadian airport authorities perform differently from those governed/operated by U.S. airport authorities. In other words, in Model II we distinguish our efficiency models among three types of airport governance forms: (1) a government branch; (2) a U.S. airport authority; and (3) a Canadian airport authority.

Part A of Table 2 reports the estimation results for the kernel of the translog variable cost functions, including the effects of airport characteristics on variable costs. Part B reports the estimation results of the Technical Inefficiency Model; i.e., impacts of governance forms on technical efficiency of the airports which are of our particular interest in this paper.

Table 2: Stochastic Cost Frontier Estimation Results

A. Estimation Results for *Translog* Variable Cost Function				
	Model 1		Model II	
Parameters	Coefficient	t-statistics	Coefficient	t-statistics
α (constant)	-0.934	-3.79**	-0.936	-3.47**
ω_1 (Year 2003)	0.043	3.29**	0.040	3.21**
ω_2 (Year 2004)	0.022	0.94	0.021	0.87
ω_3 (Year 2005)	0.048	1.89*	0.044	1.72*
ω_4 (Year 2006)	0.066	2.82**	0.059	2.46**
ω_5 (Year 2007)	0.085	3.01**	0.082	2.78**
ω_6 (Year 2008)	0.117	2.61**	0.115	2.50**
γ (%International)	0.684	2.34**	0.652	2.32**
φ (Canadian dummy)	-0.241	-1.13	-0.236	-1.12
Coefficients of Outputs				
β_1 (non-aeronautical output)	0.325	3.36**	0.338	3.60**
β_2 (passengers)	0.290	3.21**	0.269	3.18**
β_3 (aircraft movements)	0.081	1.17	0.077	1.21
Coefficients of Proxy Capital Measures				
λ_1 (runway)	0.088	0.50	0.095	0.61
λ_2 (number of gates)	0.108	1.05	0.111	1.06
λ_3 (terminal size)	0.017	0.26	0.013	0.21
Coefficients of input prices				
δ_1 (wage)	0.394	2.99**	0.416	2.91**
Coefficient for Interactions between Governance Structure and Input Price				
ρ_1 (Government − branch $*$ wage)	-0. 069	-1.57	-0.058	-1.29
ρ_2 (Canadian Airport Authority $*$ wage)			0.014	0.31
Coefficients of Interactions among Outputs				
ϕ_{11} (non-aeronautical * non-aeronautical)	0.361	2.33**	0.356	2.43**
ϕ_{22} (passenger * passenger)	0.276	0.61	0.243	0.54
ϕ_{33} (aircraft movements * aircraft movements)	-0.241	-0.88	-0.270	-1.02
ϕ_{12} (non-aeronautical * passenger)	-0.247	-0.97	-0.232	-0.93
ϕ_{13} (non-aeronautical * aircraft movements)	-0.075	-0.29	-0.026	-0.17
ϕ_{23} (passenger *aircraft movements)	0.044	0.24	0.083	0.31
Coefficients of Interaction between Input Prices				
τ_{12} (wage *wage)	0.172	0.76	0.185	0.97
Coefficients of Interaction between Outputs and Input Prices				
ϑ_{11} (non − aeronautical $*$ wage)	-0.056	-0.28	-0.055	-0.29
ϑ_{21} (passenger * wage)	-0.393	-1.48	-0.305	-1.11
ϑ_{31} (aircraft movement * wage)	0.511	2.30**	0.505	2.18**
B. Estimation Results for the Technical Inefficiency Model (Impacts of Governance Form)				
Parameters			Coefficient	t-statistics
ς_0(Constant)	-0.798	-3.1**	-0.766	-3.04*
ς_1(Government -branch dummy)	0.141	1.75*	0.145	1.77**
ς_2(Canadian Airport Authority dummy)			0.028	0.22
$\sigma_z^2 + \sigma^2$ (Variance Parameter)	0.058	-	0.061	-
$\frac{\sigma_z^2}{\sigma_z^2 + \sigma^2}$ (Ratio of the Variances)	0.744	-	0.755	-
Log-likelihood value	***264.39***		***266.12***	

** Significant at $\alpha = 0.05$; * Significant at $\alpha = 0.10$

Hypotheses Tests for Model Choice

Does Canada's airport authorities' efficiency performance differ from that of U.S. airport authorities? To answer this question, we need to compare Model I and Model II in Table 2. Model II includes two more parameters than Model I, namely, ρ_2 (Canadian Airport Authority $*$ wage) in the allocative efficiency part A, and ς_2 (Canadian Airport Authority dummy) in the technical efficiency part B.

