Staged Privatization: Transforming SOEs into Market-Based Firms^{*}

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Abstract: Most privatizations around the world, especially in developed economies, are staged processes involving multiple stages of shares lockup and unlocking in the stock market. This paper proposes a theory on staged or step-by-step privatization. We show that such an approach is efficient, in the sense that it can successfully transform state-owned enterprises into *efficient* market-based firms. Our theory explains the popularity of staged privatizations around the world. We have also conducted empirical analysis, yielding supporting evidence for our theory.

Keywords: staged privatization, lockup policy, tradable shares, nontradable shares

JEL Classification: D23, D73, P31

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1. Introduction

Privatization is a global phenomenon. It is a significant strategic policy for some countries, and nothing short of a revolution for others. Researchers have looked at various aspects of privatization. We here focus on one particular issue: how to privatize. The experiences of big-bang and gradual reforms have proven this issue to be important. All privatizations serve the same purpose: transform a state-owned enterprise (SOE) into a well-functioning market-based firm. In this paper, we identify an incomplete-contract approach that can transform an SOE into an *efficient* market-based firm. We have also conducted empirical analysis using data from the recent Chinese privatization program, yielding supporting evidence for our theory.

Privatizations around the world are typically carried out in one of three ways: asset sale, voucher privatization, or share issue privatization (Bonin & Wachtel, 2003). In an asset sale, the government sells ownership of an SOE directly to an existing private firm, an institution or a small group of individuals. Such deals are typically made through direct face-to-face negotiations. In a voucher privatization, the government distributes vouchers (paper claims of ownership) to citizens. These vouchers are usually free, or almost free, and are available to most citizens. In a share issue privatization (SIP), the government sells equity shares to the public. The government may sell a fraction or all of an SOE through any one of these methods. Asset sales occur more commonly in developing economies involving small SOEs and are prone to corruption. Voucher privatizations occur mainly in transition economies and the results are mostly disappointing. SIP is the dominant form of privatization in terms of asset value, especially for large SOEs and for countries with well-developed capital markets, such as European countries and Japan. For example, the Spanish government raises more than 83% of privatization revenue from SIPs. SIPs can also be used to jump-start the development of a nation's stock market, such as that for China.

Prior studies have shown that most privatizations in practice are carried out through a multi-stage process in which shares are temporarily locked up. Perotti (1995, Table 2) found many cases of staged privatization in the UK. Biais & Perotti (2002) noted that measures are often in place in privatization schemes that make it costly or even impossible to resell the shares of recently privatized firms quickly. Most shares of privatized firms are initially non-tradable, are distributed through a pension scheme or are placed under a reward scheme for long-term holdings. Countries where privatized firms exhibit such features include France, the U.K., Czech Republic, Turkey, Mongolia, Bolivia, Zambia, Morocco, Nigeria, Tunisia, Jamaica, Chile, Mexico, Argentina, and Columbia. The reward schemes tend to exist in Western countries (e.g., the U.K.) and the pension schemes in South American countries. Bortolotti *et al.* (2003) also indicated that partial sales are a common feature of privatization processes. Gupta

(2005) observed that most privatizations begin with a period of partial privatization in which only non-controlling portions of firms are sold on the stock market. Jones *et al.* (1999) observed that only 11.5% of the firms in 59 countries sold all of their capital at once through SIP and less than 30% sold more than half of their capital in the initial public offering (IPO). The general belief is that, privatization—when done right—works well. Across countries, those with well-developed markets tend to do well in privatization, such as New Zealand, the UK, Mexico and Chile.

British Telecom, for example, was completely privatized in stages. An IPO of 50.2% of its shares in 1984 was followed by two secondary offerings in 1991 and 1993. The privatization of British Telecom was the largest equity offering in history at the time and considered to be one of the most successful privatizations in the world. This privatization is believed to have triggered other privatization programs around the world. The Japanese Nippon Telegraph and Telephone (NTT) was partially privatized in stages. The process involved an IPO in 1985 and two subsequent secondary offerings in late 1987 and 1988, leaving 51% of NTT shares in the hands of the government. The privatization of NTT set a new record for IPO issue size at that time.

Why should privatization be staged? Why is an SOE not sold all at once? What is the role of a lockup? There are a few theoretical papers on these issues. Different authors present different arguments on the practice of staged privatization. Zou (1994) studied dynamic privatization in a growth model, with an endogenous time span of privatization as we do. In his paper, convergence to a market-based firm is determined by the adjustment cost of privatization and the efficiency difference between SOEs and privately owned firms. We focus on the incentive to the insiders in restructuring effort. The restructuring includes establishing an effective board of directors, introducing strategic partners, and ensuring a profit-oriented management. A key technical difference between our model and the existing literature, including Zou (1994), is that the speed of privatization is endogenous in our model but exogenous in those of others. In fact, this speed of privatization is a crucial incentive instrument in our model.

Perotti (1995) further observed that SOEs in both developed and developing countries are mostly privatized through a sequence of partial and staggering sales. In addition, Perotti found that governments often temporarily take a risk-bearing role even well after the transfer of control to the private sector. Perotti proposed two explanations for these behaviors. One is the existence of temporary market capacity constraints (downward sloping demand). The other is based on a confidence-building strategy on the part of the government in its willingness to retain a stake in the firm. The latter is explained as follows. The government may or may not demand tax earnings from private shares (those shares of an SOE sold to private individuals). If the government does not sell the firm all at once, its tax revenue from the firm will be lower, which may indicate that this government has no intention of taxing earnings from the shares.

Hence, partial privatization can serve as a signal of a no-tax government. In a separating equilibrium, a no-tax government uses staged privatization, while a taxing government uses one-time privatization. The tax reduces the firm's incentive to invest. Hence, this equilibrium may explain why more often than not governments privatize SOEs in stages. Notice that Perotti treated the length of lockup as exogenous, with a portion of the shares being sold at $t = 1$ and the rest being sold at $t = 2$. In contrast, the lockup in our model is endogenous.

There are a few other studies on staged privatization. Katz & Owen (1995) treated an SOE as an asset for sale, which the government needs to package before selling, including providing sufficient ownership for the buyer and enough subsidy for the firm. Boycko, Shleifer & Vishny (1996) studied privatization by a divided government. Cornelli & Li (1997) presented an auction model, in which the optimal privatization scheme uses the number of shares sold as an instrument to attract the most valuable investors. Vickers & Yarrow (1988) and Jenkinson & Mayer (1994) suggested selling firms in tranches, instead of selling them in one go. Schmitz (2000) identified conditions under which private ownership, government ownership or partial ownership can be optimal. Biais & Perotti (2002) analyzed a political process of privatization in a democracy. There are also some empirical studies that test these theories, including Perotti & Guney (1993), Dewenter & Malatesta (1997), Bel (1998), Farinós *et al.* (2007), and Huyghebaert & Quan (2009, 2011). Bel (1998) and Farinós *et al.* (2007) offered evidence from Spain supporting staged privatization. Huyghebaert & Quan (2009, 2011) showed many substantial differences between SIPs and private-firm IPOs. One key difference between prior literature and our theory is that prior literature studies a fully government-controlled privatization process, while we propose a market-oriented one, which is particularly relevant to developed economies with well-developed markets. Further, by specifying a lockup effect on demand, Jiang & Wang (2012) analyzed how various factors such as the lockup effect, demand elasticity, growth potential and business fluctuations affect staged privatization for Chinese privatizations. One key difference between our theory and theirs is that our scheme successfully transforms an SOE into an efficient market-based firm while theirs may or may not.

We consider a privatization program with two steps, with the objective of transforming an SOE into an efficient market-based firm. In the first step, the firm is divided into equity shares, with a portion of the shares being sold to the public. These shares are tradable on the stock market and the rest are nontradable. After the first step, the SOE becomes a partially privatized SOE. In the second step, the government allows the nontradable shares to become tradable after a lockup period. In the literature, such as Perotti (1995), the length of the lockup period is exogenous. In our model, however, there are multiple stages of lockup and the length of each lockup period is endogenous (an optimal choice). On the unlock day, a nontradable shareholder optimally unlocks a portion of her shares and locks up the rest for a further optimal length of time. This setup is more consistent with practice. Our endogenously determined lockups imply the equilibrium speed of staged privatization—a key feature of our model. For

example, if the economic environment experiences a downturn, the speed of privatization will automatically be reduced as each nontradable shareholder will choose to lock up her remaining shares for a longer period of time. Also, our empirical analysis shows that nontradable shareholders of SOEs choose statistically the same lockup lengths as nontradable shareholders of non-SOEs, implying that their behavior is determined by market principles. This means that privatization in our model is a market process, while in prior literature privatization is a centrally planned process.

