Effects of Government Quality and Institutional Choice on Efficiency of the U.S. Commercial Airports

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Abstract

Major commercial airports in the U.S. are operated by local governments either directly as government branches or indirectly via airport or port authorities. Recent research has uncovered that the institutional arrangements on airport governance structure matter for airport efficiency. In this paper, we test the hypothesis that connects efficiency of airports to government quality measured by degree of corruption. We first develop a theory which predicts the impacts of corruption on productivity and variable input allocation of airports under the three alternative institutional arrangements being used in the United States. We then test the predictions by estimating a stochastic variable cost frontier model which incorporates both technical and allocative efficiency of airports. The empirical evidences confirm the theoretical predictions by revealing the following: (1) in the absence of corruption, productivity of airport authorities is higher than that of city-owned and operated airports; (2) corruption is found to lower productivity of airport authorities but not to affect productivity of airports under the other two institutional choices; (3) in the absence of corruption, airports under all the three institutional arrangements over-utilize direct labor relative to non-labor inputs including outsourcing of services; and (4) corruption lowers the degree of the relative over-utilization of labor inputs in airports.

Keywords: allocative efficiency, technical efficiency, institutional choice, career concerns, corruption, stochastic frontier analysis

1. Introduction

Major airports around the world were traditionally owned and operated by national or local governments. However, starting with the privatization of the three airports in London (Heathrow, Gatwick, and Stansted), there has been a world-wide trend of airport privatization. Although U.S. congress also created an Airport Privatization Pilot Program in 1996, the program is making very slow progress. Reforming airport governance structure in the United States has in general taken the form of transferring airport management from local governments to special purpose and independent airport authorities, which are not-for-profit public entities and are by-and-large financially self-sustaining. Although transfers of airport management from local governments to independent airport authorities were caused by different reasons, the general belief is that compared to general-purpose local governments, the mission-focused airport authorities can manage airports in more efficient ways. Indeed, the findings in Oum, Yan, and Yu (2008) and Craig, Airola and Tipu (2009) support this general belief.

Efficiency of airports affects the economic performance of regions. When an airport is publicly owned, a higher efficiency of the airport implies a lower budget burden to the local government. Moreover, efficiently managed airports facilitate air travel by reducing travel costs through reducing flight delays and various charges to both aeronautical and non-aeronautical services such as parking and concessions. Air travel has a significant positive effect on regional economy by boosting growth in population, employment, and income as documented in Brueckner (2003), Green (2007) and Blonigen and Cristea (2012).

In this paper, we argue that the effects of transferring airport management from local governments to airport authorities on airport cost efficiency depend on government quality, which is measured by the extent of corruption. Corruption affects economic development. Shleifer and Vishny (1993) point out the distortion to economy caused by bribes, which are the major form of corruption, is similar to the one from taxes. Moreover, corruption is usually illegal and efforts to avoid detection and punishment cause corruption to be more distortionary and pernicious than taxation. Empirical findings support this argument. At the macro level, Mauro (1995, 1998) and Ades and Di Tella (1999) find a negative relationship between investment and corruption. At the micro level, Dal Bó and Rossi (2007) find that countries with higher corruption tend to have more inefficient electricity distribution firms. Empirical evidences in Fisman (2001), Svensson (2003), Clarke and Xu (2004), Di Tella and Schargrodsky (2003), Khwaja and Mian (2004), and Cai, Fang, and Xu (2009) show that corruption can divert firms' managerial efforts from productive activities to rent-seeking activities such as building political connections.

Like modern corporations, business decisions of an airport authority are made by the management led by the CEO, whose behavior is monitored by a board of directors. However, airport authorities are different from private firms. First, airport authorities are still public entities such that their managers are not incentivized by profit-maximization. Second, board members of airport authorities are appointed by state/county/city government such that government is still involved in decision making of airport authorities. Based on the number of government officials convicted for corruption by the Federal justice department, the index created by Glaeser and Saks (2006) shows that the corruption rate varies substantially across the states. Motivated by the literature on the economic consequences of corruption and the observation on internal organization of airport authorities, we ask the question: are the effects of transferring airport management from local governments to airport authorities in the U.S. affected by the corrupt environments in which the airports must operate?

We investigate the research question by employing a simple principal-agent model to characterize the decision making of airport authorities. In the principal-agent model, the principal or the board of an airport authority is delegated to pursue government goals through costly monitoring; the agent or the manager of the airport authority is incentivized by "career concerns" instead of profit-maximization; and thus, agency problems arise because of this divergence between the preferences of the manager and the board. As such, the model integrates three strands of literature: the theory in political economy on the goals of politicians (Kemp 1991 and Kodrzycki 1994), the career concern models on the incentive of managers (Holmstrom 1982), and the agency theory of the firm (Jensen and Meckling 1976).

We compare airport authorities with city-owned airports, the decision-making of which is modeled by the career concerns models with multiple tasks analyzed in Dewatripoint, Jewitt and Tirole (1999a, b). The comparison first formalizes the general belief that transferring airport management can lead to productivity gain from being focused when the board's monitoring efforts are high. However, the comparison suggests also that airport authorities may not outperform city-owned airports in productivity when the board's monitoring efforts are low.

In our analysis, corruption matters for airport efficiency by affecting airports' decision making. We explain such impacts based on the fact that the accountability of public policy outcomes in highly corrupt environments is low.[1] As a result of low accountability of public policy outcomes, the board of an airport authority puts low efforts in monitoring. Therefore, transferring airport management from local governments to airport authorities cannot improve airport productivity in corrupt environments. Furthermore, airport authorities in corrupt environments tend to use outsourcing to replace in-house labor. Outsourcing services can in fact lead to a more efficient input allocation if political patronage was an important goal pursued by government.

Using a unique data set from 55 major airports in the U.S. from 2001 to 2009, we test the above theoretical hypotheses empirically. The empirical model for such purposes is a stochastic variable cost frontier model which incorporates both the efficiency determined by productivity (*technical efficiency*) and the efficiency determined by variable input mix (*allocative efficiency*). We explain technical and allocative efficiency of airports as functions of institutional arrangements of the airports and corrupt environments under which the airports are operated after controlling for airport, city, and state characteristics. It is also possible that institutional arrangements of airports are caused by efficiency concerns. However, as we will describe in detail later, institutional arrangements of most airports in our data were determined much earlier than the period covered by the study; even such decisions were driven by factors that affect airport efficiency, the impacts of those factors on current airport efficiency are expected to be small. In any case, we recognize that the

[1] Evidences that a low accountability of public-policy making is associated with a high-degree of corruption can be found in Heywood (1997), Persson and Tabellini (2000), Adserá, Boix, and Payne (2003), Alt and Lassen (2003), and Lederman and Loayza (2003).

exogenous institutional arrangement is an important assumption, so we later conduct a sensitivity analysis to assess its effects on our findings. In the sensitivity analysis, we use state laws and city characteristic as instruments for endogenous institutional arrangements.

Our empirical findings are broadly consistent with the theoretical predictions. Based on the results from both theoretical and empirical analysis, we argue that transferring airport management from local governments to airport authorities is unlikely to be sufficient to take full advantage of efficiency improvement. Other forms of reforming airport governance structure, such as airport privatization, should receive more attention.

2. The Theory

2.1 Model setup

We assume that an airport is required to meet an output target which is exogenously determined by air transport needs of the city and the region. We use $\bar{q}$ to denote the output target; as long as the actual output is not less than $\bar{q}$, the society cares only about the cost efficiency of the airport. We therefore model the production function of an airport as $q = (\bar{q} + e_p + \theta + \varepsilon_p) \cdot F(\bar{k}, l, m)$, where the total productivity depends on managerial efforts (e_p) in coordinating production process, managerial talent (θ) and a random noise representing productivity shock (ε_p). Managerial talent is a random variable and it is independent with the productivity shock. We further assume that $\theta \sim N(\bar{\theta}, \sigma_\theta^2)$ and $\varepsilon_p \sim N(0, \sigma_\varepsilon^2)$. Capital inputs are fixed at $\bar{k}$ in the short run and two variable inputs are labor (l) and non-labor variable inputs (m), which include purchased goods and services (outsourcing). In order to meet the output target, inputs at an airport are always set in a way such that $\Pr(q \le \bar{q})$ is very small for all e_p and θ.

As public entities, U.S. commercial airports are required to adopt the weight-based aviation charges for aircraft landings. Let p denote the unit aviation charge ($ per seat), the measure of an airport's cost efficiency at the realized output is represented by the short-run profit function

$$\pi = p \cdot q - w_l \cdot l - w_m \cdot m \tag{1}$$

where w_l and w_m denote the unit prices of labor and non-labor inputs respectively (variable inputs prices are also assumed to be exogenously given to an airport). The cost efficiency can be affected by technical inefficiency which corresponds to an over-utilization of inputs given outputs and input mix and is measured as $e_p + \theta + \varepsilon_p$, and allocative inefficiency which corresponds to a deviation of marginal rate of substitution from the ratio of inputs' prices.

2.2 Decision making of airport authorities in the absence of corruption

Airport authorities are mission-focused to manage airport operations. They have also managerial autonomy to allocate inputs in production because they fund their daily operations using retained earnings instead of using local tax revenue. The board members of an airport authority are appointed by state/county/city government.

