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Abstract

By considering a simple Nash bargaining solution, we analyze shoddy construction of public infrastructure that stems from political corruption. In our model, the business manager of a construction firm and the bureaucrat collude—the firm makes infrastructure with shoddy construction and the bureaucrat condones it by taking a bribe. We find that the size of a public works project, the marginal cost savings from the shoddy construction, and the probability of a major earthquake affect the degree of the shoddy construction. Punishment deters shoddy construction, but punishment that is too heavy may induce the business manager and the bureaucrat to escape abroad. In this case, the earthquake resistance of the public infrastructure decreases to a dangerously low level.

JEL Classifications: D72; D73; K42

Keywords: Shoddy Construction, Earthquake Resistance, Corruption, Collusion

1. Introduction

Until recently, public works construction has been a hotbed of political corruption.[1] It is well known that corruption in public construction worsens economic welfare through several channels. According to Flyvbjerg and Molloy (2011), one typical distortion is when a bureaucrat overestimates the benefits of an infrastructure and underestimates the construction cost intentionally, and then the government builds excess infrastructure. Another is when a bureaucrat distorts the bidding of public purchases to create rent.[2] However, the most serious problem arising from political corruption is *shoddy construction* of public infrastructure, because such infrastructure kills a large number of people when a major earthquake occurs. Ambraseys and Bilham (2011), in their article published in *Nature*, reports statistical support for a correlation between corruption and loss of life in earthquakes. In the field of economics, Escaleras et al. (2007) and Keefer et al. (2011) also conduct more sophisticated statistical analysis and conclude that public sector corruption is positively related to earthquake deaths.

Reduction of earthquake resistance of infrastructure stems from collusion between construction firms and bureaucrats. The firm is involved in the shoddy construction of the infrastructure, and the bureaucrat condones it by taking a bribe. The methods of shoddy construction include, for example, excised steel bars, diluted concrete, and depthless piling these activities save construction cost and reduce quake resistance of completed public infrastructure. Such illicit activities are easily found by independent inspections on the building site; however, once the public infrastructure is finished, it is difficult to detect the shoddy construction. Since the reduction of earthquake resistance increases the probability that the public infrastructure collapses when a major earthquake occurs, shoddy construction raises the fatalities from an earthquake.

The essential problem of shoddy construction arises from collusive ties between construction firms and bureaucrats. Thus, considering a simple Nash bargaining solution, we study the earthquake resistance of public infrastructure.[3] Because the shoddy construction

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[1] For example, Hardoon and Heinrich (2011) rank 19 sectors based on a score for perceptions of foreign bribery; public works contracts and construction is the worst among the sectors.

[2] Auriol (2006) studies capture and extortion in public purchase by developing an auction theorem with corruption and shows that the total cost of capture is between 1.2 and 2.88 times the amount of bribe based on a calibration.

[3] Tirole (1986) considers the collusion problem by introducing a principle-supervisor-agent hierarchy model. Laffont and Tirole (1991), Kofman and Lawarree (1993, 1996), Strausz (1997), and Kessler (2000) expand this framework. Applying the hierarchical collusion model, Auriol (2006) analyzes collusion in public construction as mentioned in footnote 3. In contrast, we attempt to consider collusion in public construction by using a simple Nash bargaining solution.

reduces the earthquake resistance, the public infrastructure may collapse stochastically when a major earthquake occurs. When the public infrastructure collapses, the shoddy construction is discovered and the business manager of the construction firm and the bureaucrat who had inspected the infrastructure are punished. We find that, when collusion is committed, earthquake resistance decreases with a large marginal cost for maintaining the earthquake resistance and with a large public infrastructure. Moreover, a large probability of earthquake occurrence and heavy punishment deter shoddy construction, but punishment that is too heavy may induce the business manager and the bureaucrat to escape abroad, and the earthquake resistance of the infrastructure worsens significantly.

In this study, we focus on the relationship between earthquake resistance of infrastructure and corruption. Bose et al. (2008) theoretically examines the impact of corruption on the quality of public infrastructure and empirically shows that corruption worsens the quality of electricity, water, and roads. Considering a majority voting model, Anbarci et al. (2005) points out that enforcement of high-level building codes often fails in developing countries because the per capita income is simply too low or there are conflicts between different segments of society. Rahman et al. (2017, p.796) empirically investigates whether earthquakes trigger political transitions and concludes that, "while not leading to a full-fledged regime transition, earthquake shocks open a new window of opportunity, but this is narrowed by improved economic conditions."