Our study aims at developing a unique theory to explain staged privatization. Different from prior literature, we focus on efficient privatization. In our theoretical analysis, we show that an incomplete-contract approach with an ex-post lockup option implies efficient privatization (Proposition 1). This approach yields a multi-stage privatization resembling many privatizations around the world, including the hugely successful one that has been carried out by the Chinese since 1990. In contrast, a complete-contract approach with an ex-ante lockup decision implies inefficient privatization (Proposition 4). This latter approach yields a one-time upfront privatization resembling the Russian privatization and some privatizations in Eastern Europe.

China offers a good example of extensive and successful privatizations and a rich set of data for our empirical analysis. Starting in 1990, every listed firm (including non-SOEs) except four was divided into tradable and nontradable shares. As a SIP, the Chinese capital market in 2005 was defined by a split-share structure, with about one third of domestically listed shares being tradable and the rest being nontradable. Then in 2005, the government announced the second privatization step, the split-share reform (SS reform), in which all nontradable shares became tradable shares after an initial lockup. The unlocking of nontradable shares is implemented over time based on certain qualification guidelines. Up to 2008, a total of 65 groups of firms had become qualified for unlocking, which consists of about 90% of the listed firms. This privatization has turned out to be one of resounding success. With rich data from the Chinese privatization, we have conducted an empirical study on our theory. In our empirical analysis, for firms that went through the SS reform before the end of 2006 (more than 90% of all listed firms), we show that the ones that did so earlier have higher ROA (return on assets), ROE (return on equity), and MB (market to book value). This is consistent with the prediction of our theory that the performance of a partially privatized SOE is as a criterion for early unlocking of the firm's nontradable shares.

This paper is organized as follows. In Section 2, we set up the model. In Section 3, we present the theory. In Section 4, we extend the theory. In Section 5, we conduct empirical analysis using data on listed firms in the Chinese stock market. We conclude the paper in Section 6. The proofs are all given in the Appendix.

2. The Model

The Reform Program

Consider a privatization program with two steps and the objective of transforming an SOE into an efficient market-based firm. In the first step, the firm is divided into equity shares, with a proper portion θ of the shares being sold to the public. These shares are tradable (called T-shares) on the stock market and the rest are nontradable (called N-shares). Each share guarantees one share of output. Holders of the T-shares are called T-holders and holders of the N-shares are called N-holders. After the first step, the SOE becomes a partially privatized SOE. In the second step, the government allows the N-shares in the partially privatized SOE to become tradable after a lockup period, where the lockup policy is based on the SOE's restructuring effort.

The Objective of Privatization: Efficiency

Specifically, consider a privatization program in interval $[0, 1]$, where the program starts at $t = 0$ and output is produced at $t = 1$. There is one T-holder (representing private shareholders) and one N-holder (representing insiders or controlling shareholders). The production function is

$$y = f(a, k),$$

where a is the effort from the N-holder and k is the capital stock. Assume that a is nonverifiable ex ante but observable ex post.³ Since a is nonverifiable ex ante, the government cannot impose a ex ante; it has to provide incentives to induce a certain a . Since a is observable ex post, an ex-post government policy can depend on it. These two government behaviors are consistent with observations in practice. We call a the restructuring effort. The costs for these two inputs are $c(a)$ and k . Given the real interest rate (the rental rate of capital) r , efficiency is determined by

$$f_a(a^*, k^*) = c'(a^*), \quad f_k(a^*, k^*) = r, \quad (1)$$

where f_a and f_k are partial derivatives of f with respect to a and k , respectively. The first equation in (1) means that the owners/insiders of the firm invest efficiently in the firm; the second equation implies that the firm uses capital efficiently.

The government's objective is to transform a firm into an efficient market-based firm, as defined by (1). Given the objective in (1), in the following, we propose a two-stage privatization program starting at $t = 0$ that transforms the firm into a market-based firm by the end of the

³ The original explanation of statements "nonverifiable ex ante but observable ex post" and "ex-ante nonverifiable but ex-post verifiable" is available in Grossman & Hart (1986).

reform process at $t = 1$. The key is the nonverifiable restructuring effort a —the reform program needs to provide sufficient incentives for the controlling shareholders to spend effort on restructuring.

The Reform Strategy: Staged Privatization

At $t = 0$, the government announces a reform policy as defined by the initial proportion θ of tradable shares. Assume that θ is verifiable ex ante, which means that the government can impose θ ex ante. Sometime later after the government has observed a , the government announces another reform policy as defined by a lockup length λ . We assume that λ is ex-ante nonverifiable, i.e., the government cannot commit to λ ex ante but it can impose λ ex post. Since a is observed before λ is decided, λ can be made dependent on a . Function $\lambda(a)$ means that the government will allow a firm to unlock its N-shares ex post at $t = \lambda(a)$ only if the firm has completed restructuring up to the level a or above.

Thus, the ex-ante reform policy is θ and the ex-post reform policy is $\lambda(\cdot)$. At $t = 1$, the firm is completely operating under market forces, as shown in Figure 1. This process can be rigorously defined by an incomplete contract at $t = 0$ in which the government imposes θ ex ante and retains the right to decide λ ex post. One key feature of an incomplete contract is that it can contain rights to decide certain matters ex post.

Figure 1. The Timeline of the Privatization Scheme

Demand for Shares

Holders of tradable shares can trade their shares. However, different shareholders have different discount rates $\delta \in (0, 1)$ of time preference. All shareholders want the opportunity to trade their shares; they want to sell their shares to those who have a larger δ (less discount on future) than their own.

It is known in many studies that the demand for shares is downward sloping at any moment in time (Perotti, 1995; Field & Hanka, 2001; Brav & Gompers, 2003). We now model this demand by heterogeneous time preferences among shareholders. Each holder has a certain discount on the future. If her N-shares can be unlocked earlier, she can sell them earlier to a person whose discount factor is larger. In practice, the rates of time preference can be very different among people. That is, less optimistic holders sell shares to more optimistic holders. For example, an elderly may have a much higher discount on the future than a young person.

If the income from a share paid at $t = 1$ is y for a holder with a rate of time preference ρ per unit of time, the share at t is worth $ye^{-\rho(1-t)} = y\delta^{1-t}$, where $\delta \equiv e^{-\rho}$. We call δ a measure of the person's time preference on future income. A larger δ means less discount on future income. Hence, anyone with time preference $\hat{\delta} \geq \delta$ will be willing to buy the share at price $p_t \equiv y\delta^{1-t}$ at time $t \in [0, 1)$. Suppose that the potential demand or the total market interest in the stock is n shares and the total supply of shares is one unit, where

$$n = \text{the total number of buyers in the market}$$

if each buyer buys at most one share. Let the density of potential demand be $F(\delta)$, for $\delta \in [0, 1]$. Then, the total demand at price p_t is $n[1 - F(\delta)]$. Hence, the demand function for shares at time t is

$$x_t(p_t) = n[1 - F(\delta)] = n \left\{ 1 - F \left[\left(\frac{p_t}{y} \right)^{\frac{1}{1-t}} \right] \right\}. \quad (2)$$

This demand is downward sloping in price.

3. Staged Privatization as an Efficient Solution

In this section, we identify an efficient solution based on an incomplete contract between the government and the firm. The solution is a multi-stage privatization program.

The First Stage of Privatization

In the first stage, the focus of the reform is to raise enough capital for the firm. Instead of relying on the government to provide funding, once the reform process is started, the firm will be financially on its own and it will be allowed to retain its own revenue.