The board's Objectives. One of the main incentives for government contracting-out, as indicated by Savas (1987), Kemp (1991), Lopez-de-Silanes, Shleifer and Vishny (1997), is to get rid of budget burden, which is also the main incentive for local governments to transfer airport management to independent airport authorities, as summarized in Reimer and Putnam (2009). As the representative of the government, the board of directors of an airport authority cares the cost efficiency of the airport because a self-funding airport leads to lower public budgets. By appointing board members, local governments can still pursue political goals even after transferring airport management. Kemp (1991) and Kodrzycki (1994) point out that the main political goal pursued by politicians through public provision is to win the support of public employee unions. We assume here that the board of an airport authority still pursues the goal, or at least avoids active opposition from public employee unions. The way to model this objective is to define a threshold ratio of non-labor to labor variable inputs and the threshold is denoted by m_0/l_0. A positive deviation from the threshold, which is defined as $\tilde{m} \equiv \max\left\{0, \frac{m}{l} - \frac{m_0}{l_0}\right\}$ with m/l denoting the actual variable input ratio, generates disutility to the board. The utility function of the board is $\alpha \cdot \left(E\left(e_p + \theta + \varepsilon_p\right) - h(\tilde{m})\right) = \alpha \cdot \left(E\left(y_p\right) - h(\tilde{m})\right)$. In the utility function, $h(\tilde{m}) \geq 0$, $h(0) = 0$ and $h'(\cdot) \geq 0$; α captures the intensity of the board's preference for government objectives.

The manager's objectives. As a not-for-profit entity, the manager of an airport authority is motivated by career concerns; a high performance in managing airport operation raises labor market's perception of his ability and translates into future job opportunities. Since all information about the manager's talent is captured by $y_p \equiv e_p + \theta + \varepsilon_p$, the labor market can infer the manager's ability by observing the airport's productivity. The reward (R) to the manager is then $R = E\left(\theta \middle| y_p\right)$.

With managerial autonomy, the manager can pursue cost efficiency through efficient allocation of inputs. However, career concerns do not offer the manager the incentive to allocate inputs efficiently because a more efficient allocation of inputs cannot signal the manager's ability to the labor market. What the manager could do with managerial autonomy is to pursue personal benefits via changing the allocation of inputs. Because of the low accountability of outsourcing, we model that the manager could use outsourcing to replace in-house labor in order to gain private benefits. The potential source of agency problems in our setting can be interpreted as a "pet project" that uses outsourcing and generates benefits to the manager.

By monitoring, the board can push the manager toward the government objectives. We use γ to denote the units of monitoring. With more monitoring, the accountability of outsourcing transactions is higher such that private benefits generated from such transactions to the manager are less. The benefits from the pet project is denoted by $e_g g(\tilde{m}, \gamma)$ with e_g denoting the efforts spent in pursuing the pet project; $g(\tilde{m}, \gamma) \geq 0$ and $g(\tilde{m}, \gamma) = 0$ if $\tilde{m} = 0$, which basically state that the manager can gain positive benefits by deviating from government's target on the ratio of non-labor to labor variable inputs. We assume also that $\frac{\partial g(\tilde{m}, \gamma)}{\partial \tilde{m}} > 0$, $\frac{\partial^2 g(\tilde{m}, \gamma)}{\partial \tilde{m}^2} < 0$, $\frac{\partial g(\tilde{m}, \gamma)}{\partial \gamma} < 0$, and $\frac{\partial^2 g(\tilde{m}, \gamma)}{\partial \tilde{m} \partial \gamma} < 0$. The first two inequalities state that the benefits from the pet project are a strictly increasing and concave function of resource reallocation. The latter two inequalities state that the benefits and marginal benefits of the pet project are strictly decreasing with respect to the board's monitoring. The manager's expected utility function is $E\left(E\left(\theta \middle| y_p\right)\right)+e_g g(\tilde{m},\gamma)$. In the first term of the expected utility function, the inside expectation is with respect to talent and the outside expectation is with respect to productivity.

Decision making of the airport authority. Given the monitoring from the board and market expectation for the manager's effort level e_p^e, the manager of an airport authority solves

$$\max_{e_p, e_g, \tilde{m}} E\left(E\left(\theta \middle| y_p, e_p^e\right)\right)+e_g \cdot g(\tilde{m},\gamma)-C_a\left(e_p+e_g\right) \tag{2}$$

$C_a\left(e_p+e_g\right)$ is the cost of the manager's total efforts. Taking the manager's response to monitoring into account, the board solves

$$\max_{\gamma} \alpha \cdot \left(E\left(y_p\right)-h(\tilde{m})\right)-C_b(\gamma) \tag{3}$$

where $C_b(\gamma)$ is the board's cost of monitoring. Both $C_a\left(e_p+e_g\right)$ and $C_b(\gamma)$ are assumed to be convex functions of efforts.

Equilibrium. We first characterize the manger's equilibrium efforts given a monitoring level from the board. Because the manager's efforts on the productive activity and on the pet project are not separable, we can divide the discussion into two situations – to pursue and not to pursue the pet project.

When the manager does not pursue the pet project $(\text{i.e.}\ e_g=0)$, the manager chooses efforts spent on productive activities $\left(e_p\right)$ given a labor market's expectation $\left(e_p^e\right)$ to maximize his expected payoff. Let the solution function be $e_p\left(e_p^e\right)$ and the solution function is a self-map on the effort space. The equilibrium effort level, which is denoted by e_p^*, is the fixed-point of the self-map and it satisfies the following first-order condition[2]:

[2] Detail derivations are presented in the technical appendix of the paper.

$$C_a'\left(e_p^*\right)=\frac{1}{1+\sigma_\varepsilon^2/\sigma_\theta^2} \tag{4}$$

When the manager spends efforts on the pet project $\left(e_p=0\right)$, he chooses efforts on the pet project and a positive deviation from the government's targeted variable input ratio to maximize his payoff. The optimal decisions can be characterized by the following first-order conditions

$$C_a'\left(e_g\right)=g\left(\tilde{m},\gamma\right) \quad \text{and} \quad \frac{\partial g\left(\tilde{m},\gamma\right)}{\partial \tilde{m}}=0 \tag{5}$$

We use $e_g^*(\gamma)$ and $\tilde{m}^*(\gamma)$ to denote the solutions from the first-order conditions and they are functions of monitoring. The following proposition characterizes the manager's optimal decision rule responding to the board's monitoring.

Proposition 1:

1. Both $e_g^*(\gamma)$ and $\tilde{m}^*(\gamma)$ are strictly decreasing function of γ.

2. There exists uniquely a $\bar{\gamma}$. When $\gamma>\bar{\gamma}$, the manager does not pursue the pet project such that $e_g^*=0$, $\tilde{m}^*=0$ and e_p^* is determined by equation (4). When $\gamma<\bar{\gamma}$, the manager pursues the pet project such that $e_p^*=0$, $e_g^*=e_g^*(\gamma)$ and $\tilde{m}^*=\tilde{m}^*(\gamma)$.

Proof: In the technical appendix of the paper.

Equilibrium monitoring efforts of the board are characterized as follows.

Proposition 2: Equilibrium monitoring effort level γ^* satisfies:

1. $\gamma^*\in[0,\bar{\gamma}]$.

2. γ^* is strictly increasing with respect to α in the open interval $(0,\bar{\gamma})$.

3. γ^* is less likely to be $\bar{\gamma}$ when α is less.

Proof: In the technical appendix of the paper.

When the board chooses the high monitoring effort level, that is, $\gamma^* = \bar{\gamma}$, the manager of the airport authority is *ex ante* indifferent between pursuing and not pursuing the pet project. Therefore, he will not switch his efforts from productive activities to the pet project.

2.3 Decision making of city-owned airports in the absence of corruption

A city-owned airport is normally operated by a government branch such as the Department of Aviation. Dewatripoint, Jewitt and Tirole (1999a, b) use a career concerns model with multiple tasks to capture the stylized facts[3] summarized in Wilson (1989) about U.S. government agencies. We use such a modeling framework to characterize the decision making of city-owned airports. Because operations of a city-owned airport can be funded by local tax revenues and the funding source restricts the airport's flexibility to change inputs allocation, we assume that the ratio between labor and non-labor variable inputs is exogenously given (determined by the public) at a city-owned airport.

As a bureaucrat, the manager of a city-owned airport pursues multiple tasks including airport cost efficiency. Let n denote the number of tasks pursued by the bureaucrat, the performance of task i (y_i) is determined by $y_i = e_i + \theta + \varepsilon_i$, where e_i denotes the effort spent on the task and ε_i represents the noise; $\varepsilon_i \sim_{iid} N(0, \sigma_\varepsilon^2)$ and talent (θ) is assumed to be the same for all the tasks. The task of airport efficiency is then the one when $i = p$.

In the model the bureaucrat is the "agent" and the voters represent the "principal". Timing of events in each period is as follows. First, the Constitution defines a measure of performance in which the bureaucrat's ability is evaluated. Second, the bureaucrat allocates efforts across multiple tasks. Third, talent and noises realize as random draws from their own distributions and the performances on the tasks are determined. Finally, the voters observe the performances $y \equiv (y_1, \ldots, y_n)$ and takes actions that result in reward to the bureaucrat. The reward function is $R(e_1, \ldots, e_n) = E(\theta | y)$. The cost of efforts is given by $C(e_1, \ldots, e_n) = C(e_1 + \cdots + e_n) = C(e)$ and

[3] These stylized facts include Limited financial incentives, multiple objectives and limited autonomy.

the cost function is assumed to be a convex function of total efforts. Let $e^e \equiv \left(e_1^e, \ldots, e_n^e\right)$ denote the public perception of the bureaucrat's effort levels, the problem faced by the bureaucrat is then to choose efforts to maximize his expected utility

$$\max_{(e_1, \ldots e_n)} E\left(E\left(\theta \middle| y, e^e\right)\right) - C(e) \tag{6}$$

Two results emerge from the career concerns model with multiple tasks. First, increasing number of tasks reduces total effort level of the bureaucrat (Dewatripont, Jewitt and Tirole 1999b); and second, the bureaucrat may misallocate efforts among tasks (Alesina and Tabellini 2008).

If the multiple tasks are equally important to the voters such that the bureaucrat is evaluated based on the aggregate performance $Y_n \equiv \sum_{i=1}^{n} y_i$, the career concerns model for city-owned airports is a special case of the one in Dewatripont, Jewitt and Tirole (1999b), which shows that the positive equilibrium level of total efforts ($e^* \equiv \sum_{i=1}^{n} e_i^*$) is determined by

$$C'\left(e^*\right) = \frac{1}{n + \sigma_\varepsilon^2 / \sigma_\theta^2} \tag{7}$$

Under the assumption that the cost of efforts is a convex function, increasing the number of tasks decreases the positive equilibrium level of total efforts.