The remainder of this paper is organized as follows. In the next section, we introduce our model of collusion, and then in Section 3, we consider the earthquake resistance of public infrastructure. In Section 4, we extend the model by considering the possibility that the business manager and the bureaucrat escape abroad before a major earthquake occurs. In Section 5, we provide the concluding remarks.

2. The Model

We consider a simple economy consisting of two players: a business manager of a construction firm and a bureaucrat belonging to a government, which has placed an order for public works construction. The firm has already received the contract for the public project, such as a dam, bridge, hospital, or school. The closed bid of the public project is historically given in our model.[4] The bureaucrat inspects the building site to make sure that the firm

[4] The bidding process of public purchases is also a hotbed of political corruption, as analyzed by Auriol (2006). However, the essential problem of shoddy construction arises from collusion, so, for simplification, we exclude the bidding process in our model.

executes the public project properly. We assume that the business manager and the bureaucrat can collude; the firm performs shoddy construction, and the bureaucrat condones it by taking a bribe. If the firm reduces the construction cost by the shoddy construction, the earthquake resistance of the public infrastructure erodes and the probability of the infrastructure's collapse rises when a major earthquake occurs. When the building collapses, the crime of shoddy construction is discovered and both the business manager and the bureaucrat are punished.

The size of a public works project is denoted by X. The marginal cost of construction, MC, is given by

$$MC = \gamma \cdot Q, \tag{1}$$

where $Q \in [0,1]$ is the earthquake resistance of the public infrastructure, which can be selectable by the firm. $Q = 1$ implies that the building satisfies the earthquake resistance standards, and we assume that the building does not collapse even when a major earthquake occurs. The earthquake-resistance standards need to be met in the original contract. We define the shoddy construction as the decrease of Q. $\gamma > 0$ represents the marginal cost for improving earthquake resistance.[5] When a major earthquake occurs, the probability of the collapse of the infrastructure is

$$q = 1 - Q. \tag{2}$$

The profit of the firm is $\pi = (P - MC)X$, where P is the unit price of the construction. We assume that the closed contract guarantees the firm a non-negative profit even when the firm builds a public infrastructure that meets earthquake-resistance standards $Q = 1$. Thus, we set the price as $P = (1+\alpha)\gamma$; $\alpha \geq 0$ is the markup rate. Thus, when the firm maintains the earthquake-resistance standards, the profit of the firm $\bar{\pi}$ is

$$\bar{\pi} = (P - MC)X = \alpha\gamma X. \tag{3}$$

On the other hand, when collusion is committed, the expected profit of the firm is

$$E\pi = (P - MC)X - b - \rho q\theta = (\alpha + q)\gamma X - b - \rho q\theta, \tag{4}$$

where b is a bribe, $\rho \in (0,1)$ is the probability of a major earthquake occurrence, and $\theta > 0$ is the punishment when the shoddy construction is discovered.[6]

The utility function of the bureaucrat is given by $U = Bb^{\eta}$, where $B > 0$ and $\eta \in (0,1)$.

[5] Because the scale of public construction X is fixed, the marginal cost with respect to X does not have any effect in our model. Thus, we omit the marginal cost for the size of public construction; we consider only the marginal cost of the earthquake resistance Q.

[6] We assume that the utility function of the business manager is linear, that is, he/she obtains one unit of utility from one unit of profit.

For simplicity, we assume that the punishment for the bureaucrat is that same as that for the business manager. When collusion is committed, the expected utility is

$$EU = Bb^{\eta} - \rho q \theta . \tag{5}$$

If the collusion does not hold, the utility is

$$\overline{U} = 0 . \tag{6}$$

The timing of our game is summarized as follows.

Stage zero: The contract for the public works construction is closed. The contract is historically given in our model.

Stage one: The business manager and the bureaucrat decide on whether to collude on the shoddy construction.

Stage two: The firm builds the public infrastructure.

Stage three: A major earthquake stochastically occurs. Depending on the degree of the shoddy construction, the public infrastructure collapses stochastically. When the building collapses, both the business manager and the bureaucrat are punished.