The t-statistics for both of these parameter estimates indicate that neither of the following two hypotheses can be rejected when we test each of the following two hypotheses one at a time sequentially:

Ho. ρ_2 (Canadian Airport Authority $*$ wage) = 0 *H1* $\rho_2 \neq 0$

Ho. ς_2 (Canadian Airport Authority dummy) = 0 *H1* $\varsigma_2 \neq 0$

The following joint hypotheses on both homogeneous allocative inefficiency parameters and technical inefficiency parameters for U.S. and Canadian airport authorities can be tested using the asymptotic likelihood ratio test criterion: [7]

Ho $\rho_2 = \varsigma_2 = 0$

Since the computed Chi-square statistic, $\lambda = -2\{log[\widehat{L(\hat{\theta}_R)}] - log[\widehat{L(\hat{\theta}_U)}]\}$ = -2 (264.39-266.12) = 3.46, is much smaller than the critical value (5.99) of the Chi-square distribution with 2 df at 5% level, we cannot reject the hypothesis that both allocative inefficiency and technical inefficiency parameters are identical between U.S. and Canadian airport authorities. In other words, this Likelihood Ratio (LR) test result shows that Model I (Canadian airport authorities are identical to U.S. airport authorities in terms of both the allocative inefficiency and technical inefficiency parameters in the model) could not be rejected in favor of Model II (Canadian airport authorities have distinctly different inefficiency parameters from the U.S. airport authority model). Although some experts argue that Canadian airport authorities differ from their U.S. counterparts in terms of their relationship with airlines, financial sources available, and selection of board members, and thus should be considered as different types of airport governance, our test results show that as far as their allocative inefficiency in terms of using labor-soft cost input mix and technical inefficiency are concerned, Canadian and U.S. airport authorities appear to be identical. Therefore, in the rest of this paper we will focus on discussing our empirical results mostly based on Model I. Model II will be referred to occasionally when we need to discuss potential differences on the efficiency performance between Canadian and the U.S. airport authorities, albeit they are not statistically significantly different at 5% level.

Does the non-neutrally input augmenting allocative inefficiency specification in our translog cost function improve our cost measurement? In Model I of Table 2, the parameter estimate ρ_1 (for government branch dummy * wage) is only marginally significantly from zero only at 12% level, but not significant at 5% level. The negative coefficient, -0.069, implies that there is evidence, albeit weak, that the labor cost (soft cost input) share at the airports operated by a government branch (an airport authority) is, on average, 6.9% less (more) than a similar airport operated by an airport authority (a government branch). The airports operated by a government branch may be forced to outsource more of their services, such as police and fire fighting services, and ground access services. (a part of soft cost input) to government departments.

Does our stochastic frontier technical inefficiency model significantly improve accuracy of technical inefficeincy measurement? In both Models I and II, the ς_0 (constant) coefficient in the technical inefficiency model is statistically very significant. This implies that the stochastic frontier specification with the half normal truncated distribution of technical inefficiency significantly improves the measurement of inefficiency over the model without the half normal inefficiency specification. Similarly, the coefficient ς_1 (government branch dummy) is statistically significantly different from zero at 5% level in both Models I and II. This implies that specifying our stochastic frontier technical inefficiency model differently between the airports operated by airport authorities and those operated by government branches has significantly improved the accuracy of technical inefficiency measurement. The coefficient estimate, 0.141, implies that, on average, the technical inefficiency for airports operated by government branches is about 14% larger than those operated by airport authorities.