Under multiple-tasks environment, the bureaucrat may focus on tasks which are more helpful in signaling his ability. Alesina and Tabellini (2008) show that such a misallocation of efforts can be caused by uncertain voters' preferences[4].

2.4 Comparing productivity and inputs allocation across institutional arrangements

We assume that talents and effort cost functions are the same for both the manager and the bureaucrat. By comparing equation (4) with equation (7) and by using proposition 1, we can conclude:

[4] We present a detail illustration on this point in the technical appendix of the paper.

Proposition 3: When the monitoring efforts from the board are high $(\gamma^* = \bar{\gamma})$, productivity of an airport authority is the upper bound of the productivity that a city-owned airport can have. When the monitoring efforts from the board are low $(\gamma^* < \bar{\gamma})$, the productivity of an airport authority represents the lower bound of the productivity that a city-owned airport can have.

As for the allocation of inputs, the ratio of non-labor to labor variable inputs at a city-owned airport is set to meet the government's political goals, which are also the objectives of input allocation in an airport authority when the monitoring efforts from the board are high. However, when the monitoring efforts from the board are low, the manager of the authority would deviate from the government political goals to use outsourcing to replace in-house labor in order to derive private benefits. We therefore conclude:

Proposition 4: When the monitoring efforts from the board are high $(\gamma^* = \bar{\gamma})$, the ratio of non-labor to labor variable inputs in an airport authority is not different with the one in a city-owned airport. When the monitoring efforts from the board are low $(\gamma^* < \bar{\gamma})$, the variable input ratio in an airport authority is larger than the one in a city-owned airport.

The lower ratio of labor to non-labor variable inputs can in fact imply a higher allocative efficiency if job creation in public sectors is important in government's goals such that labor input is relatively over-utilized under government control.

2.6 Impacts of corruption

Corruption in this paper follows the definition in Treisman (2000) as the misuse of public office for private gains. Since different institutional arrangements affect decision making of airports and therefore lead to different efficiency outcomes, the first channel that corruption can affect airport efficiency is to affect institutional choice of airports. What are the effects of corruption on airport institutional choice? There is no a clear-cut answer in theory to this question. As pointed out by Shleifer (1998), corruption has two conflict effects on government decision on "in-house provision" vs. "contracting out" of public services. On one hand, politicians can be in a better position to pursue political benefits when airports are kept in the hand of government. On the other hand, contracting-out could be used by politicians as a way to take private benefits (bribes) from providers. Findings in Reimer and Putnam (2009) show that transfers of airport management in the United States can be attributed to various reasons, which include lack of funding of individual airports and certain special events. In this paper, we therefore focus on another channel in which corruption affects airport efficiency through affecting decision making of airports.

Our explanation on the effects of corruption on airports' decision making is based on the relationship between the accountability of policy making and corruption. Many studies in both political science and economics[5] identify that a low accountability of public-policy making is associated with a high degree of corruption. Using data from American states, Alt and Lassen (2003) find that corruption is less in states where voters are better informed about public policy outcomes[6]. We therefore assume that the accountability of public policy outcomes is lower in more corrupt environments. Based on this assumption, we illustrate how corruption affects airports' decision making under different institutional arrangements.

Airport authorities. Corruption is not supposed to affect the job market's assessment on the manager's ability. However, because the benefits to the government by pushing the manger toward the goals of increasing productivity and job creation are lower when outcomes of public policies are less informed to the voters, corruption could lower the board's preferences toward government goals. The effects of corruption on the efficiency of airport authorities can be summarized as follows.

Proposition 5: The manager of an airport authority is more likely to focus only on the pet project when the environment is more corrupt (from proposition 2). When the manager focuses only on the pet project, the ratio of non-labor to labor variable inputs is larger if the environment is more corrupt (from proposition 1).

[5] Examples include Heywood (1997), Persson and Tabellini (2000), Adserá, Boix, and Payne (2003), Alt and Lassen (2003), and Lederman and Loayza (2003).

[6] Explanations to the link between low accountability of public policy outcomes and high corruption include: 1. the politicians and bureaucrats are in a better position to pursue rent-seeking activities when the accountability of public policy outcomes is lower; and 2. in more corrupt environments, the politicians and bureaucrats are more likely to implement practices which reduce the accountability of public policy making in order to extract private benefits because the cost of doing so is less in more corrupt environments.

City-owned airports. The low accountability of public-policy outcomes implies that the voters are not well informed about the performances of the mandated tasks pursued by the bureaucrat. We model this by assuming that instead of observing y_i, the public can only observe $\tilde{y}_i = y_i + \eta_i$, where $\eta_i \sim_{iid} N\left(0, \sigma_\eta^2\right)$. The variance of η_i, which captures the noise associated with the voters' information on performance of mandated tasks, is larger when the environment is more corrupt. Adding the noise term implies that the first order condition in equation (9), which determines the positive equilibrium level of total efforts devoted by the bureaucrat , is modified as $C'\left(e^*\right) = \frac{1}{n + \left(\sigma_\eta^2 + \sigma_\varepsilon^2\right) / \sigma_\theta^2}$. We can have the following conclusion.

Proposition 8: The bureaucrat devotes less total efforts on the mandated tasks when the environment is more corrupt.

2.7 Predictions to guide empirical analysis

Having analyzed decision making of airports under different institutional arrangements and corrupt environments, we are now ready to draw several predictions which guide our empirical analysis.

We first predict impacts of corruption on airport productivity and such impacts are different for different institutional arrangements. For a city-owned airport, corruption diverts the bureaucrat's effort away from mandated tasks. However, the impacts of the diversion on the airport's productivity can be large only when the voters have strong preferences toward airport efficiency such that the Constitution specifies efficiency of the airport as the only one task to the bureaucrat. When the number of mandated tasks is large such that the bureaucrat's total efforts as well as efforts allocated to individual tasks are low, the deviation from mandated tasks caused by corruption has small impacts on the airport productivity. In the extreme case when the bureaucrat misallocates his efforts because of uncertain voters' preferences such that airport efficiency is allocated zero effort, the diversion from mandated tasks caused by corruption has no impacts on the airport's productivity. For an airport authority, corruption diverts the board's efforts away from monitoring which pushes the manager toward maximizing the airport's productivity. Facing no monitoring, the manager of the authority focuses only on the pet project. We have the following prediction.

Prediction 1: Corruption affects productivity of airport authorities negatively but has no significant impacts on productivity of city-owned airports.

We then predict the impacts of corruption on resource allocation of airports. In our theoretical analysis, corruption will not affect resource allocation of a city-owned airport because the airport has little managerial autonomy in allocating inputs. For an airport authority, our model predicts that higher corruption leads to lower monitoring efforts from the board. The lower monitoring level in turn leads to lower managerial efforts on improving airport productivity and higher managerial efforts on pursuing private benefits via outsourcing.

Prediction 2: Corruption affects the ratio of non-labor to labor variable inputs of airport authorities positively.

The last prediction is on the comparison of productivity across institutional arrangements under different corruption environments. Because airport authorities can only be benefited from being focused when the board's monitoring efforts are high, we have the following prediction.

Prediction 3: Airport authorities are more technically efficient than airports operated by local governments in low corruption environments but not in high corruption environments.

3. Empirical Analysis

In this section, we first describe data used in the empirical analysis and then outline econometric models which test our theoretical predictions. Finally, we discuss identification issues faced by the analysis.

3.1 Data

The sample consists of a balanced panel of 55 U.S. airports between 2001 and 2009. The data are compiled from various sources including Airport Council International (ACI), the U.S. Federal Aviation Authority (FAA), International Air Transport Association (IATA), and airport annual reports. Some data were obtained directly from the airports. Details on the data are provided in various issues of the ATRS Global Airport Benchmarking Report (for example, Air Transport Research Society, 2011).

In order to study the cost efficiency of airports, we need information on outputs, inputs, prices of variable inputs for each of the airports. We consider three output measures, namely the number of passengers, the number of aircraft movements (ATM) and revenues from non-aeronautical services including concessions, car parking, and numerous other services. These services are not directly related to aeronautical activities in a traditional sense, but they are becoming increasingly more important for airports around the world and account for over 60% of the total revenues for many airports. Variable inputs used by airports can be classified into three categories: (1) labor, measured by the number of (full time equivalent) employees who are on the airport operator's payroll; (2) purchased goods and materials; and (3) purchased services including outsourcing/contracting out. In practice, few airports provide separate expense accounts for the purchased (outsourced) services and purchased goods and materials. Thus, we decided to combine (2) and (3) to form a so-called 'non-labor variable input". This non-labor variable input includes all expenses not directly related to capital or labor input costs. The price of labor input is measured by the average compensation per employee (including benefits). In addition to the variable inputs, two physical capital input indicators are considered: number of runways and total size of passenger terminal area measured in square meters.

Among the 55 airports, 28 are operated by local government (city or state) and 18 are managed by an independent and autonomous management authority via a long term lease. Two airports (Nashville and Minneapolis-St. Paul) are 100% government corporation ownership and management and we group them into the category of airport authority. Most of the airport authorities and public corporations were created much earlier than the time period covered by our study. Finally, seven airports are operated by port authorities, which are entities operating both seaports and airports.

The 55 airports are located in 30 states. Using the number of government officials convicted for corrupt practices through the Federal justice department, Glaeser and Saks (2006) construct corruption rate per capita for each of the 50 U.S. states. We use this state-level corruption rate as the measure of the corrupt environment faced by the airports in our sample. Table 1 lists the 55 airports, their institutional arrangements, the states where they are located, and the corruption rates of the states.[7]

Table 2 presents some summary statistics of the sample. These summary statistics indicate that there are large variations among the sample airports in the sample period (2001-2009) in terms of their size. For example, the annual number of airport passengers ranges from 2.2 million passengers to 83 million passengers. Labor cost shares range from 4% to 73%.