Specifically, in the first stage, the government sells a portion θ of the firm's shares to the public. With the demand function in (2), the demand for shares at $t = 0$ is

$$x_0(p) = n \left[1 - F \left(\frac{p}{y} \right) \right].$$

Given the supply θ of shares in the market, the equilibrium condition in the stock market is

$$x_0(p_0) = \theta,$$

which determines the equilibrium share price at $t = 0$:

$$p_0 = yF^{-1} \left(1 - \frac{\theta}{n} \right).$$

Hence, the financial capital raised from the initial share issue is

$$k = p_0\theta = \theta yF^{-1} \left(1 - \frac{\theta}{n} \right).$$

Therefore, to achieve efficient privatization, given the first-best investments a^* and k^* defined in (1), the government chooses $\theta \in [0, 1]$ such that

$$k^* = \theta f(a^*, k^*) F^{-1} \left(1 - \frac{\theta}{n} \right). \quad (3)$$

If $f(a^*, k^*) > k^*$, by Lemma 1 in the Appendix, when n is large enough, we can guarantee the existence and uniqueness of θ that satisfies (3).

One advantage of this staged privatization is that it allows the firm to raise enough working capital in the first stage. This working capital is necessary for transforming the firm into an efficient market-based firm in the second stage.

The Second Stage of Privatization

In the second stage, the reform is based on a government's lockup policy $\lambda(a)$. Given the government's policies $\{\theta, \lambda(a)\}$, the N-holder considers her optimization problem. On the one hand, with her effort a , the N-holder is allowed to sell up to $1 - \theta$ shares at time $t = \lambda(a)$. By (2), the demand at $t = \lambda(a)$ is

$$x_\lambda(p) = n \left\{ 1 - F \left[\left(\frac{p}{y} \right)^{\frac{1}{1-\lambda}} \right] \right\}.$$

Since the total supply of shares in the market is 1 at $t = \lambda(a)$, the equilibrium condition is

$$n \left\{ 1 - F \left[\left(\frac{p_\lambda}{y} \right)^{\frac{1}{1-\lambda}} \right] \right\} = 1,$$

which implies the share price at $t = \lambda(a)$:

$$p_\lambda = y \left[F^{-1} \left(1 - \frac{1}{n} \right) \right]^{1-\lambda}.$$

On the other hand, at $t = \lambda(a)$, if the N-holder has discount factor δ , a share is worth $y\delta^{1-\lambda}$ to her if she holds on to the share. Hence, the N-holder will sell shares if and only if $y\delta^{1-\lambda} \leq p_\lambda$ or $\delta \leq \delta_n$, where

$$\delta_n \equiv F^{-1} \left(1 - \frac{1}{n} \right). \quad (4)$$

This δ_n is the upper bound of the time preference of the shareholders who prefer to sell their shares.⁴ Hence, for an N-holder with effort a and time preference $\delta \leq \delta_n$, her payoff at $t = 0$ is

$$\pi_N(a) = p_\lambda(1 - \theta)\delta^\lambda - c(a) = f(a, k)\delta_n^{1-\lambda(a)}(1 - \theta)\delta^{\lambda(a)} - c(a). \quad (5)$$

⁴ If $n \rightarrow \infty$, then $\delta_n \rightarrow 1$; that is, virtually any N-holder will sell her shares in a large economy. If so, an N-holder can always find a buyer who would prefer to pay a higher price than her own valuation.

The key question is whether or not she is willing to make a large enough effort a to improve the firm before she is allowed to sell her shares in the firm. To induce the N-holder to make a sufficient amount a^* of effort, the lockup policy $\lambda(\cdot)$ needs to be properly designed. We indeed find such a $\lambda(\cdot)$ in the following.

The Solution

The following proposition states that the above privatization scheme can lead to an efficient solution. The proof is in the Appendix.

Proposition 1. *A staged privatization program $\{\theta, \lambda(\cdot)\}$ can transform a firm into an efficient firm with the first-best investments a^* and k^* if the N-holders of the firm (the original owners of the firm) have time preference δ satisfying*

$$\delta \leq \delta_n - \frac{1}{1-\theta} \int_0^{a^*} \frac{dc(\tau)}{f(\tau, k^*)}, \quad (6)$$

where the amount θ of tradable shares in the first stage of privatization is determined by

$$k^* = \theta f(a^*, k^*) F^{-1} \left(1 - \frac{\theta}{n} \right), \quad (7)$$

and the lockup policy in the second stage of privatization is defined by

$$\lambda(a) = \begin{cases} \frac{\ln \delta_n - \ln \left[\delta + \frac{1}{1-\theta} \int_0^a \frac{dc(\tau)}{f(\tau, k^*)} \right]}{\ln(\delta_n/\delta)}, & \text{if } a < a^*, \\ \frac{\ln \delta_n - \ln \left[\delta + \frac{1}{1-\theta} \int_0^{a^*} \frac{dc(\tau)}{f(\tau, k^*)} \right]}{\ln(\delta_n/\delta)}, & \text{if } a \geq a^*. \blacksquare \end{cases} \quad (8)$$

The privatization steps in Proposition 1 are just like those in a typical SIP in practice. In the first stage, the government sells a portion of the equity shares of a privatizing firm to the public. In the second stage, after several years, the government allows the firms to unlock N-shares in steps and sell them in the secondary market. Our theory indicates that this privatization scheme can transform an SOE into an efficient market-based firm at the completion of the program.

The lockup policy in (8) is decreasing and, if the marginal cost of effort is constant, it is also convex, as shown in Figure 2. A decreasing $\lambda(a)$ means that a firm with higher investment a will be allowed to unlock its N-shares earlier, so firms are enticed to invest more for the opportunity to unlock their shares early. A convex $\lambda(a)$ means that the reward of early unlocking is diminishing with investment. By conditioning the unlocking of N-shares on investments, the government can induce sufficient investments from SOEs' original owners or insiders in the

first stage of privatization, since the more investments the SOEs make, the sooner they can sell their N-shares to the market and make more profits. This finding is consistent with Gupta *et al.* (2008).

Figure 2. The Lockup Policy in Staged Privatization

In this scheme, the unlock time $\lambda(a^*)$ is announced after a^* is invested. Proposition 1 indicates that leaving the timing of the unlocking of N-shares open ex ante can induce efficient incentives in restructuring. In contrast, as shown in Proposition 4, if the lockup is decided ex ante, the solution is inefficient.

The government allows only those firms that have undergone sufficient restructuring to unlock their N-shares. In equilibrium, all the owners with preferences satisfying (6) are expected to choose $a = a^*$ and hence are allowed to unlock their N-shares at $t = \lambda(a^*)$. In practice, to implement this privatization scheme, $\lambda(a^*)$ can be stated as the minimum lockup length. More efficient firms are unlocked earlier; only the least efficient ones would have a prolonged lockup period.

A condition such as (6) is necessary for the government's incentive scheme to work. For those N-holders who view the current and future incomes as basically the same, this scheme cannot work. As the later two propositions will show, in a risky and large economy, the scheme can work for virtually all firms.

Our theory is consistent with the general assessment of privatization in the literature: privatization, when done properly, works well. There are extensive empirical findings supporting this assessment, including Kikeri *et al.* (1992), Shirley (1992), Megginson *et al.* (1994), Bel (1998) and Farinós *et al.* (2007) who offer evidence showing efficiency improvement after staged privatization.

Remark 1. In the model, the N-holders receive N-shares for free. In reality, some receive N-shares for free while others get them for a small price. It is simple to modify the model to take the latter into account. The result is not affected since a charge on N-shares is equivalent to a upfront monetary transfer.

Remark 2. The government's lockup policy λ can also be based on a more general signal of the form $\phi(a) + \tilde{\varepsilon}$ with noise $\tilde{\varepsilon}$ as long as the signal is observable ex post and ϕ is 1-1. Here ϕ being 1-1 implies that the signal can fully reveal a , and the signal being ex post observable means that the noise $\tilde{\varepsilon}$ is known at the time when the lockup policy is formulated.

Remark 3. We can allow an initial capital stock k_0 so that the production function becomes $f(a, k_0 + k)$, where k is the additional capital raised by an initial share sale in addition to the existing stock k_0 . The same result holds.