3. The Equilibrium

In this section, we analyze the degree of the shoddy construction and the amount of the bribe. When the business manager and the bureaucrat select q and b, respectively, there is a unique Nash equilibrium $(b,q) = (0,0)$. When the Nash equilibrium holds, shoddy construction does not occur. This is the reference point of bargaining. From (3), (4), (5), and (6), the participation constraints of the bureaucrat and the business manager are, respectively,

$$EU - \overline{U} = Bb^{\eta} - \rho q \theta \geq 0 , \tag{7.a}$$

$$E\pi - \overline{\pi} = (\gamma X - \rho \theta) q - b \geq 0 . \tag{7.b}$$

Thus, the Nash product is

$$V = \beta \log[EU - \overline{U}] + (1-\beta) \log[E\pi - \overline{\pi}]$$

$$= \beta \log[Bb^{\eta} - \rho q \theta] + (1-\beta) \log[(\gamma X - \rho \theta) q - b] , \tag{8}$$

where β is the bargaining power of the bureaucrat. By the Nash bargain solution, we have

$$b^* = \left(\frac{\eta B(\gamma X - \rho\theta)}{\rho\theta} \right)^{\frac{1}{1-\eta}}, \tag{9}$$

$$q^* = \left(\beta + \frac{1-\beta}{\eta} \right) \left(\frac{\eta B}{\rho\theta} \right)^{\frac{1}{1-\eta}} (\gamma X - \rho\theta)^{\frac{\eta}{1-\eta}}. \tag{10}$$

The results of the comparative statics are summarized in the following proposition.

Proposition 1

(i) The earthquake resistance of the public infrastructure decreases with a large marginal cost for improving earthquake resistance and with a large public infrastructure, that is, $\frac{\partial q^*}{\partial \gamma} > 0$ and $\frac{\partial q^*}{\partial X} > 0$.

(ii) The earthquake resistance of the public infrastructure increases with a large probability of a major earthquake and heavy punishment, that is, $\frac{\partial q^*}{\partial \rho} < 0$ and $\frac{\partial q^*}{\partial \theta} < 0$.

(iii) The earthquake resistance of the public infrastructure increases with the high bargaining power of the bureaucrat, that is, $\frac{\partial q^*}{\partial \beta} < 0$.

The first and second results are straightforward. Because γX denotes the marginal benefit of the firm from the reduction of the earthquake resistance, the firm can save a large amount of construction costs by committing shoddy construction when γ and X are large. The high probability of an earthquake occurrence and heavy punishment deter shoddy construction. On the other hand, the third result stems from the assumption that the business manager is risk-neutral while the bureaucrat is risk-averse.

4. The Extended Model

Proposition 1 suggests that heavy punishment improves the earthquake resistance of public construction. Moreover, because heavy punishment violates the participation constraints (7.a) and (7.b), prohibitory punishment, including life imprisonment or death penalty, deters shoddy construction. However, we have the question of whether such punishment is always effective. Because there is normally a time interval between when the public infrastructure is completed and when a major earthquake occurs, the business manager and the bureaucrat have enough time to escape, frequently, by going abroad. In this case, it would be difficult to catch them. In this section, we develop the previous model by considering a possibility that the business manager and the bureaucrat can escape abroad after the public project is completed.

We assume that the business manager and the bureaucrat can surely escape by incurring flight costs $\psi > 0$. Moreover, for simplicity, we exclude cases in which one of them escapes alone.

The timing of the extended game is summarized as follows; the changes are written in *italics*.

Stage zero: The contract of the public works construction is closed. The contract is historically given in our model.

Stage one: The business manager and the bureaucrat decide on whether to collude on the shoddy construction. *Moreover, the business manager and the bureaucrat decide on whether to escape if they collude and commit shoddy construction.*

Stage two: The firm builds the public infrastructure. *According to the decision in stage one, they may escape by incurring a flight cost.*

Stage three: A major earthquake stochastically occurs. In this case, depending on the degree of the shoddy construction, the public infrastructure collapses stochastically. When the infrastructure collapses, *and when the business manager and the bureaucrat do not escape in stage two*, both of them are punished.