3.2 Econometric Model

The empirical models are guided by the developed theory to test the impacts of corruption on productivity and inputs allocation of airports under different institutional arrangements. For the purpose, we specify a short-run production cost function of airport i at time t as $C_{it}^{*}\left(Q_{it}, W_{it}^{*}, K_{it}\right)$, where Q_{it} is the vector of outputs; W_{it}^{*} is the vector of variable inputs' shadow prices; and K_{it} is the vector of fixed capital inputs. We include three outputs in vector Q_{it} (number of aircraft movements; number of passengers; and non-aeronautical output), two variable input prices in vector W_{it}^{*} (labor price and non-labor variable input price), and two fixed capital inputs in vector K_{it} (number of runways and terminal size).

The observed actual production cost, which is denoted by $C_{it}\left(Q_{it}, W_{it}^{*}, K_{it}\right)$, can deviate from the cost frontier because of technical and allocative inefficiency. In order to model allocative efficiency, we follow Atkinson and Cornwell (1994) and Kumbhakar and Tsionas (2005) to let shadow prices of variable inputs be parametrically related to their market prices $\left(W_{it} \equiv \left(w_{1it}, w_{2it}\right)\right)$ such that $W_{it}^{*} \equiv \left(w_{1it}^{*}, w_{2it}^{*}\right) = \left(\lambda_1 w_{1it}, \lambda_2 w_{2it}\right)$, where subscripts 1 and 2 index labor and non-labor variable inputs respectively and $\lambda_1, \lambda_2 > 0$. The allocative efficiency is measured then by the parameter vector $\lambda \equiv \left(\lambda_1, \lambda_2\right)$ and an airport is allocatively efficient if

[7] A corruption rate of 0.23 (for CA) means that 0.23 public officials who were convicted for corruption every year for every 100,000 population.

$\lambda_1/\lambda_2 = 1$. $\lambda_1/\lambda_2 < 1$ implies the over-utilization of labor input relative to non-labor variable inputs and $\lambda_1/\lambda_2 > 1$ implies the relative over-utilization of non-labor variable inputs.

As for technical inefficiency, we let $x^*_{jit}(Q_{it}, W^*_{it}, K_{it})$ denote the conditional demand function of variable input j and $j = 1,2$. The actual variable input (x_{jit}) can be inflated by technical inefficiency and we specify $x_{jit} = \exp(\Delta_i) \cdot x^*_{jit}(Q_{it}, W^*_{it}, K_{it})$, in which $\exp(\Delta_i)$ captures overutilization of inputs caused by technical inefficiency given outputs and inputs mix. By Shephard's lemma we express the actual variable cost as

$$\begin{aligned} C_{it}(Q_{it}, W^*_{it}, K_{it}) &= \exp(\Delta_i) \cdot \sum_{j=1}^{2} w_{jit} x^*_{jit}(Q_{it}, W^*_{jit}, K_{it}) = \exp(\Delta_i) \cdot \sum_{j=1}^{2} w_{jit} \frac{\partial C^*_{it}(Q_{it}, W^*_{it}, K_{it})}{\partial w^*_{jit}} \\ &= \exp(\Delta_i) \cdot \sum_{j=1}^{2} w_{jit} \frac{\partial \ln C^*_{it}(Q_{it}, W^*_{it}, K_{it})}{\partial \ln w^*_{jit}} \frac{C^*_{it}(Q_{it}, W^*_{it}, K_{it})}{w^*_{jit}} = C^*_{it}(Q_{it}, W^*_{it}, K_{it}) \cdot \exp(\Delta_i) \cdot \sum_{j=1}^{2} \frac{S^*_{jit}}{\lambda_j} \end{aligned} \quad (12)$$

where S^*_{jit} is the shadow share of variable input j and $j = 1,2$; $\exp(\Delta_i)$ measures the deviation from the cost frontier caused by technical inefficiency and $\sum_{j=1}^{2} S^*_{jit}/\lambda_j$ measures the deviation from the cost frontier caused by allocative inefficiency.

Equation (12) leads to the following empirical cost equation

$$\ln C_{it} = \ln C^*_{it}(Q_{it}, W^*_{it}, K_{it}) + \ln\left\{\sum_{j=1}^{2} \lambda_{ji}^{-1} S^*_{jit}\right\} + \Delta_i + \varepsilon^c_{it} \quad (13)$$

where ε^c_{it} represents the noises associated with the cost observations.

By definition, the actual labor share is $S_{1it} = w_{1it} x_{1it}/C_{it} = w_{1it} \exp(\Delta_i) x^*_{1it}/C_{it}$ and the shadow labor share is $S^*_{1it} = \lambda_{1i} w_{1it} x^*_{1it}/C^*_{it}$. Combining these two equations with equation (12), we have the following observed labor share equation.

$$S_{1it} = \frac{\lambda_{1i}^{-1} S^*_{1it}}{\sum_{j=1}^{2} \lambda_{ji}^{-1} S^*_{jit}} + \varepsilon^s_{it} \quad (14)$$

The random term ε_{it}^{s} represents measurement error to the labor share equation. Efficiency of parameter estimates to the cost equation can be improved by incorporating variable inputs' share equations. Since we have only two variable inputs, in order to avoid the singularity problem, we chose to use the labor share equation only[8].

Equations (13) and (14) are treated as a Non-linear Seemingly Unrelated Regression (SUR) model. In the equations, the size of Δ_i measures technical efficiency of airport i. Because only the ratio $\lambda_i \equiv \lambda_{1i}/\lambda_{2i}$ can be identified, we normalize $\lambda_{2i} = 1$ in estimation and the estimates of λ_i measure allocative efficiency of airports. In order to restrict λ_i to be non-negative, we further specify $\lambda_i = \exp(o_i)$. Our research question is to identify the effect of corruption on both Δ_i and o_i under different institutional arrangements.

3.3 Identification and Estimation

The specified econometric model hypothesizes that airport efficiency, both technical and allocative, is affected by airport institutional arrangements and corruption. In order to test empirically such hypotheses, we compile data from 55 U.S. airports with different institutional arrangements. The 55 airports are from 30 states which vary in the corruption index constructed by Glaeser and Saks (2006). Empirical identification on the relationship between airport efficiency and institutional arrangements/corruption relies on such a variation in data but it faces several challenges.

The first identification issue is that institutional arrangements of airports may be endogenous. Local governments may strategically transfer management of efficient or inefficient airports to independent authorities. Our statistical inference would be biased in such cases. However, Lopez-de-Silanes, Shleifer and Vishny (1997) show that political factors are the most important determinants for local governments' decisions on in-house provision vs. contracting out public services. These political factors include support from public employee unions, job creation in public sectors, and tax burden. By reviewing cases of airport management transfers from local governments to airport authorities, Reimer and Putnam (2009) find that lack of funding of

[8] The empirical results are invariant to the choice of either labor cost share equation or other variable input cost share equation.

individual airports has often been the most common reason of such transfers. Finally, as shown in Table 1, institutional arrangements of most airports in the sample are predetermined to our analysis. Some airports are operated by the port authorities just because they are located close to major seaports with long history and operated by powerful port authorities. Unlike an airport authority which operates local airport(s) only, a port authority operates both local sea port(s) and local airport(s). We therefore assume that institutional arrangements are not endogenously determined in the baseline estimations.

We later conduct a sensitivity analysis to assess the impacts of the assumption of exogenous institutional arrangements on the results by using the instrument variable approach, which requires a set of valid instruments that are exogenous but correlated with the decision to transfer airports' management from local government to airport authority. The first set of instruments includes state laws. Lopez-de-Silanes, Shleifer and Vishny (1997) argue that state laws may have important effects on local government decisions of outsourcing government services and this argument is empirically confirmed by Levin and Tadelis (2010). We follow these two studies to use the instruments which are dummies indicating the following: 1. whether city officials are subject to ethics code; 2. whether state law permits short-term borrowing; 3. whether state imposes city debt limits; 4. whether state mandates balanced budget; 5. whether state assesses property tax; and 6. whether law mandates state audit of local accounts. The second set of instruments includes city characteristics such as city land area, age of the city (years after incorporation), and the form of city governance (mayor vs. manager).

The second identification issue is that omitted airports' characteristics, which are correlated with institutional arrangements and corruption rate and are beyond managerial control, can also affect efficiency of airports. Our empirical strategy to address this identification issue is to construct a set of control variables, which is denoted by Z_i, to capture the impacts of airport characteristics on airport cost efficiency. The first set of control variables in Z_i includes those measuring difference in airports' technology. Airports in the data include both ones such as San Francisco International Airport (SFO) which serves a large volume of international passengers and ones such as Santa Ana Airport (SNA) which serves mainly domestic passengers.

Serving international passengers requires additional space (for example, immigration and customs) which may affect costs of airports. We therefore construct the percentage of international passengers for each of the sampled airports. Similarly, serving passengers and serving air cargo require different technologies and we use the percentage of cargo traffic to control for airport heterogeneity in that dimension. Several airports such as Chicago O'Hare (ORD) Airport in the data are the hubs of major airlines. At their hubs, airlines' operations involve lots of hubbing activities which boost both the number of scheduled flights and the number of connecting passengers. Since hub airports are expected to have different production technology from spoke airports, we include the hub airport dummy to capture such difference.

Airports in the sample face different natural conditions and market characteristics which affect the airports' operations. We use average temperature in January, average temperature difference between January and July, and tourist city dummy , population of Metropolitan Statistical Area (MSA), median MSA household income, and a dummy variable indicating whether there are multiple major airports in the MSA to control for different natural conditions and market characteristics faced by the airports. Because large metropolitan areas including San Francisco Bay Area, Los Angeles, New York City, Washington D.C., and Chicago have more than one airport in the sample, we include the dummies indicating these metropolitan areas in order to capture possible group effects in airports' operations.