Remark 4. The T-holder's individual rationality (IR) condition can be guaranteed by a upfront financial transfer. After the announcement of the government policy $(\theta, \lambda(\cdot))$ at $t = 0$, both parties know the solution (k^*, a^*) and the resulting social welfare W^* in equilibrium, and they can bargain for a financial transfer. With Nash bargaining, the N-holder's payoff becomes $\pi_N(a) - \rho W^*$ instead of $\pi_N(a)$ in (5), where ρW^* is the financial transfer from the N-holder to the T-holder and $\rho \in [0, 1]$. Since this ρ is set upfront, this financial transfer ρW^* has no effect on the solution (k^*, a^*) . Since this ρ is arbitrary to our model, we can find a ρ to ensure the IR conditions for both the T-holder and N-holder (as long as $W^* > 0$, such a ρ exists). If the T-holder's IR condition is satisfied, he will approve the government's privatization scheme.

4. Extensions

4.1. Staged Privatization under Uncertainty

In this section, we introduce uncertainty into the model. We show that uncertainty will not change our conclusion.

Suppose that output is uncertain ex ante with

$$\tilde{y} = \tilde{A}f(a, k), \quad (9)$$

where $E(\tilde{A}) = 1$ and $\text{var}(\tilde{A}) = \sigma^2$. Suppose that an N-holder has mean-variance preferences of the form:

$$u(\tilde{y}) = E(\tilde{y}) - \beta \text{var}(\tilde{y}) = f(a, k) - \beta \sigma^2 [f(a, k)]^2.$$

Here, β is a measure of risk aversion and σ is a measure of risk. We assume that all the shareholders have the same risk preference (the same β).⁵

⁵ Like time preferences, we can also consider a distribution of heterogeneous risk preferences among the shareholders. The main result still holds. In fact, heterogeneous time preferences have arguably included heterogeneous risk preferences as a special case.

The government's objective is again to transform the firm into an ex-ante efficient firm. That is, given the real interest rate r , the government will try to transform the firm into a market-based firm as defined by

$$f_a(a^*, k^*) = c'(a^*), \quad f_k(a^*, k^*) = r.$$

Each share for a shareholder with time preference δ is worth $u(\tilde{y})\delta^{1-t}$ at t . Anyone with time preference $\hat{\delta} \geq \delta$ will be willing to buy the share at price $p_t \equiv u(\tilde{y})\delta^{1-t}$ at t . Suppose that the potential demand or the total market interest in the stock is n shares and the total supply of shares is one unit. Let the density of potential demand be $F(\delta)$, for $\delta \in [0, 1]$. Then, the total demand at the price p_t is $n[1 - F(\delta)]$. Hence, the demand function for shares at t is

$$x_t(p_t) = n[1 - F(\delta)] = n \left\{ 1 - F \left[\left(\frac{p_t}{u(\tilde{y})} \right)^{\frac{1}{1-t}} \right] \right\}.$$

We have a downward sloping demand.

In the first stage, the government sells a portion θ of the firm's shares to the market. With the total supply of shares in the market being θ at $t = 0$, the equilibrium share price is

$$p_0 = u(\tilde{y})F^{-1} \left(1 - \frac{\theta}{n} \right).$$

Hence, the financial capital raised from the initial share issue is

$$k = p_0\theta = u(\tilde{y})F^{-1} \left(1 - \frac{\theta}{n} \right) \theta.$$

Then, the government should choose θ such that

$$k^* = \theta[1 - \beta\sigma^2 f(a^*, k^*)]f(a^*, k^*)F^{-1} \left(1 - \frac{\theta}{n} \right). \quad (10)$$

If $f(a^*, k^*) > k^*$, when n is large enough, we can guarantee the existence and uniqueness of θ .

In the second stage, the reform is based on a government's lockup policy $\lambda(a)$. Given the government's policies $\{\theta, \lambda(a)\}$, the N-holder considers her optimization problem. With her effort a , she will be allowed to sell up to $1 - \theta$ shares at date $t = \lambda(a)$. With the total supply of shares in the market being 1 at $t = \lambda(a)$, the equilibrium price is

$$p_\lambda = u(\tilde{y}) \left[F^{-1} \left(1 - \frac{1}{n} \right) \right]^{1-\lambda}.$$

If the N-holder has discount factor δ , each share is worth $u(\tilde{y})\delta^{1-\lambda}$ to her if she does not sell the share. This shareholder will sell shares if $u(\tilde{y})\delta^{1-\lambda} \leq p_\lambda$ or $\delta \leq \delta_n$, where δ_n is defined in (4). Hence, for an N-holder with time preference $\delta \leq \delta_n$, her payoff at $t = 0$ is

$$\pi_N(a) = p_\lambda(1 - \theta)\delta^\lambda - c(a) = [1 - \beta\sigma^2 f(a, k)]f(a, k)\delta_n^{1-\lambda(a)}(1 - \theta)\delta^{\lambda(a)} - c(a). \quad (11)$$

As shown in the following proposition, we again find an efficient solution. The proof is shown in the Appendix.

Proposition 2. A staged privatization program $\{\theta, \lambda(\cdot)\}$ can transform a firm into an efficient firm with the first-best investments a^* and k^* if the N-holder of the firm has time preference δ satisfying

$$\delta \leq \delta_n - \frac{1}{1-\theta} \int_0^{a^*} \frac{dc(\tau)}{f(\tau, k^*)[1 - \beta\sigma^2 f(\tau, k^*)]}, \quad (12)$$

where the amount θ of tradable shares in the first stage of privatization is determined by

$$k^* = \theta[1 - \beta\sigma^2 f(a^*, k^*)]f(a^*, k^*)F^{-1}\left(1 - \frac{\theta}{n}\right),$$

and the lockup policy in the second stage of privatization is defined by

$$\lambda(a) = \begin{cases} \frac{\ln \delta_n - \ln \left\{ \delta + \frac{1}{1-\theta} \int_0^a \frac{dc(\tau)}{f(\tau, k^*)[1 - \beta\sigma^2 f(\tau, k^*)]} \right\}}{\ln(\delta_n/\delta)} & \text{if } a < a^*, \\ \frac{\ln \delta_n - \ln \left\{ \delta + \frac{1}{1-\theta} \int_0^{a^*} \frac{dc(\tau)}{f(\tau, k^*)[1 - \beta\sigma^2 f(\tau, k^*)]} \right\}}{\ln(\delta_n/\delta)} & \text{if } a \geq a^*. \quad \blacksquare \end{cases}$$

Similarly, instead of proportional uncertainty in (9), suppose that output has the following additive form:

$$\tilde{y} = f(a, k) + \tilde{\varepsilon}, \quad (13)$$

where $E(\tilde{\varepsilon}) = 0$ and $\text{var}(\tilde{\varepsilon}) = \sigma^2$. Again, suppose that the N-holder has mean-variance preferences of the form

$$u(\tilde{y}) = E(\tilde{y}) - \beta \text{var}(\tilde{y}) = f(a, k) - \beta\sigma^2.$$

Then, in the first stage, the government should choose θ such that

$$k^* = \theta[f(a^*, k^*) - \beta\sigma^2]F^{-1}\left(1 - \frac{\theta}{n}\right). \quad (14)$$

In the second stage, the reform is based on the government's lockup policy $\lambda(a)$, taking into account the payoff of the N-holder with time preference $\delta \leq \delta_n$:

$$\pi_N(a) = p_\lambda(1 - \theta)\delta^\lambda - c(a) = [f(a, k) - \beta\sigma^2]\delta_n^{1-\lambda(a)}(1 - \theta)\delta^{\lambda(a)} - c(a). \quad (15)$$

We again find an efficient solution, as stated in the following proposition. The proof is available in the Appendix.