Results of Joint Hypotheses Tests

Table 3 presents the test statistics for and the results of further likelihood ratio tests on the following three important joint hypotheses:

(a) H_0: $\varsigma_0 = \varsigma_1 = 0$: The conventional econometric model without stochastic frontier technical inefficiency component and without differential technical inefficiency effects between the airport authority and the government branch

(b) H_0: $\rho_1 = \varsigma_0 = \varsigma_1 = 0$: The model without specification of stochastic frontier, differential allocative inefficiency or differential technical inefficiency between the two forms of governance

(c) H_0: $\rho_1 = \varsigma_1 = 0$: The effects of the differential allocative inefficiency and differential technical inefficiency between the airport authority and the government branch are jointly zero; i.e., $\varsigma_0 \neq 0$, *but* $\rho_1 = \varsigma_1 = 0$.

Table 3: Hypothesis Tests on Stochastic Cost Frontier Model I

Null Hypothesis	Log[Likelihood($\hat{\theta}_R$)]	log[Likehood($\hat{\theta}_U$)]	$\chi^2_{0.95}$ critical value	Computed Test Statistics
	–	–	–	–
(a) H_0: $\varsigma_0 = \varsigma_1 = 0$	261.19	264.39	5.99	6.38**
(b) H_0: $\rho_1 = \varsigma_0 = \varsigma_1 = 0$	258.88	264.39	7.82	11.01**
(c) H_0: $\rho_1 = \varsigma_1 = 0$	259.71	264.39	5.99	9.35**

** Significant at $a = 0.05$; * Significant at $a = 0.10$

Based on the likelihood ratio test statistics reported in Table 3, all three hypotheses are rejected at least at 5% level of significance in favor of the respective alternative hypotheses. It is worth pointing out that although the allocative inefficiency parameter ρ_1 was only marginally significant in our stand-alone test, the null hypotheses of zero coefficients were strongly rejected at 5% level in the joint tests (b) and (c) above with the technical inefficiency differential between government branch and airport authority management cases. This implies that when measuring efficiencies for North American airports, it is worth incorporating both the allocative inefficiency and the technical inefficiency modules in stochastic frontier models as we have done in this paper.[8]

Empirical Results from the Chosen Model

Effects of airport governance structure on airport input mix. The impact of the airport governance structures on variable input usage is identified via the coefficient of the labor price (wage) interacted with the government branch dummy variable in Model I. While the coefficient was only marginally significant at 12% level when we tested the single coefficient by itself, it was strongly significant when it was jointly tested with the technical inefficiency parameters. The value of the coefficient,

-0.069, implies that on average the airports operated by a government branch tend to have about 6.9% lower labor cost share (equivalently, 6.9% higher soft cost input share) than those operated by an airport authority (base case in our allocative inefficiency specification).[9]

This result is partly because many airports operated by a government branch do not have some functional departments (e.g., accounting and security) and use these services supplied by the local government departments. Partly as a result of the procurement provisions of the local government, airports run by a government branch may not purchase services from the most cost-effective source, and thus tend to have a higher soft cost share because of higher outsourcing activities.

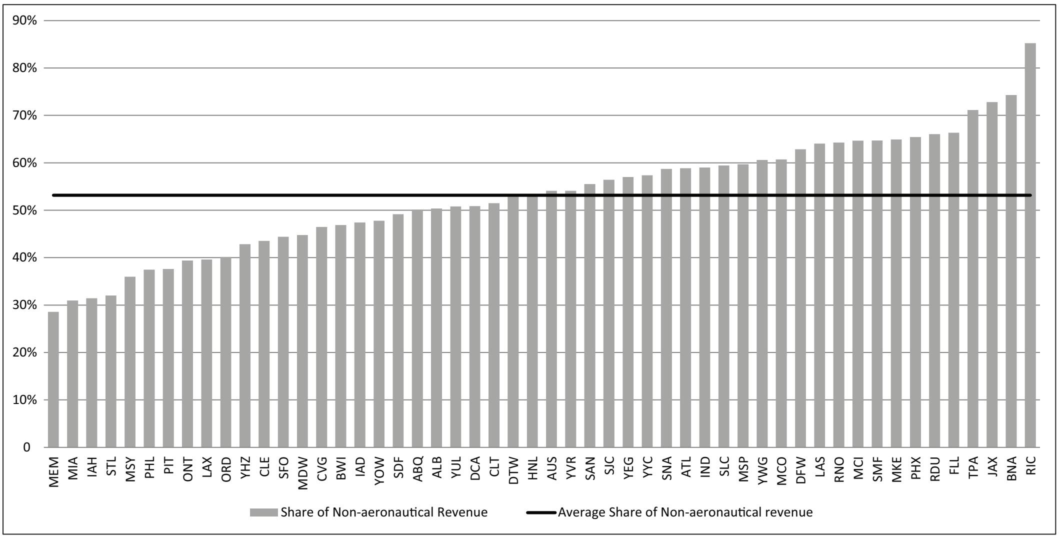
Effects of airport governance structure on technical inefficiency. Part B of Table 2 shows the effect of governance structures on airport technical inefficiency. The coefficient for airports operated by a government branch is positive and significant at the 10% and 5% levels in Model I and II, respectively. Our results show that the airports run by a government branch are on average 14% technically less efficient than those run by a Canadian or U.S. airport authority. Consistent with the results obtained by Craig et al. (2005) and Oum et al. (2008), our finding confirms that independent institutions, such as the airport authorities, achieve a higher efficiency performance since they enjoy sufficient freedom to operate airports in a commercially oriented manner. While separated from other government departments, the aviation branch operates under the general requirements of the local government bureaucracy and thus is influenced by other political activities. Such factors may hinder efficient airport operations.