Corruption measure in the empirical model is at the state level. Operation costs of airports may be affected by state characteristics which affect also corruption. We include a set of control variables which measure state characteristics in Z_i . These variables are used by Glaeser and Saks (2006) in their study to identify causes to state corruption and are compiled from the Report on Economic Freedom published by Clemson University. The state level control variables include tax revenue per capita, percentage of public employee salary in state GDP, density of public employee in state population and education level of state residents. We include further state dummies to capture possible group effects of airports which are located in the same state. Table 3 presents all the control variables along with their definitions.

The third identification issue is that outputs of an airport could be endogenously determined if the airport could price strategically. For example, facing a positive shock on ε_{it}^{c}, that is, an unexpected increase in operation costs, an airport can potentially increase its charges to transfer part of the cost increase to airport users. In this case, ε_{it}^{c} is correlated with output measures in the cost equation. However, as public entities, U.S. commercial airports have to stick to the Federal aircraft-weight-based aviation charges such that the endogeneity of output measures does not pose a serious concern to the identification.

Identification to the stochastic cost frontier system relies on a parameterization for the cost frontier. Because the cost function in (12) can be more conveniently estimated by taking log, as shown in equation (13), we choose to use the translog functional form to approximate the log cost frontier. The labor share equation in (14) can be easily derived from the translog cost frontier. Under another popular parameterization – the Generalized Leontief function, the functional form of the cost equation, which incorporates both technical and allocative efficiency, would be very complicated. We use a nonparametric approach – variable factor productivity regression, to test the robustness of our findings to the model specification.

Finally, identification to the stochastic cost frontier system faces the so-called incidental parameter problem if Δ_i and o_i are specified as individual dummies, because identification for each of these dummies relies on only nine observations (because we have panel data from 2001 to 2009). One way to overcome this problem is to specify Δ_i and o_i as random variables whose distributions are parameterized with limited number of parameters. However, identification under such a random effects specification relies on strong assumptions on the independence between Δ_i and o_i and between the random effects and the regressors. Because our research question is on the effects of corruption and institutional arrangements on airport efficiency rather than on measuring individual airports' efficiency levels, in the baseline estimations we specify

$$\Delta_i = \alpha + Z_i \Gamma + X_i B \tag{15}$$

where $Z_i\Gamma$ captures the impacts of factors beyond managerial control on airport efficiency and X_i is the vector of institutional arrangements along with their interactions with corruption, and

$$o_i = X_i B \tag{16}$$

Although specifications in (15) and (16) overcome the incidental parameter problem, they may omit other factors which affect also technical and allocative efficiency of airports. As a robustness check, we compare results from the baseline estimations with results from a two-stage approach in which Δ_i and o_i are specified as individual dummies and estimated from the stochastic frontier system; the estimated Δ_i and o_i, which are denoted by $\hat{\Delta}_i$ and $\hat{o}_i$ respectively, are then used as the dependent variables in equations (15) and (16) in the second stage regression, in which the error terms capture unobserved factors which affect the efficiencies. The standard errors of parameter estimates in the second-stage regressions should be corrected in order to account for the statistical uncertainty in $\hat{\Delta}_i$ and $\hat{o}_i$. We correct the standard errors by bootstrapping the estimated $\hat{\Delta}_i$ and $\hat{o}_i$ from their estimated asymptotic joint distribution. For each bootstrapped $\hat{\Delta}_i$ and $\hat{o}_i$, we estimate the regression equations specified in (15) and (16) jointly as a SUR model. The corrected standard errors are the averaged ones across the bootstrap repetitions.

In sum, our empirical strategy to deal with various identification challenges is to estimate the parameters under different identification assumptions and to draw conclusions based on robust findings across the estimates. Parameters in equation (13) and (14) are estimated by an efficient Generalized Method of Moments (GMM) approach, in which the moment conditions are the orthogonal conditions

$$E\left(\varepsilon_{it}^{c} \middle| H_{it}\right) = E\left(\varepsilon_{it}^{S} \middle| H_{it}\right) = 0 \tag{17}$$

where H_{it} is a set of instruments including all exogenous regressors and instruments for airport authority dummy and its interaction with corruption when institutional arrangements are treated endogenous. The GMM estimation is efficient because the weighting matrix used in estimation accounts for the contemporaneous correlation between ε_{it}^{C} and ε_{it}^{S}. Details of the estimation are contained in the technical appendix of the paper.

4. Empirical Results

We now turn our focus on the empirical models which investigate whether corruption affects airport efficiency by influencing airports' decision making. Table 4 presents results from our baseline estimations in which Δ_i and o_i are specified as in equation (15) and (16) respectively. We vary the assumption on the exogeneity of institutional arrangements and estimation samples in the baseline estimations. Since 1990, five airports in our data were transferred from local governments to airport authorities. We drop them in model 2 to make sure that institutional arrangements of airports are predetermined in the model. We also drop observations before 2003 and after 2008 in some models to exclude the short-run impacts of the event of 9/11 and the 2008 financial crisis.

As the usual practice to estimate translog cost system, we impose the symmetric and homogeneity constraints in the estimations.[9] Because it is difficult to interpret directly the results of the second order terms in a *translog* function, in the last panel of Table 4 we report the cost elasticities with respect to the three outputs and quasi fixed inputs, as well as the predicted shadow labor variable input. The positive cost output elasticities and predicted shadow labor share imply that the monotonicity conditions in outputs and input prices are satisfied. A well-defined variable cost frontier should also be concave with respect to variable input shadow prices, which requires that the Hessian matrix of the variable cost frontier with respect to the shadow prices of inputs is negative semidefinite. We do not impose this condition in estimation. The estimated coefficient of the square term of labor shadow price has a positive sign and this violates the concavity requirement.[10] However, the magnitude of this coefficient is very small (between 0.008 and 0.01 across models) and is not statistically significant.

[9] Please see the appendix for details.
[10] Please see Diewert and Wales (1987) for details.

The estimates of the cost output elasticities, across all the models, suggest on average the airports exhibit economies of scale in the short run. We do not find evidences of over or under capitalization of the airports, as indicated by the estimated cost fixed-input elasticities. In the first two models where institutional arrangements are treated exogenous, the predicted shadow labor share is substantially less than the observed labor share (about 0.39) and this suggests that on average the airports over-utilize labor inputs relative to non-labor variable inputs. However, this finding cannot hold in model 3 and 4 where institutional arrangements are treated endogenous and instrumented by state laws and city characteristics in the GMM estimation.

Allocative and technical efficiency parameters

The first two panels of Table 4 present estimation results of the allocative and technical efficiency parameters. The following findings are robust across the models. First, all airports tend to use more contracting-out to replace in-house labor in more corrupt environments; such an impact of corruption on variable inputs' allocation is the strongest in airports operated by port authority. Second, in the absence of corruption, airport authorities are on average more technically efficient than city-owned airports. Finally, corruption rate has a negative impact on productivity of airport and port authorities and such an impact is especially strong for airport authorities.

We run different robustness checks to the findings from the baseline estimations. In the first set of robustness checks, we change the model specification by specifying both Δ_i and o_i in equation (13) and (14) as airport dummies. Their estimates, which are denoted by $\hat{\Delta}_i$ and $\hat{o}_i$ from the GMM estimation, are used as dependent variables to formulate the second stage regressions $\hat{\Delta}_i = \alpha + Z_i\Gamma + X_i B + \varepsilon_{1i}$ and $\hat{o}_i = X_i B + \varepsilon_{2i}$, where X_i and Z_i are defined in equations (15) and (16). Table 5 presents estimation results of the second stage regression results.

Results from the second stage regressions are quite consistent across models. In the absence of corruption, all the airports over-utilize labor relative to non-labor variable inputs, as indicated by the negative values of the three coefficients of institutional dummies in the first panel on the allocative efficiency parameters (because $\lambda_i < 1$). As in the baseline results, corruption affects the ratio of non-labor to labor variable inputs positively and such impacts are the strongest for port authorities. As for the technical efficiency parameters, two findings found in the baseline results, that is, relative efficiency of airport authorities to city-owned airports in the absence of corruption and negative impacts of corruption on the productivity of airport authorities, are still significant in the second stage regressions.

The second set of robustness checks serve for the purpose to test the sensitivity of our findings to the cost frontier parameterization. We construct the variable factor productivity for each of the airports in each year. The three outputs and two variable inputs are aggregated by multilateral translog index which is proposed by Caves, Christensen, and Diewert (1982). We then run regressions of the constructed variable factor productivity on the institutional dummies along with their interactions with the corruption rate after controlling for airport heterogeneity measured by the variables listed in Table 3. The regression results are presented in Table 6. The variable factor productivity of airport authorities is significantly higher than the one of city-owned airports in the absence of corruption and corruption reduces the variable factor productivity of airport authorities significantly.

<u>Summary of empirical findings</u>

We now summarize the robust and significant findings from the empirical results presented in Table 4-6. First, corruption lowers the productivity of airport and port authorities and increases the ratio of non-labor to labor variable inputs in all the three types of airports. Second, among the three types of airports, corruption affects airport authorities the most on productivity and affects port authorities the most on allocation of variable inputs. Third, in the absence of corruption, airport authorities are on average more productive than city-owned airports. Another significant but less robust finding is that all the three types of airports over-utilize labor relative to non-labor variable inputs in the absence of corruption.

These empirical findings are in general consistent with the theoretical predictions. The only exception is that the theory predicts no impacts of corruption on resource allocation of city-owned airports, which are assumed to have no autonomy to allocate resources. Our empirical results indicate that similarly as in airport and port authorities, the management of city-owned airports are likely to exploit personal benefits via changing the allocation of inputs under highly corrupt environments. The identified agency problem of city-owned airports under corrupt environments can in fact have intuitive interpretation under our theoretical framework; the low accountability of public policy outcomes in highly corrupt environments leads to a low monitoring of the bureaucrats' behavior by the voters, and as such, the bureaucrats can have certain degree of autonomy to exploit for personal benefits via changing the allocation of inputs.