When the business manager and the bureaucrat commit shoddy construction and escape after the construction is completed, the utility of the bureaucrat and the profit of the firm are, respectively,

$$\widetilde{U} = B \cdot b^{\eta} - \psi \,, \tag{11.a}$$

$$\widetilde{\pi} = [\alpha(\gamma + \sigma) + \gamma q]X - b - \psi \,. \tag{11.b}$$

Note that we assume that they can surely escape by incurring the flight cost. When collusion is not committed, their profit and utility are the same as in (6) and (3). The participation constraints in the case of an escape are, respectively,

$$\widetilde{U} - \overline{U} = Bb^{\eta} - \psi \geq 0, \tag{12.a}$$

$$\widetilde{\pi} - \overline{\pi} = \gamma X q - b - \psi \geq 0. \tag{12.b}$$

Thus, the Nash product in this case is

$$\widetilde{V} = \beta \log[\widetilde{U} - \overline{U}] + (1-\beta)\log[\widetilde{\pi} - \overline{\pi}]$$

$$= \beta \log[Bb^{\eta} - \psi] + (1-\beta)\log[\gamma X q - b - \psi]. \tag{13}$$

In the same manner as in the previous section, we maximize (13) with respect to b and q. Straightforwardly, we have a corner solution of the probability of collapse as $q^{**} = 1$, that is, the earthquake resistance of the public infrastructure is the minimum and the infrastructure surely collapses when a major earthquake occurs. The equilibrium bribe b^{**} must satisfy the following equation:

$$[\beta\eta + (1-\beta)]B(b^{**})^{\eta} - \beta\eta B(\gamma X - \psi)(b^{**})^{\eta-1} - (1-\beta)\psi = 0. \tag{14}$$

To get an analytical solution, we assume that only the bureaucrat has bargaining power, that is, $\beta = 1$.[7] Substituting it into (14), we have

$$b^{**} = \gamma X - \psi. \tag{15}$$

From (12.a), (12.b), (15), and $q^{**} = 1$, the participation constraints are changed to

$$\widetilde{U}(b^{**}) - \overline{U} = B(\gamma X - \psi)^{\eta} - \psi \geq 0, \tag{16.a}$$

$$\widetilde{\pi} - \overline{\pi} = 0. \tag{16.b}$$

Next, we consider the condition of whether the bureaucrat and the business manager escape after the public infrastructure with shoddy construction is completed. For comparison, we also set $\beta = 1$ in the case that the business manager and the bureaucrat do not escape. Substituting (9), (10), and $\beta = 1$ into (7.a) and (7.b), we have

[7] Alternatively, substituting $\beta = 0$ into (14), we have $B \cdot b^{\eta} - \psi = 0$. Obviously, this implies that $\widetilde{U} = \overline{U} = 0$.

$$EU(b^*) - \overline{U} = (1-\eta)B\left[\frac{\eta B(\gamma X - \rho\theta)}{\rho\theta}\right]^{\frac{\eta}{1-\eta}} \geq 0 \, , \tag{17.a}$$

$$E\pi - \overline{\pi} = 0 \, . \tag{17.b}$$

In the case of $\beta = 1$, when the collusion does not hold, the utility of the bureaucrat is zero, that is, $\overline{U} = 0$. Thus, this is equivalent to the problem that the bureaucrat maximizes his/her utility subject to the participation constraint of the business manager. In this case, the bureaucrat takes all the rent.[8]

There are potentially three kinds of equilibria: (i) shoddy construction with flight (shoddy construction is committed and the bureaucrat and the business manager escape), (ii) shoddy construction without flight (shoddy construction is committed and the bureaucrat and the business manager do not escape), and (iii) no shoddy construction (shoddy construction is not committed). Figure 1 illustrates the regions in which an equilibrium occurs. These regions are characterized by following equations:

$$\gamma X = \left(\frac{\psi}{B}\right)^{\frac{1}{\eta}} + \psi \, , \tag{18}$$

$$\theta = \frac{\gamma X}{\rho} \, , \tag{19}$$

$$\theta = \frac{\gamma X}{\rho}\left[\frac{1}{\eta B}\left\{\frac{B(\gamma X - \psi)^{\eta} - \psi}{(1-\eta)B}\right\}^{\frac{1-\eta}{\eta}} + 1\right]^{-1} . \tag{20}$$

The detailed derivation of Figure 1 is given in the Appendix. Note that an increase in escape cost ψ shifts (18) to the right and (20) upward. In addition, an increase in the probability of an earthquake occurrence ρ flattens (19) and (20). We summarize the results from Figure 1 in Proposition 2.

Proposition 2

(i) Shoddy construction with flight tends to occur when the punishment θ is heavy and the marginal benefit of shoddy construction γX is large.

(ii) Shoddy construction without flight tends to occur when θ is small and γX is large.

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8 The assumption that one player takes all the rent is standard in considering the political collusion problem, for example, Auriol (2006) and Bac and Bag (2006).