Canadian vs. U.S. airport authorities. As discussed already, our result shows there is not any statistically significant efficiency difference between airports operated by U.S. airport authorities and those run by Canadian airport authorities. Casual commentators normally favor Canadian airport authorities over U.S. airport authorities since politically motivated appointment of board members leaves U.S. airport authorities vulnerable to political influence on airports' business decisions. Our empirical results do not support such argument.

The effects of airport characteristics on costs and/or efficiency. The stochastic frontier cost Models I and II reported in Table 2 give remarkably similar results on the effects of various airport characteristics on the variable cost frontier. All the parameter estimates of the two models have identical signs. All the coefficients statistically significant in Model I are also statistically significant in Model II. Since Model I (Canadian airport authorities are identical to U.S. airport authorities in terms of both the allocative inefficiency and technical inefficiency parameters in the model) could not be rejected in favor of Model II (Canadian airport authorities have distinctly different inefficiency parameters from the U.S. airport authority model), only the parameter estimates of Model I are used to describe below the effect of each airport characteristics on the cost frontier.

Non-aeronautical output is one of the most statistically significant variables, and has a positive coefficient of about 0.325. This indicates that a 1% increase in non-aeronautical service output, holding other variables constant, causes total variable cost to increase by only about 0.325%. The strong statistical significance of this coefficient implies that omission of non-aeronautical services output in measuring airport cost and/or efficiency would cause a serious bias on the empirical results by committing model specification error. Figure 1 shows that although the share of non-aeronautical revenue in the airport's total revenue varies across our sample airports, the average value is well over 50%. This implies that, for an average airport, a 10% increase in non-aeronautical revenue would increase an airport's total revenue by 5% while increasing costs only by 3.25%. Therefore, omission of non-aeronautical revenue would lead to over-estimation of costs (or equivalently, under-estimation of efficiency or productivity) for the airports whose management focuses on generating a higher percentage of total revenues from non-aeronautical services, including commercial services.

Figure 1: Share of Non-Aeronautical Revenue for Sample Airports in 2008



The three proxy capital stock measures (the number of runways, number of gates and terminal size) are neither individually nor jointly statistically significant in our cost function. The inclusion of these proxy variables does not seem to help improve our cost function. This means that although it is extremely difficult, if not impossible, to construct a capital stock index consistently comparable across all airports in different jurisdictions with different accounting systems and taxes/subsidies, there is a need to continue with the effort for constructing such capital stock series.

Most of the year, dummy variables (base year 2002) are individually statistically significant and positive, and all year dummy variables together are jointly statistically significant in our cost function. These positive coefficients indicate upward shifts of the cost frontier in the post-2001 period even after controlling for the effects of all of the variables included in our model. This may be because airports in North America had to bear the ever-increasing security costs in the post 9/11 period.