Corruption affects also the productivity of port authorities because port authorities have similar internal organization as airport authorities; the lower monitoring efforts from the board in more corrupt environment induce lower efforts of the manager on productive activities. The impacts of corruption on productivity in port authorities are not as strong as in airport authorities because similar to city-owned airports, port authorities manage multiple transport facilities and therefore pursue multiple tasks, which reduce the productivity of port authorities even in the absence of corruption. Corruption affects port authorities the most on allocation of variable inputs because port authorities have managerial autonomy and operate more complicated business which leads to a lower accountability of resource allocation than the case of airport authorities.

5. Discussions

Findings from this paper have important policy implications to reforming airport governance structure in the United States. The theoretical analysis and the empirical findings suggest that transferring airport management from local governments to airport authorities cannot take full advantage of reforming governance structure in order to improve airport efficiency. Our basic argument to this point is that decision making of airport authorities is still affected very much by the government. In a low corruption environment, an airport authority's decision-making is done primarily to pursue political goals. The political influences along with the lack of internal incentives hinder the manager's efforts to exploit more efficient input allocation. In a high corruption environment, the board of an airport authority board is likely to ill-function, leading to severe agency problems in the airport operations. Although the U.S. congress created an Airport Privatization Pilot Program in 1996, the program is making very slow progress in reforming airport governance structure. Airport privatization has certainly advantages for overcoming the problems associated with airport authorities, especially in highly corrupt environments. Private airports are better insulated from political influences and give managers stronger incentives to exploit efficient inputs allocation. Also, internal organization of private airports is expected to function better than airport authorities especially in highly corrupt environments. The findings of this paper suggest that any airport privatization program should pay more attention to reforming airport governance structure.

In a recent paper, Yan and Winston (2012) show that privatization can create a competitive airport market in metropolitan areas served by multiple commercial airports such as San Francisco and New York. Airport inefficiency caused by government corruption could be offset by airport competition. In this paper, we use a dummy variable indicating the existence of multiple commercial airports in a metropolitan area to capture possible effects of airport competition on efficiency. The coefficient of the dummy variable is not statistically significant in all of the models. However, such a result cannot be interpreted as the evidence showing that airport competition has no significant effects on airport efficiency, because under public ownership, U.S. commercial airports have no freedom to charge strategically to compete with each other. Airport efficiency caused by government corruption could also be offset by competition among transport modes. Behrens and Pels (2012) and Fu, Oum, and Yan (2012) document air-high speed rail competition in intercity markets of Europe and Japan, respectively The relationship between airport efficiency and market competition, both within and across transport modes, can be an interesting question for future research.

Our analysis is restricted to U.S. airports. It would be interesting to know if the findings of the paper are only U.S. phenomena, or do they extend to other countries, different continent and/or worldwide airports as well? Another limitation of our analysis is that we use physical capital stocks – terminal size and number of runways, as proxy measures of capital inputs of airports. Such measures cannot capture effects of “pork” spending on airports such as building plating restrooms and lounges. Such spending is particularly important for airport cost efficiency studies. Future research on this topic is well advised to consider alternative measures for capital inputs such as, for example, capital stock measures constructed by investment flow data.

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Table 1. List of Airports

Airport Code	State	Institutional Arrangement	Year that airport authority/corporation were created	State corruption rate [a]
ABQ	NM	City government	--	0.263
ALB	NY	Airport authority	1993	0.439
ATL	GA	City government	--	0.373
AUS	TX	City government	--	0.209
BNA	TN	Public corporation	1970	0.464
BOS	MA	Port authority	--	0.240
BWI	MD	City government	--	0.230
CLE	OH	City government	--	0.341
CLT	NC	City government	--	0.170
CVG	IN	Airport authority	1943	0.190
DCA	DC	Airport authority	1987	0.329 [b]
DEN	CO	City government	--	0.151
DFW	TX	Airport authority	1968	0.209
DTW	MI	Airport authority	2002	0.181
EWR	NJ	Port authority	--	0.273[c]
FLL	FL	Airport authority	1948	0.368
HNL	HW	State government	--	0.295
IAD	VA	Airport authority	1987	0.329
IAH	TX	City government	--	0.209
IND	IN	Airport authority	1962	0.190
JAX	FL	Airport authority	2001	0.368
JFK	NY	Port authority	--	0.439
LAS	NV	City government	--	0.222
LAX	CA	City government	--	0.232
LGA	NY	Port authority	--	0.439
MCI	MO	City government	--	0.248
MCO	FL	Airport authority	1975	0.368
MDW	IL	City government	--	0.458
MEM	TN	Airport authority	1969	0.464
MIA	FL	City government	--	0.368
MKE	WI	City government	--	0.150
MSP	MN	Public corporation	1943	0.121
MSY	LA	City government	--	0.513
OAK	CA	Port authority	--	0.232
ONT	CA	City government	--	0.232
ORD	IL	City government	--	0.458
PBI	FL	City government	--	0.368
PDX	OR	Port authority	--	0.074
PHL	PA	City government	--	0.361
PHX	AZ	City government	--	0.158
PIT	PA	Airport authority	1999	0.361
RDU	NC	Airport authority	1939	0.170
RIC	VA	Airport authority	1975	0.329
RNO	NV	Airport authority	1977	0.222

SAN	CA	Airport Authority	2003	0.232
SAT	TX	City government	--	0.209
SDF	KY	Airport authority	1928	0.333
SEA	WA	Port authority	--	0.104
SFO	CA	City government	--	0.232
SJC	CA	City government	--	0.232
SLC	UT	City government	--	0.130
SMF	CA	City government	--	0.232
SNA	CA	City government	--	0.232
STL	MO	Airport authority	1968	0.248
TPA	FL	Airport authority	1945	0.368

Note: [a] The corruption rate measures the number of public officials who were convicted for corruption every year for every 100,000 population. The rate is constructed by dividing the total number of federal convictions of public officials for public corruption from 1976 to 2002 by average population in the state in the same period.

[b] There is no corruption rate for D.C. in Glaeser and Saks (2006). The two airports, DCA and IAD (which is located in Virginia), are operated by the same airport authority. We therefore use the corruption rate of Virginia for DCA.

[c] The Newark airport (EWR) has the same ownership as the two NYC airports – JFK and LGA. Although corruption rates in New Jersey and New York are different, we assume that the three airports face the same corruption environment. In estimation, we use the corruption rate of New York for the three airports.

Table 2. Summary Statistics of Airport Data

Variables	*Mean (standard error) or fraction in the sample*
Output Measures	
Number of Passengers (million US $ per year)	22 (18)
Number of Aircraft Movements (000's per year)	304 (197)
Non-Aeronautical Revenue (000's PPP deflated $ per year)	76 (55)
Variable Inputs	
Number of Employee	577 (499)
Non-labor Variable Cost (million US $ per year)	63 (53)
Fixed Inputs	
Number of Runways	3.37 (1.23)
Terminal Size (000's Squared Meter)	186 (161)
Variable Inputs' Prices	
Wage Rate (000's US $ per year)	83 (59)
Variable Input's Share	
Labor Cost Share	0.39 (0.14)
Number of Observations	495

Table 3. List of Control Variables for Airport Heterogeneity

Variables	Description
% of international passengers	
% of cargo output	Measured in terms of Work Load Unit (WLU), a commonly used output measure in the aviation industry that combines passenger and cargo traffic volume. One WLU is defined as one passenger or 100 kg of cargo.
Average temperature in Jan.	
Average temperature difference between Jan. and July.	
MSA population	from the 1990 Census
MSA average household income	from the 1990 Census
Tourist city dummy	1 if in Nevada or Florida
Hub airport dummy	We define following hubs in the U.S. markets: Chicago-O'Hare (American. United), Cleveland (Continental), Newark (Continental), Atlanta (Delta), San Francisco (United), Dallas-Ft. Worth (American), Philadelphia (US Airways), Phoenix (US Airways), Detroit (Northwest), St. Louis (American), Houston (Continental), Washington-Dulles (United), Minneapolis-St. Paul (Northwest), Cincinnati (Delta), Salt Lake City (Delta), Denver (United), and Miami (American).
Tax per capita of state in 1992	compiled from the Report on Economic Freedom published by Clemson University
Ratio of public vs. private sector salary of state in 1992	compiled from the Report on Economic Freedom published by Clemson University
Population of state	from the 1990 Census
Income per capita of state	from the 1990 Census
% with 4+ years of college education of state	from the 1990 Census
Multiple airports	1 if there are multiple commercial airports in the metropolitan area
NYC	
Washington D.C.	
Chicago	
San Francisco	
Los Angeles	
Miami	
Texas	
Florida	
Indiana	
Missouri	
North Carolina	
Nevada	
Pennsylvania	
Tennessee	
Western states	Western states include: AZ, CA, CO, HW, NV, OR, WA, and UT.
Eastern states	Eastern states include: DC, FL, GA, KY, MA, MD, NC, NJ, NY, PA, TN, and VA.