Proposition 3. A staged privatization program $\{\theta, \lambda(\cdot)\}$ can transform a firm into an efficient firm with the first-best investments a^* and k^* if the N-holder of the firm has time preference δ satisfying

$$\delta \leq \delta_n - \frac{1}{1-\theta} \int_0^{a^*} \frac{dc(\tau)}{f(\tau, k^*) - \beta\sigma^2}, \quad (16)$$

where the amount θ of tradable shares in the first stage of privatization is determined by

$$k^* = \theta f(a^*, k^*) F^{-1} \left(1 - \frac{\theta}{n} \right),$$

and the lockup policy in the second stage of privatization is defined by

$$\lambda(a) = \begin{cases} \frac{\ln \delta_n - \ln \left\{ \delta + \frac{1}{1-\theta} \int_0^a \frac{dc(\tau)}{f(\tau, k^*) - \beta\sigma^2} \right\}}{\ln(\delta_n/\delta)}, & \text{if } a < a^*, \\ \frac{\ln \delta_n - \ln \left\{ \delta + \frac{1}{1-\theta} \int_0^{a^*} \frac{dc(\tau)}{f(\tau, k^*) - \beta\sigma^2} \right\}}{\ln(\delta_n/\delta)}, & \text{if } a \geq a^*. \blacksquare \end{cases}$$

The results in Propositions 2 and 3 indicate that, if risk and/or risk aversion is high enough and if the economy is large enough ($n \rightarrow \infty$), virtually all N-holders will be enticed by the privatization scheme to improve their firms before unlocking their shares. The end result is that these firms will become efficient market-based firms.

4.2. One-Time Privatization under a Complete Contract

Suppose now that the government takes a complete-contract approach. In this case, a lockup is announced and committed ex ante. The payoff of an N-holder with time preference $\delta \leq \delta_n$ is

$$\pi_N(a) = p_\lambda(1-\theta)\delta^\lambda - c(a) = f(a, k)\delta_n^{1-\lambda}(1-\theta)\delta^\lambda - c(a).$$

Since λ is independent of a , the first-order condition (FOC) $\pi'_N(a) = 0$ implies

$$f_a(a, k)(1-\theta)\delta^\lambda \delta_n^{1-\lambda} = c'(a). \quad (17)$$

This indicates that the efficient condition $f_a(a, k) = c'(a)$ can never be satisfied. Hence, we know that staged privatization with a pre-determined lockup is inefficient.

Then, government policies $\{\theta, \lambda\}$ are determined by

$$\begin{aligned} & \max_{a, k, \lambda, \theta} f(a, k) - rk - c(a) \\ & \text{s.t. } f_a(a, k)(1-\theta)\delta^\lambda \delta_n^{1-\lambda} = c'(a), \\ & k = \theta f(a, k) F^{-1} \left(1 - \frac{\theta}{n} \right). \end{aligned} \quad (18)$$

The following proposition shows that the optimal lockup is $\lambda^* = 0$ in this case. The proof is in the Appendix.

Proposition 4. *If the lockup is decided ex ante, the optimal lockup is to have no lockup. That is, a one-time privatization is optimal. This solution is inefficient.*

The difference between the two privatization strategies can be understood as the difference between complete and incomplete contracts. Our solutions indicate that, if a lockup is chosen ex ante, it cannot be dependent on effort and the optimal solution is inefficient; on the other hand, if a lockup is chosen ex post (after effort is invested), it can be dependent on effort and the optimal solution is efficient.

5. Empirical Analysis

5.1. The Empirical Model

In this section, we offer empirical analysis on staged privatization in China. Although staged privatization is typical in privatization programs around the world, for an empirical study, we can only find rich data from China. For China, economic growth hinges almost exclusively on privatization and its privatization program has been characterized by step-by-step privatizations. This privatization process involves a large number of firms, covering all industrial sectors. Our empirical analysis is based on the companies listed on China's two stock exchanges. Among all publicly listed companies in China (over 1,400 firms), more than 60% of them are SOEs. This provides us with a rich set of data to test our theory.

The first stage of the most recent privatization program in China started in 1990, which led to the creation of China's stock exchanges in 1990 and 1991. After that, the publicly listed SOEs became partially privatized SOEs and the shares of all the listed firms except four, including private firms, were divided into tradable and nontradable shares. From then on, SOEs refer to partially privatized SOEs. An N-holder in China is either a legal-person shareholder, who receives dividends just like a T-holder, or the government. A legal person is an institution or a person, including a foreigner, who is entitled to the legal rights and responsibilities of a contract. While T-holders obtain their shares from the stock market, N-holders obtain their shares through various other means. For example, when a firm or the government wants to introduce a strategic partner (including another firm or a foreigner), it negotiates with the potential partner for a portion of the firm's equity at an agreed price. With the introduction of the second stage of the privatization program (the SS reform) in 2005, as a holder of non-tradable shares and typically with a large shareholding, a legal-person holder has incentives to improve the firm. Even when a holder is the government, we have ample evidence that it makes an effort to improve SOEs. The central government actively puts pressure on local governments to improve the firms' situations. In fact, the central government sets specific

targets for local governments to satisfy within certain time limits. These targets are aimed at meeting the requirements of the SS reform.

N-holders play an important role in the Chinese reform. A few factors determine their importance. First, they are typically large shareholders (very large by Western standard with each typically having 30-60% share holdings). N-holders in a Chinese firm are always among the biggest five shareholders. These shareholders control most of the important management positions. In contrast, managers' shareholdings are negligible and T-holders are usually scattered and each holds a tiny portion of the firm. Second, holders of N-shares receive the same amount of dividend as holders of T-shares. Third, N-holders are often local governments or institutions that are closely related to or controlled by local governments. Some firms introduce foreign investors as legal-person holders. Although foreign involvement is small overall, in those firms in which foreigners are involved, foreigners typically hold a large portion of the shares (28% on average). In this situation, commitment from N-holders serves as a signal to the market that they will continue to contribute to the firm rather than expropriate minority shareholders by cashing out their investment at the earliest opportunity. Hence, lockups in the Chinese reform may be an effective way to mitigate moral hazards. This is a key component of our theoretical model.

Our theory predicts that firms making a larger restructuring effort and hence giving a better performance will be selected for the SS reform earlier. We will test two implications of this prediction. Firstly, better performance can be an indication that N-holders have made sufficient effort on a firm. Hence, we will test whether firms with higher profitability are selected for the reform earlier. Secondly, N-holders' recommendations and evaluations can heavily influence a CEO's promotion or demotion, particularly since N-holders are often local governments or institutions that are closely related to or controlled by local governments. If so, the sensitivity of turnover to performance will reflect the effect of N-holders' incentive schemes on CEOs. Hence, we will test whether the sensitivity of CEO turnover to performance is higher for firms that went through the reform earlier.

The Chinese capital market is considered to be immature because of weak investor protection, an inactive takeover market, ineffective external monitoring by large shareholders, high ownership concentration, low managerial ownership, and the dominance of state ownership. La Porta et al. (1998, 2000) and Volpin (2002) found evidence that corporate governance in such an environment is poor and that managers are highly entrenched. Further, SOEs both in developed and developing markets are known to have multiple tasks, which may lower their incentive to maximize profit and market value. One mechanism for dealing with this problem consists of promotion and demotion. We indeed find that the government employs promotions and demotions as a measure to entice top managers of SOEs to work hard. We find that the top manager turnover rate is about 18% in our sample. Similar findings were presented by Chang & Wong (26%, 2009), Kato & Long (24%, 2006), and Firth *et al.* (40%, 2006). These

rates are higher than those in the US as documented by Denis et al. (13%, 1995) and Huson et al. (9%, 2004) and those in Japan as documented by Kang *et al.* (13%, 1995) and Kaplan (15%, 1994). The higher turnover rate may explain the higher sensitivity of turnover to performance in China. Hence, our dependent variable is the turnover of the top manager; moreover, we will use an ordered multiple choice indicator rather than the traditional binary choice indicator as the dependent variable. This multi-choice indicator can indicate a manager's many career changes, including a demotion, a promotion or a lateral change of jobs, while the binary choice indicator can only indicate whether or not a turnover was voluntary.

5.2. Data and Variables

Our data comes from two major sources. Financial data is obtained from China Stock Market & Accounting Research (CSMAR). CSMAR covers daily market transactions, including financial and corporate governance data of all listed firms in China. Information on the destinations of departing managers is collected from firms' annual reports and internet publications.