The percentage of international traffic has a statistically significant positive coefficient, meaning that the airport in which international passengers account for a larger share of total traffic faces more upward pressure on airport operating costs than a similar airport with a lower share of international traffic. The parameter estimate, 0.68, indicates that airports with one percentage point higher international passenger share are expected to have 0.68% higher operating costs, ceteris paribus.

Canada country dummy has a negative coefficient but is not statistically significant. This implies that airports in Canada and the United States have similar cost structures.

CONCLUDING REMARKS

This study has found that the choice between the two dominant forms of airport governance in Canada and the United States, i.e., airport authorities vs. government branches, has a significant effect on cost efficiency performance of the airport. In particular, our findings indicate that airports operated by an airport authority outperform those operated by a government branch by, on average, 14% in terms of technical efficiency. This result provides new supporting evidence for the argument that the governance form in which management can exercise a greater degree of autonomy and face less political pressure are more likely to improve efficiency performance. Furthermore, by modeling the interrelationship between governance form and airport variable input usage, we found that the airports run by a government branch tend to have a higher share of the soft cost input cost (including outsourcing cost) than those run by an airport authority. Since little attention has been paid to the influence of governance forms on an airport's input mix, this paper provides a greater account of the impact of governance forms on efficiency performance, and offers a new platform for improving cost frontier specifications for future studies.

Estimation of the hypotheses tests led us to conclude: (a) The efficiency performance and cost structure of the airports operated by Canadian airport authorities are not statistically different from those operated by U.S. airport authorities; (b) our stochastic frontier specification of our cost model significantly improved the accuracy of efficiency measurement, suggesting to future research that it is worth incorporating both the allocative inefficiency and the technical inefficiency modules in the stochastic cost frontier models for measuring airport efficiency.

In addition, our results also show that it is important to include non-aeronautical services as a part of airport outputs because, otherwise, empirical results on cost efficiency would get biased against the airports whose management focuses on increasing commercial and other non-aeronautical revenues.

The empirical constructs of the current study offer a useful starting point for a more in-depth analysis of the effects of airport governance forms. To further extend our study, it is possible to formulate more flexible models that account for the presence of observed and unobserved heterogeneity across individual airports. Due to estimation problems, we had to simplify our model structure dealing with the interrelationship between governance forms and airport input mix, which clearly is one of the potential future improvements in model specification and estimation. In addition, the incorporation of the nature of contractual relationships between airports and airlines (major customers) is another area that warrants further research. The complex specification required for such work, however, may increase the computational complexity and difficulty.

Endnotes

1. A growing number of economists argue that the two-sided platforms (airports and airlines) internalize the "demand externalities" that each agent in isolation cannot internalize efficiently. Rochet and Tirole (2006) define the two-sided markets as a situation in which the volume of transactions between end-users depends not only on the overall level of the fees charged by the platform but also on the way in which the transactions are structured and governed.

2. By estimating a stochastic cost frontier via a Bayesian approach, they found that the airports run by an airport authority perform far more efficiently than those operated by a government branch in North America.

3. Airport studies of efficiency utilizing parametric and non-parametric approaches are reviewed and summarized in Liebert and Niemeier (2010).

4. Deterministic kernel is the costs of a fully efficient institution in absence of random factors.

5. The soft cost input consists of all costs and expenses other than personnel costs and capital expenditure.

6. Since we believe there is no way of creating consistent measures of airport capital inputs or capital stocks comparable across airports in different jurisdictions, we decide to use these three physical measures of capital stocks as quasi-capital input measures.

7. Let θ be a vector of parameters to be estimated, and H_0 specify hypothesized restrictions on these parameters. Let $\hat{\theta}_U$ be the ML estimator of θ obtained without imposing the parameter restrictions and be $\hat{\theta}_R$ the constrained ML estimator. If we let $\widehat{L}(\hat{\theta}_U)$ and $\widehat{L}(\hat{\theta}_R)$ be the likelihood functions evaluated at these two estimates, then it is well known that the following likelihood ratio test statistics (λ) is asymptotically Chi-square distributed with degrees of freedom equal to the number of restrictions imposed in the null hypothesis H_0, provided H_0 is true.
$$\lambda = -2\{log[\widehat{L}(\hat{\theta}_R)] - log[\widehat{L}(\hat{\theta}_U)]\}$$

8. Furthermore, the ratio of variances reported at the bottom of Table 2 indicates that about 74% of the total variation is accounted for by our technical inefficiency model (Part B in Table 2). This is another indicator that the incorporation of our technical inefficiency frontier in our translog cost function was a worthwhile practice.