Table 4. Results of the Baseline Estimations[a]

Coefficients	(1) Full sample and treat institutional arrangements exogenous	(2) Drop airports with institutional change after 1990; drop observations before 2003 or after 2008; and treat institutional arrangements exogenous	(3) Full sample and treat institutional arrangements endogenous	(4) Drop observations before 2003 or after 2008; and treat institutional arrangements endogenous
Panel A: Allocative efficiency				
City	-2.7229	-2.8608	-0.1379	-0.1088
	(0.7188)	(1.4870)	(0.1108)	(0.1242)
Airport authority	-2.9462	-2.8608	-0.2018	-0.1088
	(0.7111)	(1.4870)	(0.2170)	(0.1242)
Port authority	-2.4854	-2.8608	0.0273	-0.1088
	(0.7221)	(1.4870)	(0.1634)	(0.1242)
City × Corruption	1.4413	1.8401	1.3680	1.2856
	(0.3644)	(0.3554)	(0.5791)	(0.5351)
Airport authority × Corruption	1.5062	1.1179	1.4264	1.1367
	(0.3679)	(0.3093)	(0.6419)	(0.5037)
Port authority × Corruption	2.8412	3.8193	3.0068	3.3153
	(0.5822)	(0.6211)	(0.8768)	(0.7984)
Panel B: Technical efficiency (City owned airports are the base)				
Airport authority	-0.5939	-0.5357	-2.2035	-1.3209
	(0.1213)	(0.1376)	(0.2774)	(0.2460)
Port authority	-0.0716	0.2635	-0.5565	-0.5944
	(0.1364)	(0.2068)	(0.1891)	(0.1307)
City × Corruption	1.1770	2.9699	0.0587	0.0553
	(0.3400)	(0.6463)	(0.0832)	(0.1389)
Airport authority × Corruption	3.0130	4.2902	7.5895	4.0898
	(0.4258)	(0.9510)	(0.8521)	(0.8664)
Port authority × Corruption	1.2107	2.3157	1.5129	1.9601
	(0.4422)	(0.5449)	(0.5911)	(0.6704)
Panel C: Cost structure parameters				
Short-run cost elasticity of aircraft movements	0.0980	0.2034	0.2707	0.2147
	(0.0714)	(0.0991)	(0.0950)	(0.1089)
Short-run cost elasticity of number of passengers	0.2225	0.1612	0.1259	0.0872
	(0.0756)	(0.1059)	(0.0871)	(0.0947)
Short-run cost elasticity of non-aeronautical revenue	0.2779	0.1910	0.3188	0.3916
	(0.0470)	(0.0674)	(0.0583)	(0.0796)
Predicted shadow labor share	0.0926	0.0805	0.4431	0.4430
	(0.0401)	(0.0863)	(0.0367)	(0.0461)
Short-run cost elasticity of number of runways	0.0877	0.0136	-0.1103	-0.0456
	(0.0561)	(0.0794)	(0.0723)	(0.0857)
Short-run cost elasticity of terminal size	0.0329	0.0266	0.0885	-0.0124
	(0.0328)	(0.0485)	(0.0716)	(0.0499)
Number of airports	55	50	55	55
Number of observations	495	300	495	330

[a] Numbers in parentheses are standard errors. Year fixed effects and control variables listed Table 3 are included in all estimations. All elasticities are evaluated at the sample mean of variables.

Table 5. Robustness Checks: Estimation Results from the Second-Stage Regressions

	(1) Full sample and treat institutional arrangements exogenous	(2) Full sample; treat airport authority and Airport authority × Corruption as endogenous and use state laws and city characteristics as instruments for 2SLS estimation	(3) Drop airports with institutional change after 1990 and observations before 2003 and after 2008
Allocative inefficiency parameters			
City	-1.9417 (0.3765)	-1.9417 (0.3776)	-1.9417 (0.3675)
Airport authority	-2.2210 (0.4694)	-2.4540 (0.7436)	-2.5927 (0.5130)
Port authority	-1.6517 (0.5579)	-1.6517 (0.5596)	-1.6517 (0.5446)
City × Corruption	1.8699 (1.3102)	1.8699 (1.3142)	1.8699 (1.2789)
Airport authority × Corruption	1.9693 (1.4888)	2.7828 (2.4510)	2.7758 (1.6521)
Port authority × Corruption	3.2210 (1.9254)	3.2210 (1.9313)	3.2210 (1.8794)
Technical inefficiency parameters (city-owned airports as the base)			
Airport authority	-1.5173 (0.4961)	-1.9993 (1.0654)	-1.7645 (0.4337)
Port authority	0.0027 (0.4157)	-0.0487 (0.4864)	1.1364 (0.8273)
City × Corruption	0.1785 (1.3187)	0.0984 (1.8565)	3.7059 (2.6569)
Airport authority × Corruption	5.7806 (2.0034)	7.5484 (3.1387)	9.7049 (3.2168)
Port authority × Corruption	0.4919 (1.7018)	0.6962 (1.7588)	-0.6645 (1.6945)
Number of Observations	55	55	50

[a] Numbers in parentheses are standard errors obtained by using the bootstrap technique which account for statistical uncertainty in the first-stage estimation. Year fixed effects and control variables listed Table 3 are included in all estimations.

Table 6. Additional Robustness Checks: Estimation Results from the Variable Factor Productivity Regressions (City-owned airports as the base)

	(1) Full sample and treat institutional arrangements exogenous	(2) Full sample; treat airport authority and Airport authority × Corruption as endogenous and use state laws and city characteristics as instruments for 2SLS estimation	(3) Drop airports with institutional change after 1990 and observations before 2003 or after 2008
Airport authority	1.3383 (0.1783)	3.7694 (0.4191)	1.7036 (0.2595)
Port authority	0.1479 (0.1077)	0.5255 (0.1451)	-0.0773 (0.1506)
City × Corruption	0.0045 (0.1417)	0.2661 (0.2387)	-0.0482 (0.1958)
Airport authority × Corruption	-4.4101 (0.5815)	-12.153 (1.4101)	-5.2614 (0.8090)
Port authority × Corruption	-1.2528 (0.4887)	-3.0488 (0.6503)	-1.1610 (0.5994)
Number of Airports	55	55	50
Number of Observations	495	495	300

[a] Numbers in parentheses are standard errors. Year fixed effects and control variables listed Table 3 are included in all estimations.

Appendix (Not for publication)

The appendix describes the technical details of the theoretical models and empirical estimation in the text.

Characterizing the equilibrium efforts of the manager of an airport authority on productive activities

When the manager of an airport authority does not pursue the pet project $\left(\text{i.e. } e_g = 0\right)$, the manager chooses efforts spent on productivity activities $\left(e_p\right)$ given a market's expectation $\left(e_p^e\right)$ to maximize his expected payoff. Let the solution function be $e_p\left(e_p^e\right)$ and the solution function is a self-map on the effort space. The equilibrium effort level, which is denoted by e_p^*, is the fixed-point of the self-map and it satisfies the following first-order condition:

$$\frac{d}{de_p}\left(\int\left(\int \theta \frac{f\left(\theta, y_p \middle| e_p^*\right)}{f\left(y_p \middle| e_p^*\right)} d\theta\right) f\left(y_p \middle| e_p\right) dy_p\right)\Bigg|_{e_p=e_p^*} = C_a'\left(e_p^*\right) \tag{A1}$$

where $f\left(\theta, y_p \middle| e_p\right)$ is the joint density of talent and productivity given a market's expectation on the manager's efforts and $f\left(y_p \middle| e_p\right) = \int_\theta f\left(\theta, y_p \middle| e_p\right) d\theta$. The first-order condition in (A1) implies

$$\operatorname{cov}\left(\theta, \frac{f_{e_p}\left(y_p \middle| e_p\right)}{f\left(y_p \middle| e_p\right)}\right) = C_a'\left(e^*\right) \tag{A2}$$

where $f_{e_p}\left(y_p \middle| e_p\right)$ denotes the first-order derivative of the marginal density with respect to effort level. Given the independent normality assumptions on the distributions of θ and ε_p, we have

$$\operatorname{cov}\left(\theta, \frac{f_{e_p}\left(y_p \middle| e_p\right)}{f\left(y_p \middle| e_p\right)}\right) = \frac{1}{1 + \sigma_\varepsilon^2 / \sigma_\theta^2} \tag{A3}$$

(A2) and (A3) lead to the first order condition in equation (4) of the text.

Proof of Proposition 1

For point 1, differentiating the first-order conditions in (9) with respect to γ, we have

$$C_a''(e_g)\frac{de_g^*(\gamma)}{d\gamma} = \frac{\partial g(\tilde{m},\gamma)}{\partial \tilde{m}}\frac{d\tilde{m}^*(\gamma)}{d\gamma} + \frac{\partial g(\tilde{m},\gamma)}{\partial \gamma} \tag{A4}$$

$$\frac{\partial^2 g(\tilde{m},\gamma)}{\partial \tilde{m}^2}\frac{d\tilde{m}^*(\gamma)}{d\gamma} + \frac{\partial^2 g(\tilde{m},\gamma)}{\partial \tilde{m}\partial\gamma} = 0 \tag{A5}$$

From the assumptions $\frac{\partial g(\tilde{m},\gamma)}{\partial \tilde{m}} > 0$, $\frac{\partial^2 g(\tilde{m},\gamma)}{\partial \tilde{m}^2} < 0$, $\frac{\partial g(\tilde{m},\gamma)}{\partial \gamma} < 0$ and $\frac{\partial^2 g(\tilde{m},\gamma)}{\partial \tilde{m}\partial\gamma} < 0$, we can have both $\frac{de_g^*(\gamma)}{d\gamma} < 0$ and $\frac{d\tilde{m}^*(\gamma)}{d\gamma} < 0$.

For point 2, since we assume that $g(\tilde{m}^*(\gamma),\gamma) > \frac{1}{1+\sigma_\varepsilon^2/\sigma_\theta^2}$ for some γ, this conclusion can be obtained by showing that $g(\tilde{m}^*(\gamma),\gamma)$ is strictly decreasing in γ. From point 1, it is straightforward to show $\frac{dg(\tilde{m}^*(\gamma),\gamma)}{d\gamma} = \frac{\partial g(\tilde{m}^*(\gamma),\gamma)}{\partial \tilde{m}}\frac{d\tilde{m}^*(\gamma)}{d\gamma} + \frac{\partial g(\tilde{m}^*(\gamma),\gamma)}{\partial \gamma} < 0$.

