Effects of Government Quality and Institutional Choice on the Efficiency of Airports in the United States

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January, 2011

1. Introduction

An airport links local industries and residents to new markets, products, customers, relatives and friends around the world, making it a critical component of a region's trade and commerce with other regions and countries. Efficiency of airports affects the economic performance of regions. For example, Bruckner (2003) documents evidence on the link between airline traffic and employment in US metropolitan areas. In this paper, we investigate the connection between the efficiency of airports in the United States and institutional arrangement on these airports' governance structure (henceforth referred to as "institutional arrangements"), as well as how government quality, in particular, the extent of corruption would affect airport efficiency under different institutional arrangements.

Most of the commercial airports in the United States are owned and operated by a branch of city/state government or an independent airport authority, which is a not-for-profit public entity and is by-and-large financially self-sustaining. There are also several airports which are operated by port authorities. Unlike an airport authority which operates local airport(s) only, a port authority operates the local seaport(s) as well as the local airport(s). Empirical findings in Oum, Yan, and Yu (2008) and Craig et al. (2009) suggest that institutional arrangements matter for airport efficiency. For airports in the United States, those operated by airport authorities are more cost efficient than those operated by local governments and port authorities. The higher cost efficiency achieved by airport authorities is likely to be attributed to the larger managerial autonomy associated with airport authorities.

In this paper, we argue that government quality, which is measured as the extent of corruption, matters also for airport efficiency. Corruption affects economy development. Shleifer and Vishny (1993) point out the distortion to economy from 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 than taxation. Empirical findings support this argument. At the macro level, Mauro (1995, 1998) shows that countries with higher corruption have a lower ratio of both total and private investment to

GDP and spend less on education. Ades and Di Tella (1999) find also 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. Fisman and Svensson (2007) find a strong negative effect of bribery payments on firm growth. Empirical evidences in Svensson (2003), Clarke and Xu (2004), Di Tella and Schargrodsky (2003), and Cai, Fang, and Xu (2009) show that decision making of firms is affected by corruption. Fisman (2001) and Khwaja and Mian (2004) studies the value of political connections to firms. Existence of such a value can divert firms' managerial efforts from productive tasks to rent-seeking activities.

Using data on the number of government officials convicted for corrupt practices through the Federal justice department, Glaeser and Saks (2006) construct corruption rate for each of the states in the U.S. and the corruption rate varies substantially across the states. Motivated by the literature on the economic consequences of corruption, we ask the question: Is the efficiency of airports in the U.S. affected by the extent of corruptive environments within which the airports must operate? We propose this hypothesis because all commercial airports in the U.S., regardless of their institutional arrangements, are public entities such that government is involved in their decision making. The impacts of corruption on airport efficiency, if they exist, are expected to be different across institutional arrangements because airports with different institutional arrangements have different degrees of managerial autonomy.

We investigate the proposed research question by first constructing a simple theory to illustrate the impacts of institutional arrangements on airport efficiency, and more importantly, the impacts of corruption on airport efficiency under different institutional arrangements. The constructed theory predicts that corruption would affect airport productivity negatively; among the three major airport institutional arrangements in the U.S., productivity of airports operated by airport authorities would be affected the most by corruption. In particular, compared to airports owned by local governments, airport authorities can achieve a higher productivity only under non-corrupt environments. The constructed theory predicts also that airports operated by airport and port authorities tend to have a larger ratio of non-labor variable inputs to labor input under more corrupt environments.

We then test the theoretical predictions empirically based on a unique data set from 54 airports in the U.S. from 2001 to 2004. The empirical model for such a purpose is a stochastic variable cost frontier model which accounts for both efficiency associated with productivity and efficiency associated with variable inputs allocation. Empirical findings are broadly consistent with the theoretical predictions. We quantify the impacts of corruption on airport efficiency under different institutional arrangements from the estimates and discuss policy implications of the findings to reforming airport governance structure in the U.S.

2. The Theory

In this section, we build a simple theory to explain how quality of government, in particular, the extent of corruption would affect efficiency of airport operations by influencing both productivity, which is defined as the ratio of output to input at a given mix of inputs, and input mix. We first analyze an airport's decision making under different institutional arrangements in the absence of corruption. We then characterize how the decision making of airports can be affected by corruption. Findings from this theoretical analysis will be used to guide the empirical analysis in the next section.

2.1 Model Setup

We consider that an airport has the production function of $q = (e_p + \theta + \varepsilon_p) \cdot F(\bar{k}, l, m)$, where the total productivity depends on managerial efforts (e_p) in monitoring and 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. Capital inputs are fixed at $\bar{k}$ in the short run and two variable inputs are labor (l) and non-labor variable inputs (m). Typically, an airport's non-labor variable inputs include purchased goods/materials and purchased services including items outsourced/contracted out.

We assume that the airport is required to meet an output target which is exogenously determined by the air transport needs of the city/region. We use $\bar{q}$ to denote the output target. As long as the realized output is not less than $\bar{q}$, the society cares only the cost efficiency of the airport, that is, whether the airport is producing the realized output level in the cheapest way. For simplicity, in the remainder of the paper we assume that all airports always meet the output target. In other words, the manager of an airport always choose inputs and efforts in such a way that the event of $q < \bar{q}$, where q denote the realized output level, has a very small probability of occurrence.

Let p be the unit price of the output (for example, landing fee); the unit price is assumed to be exogenously given; and 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). Then the measure of the cost efficiency at the realized output is represented by the short-run profit function

$$\pi = p \cdot q - w_l \cdot l - w_m \cdot m \qquad (1)$$

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. We first investigate the impacts of institutional arrangements on the cost efficiency.

City owned airports. A city owned airport is normally operated by a government branch such as the Department of Aviation. The stylized facts summarized in Wilson (1989) about U.S. government agencies are:

1. Limited financial incentives. A bureaucrat is motivated more by "career concerns" than by monetary benefits.
2. Multiple objectives. Unlike private firms focusing on maximizing profits, a bureaucrat has multiple objectives. For example, the missions stated in the Chicago Department of Aviation, which manages both O'Hare and Midway airport, include efficient and safe travel, enhancing economic activity and job creation at the airports, managing operations of the airports, etc.

3. Limited autonomy. Government agencies face many restrictions in their managerial decisions. For example, city owned airports are in general required to use services (such as fire fighting) provided by the local governments.

In order to capture above stylized facts in decisions of government agencies, Dewatripoint, Jewitt and Tirole (1999a, b) extend the career concerns model in Holmstrom (1982) to the case of a multitask environment. Such a modeling framework has been used by Maskin and Tirole (2001), Besley and Coate (2003), Schultz (2003), and Alesina and Tabellini (2007, 2008) to analyze behavior of politician and bureaucrats. Our model on behavior of city-owned airports is also based on the framework.

Since a city-owned airport has limited autonomy to allocate variable inputs in the airport's production process, we assume that the ratio between labor and non-labor inputs is fixed at a city-owned airport. Under this assumption, the cost efficiency of the airport evaluated at the realized output level is totally determined by the productivity $y_p \equiv e_p + \theta + \varepsilon_p$, which can be inferred by the society after observing the output level and employed variable inputs.

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; talent (θ) is assumed to be the same for all the tasks. The task of airport efficiency is then the one when $i = p$.

Under the framework of the career concerns model, for a city-owned airport, the bureaucrat is the "agent" and the voters represent the "principal". Distributions of talent and random noises to performances are public knowledge but efforts chosen by the agent in pursuing multiple tasks are unobserved by the principal. Typical distribution assumptions on the talent and random noises are $\theta \sim N\left(\vec{\theta}, \sigma_\theta^2\right)$ and $\varepsilon_i \sim_{iid} N\left(0, \sigma_\varepsilon^2\right)$. 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 $y \equiv (y_1,..., y_n)$ and takes actions that result in reward to the bureaucrat. We use R to denote the reward and R is the principal's assessment of the agent's talent, that is $R(e_1,..., e_n) = E(\theta|y)$. Efforts are costly to the agent. We use $C(e_1,..., e_n)$ to denote the cost function and assume that the cost function is additive such that $C(e_1,..., e_n) = C(e_1 + \cdots + e_n) = C(e)$. Furthermore, the cost function is assumed to be a convex function of total efforts. Let $e^e \equiv (e_1^e,..., e_n^e)$ 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

$$\max_{(e_1,...,e_n)} E\left(E\left(\theta \middle| y, e^e\right)\right) - C(e) \tag{2}$$

Airport authority. Airport authorities are not-for-profit/non-shareholder entities that re-invest retained earnings into future airport development programs and are by-and-large financially self-sustaining. Like a modern corporation, an airport authority is managed by a manager (CEO), whose behavior is monitored by a "board of directors". The board members are appointed by state/county/city government and we assume that the board members are delegated to monitor the behavior of the manager to maximize the objectives of government. Key differences between an airport operated by city government and an airport authority are:

1. The manager of an airport authority is appointed to manage day-to-day operations of the airport. The only task assigned to the manager is then to maximize productivity of the airport.
2. Since an airport authority funds its daily operations using retained earnings rather than local tax revenue, the manager has the managerial autonomy to allocate inputs (in-house labor vs. contracting out) in production.