We trace the career paths of departing managers in SOEs, including both former government officials appointed by governments and professional managers hired by governments. We define turnover as when a manager departs. There were a total of 1104 turnovers in the SOEs from 2001 to 2006. Some turnovers were voluntary such as a resignation due to health problems, but others were forced such as an early termination of a manager's contract. Some turnovers were punishments such as demotions, some were rewards such as promotions, yet others were lateral changes of jobs with no implication of a demotion or promotion. In order to distinguish among these different cases of departure, we trace the destinations of the departing managers. We manually collected this data from firms' annual reports and internet publications, which are available at www.baidu.com. We find that, among the departures of CEOs, 219 were promotions, 640 were demotions, 17 were lateral movements, and 49 were retirements. We could not find related information for the other 179 cases. So our dependent variable is a multi-choice indicator, which is equal to -1 if the CEO was demoted, 1 if the CEO was promoted, and 0 if it was a lateral movement, official retirement or no change.

Our empirical analysis focuses on CEO turnover among listed firms whose ultimate controllers are the central and local governments. We exclude banks, insurance companies and other financial firms because they use different accounting measures. If there are multiple turnovers in a certain year, we count the first observation only. We treat short-term turnovers as outliers, and we do not expect frequent turnovers to be correlated with the firm's performance. The average annual turnover rate of CEOs is found to be about 18%.

Table 1 presents the summary statistics of all variables of interest for the study period. To measure a firm's performance, we generate four variables—ROA, ROE, Tobin's Q, and a loss

indicator. ROA is the industry-adjusted return on asset and is defined as the difference between a firm's ROA and the industry mean, where a firm's ROA is calculated as the ratio of earnings before interest and tax (EBIT) to total assets. Similarly, ROE is the industry-adjusted return on equity and is defined as the difference between a firm's ROE and the industry mean, where a firm's ROE is calculated as the ratio of EBIT to total equity. While ROA and ROE measure a firm's accounting performance, we use Tobin's Q as an approximation of a firm's market value, which is calculated by dividing the sum of firm equity value, book value of long-term debt, and net current liabilities by total assets. Furthermore, to differentiate financially distressed firms from healthy ones, we generate a dummy called "loss". This dummy is 1 if a firm's EBIT is less than zero and 0 otherwise. We are also interested in a firm's growth, so we generate a variable called "growth rate" which is measured by the difference between a firm's sales growth rate and the industry mean.

We generate three more dummy variables. "First mover" is a dummy that indicates when the firm went through the SS reform; it is 1 if the firm was selected for the SS reform in 2005 and 0 otherwise. "Institutional share" is a dummy that reflects a firm's ownership structure; it is 1 if the percentage of shares held by institutional shareholders is larger than 10% and 0 otherwise. "Political connection" is a dummy that distinguishes professional managers from managers who were former bureaucrats; it is 1 if the manager had worked for the central or a local government before and 0 otherwise.

We also control for CEO age and a firm's size measured by the logarithm of total assets. Last but not least, we generate a variable called "hierarchy" that indicates whether a firm is stand-alone or affiliated with a pyramidal group; it is equal to the number of hierarchy levels from the ultimate controlling parent firm to the listed firm of interest.

Panel A of Table 1 presents the summary statistics of the discrete variables. It shows that during the study period, the turnover rate of top managers is around 18%. About 5% of the top managers were promoted to higher positions, while more than 13% of them were demoted. It also indicates that about 8% of the listed firms generated negative benefits, and more than 22% of the managers in listed SOEs had political connections and were former bureaucrats. Panel B of Table 1 presents the mean, standard deviation, minimum and maximum for each of the continuous variables.

Table 1: Summary Statistics

Panel A:					
	1	0	-1		
CEO turnover	4.48%	82.42%	13.10%		
First mover	13.75%	86.25%			
Loss	8.03%	91.97%			
Institutional share	61.20%	38.80%			
Political connection	22.08%	77.92%			

Panel B:					
	Obs	Mean	Std. Dev.	Min	Max
ROA	4882	0.083	4.697	-16.342	10.534
ROE	4684	0.135	9.269	-36.024	18.943
Growth rate	4106	0.007	1.071	-4.619	2.100
Firm size	4883	12.140	0.974	8.934	17.914
Largest shareholding (%)	4878	46.162	16.106	8.07	85
CEO age	4852	46.005	6.854	25	74
Hierarchy	4860	2.294	0.991	1	5

5.3. Empirical Results

Our theoretical model predicts that well-performing firms will be allowed to unlock their N-shares early. We first test this prediction by univariate comparisons. The firms went through the SS reform in groups, one group at a time. Excluding the initial experimental group, a total of 65 groups went through the SS reform over time. We gather every 10 groups in consecutive reform time into one batch, so that we can compare firms that went through the reform during different time periods. We have a total of 7 batches. Table 2 contains the comparison statistics between the first batch and a later batch. Table 2 indicates that early reform firms tend to have a high ROA, ROE and market value. For example, the average industry-adjusted ROA for firms in the first batch is almost 6, while that for firms in the second batch is only 3.2, and it drops further to 1.9 for firms in the third batch. The t-tests show that these differences between the firms in the first batch and later batches are statistically significant. The same conclusion can be found on other performance measures such as industry-adjusted ROE, industry-adjusted sales growth rate and Tobin's Q. Also, we find that firm sizes in different batches are not significantly different from each other, indicating that the difference in performance is not due to firm size. This preliminary evidence supports our theory.

Table 2: Statistics for Firms in Different Reform Batches

	ROA	Sales Growth Rate	ROE	Market Value	No. of Observations
First Batch	5.798	0.284	8.905	3.42E+09	259
					20.64%
Second Batch	3.265***	0.179***	5.259***	2.59E+09***	263
	t=-6.737	t=-4.579	t=-3.735	t=-3.744	20.96%
Third Batch	1.885***	0.211***	1.76***	2.39E+09***	320
	t=-12.129	t=-2.350	t=-5.780	t=-3.170	25.50%
Fourth Batch	0.085***	0.275	-13.133**	1.34E+09***	227
	t=-14.049	t=0.161	t=-1.847 (2)	t=-18.492	18.09%
Fifth Batch	0.835***	0.837	4.172***	8.70E+09	63

	t=-4.284	t=1.558	t=-2.453	t=-0.801	5.02%
Sixth Batch	-1.202***	1.56***	-3.12***	2.00E+09***	64
	t=-2.824	t=2.625	t=-2.906	t=-4.327	5.10%
Last Batch	-3.412***	0.438***	-89.26**	1.65E+09***	59
	t=-3.060	t=0.707	t=-1.706 (2)	t=-8.459	4.70%

In this table and the rest, *** indicates significance at the 1% level; ** indicates significance at the 5% level; and * indicates significance at the 10% level.

Next, we test whether managers were rewarded for good performance. Based on our theoretical model and the privatization literature, we predict that state shareholders will use promotions and demotions to motivate CEOs. Groves et al. (1995) and Pinto et al. (1993) argued that since managers' incentive plays an important role in the long process of privatization, they should be monitored in the intermediate period. Groves et al. (1995) found that demotions and promotions greatly motivated managers in 769 SOEs during 1980 and 1989 in China. Also, Fredrickson et al. (1988) and Gibelman & Gelman (2002) found that social and political factors played a role in determining managerial turnover. Although the Chinese Corporate Law requires CEOs to be determined and monitored by the board of directors, the state shareholder can exercise control through its controlling shareholdings and its authority in the appointment and dismissal of CEOs. Also, in Chinese SOEs, ownership tends to be concentrated and the board tends to be controlled by members who are directly or indirectly affiliated with the ultimate controller (the government). Through its control, the government can use promotions and demotions as the incentive mechanism for CEOs. Our theoretical analysis also implies that managers in well-performing firms are more likely to be promoted and managers in badly performing firms are more likely to be demoted and that the sensitivity of turnover to performance will be larger for firms going through the SS reform earlier.

The regression results using an ordered-logit model are presented in Table 3. As explained before, we use an ordered multiple choice indicator rather than the traditional binary choice indicator as the dependent variable. For checking the robustness of our regressions, we use both accounting-based and market-based measures of a firm's performance.

Table 3: Ordered Logit Regressions⁶

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Performance is defined as	ROA	ROA	ROE	ROE	Growth rate	Growth rate	Loss	Loss
Performance	0.035*** (4.39)	0.030*** (3.49)	0.021*** (5.19)	0.018*** (4.17)	0.134*** (3.70)	0.121*** (3.18)	-0.412*** (-3.07)	-0.343** (-2.47)
First mover×Performance		0.047* (1.97)		0.032** (2.52)		0.144 (1.19)		-1.182** (-2.33)

⁶ In all our regressions, we regard the person holding the title of general manager or chief executive as CEO. Also, to remove outliers, all the accounting measures are winsorized at the 1st and 99th percentiles.