Proof of Proposition 2

For (1), any a $\gamma^* > \bar{\gamma}$ cannot be hold because the board can always reduce monitoring efforts to boost the reward. For (2), when $\gamma^* \in (0,\bar{\gamma})$, it is the solution of $\underset{\gamma}{\operatorname{argmax}}\ \alpha\cdot\left[\bar{\theta} - h(\tilde{m}^*(\gamma))\right] - C_b(\gamma)$. The first order condition is $-\alpha\cdot h'(\tilde{m}^*)\frac{d\tilde{m}^*(\gamma)}{d\gamma}\Big|_{\gamma=\gamma^*} = C_b'(\gamma^*)$. Since the effort cost function is convex, γ^* decreases when α drops. For (3), let γ_L denote the optimal level of monitoring efforts in the interval $[0,\bar{\gamma})$, we have $\gamma^* = \bar{\gamma}$ if $\alpha\cdot\left[h(\tilde{m}^*(\gamma_L)) + c_a^{-1}\left(\frac{1}{1+\sigma_\varepsilon^2/\sigma_\theta^2}\right)\right] > C_b(\bar{\gamma}) - C_b(\gamma_L)$. $\Gamma(\alpha) \equiv \alpha\cdot\left[h(\tilde{m}^*(\gamma_L)) + c_a^{-1}\left(\frac{1}{1+\sigma_\varepsilon^2/\sigma_\theta^2}\right)\right]$ measures the utility gain to the board when the board switches monitoring level from γ_L to $\bar{\gamma}$ and the utility gain is strictly increasing with respect to α because $\Gamma'(\alpha)=h\left(\tilde{m}^*(\gamma_L)\right)+c_a^{-1}\left(\frac{1}{1+\sigma_\varepsilon^2/\sigma_\theta^2}\right)+\alpha h'(\cdot)\frac{d\tilde{m}^*(\gamma)}{\gamma}\bigg|_{\gamma=\gamma_L}\frac{d\gamma_L}{d\alpha}>0$.

$C_b(\bar{\gamma})-C_b(\gamma_L)$ increases when α decreases because γ_L is increasing with α. As such, the board is more likely to choose $\bar{\gamma}$ when α is larger.

Misallocation of efforts among mandated tasks caused by uncertain voters' preferences

Under multiple tasks environment, the bureaucrat of a city-owned airport may focus on tasks which are more helpful in signaling his ability. Alesina and Tabellini (2008) show that such a misallocation of efforts can be caused by uncertain voters' preferences. For simplicity in illustration, we use y_o to denote the aggregate performance measure of other tasks excluding airport cost efficiency such that

$$y_o \equiv \sum_{i=1}^{n-1} y_i = \sum_{i=1}^{n-1} e_i + (n-1)\theta + \sum_{i=1}^{n-1}\varepsilon_i = e_o + (n-1)\theta + \varepsilon_o \tag{A6}$$

Let ω denote a Bernoulli random variable. In each period, the voters utility is given by $U(\omega y_o + (1-\omega)y_p)$ and $\Pr(\omega=1)>\frac{1}{2}$. Facing the uncertainty, the bureaucrat is assigned an unconditional measure of performance $x=\lambda y_0+(1-\lambda)y_p$, where $\lambda\in[0,1]$. Given the assignment and the voters' expectation on effort levels (e_o^e, e_p^e), the bureaucrat solves

$$\max_{(e_o,.e_p)} E\left(E\left(\theta \middle| x, e_o^e, e_p^e\right)\right) - C(e_o+e_p) \tag{A7}$$

Because efforts are not separable, when $\Pr(\omega=1)>\frac{1}{2}$, it is optimal for the voters to set $\lambda=1$. Let e_p^* and e_o^* denote equilibrium efforts, we have $e_p^*=0$ and e_o^* is determined by the first-order condition $C'(e_o^*)=\frac{1}{n-1+\sigma_\varepsilon^2/\sigma_\theta^2}$. In this example, the bureaucrat focuses only on tasks that voters care about and therefore allocates zero effort on managing airport operation.

The empirical model with the translog parameterization

In estimation, the log variable cost frontier is approximated by the following *translog* functional form:

$$\ln C_{it}^{*}\left(Q_{it}, W_{it}^{*}, K_{it}\right) \approx \ln \widetilde{C}_{it}\left(Q_{it}, W_{it}, K_{it}\right) = \alpha + \vartheta D^{T} + \sum_{j=1}^{3}\beta_j \ln q_{jit} + \sum_{j=1}^{2}\theta_j \ln k_{jit} + \sum_{j=1}^{2}\delta_j \ln \lambda_j w_{jit}$$
$$+ \frac{1}{2}\sum_{j=1}^{3}\sum_{n=1}^{3}\phi_{jn} \ln q_{jit} \ln q_{nit} + \sum_{j=1}^{3}\sum_{n=1}^{2}\gamma_{jn} \ln q_{jit} \ln \lambda_j w_{nit} + \sum_{j=1}^{3}\sum_{n=1}^{2}\rho_{jn} \ln q_{jit} \ln k_{nit} \qquad \text{(A8)}$$
$$+ \frac{1}{2}\sum_{j=1}^{2}\sum_{n=1}^{2}\tau_{jn} \ln \lambda_j w_{jit} \ln \lambda_n w_{nit} + \sum_{j=1}^{2}\sum_{n=1}^{2}\zeta_{jn} \ln k_{jit} \ln \lambda_n w_{nit} + \frac{1}{2}\sum_{j=1}^{2}\sum_{n=1}^{2}\psi_{jn} \ln k_{jit} \ln k_{nit}$$

where D^T represents a vector of year dummies which capture technical change. The shadow share of labor inputs is expressed as

$$S_{1it}^{*} \equiv \frac{\partial \ln C_{it}^{*}\left(Q_{it}, W_{it}^{*}, K_{it}\right)}{\partial \ln w_{1it}^{*}} \approx \frac{\partial \ln \widetilde{C}_{it}\left(Q_{it}, W_{it}^{*}, K_{it}\right)}{\partial \ln w_{1it}^{*}}$$
$$= \delta_1 + \sum_{j=1}^{3}\gamma_{j1} \ln q_{jit} + \sum_{j=1}^{2}\tau_{j1} \ln w_{jit}^{*} + \sum_{j=1}^{2}\zeta_{j1} \ln k_{jit} \qquad \text{(A9)}$$

Substituting (A8) and (A9) into equations (13) and (14) of the text, we obtain the estimable variable cost frontier model which incorporates both technical and allocative efficiency.

As the usual practice to estimate the translog cost system, we impose the following constraints in estimation. 1. Symmetric constraints: $\phi_{12} = \phi_{21}$, $\phi_{13} = \phi_{31}$, $\phi_{23} = \phi_{32}$, $\tau_{12} = \tau_{21}$, $\psi_{12} = \psi_{21}$. 2. Homogeneity constraints: The variable cost frontier is homogeneous of degree 1 with respect to variable input prices, so we have $\delta_1 + \delta_2 = 1$, $\gamma_{11} + \gamma_{12} = 0$, $\gamma_{21} + \gamma_{22} = 0$, $\gamma_{31} + \gamma_{32} = 0$, $\tau_{11} + \tau_{12} = 0$, $\tau_{12} + \tau_{22} = 0$, $\zeta_{11} + \zeta_{12} = 0$, $\zeta_{21} + \zeta_{22} = 0$. A well-defined variable cost frontier should also be concave with respect to variable input prices, which requires that the Hessian matrix of the variable cost frontier with respect to input prices is negative semidefinite. As shown by Diewert and Wales (1987), the Hessian matrix is negative semidefinite if and only if $\tau \equiv \begin{pmatrix} \tau_{11} & \tau_{12} \\ \tau_{12} & \tau_{22} \end{pmatrix}$ is negative semidefinite. Combining this with homogeneity constraints, the concavity condition can be imposed by restricting $\tau_{11} \le 0$.

The GMM estimation

Let $\varepsilon_{it} = \left(\varepsilon_{it}^c, \varepsilon_{it}^s\right)'$ and $\tilde{H}_{it} = diag\left(H'_{it}, H'_{it}\right) = \begin{pmatrix} H'_{it} & \mathbf{0} \\ \mathbf{0} & H'_{it} \end{pmatrix}_{2k\times 2}$, where k denotes the size of H_{it} which includes all exogenous regressors in equation (13) and instruments for endogenous variables (institutional arrangements). the orthogonal conditions in equation (17) of the text implies

$$\mathbf{E}\left(\tilde{H}_{it}\varepsilon_{it}\right) = \mathbf{0}_{2k\times 1} \quad \text{`} \tag{A10}$$

The empirical analog to the moment conditions in (A10) is

$$J(\Theta) = (NT)^{-1}\sum_{i=1}^{N}\sum_{t=1}^{T}\tilde{H}_{it}\varepsilon_{it} \tag{A11}$$

where N is the number of airports and T is the number of years; Θ is the vector of unknown parameters in equations (13) and (14) of the text. For some weighting matrix $\Phi_{2k\times 2k}$, the GMM estimator of Θ is the solution to the following minimization problem:

$$\hat{\Theta} = \arg\min_{\Theta}\ J(\Theta)' \times \Phi \times J(\Theta) \tag{A12}$$

The optimal weighting matrix, which accounts for the cross-equation correlation, is the inverse of the variance-covariance matrix of the moment functions and takes the following form:

$$\Phi^* = \left((NT)^{-1}\sum_{i=1}^{N}\sum_{t=1}^{T}\tilde{H}_{it}\,\mathrm{var}(\varepsilon_{it})\tilde{H}'_{it}\right)^{-1} = \left((NT)^{-1}\sum_{i=1}^{N}\sum_{t=1}^{T}\tilde{H}_{it}\Omega\tilde{H}'_{it}\right)^{-1} \tag{A13}$$

We first solve the optimization problem in (A12) to obtain consistent parameter estimates by specifying Ω as identity matrix. Given consistent parameter estimates, we use the residuals to estimate Ω, thereby obtaining more efficient parameter estimates because we use the estimated optimal weighting matrix to resolve the optimization problem in (A12).