One of the main incentives for government contracting-out (outsourcing), as indicated by Savas (1987), Kemp (1991), Lopez-de-Silanes, Shleifer and Vishny (1997), is to get rid of budget burden. This is also the case for local governments to transfer airport management to independent airport authorities, as summarized in Reimer et al. (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. On the other hand, 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. Let m_0/l_0 denote the government's target ratio of non-labor to labor variable inputs and m/l denote the actual one; define $\tilde{m} \equiv \max\left\{0, \frac{m}{l} - \frac{m_0}{l_0}\right\}$, the utility function of the board is $\alpha \cdot \left[E\left(y_p\right) - h\left(\tilde{m}\right)\right]$, where $h\left(\tilde{m}\right) \geq 0$, $h(0) = 0$ and $h'(\cdot) \geq 0$; α captures the intensity of the board's preference toward government objectives.

As a not-for-profit entity, the manager of an airport authority is also 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. But different with the bureaucrat of a city-owned airport whose talent is judged by performances across multiple tasks, the manager of an airport authority is judged based on the performance of only one task y_p. With managerial autonomy, the manager can pursue cost efficiency through efficient inputs allocation. However, since all information about the manager's talent is captured by y_p, career concerns rather than profit-maximizing objective does not offer the manager the incentive to allocate inputs efficiently.

With managerial autonomy, the manager of an airport authority could pursue personal benefits via changing the allocation of inputs. Existence of such agency problems in the form of divergence between objectives of managers and shareholders in modern corporations have been widely documented (examples include Shleifer and Vishny (1997), Rajan et al. (2000), Scharfstein and Stein (2000), and Bertrand and Mullainathan (2003)). As summarized in Shleifer and Vishny (1997), pursuing private benefits by managers through resource allocation is the main cause of agency problems. Since 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 can use non-labor variable inputs (especially 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. The role of monitoring is as follows. With more monitoring, the accountability of outsourcing transactions is higher such that private benefits generated from such transactions to the manager are less. Given above considerations, we use $e_g g(\tilde{m},\gamma)$ to denote the benefits from the pet project; e_g denotes the efforts spent in pursuing the pet project. We assume $\frac{\partial g(\tilde{m},\gamma)}{\partial \tilde{m}} > 0$, $\frac{\partial^2 g(\tilde{m},\gamma)}{\partial \tilde{m}^2} < 0$, $\frac{\partial g(\tilde{m},\gamma)}{\partial \gamma} < 0$, and $\frac{\partial^2 g(\tilde{m},\gamma)}{\partial \tilde{m}\partial \gamma} < 0$, that is, the benefits from the pet project is a strictly increasing and concave function of resource reallocation $\tilde{m} \equiv \max\left\{0, \frac{m}{l} - \frac{m_0}{l_0}\right\}$; the benefits and marginal benefits of the pet project are strictly decreasing with respect to monitoring. We also assume that $g(\tilde{m},\gamma) = 0$ if $\tilde{m} = 0$.

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

$$\max_{e_p, e_g, \tilde{m}} E\left(E\left(\theta \middle| y_p, e_p^e\right)\right) + e_g \cdot g(\tilde{m},\gamma) - C_a\left(e_p + e_g\right) \tag{3}$$

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

$$\max_{\gamma} \alpha \cdot \left\lfloor E\left(y_p\right) - h(\tilde{m}) \right\rfloor - C_b(\gamma) \tag{4}$$

where $C_b(\gamma)$ is the board's cost of monitoring.

2.2 Airport's Decision making

Having set up the model, we start to characterize decision making of airports under different institutional arrangements.

City-owned airports. In the analysis for city-owned airports in the absence of corruption, we first highlight results in Dewatripont, Jewitt and Tirole (1999b) that increasing number of tasks reduces total effort level of the bureaucrat. We then highlight results in Alesina and Tabellini (2008) that uncertain voters' preferences can cause misallocation of efforts among tasks.

If the voters care about the aggregate performance from multiple tasks, only $Y_n \equiv \sum_{i=1}^{n} y_i$ matters in evaluating the bureaucrat's performance. The career concerns model for city-owned airports is then a special case of the model in Dewatripont, Jewitt and Tirole (1999b), which shows that the positive equilibrium levels of total efforts ($e^* \equiv \sum_{i=1}^{n} e_i^*$) is determined by

$$\mathrm{cov}_n\left(\theta, \frac{\hat{f}_e}{\hat{f}}\right) = C'\left(e^*\right) \tag{5}$$

where $\hat{f} \equiv \int_{\theta} f\left(Y_n, \theta \middle| e^*\right) d\theta$ denotes the marginal density of observable performance and $\hat{f}_e$ denotes the first-order derivative of the marginal density with respect to total effort level. Given the independent normality assumptions on the distributions of θ and ε_i, we have

$$\mathrm{cov}_n\left(\theta, \frac{\hat{f}_e}{\hat{f}}\right) = \frac{1}{n + \sigma_\varepsilon^2 / \sigma_\theta^2} \tag{6}$$

The covariance decreases when the number of tasks (n) increases. 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. For simplicity in illustration, we use y_o to denote the aggregate performance measure of other tasks excluding airport cost efficiency such that

$$y_o \equiv \sum_{i=1}^{n-1} y_i = \sum_{i=1}^{n-1} e_i + (n-1)\theta + \sum_{i=1}^{n-1} \varepsilon_i = e_o + (n-1)\theta + \varepsilon_o \quad (7)$$

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

$$\max_{(e_o, e_p)} E\left(E\left(\theta \middle| x, e_o^e, e_p^e\right)\right) - C(e_o + e_p) \quad (8)$$

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 $C'(e_o^*) = \frac{1}{n - 1 + \sigma_\varepsilon^2 / \sigma_\theta^2}$.

Airport authorities. Decision making of an airport authority includes decision making of the airport manager and decision making of the board. For the airport manager, given a level of monitoring and the market expectation on his productive effort, he solves the problem in (3). Since 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 spends efforts on the pet project, his decisions can be characterized by the following first-order conditions

$$C_a'(e_g) = g(\tilde{m}, \gamma) \text{ and } \frac{\partial g(\tilde{m}, \gamma)}{\partial \tilde{m}} = 0 \quad (9)$$

We use $e_g^*(\gamma)$ and $\tilde{m}^*(\gamma)$ to denote the solution from the first-order conditions and they are functions of monitoring. We can have

Proposition 1: Both $e_g^*(\gamma)$and $\tilde{m}^*(\gamma)$ are strictly decreasing with respect to γ.

Proof: Differentiating the first-order conditions in (9) with respect to γ, we have

$$C_a''(e_g)\frac{de_g^*(\gamma)}{d\gamma} = \frac{\partial g(\tilde{m},\gamma)}{\partial \tilde{m}}\frac{d\tilde{m}^*(\gamma)}{d\gamma} + \frac{\partial g(\tilde{m},\gamma)}{\partial \gamma} \tag{10}$$

$$\frac{\partial^2 g(\tilde{m},\gamma)}{\partial \tilde{m}^2}\frac{d\tilde{m}^*(\gamma)}{d\gamma} + \frac{\partial^2 g(\tilde{m},\gamma)}{\partial \tilde{m}\partial\gamma} = 0 \tag{11}$$

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 $\frac{d\tilde{m}^*(\gamma)}{d\gamma} < 0$.

Proposition 2: There exists a $\bar{\gamma}$ such that $g(\tilde{m}^*(\gamma),\gamma) < \frac{1}{1+\sigma_\varepsilon^2/\sigma_\theta^2}$ when $\gamma > \bar{\gamma}$ and $g(\tilde{m}^*(\gamma),\gamma) > \frac{1}{1+\sigma_\varepsilon^2/\sigma_\theta^2}$ when $\gamma < \bar{\gamma}$.