(iii) No shoddy construction tends to occur when θ is large and γX is small.
(iv) A large escape cost ψ curbs shoddy construction with flight but may raise shoddy construction without flight.
(v) A large probability of an earthquake occurrence ρ curbs shoddy construction without flight but may raise shoddy construction with flight.

Light punishment cannot repress shoddy construction. However, when the marginal benefit from shoddy contraction is large relative to the escape cost, heavy punishment fails to curb shoddy construction. Whenever shoddy construction makes a large profit for the business manager and the bureaucrat, heavy punishment leads them to escape after the public infrastructure with the shoddy construction is completed. When the business manager and the bureaucrat collude and decide to escape abroad, the earthquake resistance of the infrastructure worsens to a dangerously low level.

5. Concluding Remarks

Shoddy construction that stems from collusive ties between construction firms and bureaucrats is a serious problem, especially, in less developed countries. Several empirical studies suggest that shoddy construction raises earthquake mortality. Introducing a simple Nash bargaining solution, we have shown that political corruption between business managers of construction firms and bureaucrats reduces the earthquake resistance of public infrastructure. When the size of the public works project is large, the marginal cost for increasing earthquake resistance is large and/or the probability of an earthquake occurrence is small, and collusion between them tends to occur and the earthquake resistance of the infrastructure decreases. Punishment can curb shoddy construction, but heavy punishment may induce the business manager and the bureaucrat to escape. In this case, the earthquake resistance of the public infrastructure decreases to a dangerously low level.

Damage from shoddy construction is inestimable because the infrastructure kills many people when a major earthquake occurs. However, when the benefit from the reduction of earthquake resistance is large, punishment alone would not repress collusion between business managers of construction firms and bureaucrats who inspect building sites. While light punishment is not enough to deter corruption, heavy punishment induces them to escape after the infrastructure with shoddy construction is completed. An important aspect of eradicating shoddy construction may be outside independent inspector. Moreover, Bac and

Bag (2006) develop a model with a principal-supervisor-agent hierarchy by introducing an outside detector, such as media. The detection of corruption by outsiders may curb shoddy construction. Alternatively, a policy that gives an incentive to whistle-blowers on construction sites may also effectively deter shoddy construction.

Appendix

If $\widetilde{U}(b^{**}) > \overline{U}$, the bureaucrat prefers (i) to (iii). If $EU(b^{*}) > \overline{U}$, the bureaucrat prefers (ii) to (iii). If $\widetilde{U}(b^{**}) > EU(b^{*})$, the bureaucrat prefers (i) to (ii). From (16.a), we have (18); $\widetilde{U}(b^{**}) > \overline{U}$ holds in the right region of (18). From (17.a), we have (19); $EU(b^{*}) > \overline{U}$ holds in the upper area of (19). Point A is the intersection of (18) with (19); the coordinates at point A is $(\gamma X, \theta) = \left((\psi / B)^{\frac{1}{\eta}} + \psi, \left\{ (\psi / B)^{\frac{1}{\eta}} + \psi \right\} \rho^{-1} \right)$. In the northeast area of point A, $\widetilde{U}(b^{**}) > \overline{U} > EU(b^{*})$ holds; (i) shoddy construction with flight emerges. In the southwest area between (18) and (19), $EU(b^{*}) > \overline{U} > \widetilde{U}(b^{**})$ holds, and (ii) shoddy construction without flight emerges. In the northwest area between (18) and (19), (iii) no shoddy construction emerges. On the other hand, in the southeast area between (18) and (19), both $\widetilde{U}(b^{**}) > \overline{U}$ and $EU(b^{*}) > \overline{U}$ are achieved. Thus, we derive the condition that implies $\widetilde{U}(b^{**}) > EU(b^{*})$ even when (18) and (19) hold. From (16.a) and (17.a), we have (20); $\widetilde{U}(b^{**}) > EU(b^{*})$ holds in upper area of (20). We find that (20) passes point A. Moreover, (20) has a positive slope and the slope of (20) is smaller than (19) even in the right area of (18). Thus, we find that $EU(b^{*}) > \widetilde{U}(b^{**}) > \overline{U}$ holds in the lower area of (20) and $\widetilde{U}(b^{**}) > EU(b^{*}) > \overline{U}$ is achieved in the area between (19) and (20).

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Figure 1: Regions in which equilibrium occurs