Firm size	0.115*** (2.81)	0.111*** (2.72)	0.100** (2.36)	0.093** (2.19)	0.135*** (3.05)	0.132*** (2.98)	0.125*** (3.07)	0.125*** (3.08)
Largest shareholding	-0.003 (-1.15)	-0.003 (-1.15)	-0.003 (-1.23)	-0.003 (-1.18)	-0.002 (-0.92)	-0.002 (-0.87)	-0.002 (-0.97)	-0.002 (-0.94)
Institutional share	-0.197** (-2.48)	-0.198** (-2.49)	-0.181** (-2.23)	-0.180** (-2.21)	-0.119 (-1.42)	-0.119 (-1.43)	-0.158** (-2.01)	-0.151* (-1.92)
CEO age	0.004 (0.01)	0.011 (0.02)	0.192 (0.33)	0.204 (0.36)	0.968 (1.57)	0.967 (1.57)	-0.029 (-0.05)	-0.045 (-0.08)
Political connection	-0.185** (-2.05)	-0.175* (-1.93)	-0.203** (-2.21)	-0.194** (-2.11)	-0.250** (-2.52)	-0.245** (-2.47)	-0.189** (-2.09)	-0.183** (-2.03)
Hierarchy	-0.029 (-0.74)	-0.029 (-0.73)	-0.024 (-0.61)	-0.023 (-0.57)	-0.035 (-0.82)	-0.034 (-0.81)	-0.037 (-0.96)	-0.038 (-0.98)
Cut1	-0.863	-0.894	-0.958	-1.017	-0.126	-0.150	-0.763	-0.758
Cut2	4.135	4.108	4.045	3.993	4.827	4.804	4.222	4.230
No. of observations	4818	4818	4624	4624	4062	4062	4816	4816
Log Likelihood	-2701.87	-2699.95	-2590.42	-2587.31	-2300.09	-2299.41	-2706.37	-2703.87

In Models (1) and (2) of Table 3, we use the industry-adjusted ROA to measure a firm's performance. Model (1) shows that the probability that a CEO is demoted is significantly lower and the probability that a CEO is promoted is significantly higher for firms with a higher adjusted ROA. Further, if the adjusted ROA increases by one standard deviation from the mean, the probability that the CEO is demoted decreases by about 2% and the probability that the CEO is promoted increases also by about 2%. In Model (2), to test whether the sensitivity of turnover is affected by policy burdens involving privatization, we add the interaction term between the first mover and the adjusted ROA to the regression model. The dummy First Mover is 1 if the firm is selected to go through the SS reform in 2005 and 0 otherwise. About 20% of the firms went through the reform in 2005. It indicates the extent to which the managers in the SOEs have achieved the political task. Model (2) shows that the sensitivity of CEO turnover to performance increases significantly if a firm is selected to go through the reform early. Further, if a firm's adjusted ROA increases by one standard deviation from the mean and the firm is in an earlier reform batch, the probability that the CEO is demoted decreases by about 2.5% and the probability that the CEO is promoted increases by about 1% more than they do for a firm whose adjusted ROA also increases by one standard deviation but which is in a later reform batch.

Following the literature on CEO turnover, we add further control variables. We use the logarithm of total assets to control for firm size. Big firms tend to have a large impact on the economy and they may be more challenging to operate. Hence, managers in big firms may accumulate more management experience. Chang & Wong (2009), Kato & Long (2006) and Firth et al. (2006) found that managers in large firms are less likely to be forced to leave. We also found that managers in big firms are more likely to be promoted.

On monitoring, Brunello et al. (2003) did not find evidence that large minority shareholders will monitor managers effectively in Italy. However, Denis et al. (1997) found that large minority shareholders play an important role in monitoring managers in the US. In Table 3, we found that the existence of large institutional shareholders will increase forced turnovers, indicating that large minority shareholders play an important role in monitoring CEOs in China.

We further control for other variables relating to ownership structure and political connections. The biggest shareholder naturally has more incentive to monitor the manager, implying a higher turnover rate. Volpin (2002) found that the existence of a large stakeholder will enhance the negative link between CEO turnover and performance. However, a large enough shareholder may press the manager to expropriate minority shareholders, resulting in a low turnover rate. In Table 3, we show that the two effects cancel each other out and the percentage of shares held by the largest shareholder does not have a significant effect on the turnover rate.

We use the number of hierarchy levels to control for ownership structure. Volpin (2002) found that this number will not affect the relationship between turnover and performance regardless of whether a firm is standalone or affiliated with a pyramidal group. Our findings confirm that the length of the largest shareholder's control chain will not significantly affect the turnover rate.

We use a political dummy to distinguish professional managers from managers who are former bureaucrats. This dummy is 1 if the manager has worked for the central or local governments before and 0 if otherwise. Claessens & Djankov (1999) found that managers appointed by state owners perform worse than those appointed by private owners. However, political connections are regarded as an important resource in China. We include this variable to test whether a manager's political connection will influence his/her current career. Table 3 shows that a bureaucratic appointment increases the probability of demotion. Also, as a manager approaches the official retirement age, he/she is more likely to be replaced regardless of the firm's performance. Hence, we control for CEO age in our regressions. However, we find that CEO age has no significant effect on the turnover rate.

We also consider alternative measures of a firm's performance. In Models (3) and (4) of Table 3, we use the industry-adjusted ROE to measure a firm's performance. In Models (5) and (6), we use the industry-adjusted annual sales growth rate. We find that our main conclusions are robust to these alternative performance measures.

Also, Kaplan (1994) found that CEO turnover in Japanese firms are most sensitive to negative earnings. Chang & Wong (2009) found that the sensitivity of performance to turnover is more pronounced when a firm is making a loss. Hence, in Models (7) and (8), we use a loss

dummy as a performance measure. This dummy is 1 if a firm's earnings before interest and tax are less than zero and 0 if otherwise. Our main conclusions still hold with this loss measure.

Further, if we use the industry median rather than the mean to adjust the industry effect, if we use an absolute control dummy rather than the percentage of shares held by the largest shareholder, if we use an age dummy rather than the continuous age variable, if we use a dummy to separate central-government-owned firms from local-government-owned firms, or if we remove official retirements from our turnover sample, our main conclusions still hold.

Finally, to check the robustness of our main conclusions further, we use the traditional binary choice indicator as the dependent variable. This binary choice indicator separates forced turnovers from voluntary ones only. Furthermore, to control for the time-invariant firm fixed effect, we use the fixed-effect logit regression model for panel data rather than the simple cross-section data analysis; the latter ignores the correlation of the fixed effects in the same firm across time. The regression results are presented in Table 4. Again, our main conclusions hold under this specification.

Table 4: Fixed-Effect Logit Regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Performance is defined as	ROA	ROA	ROE	ROE	Growth rate	Growth rate	Loss	Loss
Performance	-0.039*** (-3.40)	-0.034*** (-2.78)	-0.021*** (-3.87)	-0.018*** (-3.13)	-0.107** (-2.42)	-0.100** (-2.14)	0.369** (2.30)	0.286* (1.72)
First mover×Performance		-0.073* (-1.65)		-0.039* (-1.86)		0.066 (-0.46)		-1.391** (-2.00)
Firm size	-0.313** (-2.04)	-0.311** (-2.02)	-0.306* (-1.88)	-0.300* (-1.84)	-0.408** (-2.15)	-0.402** (-2.11)	-0.311** (-2.02)	-0.302** (-1.96)
Institutional share	0.231** (2.15)	0.221** (2.05)	0.210* (1.89)	0.195* (1.76)	0.230** (2.02)	0.231** (2.03)	0.203* (1.90)	0.192* (1.79)
Largest shareholding	0.016* (1.94)	0.017** (2.02)	0.019** (2.23)	0.020** (2.34)	0.017* (1.82)	0.017* (1.84)	0.016** (1.96)	-0.018** (-2.11)
CEO age	0.011 (1.29)	0.012 (1.33)	0.011 (1.23)	0.011 (1.28)	-0.004 (-0.39)	-0.004 (-0.39)	0.012 (1.36)	0.012 (1.42)
Political connection	0.077 (0.51)	0.066 (0.44)	0.036 (0.23)	0.027 (0.18)	0.199 (1.14)	0.197 (1.14)	0.082 (0.54)	0.070 (0.46)
Hierarchy	-0.141 (-0.89)	-0.127 (-0.80)	-0.120 (-0.74)	-0.102 (-0.63)	-0.187 (-1.04)	-0.185 (-1.03)	-0.111 (-0.70)	-0.090 (-0.57)
No. of observations ⁷	2820	2820	2656	2656	2126	2126	2819	2819
Log Likelihood	-956.51	-955.10	-900.35	-898.51	-736.83	-736.73	-959.48	-957.41