Proof: This can be obtained by showing that $g(\tilde{m}^*(\gamma),\gamma)$ is strictly decreasing in γ. From proposition 1, we have $\frac{dg(\tilde{m}^*(\gamma),\gamma)}{d\gamma} = \frac{\partial g(\tilde{m}^*(\gamma),\gamma)}{\partial \tilde{m}}\frac{d\tilde{m}^*(\gamma)}{d\gamma} + \frac{\partial g(\tilde{m}^*(\gamma),\gamma)}{\partial \gamma} < 0$.

When the manager does not pursue the pet project, at equilibrium his efforts spent on the productive activity (e_p^*) is determined by the first order condition $C_a'(e_p^*) \equiv c_a(e_p^*) = \frac{1}{1+\sigma_\varepsilon^2/\sigma_\theta^2}$. From proposition 2, we can characterize the airport manager's decision making as follows.

Proposition 3: Let $e_p^*, e_g^*,$ and $\tilde{m}^*$ denote the optimal decisions of the manger given a level of monitoring γ. When $\gamma > \bar{\gamma}$, $e_g^* = 0$, $\tilde{m}^* = 0$ and e_p^* is determined by $c_a^{-1}\left(\frac{1}{1+\sigma_\varepsilon^2/\sigma_\theta^2}\right) = e_p^*$. When $\gamma < \bar{\gamma}$, $e_p^* = 0$ and $e_g^* = e_g^*(\gamma)$, $\tilde{m}^* = \tilde{m}^*(\gamma)$.

When $\gamma > \bar{\gamma}$, the reward to the board is $\alpha \cdot \left(c_a^{-1}\left(\frac{1}{1+\sigma_\varepsilon^2/\sigma_\theta^2} \right) + \bar{\theta} \right) - C_b(\gamma)$; when $\gamma < \bar{\gamma}$ the reward is $\alpha \cdot \left[\bar{\theta} - h\left(\tilde{m}^*(\gamma) \right) \right] - C_b(\gamma)$. This immediately implies that equilibrium monitoring effort of the board can be characterized as follows.

Proposition 4: Equilibrium monitoring effort level γ^* must satisfy:

(1) $\gamma^* \le \bar{\gamma}$;

(2) If there exists a $\gamma_L \in (0, \bar{\gamma})$ which solves $-\alpha h'\left(\tilde{m}^*(\gamma)\right)\frac{d\tilde{m}^*(\gamma)}{d\gamma} = C_b'(\gamma)$, we have

$$\gamma^* = \gamma_L \text{ if } \alpha \cdot \left[h\left(\tilde{m}^*(\gamma_L)\right) + c_a^{-1}\left(\frac{1}{1+\sigma_\varepsilon^2/\sigma_\theta^2} \right) \right] < C_b(\bar{\gamma}) - C_b(\gamma_L) \text{ and}$$

$$\gamma^* = \bar{\gamma} \text{ if } \alpha \cdot \left[h\left(\tilde{m}^*(\gamma_L)\right) + c_a^{-1}\left(\frac{1}{1+\sigma_\varepsilon^2/\sigma_\theta^2} \right) \right] > C_b(\bar{\gamma}) - C_b(\gamma_L)$$

(3) If there is no a $\gamma_L \in (0, \bar{\gamma})$ which solves $-\alpha h'\left(\tilde{m}^*(\gamma)\right)\frac{d\tilde{m}^*(\gamma)}{d\gamma} = C_b'(\gamma)$ and let $\tilde{m}^U = \tilde{m}^*(0)$, we have $\gamma^* = 0$ if $\alpha \cdot \left[h\left(\tilde{m}^U\right) + c_a^{-1}\left(\frac{1}{1+\sigma_\varepsilon^2/\sigma_\theta^2} \right) \right] < C_b(\bar{\gamma})$ and $\gamma^* = \bar{\gamma}$ if $\alpha \cdot \left[h\left(\tilde{m}^U\right) + c_a^{-1}\left(\frac{1}{1+\sigma_\varepsilon^2/\sigma_\theta^2} \right) \right] > C_b(\bar{\gamma})$.

Findings summarized in proposition 4 have intuitive interpretations. In point 2, $\alpha \cdot \left[h\left(\tilde{m}(\gamma_L)\right) + c_a^{-1}\left(\frac{1}{1+\sigma_\varepsilon^2/\sigma_\theta^2} \right) \right]$ measures utility gain to the board when the board switches monitoring level from γ_L to $\bar{\gamma}$. If the utility gain is larger than the increase in effort costs, the board will choose the high monitoring effort level. As such, it is more likely to have high (low) monitoring effort level at the equilibrium when the intensity of the board’s preferences toward the government’s political goals is stronger (weaker); when the support from the public employee unions is more (less) important to the government; when the manager's effort cost function is less (more) convex; and when the board's monitoring effort cost function is flatter (steeper). When the high monitoring effort is too costly to the board such that $C_b'(\gamma) >> 0$, the board can even choose zero monitoring effort when $h'(\cdot)$ is close to zero, that is, the marginal benefits from increasing jobs at the airport to the government is very small.

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.

Port authorities. Several airports in the U.S. are operated by independent port authorities. Different with airport authorities that manage only airports, port authorities manage both airports and other transport facilities including sea ports, tunnels, and roads. Previous analyses on decision making of city-owned airports and airport authorities can be easily extended to analyze decision-making behavior of port authorities.

On the one hand, like city-owned airports, port authorities pursue multiple tasks since they manage multiple transportation facilities. All previous analyses on the consequences of multiple tasks environment on decision making can be applied to port authorities. On the other hand, like airport authorities, port authorities have managerial autonomy to allocate inputs. The analyses on the agency problems faced by airport authorities can also be applied to port authorities. Furthermore, since port authorities operate much more complicated businesses than airport authorities do, compared to the case of airport authorities, the accountability of resource allocation of port authorities is expected to be lower. The lower accountability of resource allocation implies that for port authorities, the monitoring threshold ($\bar{\gamma}$) that forces the manager to focus on government goals is expected to be larger than the one for airport authorities.

Comparison across institutional arrangements. The analyses of airport decision making under different institutional arrangements suggest that compared to city-owned airports and port authorities, airport authorities can achieve higher productivity from being focused. When the monitoring efforts from the board are high, the equilibrium efforts from the manager are determined by $\frac{1}{1+\sigma_{\varepsilon}^{2}/\sigma_{\theta}^{2}} = C_{a}'\left(e_{p}^{*}\right)$. Compared this with equation (5) and (6), we can see that if effort cost functions are the same for both the manager and the bureaucrat, the efforts devoted by the manager of an airport authority in managing airport operation are greater than the total efforts devoted by the bureaucrat of a city-owned airport in pursuing multiple tasks. If talents are the same for the bureaucrat and the manager, productivity is higher in the airport authority than in the city-owned airport. The productivity difference can be even larger because the bureaucrat may misallocate his efforts among multiple tasks. When the monitoring efforts from the board are high, productivity of an airport authority is the upper bound of the productivity that a city-owned airport can achieve.

When the monitoring efforts from the board are low such that $\gamma^{*} < \bar{\gamma}$, the manager of an airport authority devotes zero effort in managing airport operation. In such a case, the productivity of the airport authority represents the lower bound of the productivity that a city-owned airport can have. Productivity comparison between airport and port authorities is similar to the above analysis on the productivity difference between an airport authority and a city-owned airport.

As for the allocation of inputs, a city-owned airport sets the ratio of labor to non-labor variable inputs to meet the government's political goals, which are also the objectives of input allocation in an airport (port) authority when the monitoring efforts from the board are high. In such a case, the ratio of labor to non-labor variable inputs should not be very different across institutional arrangements. However, when the monitoring efforts from the board are low for an airport or a port authority, 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. In such a case, the ratio of labor to non-labor variable inputs is lower in the airport/port authority than 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 the government's goals such that labor input is over-utilized under government control.

2.3 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 arrangement choice? There is not 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 the 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 et al. (2009) show that transfers of airport management from local governments to airport authorities in the United States can be attributed to various reasons including lack of funding of individual airports and certain special events. In this paper, we will then 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 link between the accountability of policy making and corruption. Many studies in both political science and economics[1] identify that a low accountability of public-policy making is associated with a high degree of corruption. For example, 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. On the one hand, the politicians and bureaucrats are in a better position to pursue corrupt activities when the accountability is lower. On the other hand, in a more corrupt environment, the politicians and bureaucrats are more likely to implement practices which reduce the accountability of public policy making in order to extract private benefits; the cost of doing so is less in a more corrupt environment. Therefore, we assume that the accountability of public policy outcomes is lower in more

[1] Examples include Heywood (1997), Persson and Tabellini (2000), Caiden (2001), Adserá, Boix, and Payne (2003), Alt and Lassen (2003), and Lederman and Loayza (2003).

corrupt environments. Based on this assumption, we illustrate how corruption affects airports' decision making under different institutional arrangements.