9. By applying Shephard's lemma to Model I we can give this interpretation of the coefficient ρ_1.

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APPENDIX A: List of Sample Airports, 2002-2008

North America - United States			
	Code	Airport Name	Governance Structures
1	ABQ	Albuquerque International Airport	Government Branch
2	ALB	Albany International Airport	Airport Authority
3	ATL	Hartsfield-Jackson Atlanta International Airport	Government Branch
4	AUS	Austin Bergstrom Airport	Government Branch
5	BNA	Nashville International Airport	Airport Authority
6	BWI	Baltimore Washington International Airport	Government Branch
7	CLE	Cleveland-Hopkins International Airport	Government Branch
8	CLT	Charlotte Douglas International Airport	Government Branch
9	CVG	Cincinnati/Northern Kentucky International Airport	Airport Authority
10	DCA	Ronald Reagan Washington National Airport	Airport Authority
11	DEN	Denver International Airport	Government Branch
12	DFW	Dallas/ Fort Worth International Airport	Airport Authority
13	DTW	Detroit Metropolitan Wayne County Airport	Airport Authority
14	FLL	Fort Lauderdale Hollywood International Airport	Airport Authority
15	HNL	Honolulu International Airport	Government Branch
16	IAD	Washington Dulles International Airport	Airport Authority
17	IAH	Houston-Bush International Airport	Government Branch
18	IND	Indianapolis International Airport	Airport Authority
19	JAX	Jacksonville International Airport	Airport Authority
20	LAS	Las Vegas McCarran International Airport	Government Branch
21	LAX	Los Angeles International Airport	Government Branch
22	MCI	Kansas City International Airport	Government Branch
23	MCO	Orlando International Airport	Airport Authority
24	MDW	Chicago Midway Airport	Government Branch
25	MEM	Memphis International Airport	Airport Authority
26	MIA	Miami International Airport	Government Branch
27	MKE	General Mitchell International Airport	Government Branch
28	MSP	Minneapolis /St. Paul International Airport	Airport Authority
29	MSY	Louis Armstrong New Orleans International Airport	Government Branch
30	ONT	Ontario International Airport	Government Branch
31	ORD	Chicago O'Hare International Airport	Government Branch
32	PHL	Philadelphia International Airport	Government Branch
33	PHX	Phoenix Sky Harbour International Airport	Government Branch

APPENDIX A: List of Sample Airports, 2002-2008 (continued)

34	PIT	Pittsburgh International Airport	Airport Authority
35	RDU	Raleigh-Durham International Airport	Airport Authority
36	RIC	Richmond International Airport	Airport Authority
37	RNO	Reno/Tahoe International Airport	Airport Authority
38	SAN	San Diego International Airport	Airport Authority
39	SAT	San Antonio International Airport	Government Branch
40	SDF	Louisville International Airport	Airport Authority
41	SFO	San Francisco International Airport	Government Branch
42	SJC	Norman Y. Mineta San Jose International Airport	Government Branch
43	SLC	Salt Lake City International Airport	Government Branch
44	SMF	Sacramento International Airport	Government Branch
45	SNA	John Wayne Orange County Airport	Government Branch
46	STL	St. Louis-Lambert International Airport	Airport Authority
47	TPA	Tampa International Airport	Airport Authority
North America - Canada			
	Code	Airport Name	Governance Structures
48	YEG	Edmonton International Airport	Airport Authority
49	YHZ	Halifax International Airport	Airport Authority
50	YOW	Ottawa International Airport	Airport Authority
51	YUL	Montreal-Pierre Elliot Trudeau international Airport	Airport Authority
52	YVR	Vancouver International Airport	Airport Authority
53	YWG	Winnipeg International Airport	Airport Authority
54	YYC	Calgary International Airport	Airport Authority

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