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. In our model on the decision making of a city-owned airport, the limited information of the voters on the performances can be captured by a large variance of random noise $\left(\sigma_{\varepsilon}^{2}\right)$. The variance is larger when the environment is more corrupted. From equations (5) and (6), we can immediately have the following conclusion.

Proposition 5: The bureaucrat devotes less total efforts on the mandated tasks when the environment is more corrupted.

The low accountability of policy making would also encourage the bureaucrat to pursue rent-seeking activities. Let $\eta\chi$ denote the total benefits from rent-seeking activities and the benefits depend on the bureaucrat's devoted efforts (η). Since the accountability of policy making is lower in more corrupt environments, we assume that the unit benefit from pursuing the rent-seeking activities (χ) is larger when the environment is more corrupted. The bureaucrat's problem is now

$$\max_{e_1,\ldots,e_n,\eta} E\left\{E\left(\theta \middle| y, e^e\right)\right\} + \eta\chi - C\left(e_1 + \cdots + e_n + \eta\right) \qquad (12)$$

If the bureaucrat pursues rent-seeking activities such that $\eta > 0$, he allocates zero effort to tasks specified by the Constitution since total efforts are not separable. The equilibrium efforts devoted to the rent-seeking activities (η^*) is determined by $\chi = C'\left(\eta^*\right)$.

If the bureaucrat does not pursue rent-seeking activities, he solves the problem in (2). We can then have the following proposition.

Proposition 6: The equilibrium of pursuing rent-seeking activities can exist only if $\chi \geq \dfrac{1}{n + \sigma_{\varepsilon}^{2} / \sigma_{\theta}^{2}}$ .This equilibrium is more likely if the environment is more corrupted (χ and σ_{ε}^{2} are larger).

Airport authorities. Corruption is not supposed to affect the job market's assessment on the manager's ability. Therefore, the manager's objective is not affected by corruption. However, the behavior of the board could be affected by corruption. One direct consequence of the low accountability of public-policy making in corrupt environments is that the board's preferences toward government goals could be low. The argument for this consequence is the same as before; 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 public. Proposition 4 indicates that when the board's preferences toward the political goals are weaker (α is less), the board is more likely to choose the low monitoring efforts such that the manager is more likely to pursue the personal agenda.

Furthermore, the board could also purse rent-seeking activities in a corrupt environment and therefore solve

$$\max_{\gamma,\eta} \alpha \cdot \left[E\left(y_p\right) - h(\tilde{m})\right] + \eta\chi - C_b(\gamma + \eta) \tag{13}$$

The optimal positive efforts on the rent-seeking activities are determined by $\chi = C_b'\left(\eta^*\right)$ and in this case monitoring efforts are zero. Facing zero monitoring, the manager devotes all his efforts on the pet project such that the payoff to the board at the equilibrium of pursuing rent-seeking activities is $V_b^C \equiv \alpha\left[\overline{\theta} - h\left(\tilde{m}^U\right)\right] + \eta^*\chi - C_b\left(\eta^*\right)$. Let V_b^{NC} denote the equilibrium payoff to the board does not pursue rent-seeking activities, and

$$V_b^{NC} = \begin{cases} \alpha \cdot \left[\overline{\theta} + c_a^{-1}\left(\dfrac{1}{1 + \sigma_\varepsilon^2 / \sigma_\theta^2}\right)\right] - C_b(\overline{\gamma}) & \text{if} \quad \gamma^* = \overline{\gamma} \\ \alpha \cdot \left[\overline{\theta} - h\left(\tilde{m}^*(\gamma_L)\right)\right] - C_b(\gamma_L) & \text{if} \quad \gamma^* = \gamma_L \\ \alpha \cdot \left[\overline{\theta} - h\left(\tilde{m}^U\right)\right] & \text{if} \quad \gamma^* = 0 \end{cases} \tag{14}$$

We can have:

Proposition 7: The equilibrium of pursuing rent-seeking activities can exist only if $V_b^C \geq V_b^{NC}$. This equilibrium is more likely if the environment is more corrupted (χ is larger). When positive efforts on rent-seeking activities do not exist at equilibrium ($V_b^C < V_b^{NC}$), the board is more likely to choose low monitoring efforts $\left(\gamma^* < \bar{\gamma}\right)$ at equilibrium when the environment is more corrupted (α is less).

Predictions for 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. Results from the above analyses suggest that impacts of corruption on airport productivity are different for different institutional arrangements. For city-owned airports, corruption diverts the bureaucrat's effort away from mandated tasks. However, the impacts of the diversion on airport 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 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 airport productivity.

For airport and port authorities, corruption diverts the board's efforts away from monitoring. Facing no monitoring, the manager of the authority allocates his efforts on the pet project. Productivity of airports operated by airport authorities can be affected a lot by such a diversion of efforts because monitoring from the board pushes the manager toward maximizing the airport's productivity. However, the impacts of corruption on productivity of airports operated by port authorities can be small just like what we argued for the impacts of corruption on productivity of city-owned airports.

Prediction 1: Corruption affects airport productivity negatively. Among the three airport institutional arrangements, corruption has the strongest impacts on the productivity of airport authorities.

We then predict the impacts of corruption on resource allocation of airports. Corruption will not affect resource allocation of city-owned airports because those airports have little managerial autonomy in allocating inputs. For airport and port authorities, 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 through outsourcing.

Prediction 2: Airports managed by airport and port authorities have a higher ratio of non-labor to labor variable inputs when they are in more corrupt environments.

As we argued before, a higher ratio of non-labor to labor variable inputs does not necessarily imply a lower allocative efficiency.

The last prediction is on the comparison of productivity across institutional arrangements. Given the previous comparison across institutional arrangements, we predict the following

Prediction 3: Under environments with little corruption, productivity of airport authorities is higher than the productivity of airports operated by local governments and port authorities.

3. Empirical Analysis

3.1 Data

The sample used in this paper is a subset of the data used in Oum, Yan and Yu (2008)[2] and it consists of a balanced panel of 54 U.S. airports between 2001 and 2004.

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.

[2] Oum, Yan and Yu (2008) use a larger data set including both the 54 U.S. airports and major airports of other countries to study the impacts of ownership forms on airport efficiency.

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, 2007).

In order to study the cost efficiency of airports, we need information on outputs, inputs, variable inputs prices of 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. Besides passenger services, airports provide also air cargo services. However, air cargo services are generally handled by airlines, third party cargo handling companies, and others that lease space and facilities from airports. We therefore do not include air cargo services as a separate output in this research, as airports derive a very small percentage of their income directly from air cargo services.

Variable inputs used by airports can be classified into three categories: (1) labor, measured by the number of (full time equivalent) employees who work directly for an airport operator; (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 fixed capital inputs are considered: number of runways and total size of passenger terminal area measured in square meters.

Among the 54 airports, 27 are operated by local government (city or state) and 17 are managed by an independent and autonomous management authority via a long term lease. Two airports (Tmapa and Minneapolis-St. Paul) are 100% government corporation ownership and management and we group them into the category of airport authority. Finally, seven airports are operated by port authorities.

The 54 airports are located in 30 states. We use this state-level corruption rate counstructed by Glaeser and Saks (2006) as the measure of the corruption environment faced by the airports in our sample. Compared to the country-level corruption index used by Dal Bó and Rossi (2007), this state-level corruption measure is more objective because country-level corruption index is constructed via subjective survey evidences. Table 1 lists the 54 airports, their institutional arrangements, the states where they are located, and the corruption rates of the states.

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 (2001-2004) 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%, and average annual employee compensation ranges from US$11,511 to US$101,618. It would be interesting to see how such variations would affect the observed performance of the airports.

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 airports as $C_i^*(Q_{it}, W_{it}, K_{it}, t)$, where Q is the vector of outputs, W is the vector of variable inputs prices, K is the vector of fixed capital inputs, and t represents time. The observed actual production cost (after taking log) of airport i at time t is expressed as

$$\ln C_{it} = \ln C_i^*(Q_{it}, W_{it}, K_{it}, t) + \Delta_i + \varepsilon_{it}^c \qquad (15)$$

where Δ_i denotes the deviation of actual cost from the cost frontier; ε_{it}^c represents the noises associated with the cost observations. The model includes three outputs in vector Q_{it} (number of aircraft movements q_{2it}; number of passengers q_{1it}; and non-aeronautical output q_{3it}), two variable input prices in vector W_{it} (labor price w_{1it};

and non-labor variable input price w_{2it}), and two fixed capital inputs in vector K_{it} (number of runways k_{1it}; and terminal size k_{2it}).

In equation (15), Δ_i is the parameter that we are interested in. Size of Δ_i measures technical efficiency which reflects an over-utilization of inputs given outputs and input mix of airport i. The developed theory links the size of Δ_i to managerial efforts; larger managerial efforts devoted to productivity activity imply less amount of inputs to produce a given output level. A model like this is under the stochastic frontier framework first developed by Aigner et al. (1977) and Meeusen and van den Broeck (1977). Since our central question is on impacts of corruption on airport efficiency rather than on measuring efficiency level of individual airports, we specify

$$\begin{aligned}\Delta_i = \xi_p \times \text{Port Authority}_\text{i} + \xi_A \times \text{Airport Authority}_\text{i} + \xi_{cc} \times \text{City Owned}_\text{i} \times \text{Corruption}_\text{i} \\ + \xi_{pc} \times \text{Port Authority}_\text{i} \times \text{Corruption}_\text{i} + \xi_{ac} \times \text{Airport Authority}_\text{i} \times \text{Corruption}_\text{i}\end{aligned} \quad (16)$$

where Port Authority, Airport Authority and City Owned are three dummies indicating institutional arrangement of airport i. Our theory predicts that ξ_{ac} is significantly positive; ξ_{cc} and ξ_{pc} are not significant.

We use the following example to illustrate the theoretical prediction. Consider two groups of airports, one group is in low corrupt environments and the other group is in high corrupt environments. When these airports are operated by local governments, ones in high corrupt environments are more likely to be diverted away from mandated tasks. But the average productivity difference between these two groups may not be large because airports in low corrupt environments devote little efforts to airport management when the number of mandated task is large and efforts among these tasks are misallocated. When these airports are operated by airport authorities, ones in high corrupt environments are more likely to pursue the pet project and devote zero effort in improving productivity; ones in low environments are more likely to devote all their efforts to maximize productivity. Under this institutional arrangement, the average productivity difference between these two groups of airports is expected to be large.

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

$$\ln C_i^*(Q_{it},W_{it},K_{it},t) \approx \ln \tilde{C}_i(Q_{it},W_{it},K_{it},t) = \alpha_{it} + \sum_{j=1}^{3}\beta_j \ln q_{jit} + \sum_{j=1}^{2}\theta_j \ln k_{jit} + \sum_{j=1}^{2}\delta_j \ln w_{jit}$$
$$+ \frac{1}{2}\sum_{j=1}^{3}\sum_{n=1}^{3}\phi_{jn} \ln q_{jit} \ln q_{nit} + \sum_{j=1}^{3}\sum_{n=1}^{2}\gamma_{jn} \ln q_{jit} \ln w_{nit} + \sum_{j=1}^{3}\sum_{n=1}^{2}\rho_{jn} \ln q_{jit} \ln k_{nit} \quad (17)$$
$$+ \frac{1}{2}\sum_{j=1}^{2}\sum_{n=1}^{2}\tau_{jn} \ln w_{jit} \ln w_{nit} + \sum_{j=1}^{2}\sum_{n=1}^{2}\zeta_{jn} \ln k_{jit} \ln w_{nit} + \frac{1}{2}\sum_{j=1}^{2}\sum_{n=1}^{2}\psi_{jn} \ln k_{jit} \ln k_{nit}$$

The intercept α_{it} varies across airports in order to capture the difference in cost frontier (individual heterogeneity across airports in adopted technologies) caused by the factors beyond managerial control; and varies over time in order to reflect technical change.

Variable input shares can be derived by applying the Shephard's lemma on the log cost frontier. Since we have only two variable inputs, in order to avoid the singularity problem, we chose to use the labor share equation only[3].

$$S_{it}^* \equiv \frac{\partial \ln C_i^*(Q_{it},W_{it},K_{it},t)}{\partial \ln w_{1it}} \approx \frac{\partial \ln \tilde{C}_i(Q_{it},W_{it},K_{it},t)}{\partial \ln w_{1it}}$$
$$= \delta_1 + \sum_{j=1}^{3}\gamma_{j1} \ln q_{jit} + \sum_{j=1}^{2}\tau_{j1} \ln w_{jit} + \sum_{j=1}^{2}\zeta_{j1} \ln k_{jit} \quad (18)$$

Adding the random term μ_{it} which represents measurement error to the labor share equation, we have a system of equations from which we can identify the impacts of institutional arrangements and corruption on airport productivity (technical efficiency). We treat the system of equations as a Seemingly Unrelated Regression (SUR) model and estimate the model by the iterative Feasible Generalized Least Squares (FGLS) estimator [4].

Our next step is to incorporate allocative efficiency into the stochastic cost frontier model. Let $W^* \equiv (w_1^*, w_2^*)$ denote the vector of shadow prices of labor and no-labor inputs. The shadow prices are parametrically related to market prices as $W^* \equiv (w_1^*, w_2^*) = (\lambda_1 w_1, \lambda_2 w_2) \equiv W$, where $\lambda_1, \lambda_2 > 0$. The allocative

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

[4] As the usual practice to estimate the translog cost system, we impose the following constraints in estimation.

Symmetric constraints: $\phi_{12} = \phi_{21}, \phi_{13} = \phi_{31}, \phi_{23} = \phi_{32}, \tau_{12} = \tau_{21}, \psi_{12} = \psi_{21}$.

Homogeneity constraints: The variable cost frontier is homogeneous of degree 1 with respect to variable input prices, so we have $\delta_1 + \delta_2 = 1$, $\gamma_{11} + \gamma_{12} = 0$, $\gamma_{21} + \gamma_{22} = 0$, $\gamma_{31} + \gamma_{32} = 0$, $\tau_{11} + \tau_{12} = 0$, $\tau_{12} + \tau_{22} = 0$, $\zeta_{11} + \zeta_{12} = 0$, $\zeta_{21} + \zeta_{22} = 0$.

efficiency is measured then by the parameter vector $\lambda \equiv (\lambda_1, \lambda_2)$ and an airport is allocatively efficient if $\lambda_1/\lambda_2 = 1$. Allocative inefficiency inflates an airport's actual variable cost from the cost frontier. Let $x_j(Q, K, W^*)$ denote the conditional variable input demand function and by Shephard's lemma we express the actual variable cost as

$$\begin{aligned} C &= \sum_{j=1}^{2} w_j x_j (Q, K, w_j^*) = \sum_{j=1}^{2} w_j \frac{\partial C^*(Q, K, w_j^*)}{\partial w_j^*} = \sum_{j=1}^{2} w_j \frac{\partial \ln C^*(Q, K, w_j^*)}{\partial \ln w_j^*} \frac{C^*(Q, K, w_j^*)}{w_j^*} \\ &= C^*(Q, K, w_j^*) \sum_{j=1}^{2} \frac{S_j^*}{\lambda_j} \end{aligned} \quad (19)$$

where S_j^* is the shadow share of variable input j and $\sum_{j=1}^{2} S_j^* / \lambda_j$ measures the deviation from the cost frontier caused by alloctaive inefficiency. Under the specified translog variable cost frontier, follow Atkinson and Cornwell (1994) and Kumbhakar and Tsionas (2005), we can have the following empirical variable cost equation.

$$\ln C_{it} = \ln C_{it}^*(Q_{it}, W_{it}^*, K_{it}, y) + \underbrace{\ln\left\{\sum_{n=1}^{2} \lambda_{ni}^{-1} \left[\delta_n + \sum_{j=1}^{3} \gamma_{jn} \ln q_{jit} + \sum_{j=1}^{2} \tau_{jn} \ln(\lambda_{ni} w_{jit}) + \sum_{j=1}^{2} \zeta_{jn} \ln k_{jit}\right]\right\}}_{\text{deviation from cost frontier caused by allocative inefficiency}} + \Delta_i + \varepsilon_{it}^c \quad (20)$$

where $\ln C_{it}^*(Q_{it}, W_{it}^*, K_{it}, y)$ is obtained by replacing $W_{it} \equiv (w_{1it}, w_{2it})$ as $W_{it}^* \equiv (\lambda_1 w_{1it}, \lambda_2 w_{2it})$ in equation (17). Since the actual labor share $S_{1it} = w_{1it} x_{1it} / C_{it}$ and the shadow labor share is $S_{1it}^* = \lambda_{1i} w_{1it} x_{1it} / C_{it}^*$, we can also have the following labor share equation to form a nonlinear SUR model.

$$S_{1it} = \frac{\left[\delta_1 + \sum_{j=1}^{3} \gamma_{j1} \ln q_{jit} + \sum_{j=1}^{2} \tau_{j1} \ln(\lambda_{ji} w_{jit}) + \sum_{j=1}^{2} \zeta_{j1} \ln k_{jit}\right] \lambda_{1i}^{-1}}{\sum_{n=1}^{2} \left[\delta_n + \sum_{j=1}^{3} \gamma_{jn} \ln q_{jit} + \sum_{j=1}^{2} \tau_{jn} \ln(\lambda_{ji} w_{jit}) + \sum_{j=1}^{2} \zeta_{jn} \ln k_{jit}\right] \lambda_{ni}^{-1}} + \varepsilon_{it}^s \quad (21)$$

Because only the ratio $\lambda_{1i}/\lambda_{2i}$ can be identified, we normalize $\lambda_{2i}=1$ in estimation. Under the normalization, $\hat{\lambda}_{1i} > (<) 1$ suggests that labor inputs are underutilized (overutilized) at airport i; Guided by the developed theory, we specify

$$\lambda_{1i} = \exp\begin{pmatrix} \lambda_c \times \text{City} + \lambda_p \times \text{Port Authority} + \lambda_A \times \text{Airport Authority} \\ + \lambda_{cc} \times \text{City} \times \text{Corruption} + \lambda_{pc} \times \text{Port Authority} \times \text{Corruption} \\ + \lambda_{ac} \times \text{Airport Authority} \times \text{Corruption} \end{pmatrix} \tag{22}$$

Our theory predicts that airport and port authorities would use more outsourcing to replace in-house labor in more corrupt environments. Under such a prediction, λ_{pc} and λ_{ac} are expected to be significantly positive. Our theory predicts also corruption has no impacts on resource allocation of city-owned airports such that λ_{cc} is expected to be insignificant. However, the impacts of corruption on allocative efficiency are uncertain. Although the manager of an airport or port authority is motivated by pursuing personal benefits through resource reallocation, using outsourcing to replace in-house labor can in fact increase allocative efficiency (λ_{1i} is closer to one) if political patronage is an important political goal of government. Estimation results for parameters in equation (24) will help us quantify the effects of corruption on airport allocative efficiency.

The nonlinear SUR model in equation (20) – (21) is estimated by using the iterative Feasible Nonlinear Least Squares (FNLS) estimator.

3.3 Identification Issues and Empirical Strategies

The econometric models hypothesize that airport efficiency, both technical and allocative, is affected by airport institutional arrangements and corruption. In order to empirically test such hypotheses, we compile data from 54 U.S. airports with different institutional arrangements. The 54 airports are from 30 states which vary a lot in corruption rate. Our empirical identification on the relationship between airport efficiency and institutional arrangements/corruption relies on such a variation in data. But still, the empirical identification faces several challenges.

Airports may be different in their technology because they face different factors beyond managerial control. If that is the case, variation in efficiency identified by us will actually include the variation in technology. Our empirical setting addresses this issue from two ways. First, airports included in our sample are major airports in the United Sates. Compared with the cross-country study in Dal Bó and Rossi (2007), the sample used in our analysis is expected to be more homogeneous in technology. Second, we construct many variables to control for differences across airports, cities and states. Many of these variables are believed to affect airport costs and we use these variables to control for the individual heterogeneity. The first set of control variables includes those measuring airport characteristics. We include the percentage of international passengers, the percentage of cargo traffic[5] , average temperature in January, average temperature difference between January and July, hub airport dummy[6] and tourist city dummy[7] to control for different natural conditions and market characteristics faced by airports. The second set of control variables includes characteristics at the city level. We incorporate MSA population and median household income[8], and a dummy variable indicating whether there are multiple major airports in the MSA. The last set of control variables includes characteristics at state level and these variables are collected from the Report on Economic Freedom published by Clemson University. In particular, we use 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. These state-level variables are believed to affect government quality including corruption; including these variables can capture impacts of omitted government quality measures on airport efficiency.

The second identification issue faced by us 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 a case. However, study in Lopez-de-

[5] 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.
[6] 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).
[7] One if the city is located in Nevada or Florida.
[8] MSA population and income data are from the 1990 Census.

Silanes, Shleifer and Vishny (1997) shows that political factors are the most important factors to determine 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 et al. (2009) find that lack of funding of individual airports has often been the most common reason of such transfers. Finally, some airports are operated by port authorities mainly because they are located close to major seaports with long history and operated by powerful port authorities.

Another endogeneity concern is that corruption could be endogenous. This concern may not impose serious problem to our identification because we focus on efficiency of one particular industry and the corruption measure is at the state level. It is unlikely that inefficient airports affect corruption rate of the state. If corruption in a state is caused by inefficient firms in the state, we would expect strong correlation between economic development and corruption of states. However, such a correlation is weak in empirical findings of Glaeser and Saks (2006).

4. Empirical Results

We now turn our focus on the empirical models which investigate whether corruption affects airport efficiency by influencing airports' decision making. We first present estimation results of the model incorporating technical efficiency only (equations (19) – (20)). Table 3 presents estimation results of the cost frontier. Table 4 presents results on the heterogeneity in the cost frontier across airports and the heterogeneity is captured by using observable characteristics to interact with the intercept of the cost frontier. Table 5 presents estimation results on the technical efficiency parameters.

Since it is difficult to interpret directly the results of the second order terms in a *translog* function, at the bottom of Table 3 we report the cost elasticities with respect to the three outputs and labor price, as well as the predicted labor variable input share. The positive cost elasticities and predicted variable input share imply that the monotonicity conditions in outputs and variable input prices are satisfied. 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 variable 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 constraint can be implemented by restricting $\tau_{11} \leq 0$. We did not impose this constraint in estimation. The estimated τ_{11} has a positive sign but is not significant.

There is a significant variation in the cost frontier across airports as shown in Table 4. The variation in technology is captured by airport characteristics (% of international passengers and % of cargo), city characteristics (MSA population and median household income), and state characteristics (% of government salary in state GDP and income per capita of state). In our data, there are more than one airport from the following metropolitan areas – NYC, Washington D.C., Chicago, San Francisco and Los Angeles. We use the city dummies to control for the individual effects. The airports in San Francisco are found to have a higher cost frontier compared with other airports. Cost frontier of airports varies also with time. Compared with the cost frontier in 2001, cost frontiers in 2002, 2003 and 2004 are all significantly larger.

Table 5 shows estimates of parameters regarding technical efficiency of airports which is specified in equation (18). Estimation results indicate that airport productivity varies significantly across the three institutional choices (government-branch; port authority and airport authority). Moreover, corruption rate has a significant impact on productivity of airport authorities, but does not affect significantly productivity of airports operated by port authorities or city governments. When corruption rate is low, airports governed/operated by airport authorities outperform the airports operated by port authorities or city-owned airports in productivity. For example, when corruption rate is 0.151, the 10 percentile value of the empirical distribution of corruption rate data, compared to city-owned airports the airports operated by airport authorities achieve on average about

20% higher productivity for producing the same level of output; the cost saving due to the higher productivity can be as high as 40% when airport authorities are compared with the airports operated by port authorities. However, the cost saving in airport authorities disappears when corruption rate is high. If corruption rate is as high as 0.439, the ninety percentile value of the empirical distribution of corruption rate data, productivity difference between city-owned airports and airport authorities becomes negligible.

The empirical findings confirm the theoretical prediction on the impacts of corruption on airport productivity under different institutional arrangements. Airport authorities in less corrupt environments are more likely to be monitored by the board to focus on airport management, and as such, achieve a higher productivity. In environments with high corruption, airports under all institutional arrangements achieve similarly low productivity because the managers (bureaucrats) all spend little effort in managing airport.

Our theory predicts also that corruption has different impacts on airports' resource allocation under different institutional arrangements. Airports operated by airport or port authorities have the tendency to use more outsourcing to replace in-house labor under more corrupt environments. In this way, corruption causes allocative inefficiency at these airports. We test this theoretical prediction by using the model specified in equations (22) – (24) which incorporates both technical and allocative efficiency. Estimation results to the cost frontier parameters are similar to the ones presented in Tables 3 and 4. In order to save space, we present only the estimation results on parameters regarding technical and allocative efficiency of airports. The results are presented in Table 6. The first panel (Panel A) of Table 6 shows results of technical efficiency parameters. Technical efficiency parameters presented in Table 6 are very comparable to the ones presented in Table 5. Incorporating allocative efficiency terms into the stochastic cost frontier model does not change our previous findings on the impacts of institutional arrangements and corruption on airport technical efficiency.

The second panel (Panel B) of Table 6 presents estimation results of allocative efficiency parameters which are specified in equation (24). The three coefficients associated with institutional arrangement dummies are all significantly negative. This suggests that if there was no corruption (the corruption rate is zero), airports under the three institutional arrangements all over-utilize labor input (because $\lambda_{1i} < 1$). The significantly positive coefficients of the interactions between corruption rate and the three institution dummies suggest that airports under all the three institutional arrangements tend to use more non-labor inputs to replace labor input when environments are more corrupt. The impacts of corruption on airports' resource allocation are the strongest for airports operated by port authorities and are the weakest for airports operated by city governments. These findings are broadly consistent with our theoretical prediction except that our theory predicted that city-owned airports are assumed to have no autonomy to allocate resources.

From estimation results in Table 6, we summarize efficiency measures for airports of the three institutional arrangements under different corrupt environments. We use the 10%-ile of the empirical distribution of corruption rate (0.151) in the data to represent the "low" corrupt environment, the median of the distribution (0.236) to represent the "medium" corrupt environment and the 90%-ile of the distribution (0.439) to represent the "high" corrupt environment. Results of the efficiency measures are presented in Table 7.

Numbers in the first panel of Table 7 suggest that airports operated by both city governments and airport authorities over-utilize labor input under all corrupt environments. When corruption rate gets higher, airports under all the three institutional arrangements use more non-labor inputs to replace labor input such that the degree of over-utilization of labor input in airports operated by city governments and airport authorities is reduced. The labor to non-labor variable input ratio in airports operated by port authorities is very sensitive to the change of corruption rate; airports operated by port authorities over-utilize labor input in low corruption environment but under-utilize labor input (and over-use soft-cost inputs including outsouring) in medium to high corruption environments.

Numbers in the second panel of Table 7 show the technical efficiency of airports under the three institutional arrangements. City-owned airports are treated as the base and their technical efficiency is normalized as zero under all corrupt environments because corruption has no significant impacts on their technical efficiency. The numbers confirm previous results from the model with only technical efficiency.

What are the magnitudes of cost inflation caused by misallocation of inputs? Numbers in panels 3 of Table 7 show that when corruption rate is low, the over-utilization of labor input inflates costs by 33% for city-owned airports and by 72% for airport authorities. The cost inflation from misallocation of inputs can be in fact reduced when airports use more outsourcing to replace in-house labor in more corrupt environments. For airports operated by port authorities, cost inflation from the over-utilization of non-labor inputs can be very high in high corrupt environments.

Similar to findings from the model with only technical efficiency, compared to city-owned airports, airport authorities can have 20% – 30% cost saving from higher technical efficiency in low to medium corrupt environments; but the cost saving disappears in high corrupt environments. These findings are shown by the numbers presented in the fourth panel of Table 7.

Results in the last panel of Table 7 show that by combining both allocative and technical efficiency airport authorities outperform airports of other two institutional arrangements in low corrupt environments. When corruption rate is high, airport authorities are not much different with city-owned airports in cost efficiency. Airports operated by port authorities are the least efficient group among the three institutional arrangements.

Comparison between theory and empirical findings. In sum, findings from the empirical analysis confirm our theory on the importance of corruption in determining airport efficiency. The developed theory argues that corruption diverts the board's monitoring efforts such that the manager of an airport authority devotes efforts in projects which derive private benefits. As such, airport authorities in more corrupt environments have lower productivity and higher non-labor to labor input ratio. Empirical findings confirm that in more corrupt environments, airport authorities use more inputs to produce a given output at a given input mix; at the same time, these airports use more non-labor inputs to replace in-house labor.

The developed theory also argues that airports operated by city governments or port authorities under different corrupt environments are not different in productivity. The reason is that the multiple tasks environments faced by these airports cannot induce managerial efforts devoted on airport management even when corruption is low. Indeed, our empirical findings suggest that there is no significant relationship between corruption and technical efficiency for airports operated by city governments and port authorities. Like the agency problem in airport authorities, port authorities can use resource allocation to exploit private benefits. Our theory argues that such agency problems are in fact more likely to exist in port authorities because port authorities manage very complicated businesses such that accountability of inputs allocation is even lower in port authorities than in airport authorities. Results from the empirical analysis found that inputs allocation in airports operated by port authorities is very sensitive to the change of corruption rate; these airports over-utilize non-labor inputs in medium to high corrupt environments.

Our theory assumes that city-owned airports have no managerial autonomy to reallocate inputs such that corruption has no impacts on inputs allocation of these airports. However, the empirical findings suggest that even city-owned airports tend to use more non-labor inputs to replace labor input when they are in more corrupt environments, although the correlation between corruption and inputs allocation is the weakest for city-owned airports among the three institutional arrangements.

5. Conclusion

Institutional arrangements matter for airport efficiency because they determine incentive structures of airport management. Reforming airport governance structures in the United States has in general taken the form of transferring airport management from local governments to special purpose and independent airport authorities. Although such transfers 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.

In this paper we point out the importance of government quality, which is measured as corruption, in determining airport efficiency under different institutional arrangements. We first develop a simple theory on decision making of airports under different institutional arrangements and the theory formalizes the general belief that airport authorities can gain efficiency from being focus. However, like modern corporations, airport authorities may encounter agency problems in the sense that the manager's objectives deviate from government goals. The consequences of agency problems to airport authorities are similar to the consequences of multiple tasks environment to city-owned airports. The board of directors, which are appointed by the government, can use monitoring to push the manager of an airport authority toward government goals. The monitoring efforts are affected by corrupt environments. In more corrupt environments, the board is more likely to devote efforts on corrupt activities rather than on monitoring and therefore the manager is more likely to be diverted away from government goals. Airport authorities cannot be more productive than city-owned airports in such a situation.

The empirical analysis based on 54 major airports in the United States reveals that airports operated by airport authorities outperform city-owned airports in cost efficiency only in low corrupt environments. Technical efficiency of airport authorities drops fast when corruption rate increases. Empirical findings indicate also the over-utilization of labor input in both airport authorities and city-owned airports. Surprisingly, for both the two types of airports, the allocative inefficiency caused by the over-utilization of labor input is larger in less corrupt environments, which is an evidence suggesting distortion to airport efficiency caused by political influences.

The developed theory and the empirical findings have important policy implications on reforming airport governance structure in the United States. 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 government. Politicians in low corrupt environments can influence decision making of airport authorities in order to pursue political goals. Such influences along with the lack of internal incentive hinder the manager's efforts to exploit more efficient inputs allocation. In high corrupt environments, the board of an airport authority is likely to be ill functioned such that agency problems can be severe in the airport authority.

Starting with the privatization of the three airports in London (Heathrow, Gatwick, and Stansted), there has been a worldwide trend of airport privatization. Airport privatization has certainly advantages to overcome the identified problems associated with airport authorities. Private airports are better insulated from political influences and give managers stronger incentives to exploit efficient inputs allocation. Also, internal organization of private airports can be better functioned in high corrupt environments. The U.S. congress created an Airport Privatization Pilot Program in 1996 and the program is making very slow progress in reforming airport governance structure. Findings from this paper suggest that airport privatization should receive more attention in reforming U.S. airport governance.

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Table 1. List of Airports

Airport Code	State	Institutional Arrangement	State corruption rate [a]
ABQ	NM	City government	0.263
ALB	NY	Airport authority	0.439
ATL	GA	City government	0.373
AUS	TX	City government	0.209
BNA	TN	Public corporation	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	0.190
DCA	DC	Airport authority	0.329 [b]
DEN	CO	City government	0.151
DFW	TX	Airport authority	0.209
DTW	MI	Airport authority	0.181
EWR	NJ	Port authority	0.273[c]
FLL	FL	Airport authority	0.368
HNL	HW	State government	0.295
IAD	VA	Airport authority	0.329
IAH	TX	City government	0.209
IND	IN	Airport authority	0.190
JAX	FL	Airport authority	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	0.368
MDW	IL	City government	0.458
MEM	TN	Airport authority	0.464
MIA	FL	City government	0.368
MKE	WI	City government	0.150
MSP	MN	Public corporation	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
PDX	OR	Port authority	0.074
PHL	PA	City government	0.361
PHX	AZ	City government	0.158
PIT	PA	Airport authority	0.361
RDU	NC	Airport authority	0.170
RIC	VA	Airport authority	0.329
RNO	NV	Airport authority	0.222
SAN	CA	City government	0.232
SAT	TX	City government	0.209

SDF	KY	Airport authority	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	0.248
TPA	FL	Airport authority	0.368

Note: [a] The corruption 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 per year)	21 (16)
Number of Aircraft Movements (000's per year)	324 (195)
Non-Aeronautical Revenue (000's PPP deflated $ per year)	76 (55)
Variable Inputs	
Number of Employee	572 (496)
Non-labor Variable Cost (000's US $)	69.70 (79.74)
Fixed Inputs	
Number of Runways	3.36 (1.22)
Terminal Size (000's Squared Meter)	176 (157)
Variable Inputs' Prices	
Wage Rate (000's US $ per year)	62 (18)
Variable Input's Share	
Labor Cost Share	0.39 (0.14)
Airport Characteristics	
Percentage of International Passengers	0.07 (0.10)
Percentage of Cargo	0.16 (0.16)
Number of Observations	216

Table 3. Estimation results of cost frontier [a]

Coefficients	Estimates
β_1 (number of aircraft movement (ATM))	0.8135 (0.4537)
β_2 (number of passengers (PAX))	0.3579 (0.5537)
β_3 (non-aeronautical revenue (NAR))	-0.1810 (0.4425)
θ_1 (number of runways)	-0.5551 (0.4610)
θ_2 (terminal size)	0.1485 (0.2233)
δ_1 (wage rate)	0.4013 (0.0782)
ϕ_{11} (ATM × ATM)	0.2188 (0.5919)
ϕ_{12} (ATM × PAX)	0.5922 (0.4781)
ϕ_{13} (ATM × NAR)	0.2485 (0.1976)
ϕ_{22} (PAX × PAX)	-1.1582 (0.5075)
ϕ_{23} (PAX × NAR)	0.2684 (0.2511)
ϕ_{33} (NAR × NAR)	-0.1884 (0.1889)
γ_{11} (ATM × wage rate)	0.0732 (0.0359)
γ_{21} (PAX × wage rate)	-0.1039 (0.0351)
γ_{31} (NAR × wage rate)	-0.0409 (0.0252)
ρ_{11} (ATM × number of runways)	-2.3522 (0.4930)
ρ_{12} (ATM × terminal size)	-0.4317 (0.1869)
ρ_{21} (PAX × number of runways)	1.7398 (0.3934)
ρ_{22} (PAX × terminal size)	-0.0455 (0.1617)
ρ_{31} (NAR × number of runways)	-0.5224 (0.2134)
ρ_{32} (NAR × terminal size)	0.0037 (0.1041)
τ_{11} (wage rate × wage rate)	0.0582 (0.0306)
ζ_{11} (number of runways × wage rate)	0.1281(0.0280)
ζ_{21} (terminal size × wage rate)	0.0044 (0.0177)
ψ_{11} (number of runways × number of runways)	1.9032 (0.4050)
ψ_{12} (number of runways × terminal size)	0.1800 (0.1636)
ψ_{22} (terminal size × terminal size)	0.1127 (0.0789)
Cost elasticity with respect to ATM [b]	0.04
Cost elasticity with respect to PAX [b]	0.22
Cost elasticity with respect to NAR [b]	0.73
Cost elasticity with respect to wage rate [b, c]	0.63
Predicted labor share [c]	0.40

[a] Numbers in parentheses are standard errors.
[b] The elasticities are evaluated at sample means.
[c] Non-labor variable input share equals one minus labor input share.

Table 4. Controls of heterogeneity in cost frontier [a]

Coefficients	Estimates
% of international passengers	1.3720 (0.2458)
% of cargo	0.4170 (0.1149)
Ave. temperature in Jan.	0.0002 (0.0047)
Temp. diff. between Jul. and Jan.	0.0027 (0.0054)
MSA population	0.1904 (0.0341)
MSA ave. household income	-0.7373 (0.2224)
Tourist city	-0.0568 (0.0820)
Hub airport	0.0266 (0.0486)
Tax per cap. of state	-0.2833 (0.1908)
% of government salary in state GDP	0.4118 (0.1850)
Ratio of pub. vs. priv. sector salary of state	-8.4149 (5.0896)
Number of public employee per 10,000 state resident	-0.0545 (0.1440)
Population of state	-0.0376 (0.0416)
Income per cap of state	0.1409 (0.0310)
% with 4+ years of college in a state	-0.0104 (0.0076)
Multiple airports	0.0112 (0.0669)
New York City	-0.0362 (0.1579)
Washington D.C.	-0.1068 (0.1233)
Chicago	0.1112 (0.1058)
San Francisco	0.5767 (0.1768)
Los Angeles	-0.0340 (0.1521)
Year 2002	0.0969 (0.0277)
Year 2003	0.1342 (0.0292)
Year 2004	0.1338 (0.0294)

[a] Numbers in parentheses are standard errors.

Table 5. Impacts of institutional arrangements and corruption on technical efficiency [a]

Coefficients	Estimates
ξ_p : Port authority	0.3641 (0.1623)
ξ_A : Airport authority	-0.3532 (0.1281)
ξ_{cc} : City × Corruption	-0.2337 (0.3653)
ξ_{pc} : Port authority × Corruption	-0.3477 (0.6216)
ξ_{ac} : Airport authority × Corruption	0.8501 (0.2965)

[a] Numbers in parentheses are standard errors.

Table 6. Impacts of institutional arrangements and corruption on technical and allocative efficiency [a]

Coefficients	Estimates
Panel A: Technical efficiency parameters	
ξ_p : Port authority	0.3306 (0.1489)
ξ_A : Airport authority	-0.6275 (0.1368)
ξ_{cc} : City × Corruption	-0.3368 (0.2515)
ξ_{pc} : Port authority × Corruption	0.1918 (0.6532)
ξ_{ac} : Airport authority × Corruption	1.7622 (0.4237)
Panel B: Allocative efficiency parameters	
λ_p : City	-0.8105 (0.2120)
λ_p : Port authority	-1.3719 (0.2888)
λ_A : Airport authority	-1.4909 (0.2967)
λ_{cc} : City × Corruption	1.3133 (0.5177)
λ_{pc} : Port authority × Corruption	8.5784 (1.2224)
λ_{ac} : Airport authority × Corruption	2.8749 (0.6797)

[a] Numbers in parentheses are standard errors.

Table 7. Efficiency measures summarized from estimates in Table 6

	Low Corruption Rate: 0.151 (10%-ile of corruption rate distribution)	**Medium Corruption rate: 0.236 (median of corruption rate distribution)**	**High Corruption Rate: 0.439 (90%-ile of corruption rate distribution)**
Allocative efficiency: $\lambda_{1i} = \exp\left(\begin{array}{l}\lambda_c \times \text{City} + \lambda_p \times \text{Port Authority} + \lambda_A \times \text{Airport Authority} + \lambda_{cc} \times \text{City} \times \text{Corruption} \\ + \lambda_{pc} \times \text{Port Authority} \times \text{Corruption} + \lambda_{ac} \times \text{Airport Authority} \times \text{Corruption}\end{array}\right)$			
City	0.54	0.61	0.79
Port authority	0.93	1.92	10.96
Airport authority	0.35	0.44	0.80
Technical efficiency: $\Delta_i = \xi_p \times \text{Port Authority}_i + \xi_A \times \text{Airport Authority}_i + \xi_{cc} \times \text{City Owned}_i \times \text{Corruption}_i + \xi_{pc} \times \text{Port Authority}_i \times \text{Corruption}_i + \xi_{ac} \times \text{Airport Authority}_i \times \text{Corruption}_i$			
City	0.00	0.00	0.00
Port authority	0.33	0.33	0.33
airport authority	-0.36	-0.21	0.15
Cost inflation from allocative inefficiency: $\sum_{n=1}^{2} \lambda_{ni}^{-1} \left[\delta_n + \sum_{j=1}^{3} \gamma_{jn} \ln q_{jit} + \sum_{j=1}^{2} \tau_{jn} \ln(\lambda_{ni} w_{jit}) + \sum_{j=1}^{2} \zeta_{jn} \ln k_{jit} \right]$			
City	1.33	1.25	1.10
Port authority	1.03	1.56	7.08
Airport authority	1.72	1.50	1.10
Cost inflation from technical inefficiency: $\exp(\Delta_i)$			
City	1.00	1.00	1.00
Port authority	1.43	1.46	1.52
Airport authority	0.70	0.81	1.16
Cost inflation from both allocative and technical inefficiency: $\exp(\Delta_i) \times \sum_{n=1}^{2} \lambda_{ni}^{-1} \left[\delta_n + \sum_{j=1}^{3} \gamma_{jn} \ln q_{jit} + \sum_{j=1}^{2} \tau_{jn} \ln(\lambda_{ni} w_{jit}) + \sum_{j=1}^{2} \zeta_{jn} \ln k_{jit} \right]$			
City	1.33	1.25	1.10
Port authority	1.47	2.28	10.76
Airport authority	1.20	1.26	1.28