In summary, our empirical findings are consistent with our theory. First, we find that better performing firms, as measured by higher ROA, ROE, and market value, were selected to go through the SS reform earlier. Second, the sensitivity of CEO turnover to performance is high-

⁷ The number of observations drops significantly from the earlier regressions since a fixed-effect regression excludes firms that have no turnover during the whole period.

er for firms that were selected to go through the reform in 2005 (the first year of the SS reform). Specifically, CEOs in firms that were selected for the reform earlier were more likely to be promoted if the firms performed well and were more likely to be demoted if the firms performed badly.

6. Concluding Remarks

Developed economies have shown a fondness for staged privatization through their well-developed stock markets. Even in developing countries, staged privatization through stock markets have been gaining popularity in recent years. This study provides a theory on staged privatization. We identify an efficient approach to privatize based on an incomplete-contract approach. This theory can explain the popularity of staged privatization around the world. We also offer empirical evidence in support of our theory.

A private firm's IPO also features an initial lockup, which typically lasts 180 days. There are many explanations for IPO lockups. Brav & Gompers (2003) proposed three: a signal for firm quality, a commitment device to alleviate moral hazard, and a mechanism for underwriters to extract additional compensation from the issuing firm. Our theory offers a new understanding of IPO lockups from a unique angle.

Appendix

Lemma 1: Existence and Uniqueness of θ

Lemma 1. *If $f(a^*, k^*) > k^*$ and n is sufficiently large, then equation (7) has a unique solution of $\theta \in (0, 1)$.*

Proof. Denote $\phi(\theta) \equiv \theta f(a^*, k^*) F^{-1}\left(1 - \frac{\theta}{n}\right)$. We have

$$\phi(0) = 0 \quad \text{and} \quad \phi(1) = f(a^*, k^*) F^{-1}\left(1 - \frac{1}{n}\right).$$

Since $\lim_{n \rightarrow \infty} F^{-1}\left(1 - \frac{1}{n}\right) = 1$ and $f(a^*, k^*) > k^*$, when n is sufficiently large, we have

$$\phi(0) < k^* < \phi(1).$$

Hence, by continuity of ϕ , there is at least one $\theta^* \in (0, 1)$ such that $\phi(\theta^*) = k^*$.

Further, we have

$$\phi'(\theta) \equiv y^* F^{-1}\left(1 - \frac{\theta}{n}\right) - \frac{\theta y^*}{n} \frac{1}{f\left[F^{-1}\left(1 - \frac{\theta}{n}\right)\right]},$$

where f is the density function of F . Hence, we have

$$\lim_{n \rightarrow \infty} \phi'(\theta) = y^* > 0.$$

That is, when n is sufficiently large, ϕ is strictly increasing. Therefore, θ^* is unique.

Proof of Proposition 1

Given the profit function in (5), with $k = k^*$, we have

$$\pi'_N(a) = f_a(a, k^*)(1 - \theta)\delta^{\lambda(a)}\delta_n^{1-\lambda(a)} + f(a, k^*)(1 - \theta)\lambda'(a)\delta^{\lambda(a)}\delta_n^{1-\lambda(a)} \ln\left(\frac{\delta}{\delta_n}\right) - c'(a).$$

Consider a general lockup policy $\lambda(a)$ of the following form:

$$\lambda(a) = \begin{cases} \lambda(a) & \text{if } a < a^*, \\ \lambda_0 & \text{if } a \geq a^*, \end{cases} \quad (19)$$

where $\lambda_0 \in [0, 1]$ is an arbitrary constant. For $a \geq a^*$, for any λ_0 in $[0, 1]$, we have

$$\pi'_N(a) = f_a(a, k^*)(1 - \theta)\delta^{\lambda_0}\delta_n^{1-\lambda_0} - c'(a).$$

Since $\pi'_N(a^*) < 0$ and $\pi_N(a)$ is concave in a for $a \geq a^*$, we have $\pi'_N(a) < 0$ for all $a \geq a^*$. This means that, in $[a^*, \infty)$, the N-holder will choose a^* .

On the other hand, for $a < a^*$, we need $\pi'_N(a) > 0$ or

$$f_a(a, k^*) + \lambda'(a)f(a, k^*) \ln\left(\frac{\delta}{\delta_n}\right) > \frac{c'(a)}{(1 - \theta)\delta^{\lambda(a)}\delta_n^{1-\lambda(a)}},$$

or

$$\lambda'(a) < \frac{1}{f(a, k^*) \ln(\delta/\delta_n)} \left[\frac{c'(a)}{(1 - \theta)\delta^{\lambda(a)}\delta_n^{1-\lambda(a)}} - f_a(a, k^*) \right]. \quad (20)$$

If we take $A(a) \equiv \left[\delta^{\lambda(a)}\delta_n^{1-\lambda(a)} \right]^{-1}$, then $\lambda(a) = \frac{\ln[\delta_n A(a)]}{\ln(\delta_n/\delta)}$. Hence, inequality (20) becomes:

$$\frac{A'(a)}{A(a)} < \frac{1}{f(a, k^*)} \left[f_a(a, k^*) - c'(a) \frac{A(a)}{1 - \theta} \right].$$

It is satisfied if

$$\frac{A'(a)}{A(a)} = - \frac{c'(a)}{f(a, k^*)} \frac{A(a)}{1 - \theta},$$

which implies

$$dA^{-1}(a) = \frac{1}{1 - \theta} \frac{dc(a)}{f(a, k^*)}.$$

Then, the above implies

$$A^{-1}(a) = C + \frac{1}{1 - \theta} \int_0^a \frac{dc(\tau)}{f(\tau, k^*)},$$

where C is an arbitrary constant. Obviously, $A(a)$ is decreasing, implying that $\lambda(a)$ is decreasing. Also, since

$$\lambda(a) = \frac{\ln \delta_n - \ln A^{-1}(a)}{\ln(\delta_n/\delta)},$$

We have

$$\lambda'(a) = -\frac{1}{\ln(\delta_n/\delta)} \frac{[A^{-1}(a)]'}{A^{-1}(a)} = -\frac{1}{(1-\theta)\ln(\delta_n/\delta)} \frac{1}{A^{-1}(a)} \frac{c'(a)}{f(a, k^*)} < 0,$$

$$\lambda''(a) = \frac{1}{(1-\theta)\ln(\delta_n/\delta)} \left\{ \frac{[A^{-1}(a)]'}{[A^{-1}(a)]^2} \frac{c'(a)}{f(a, k^*)} - \frac{1}{A^{-1}(a)} \frac{c''(a)f - c'(a)f_a}{[f(a, k^*)]^2} \right\}.$$

If $c(a)$ has a constant marginal cost $c(a) = \gamma a$, then we have $\lambda''(a) > 0$, i.e., $\lambda(a)$ is convex. Hence, as shown in Figure 2, this reform policy is downward sloping and convex.

Although this C can be arbitrary, we do need to restrict it to ensure $0 \leq \lambda(a) \leq 1$. To have $\lambda(a) \geq 0$ for all $a \leq a^*$, since $\lambda(a)$ is decreasing, we need $\lambda(a^*) \geq 0$ only. That is, $A^{-1}(a^*) \leq \delta_n$, or

$$C \leq \delta_n - \frac{1}{1-\theta} \int_0^{a^*} \frac{dc(\tau)}{f(\tau, k^*)}.$$

To have $\lambda(a) \leq 1$ for all $a \leq a^*$, since $\lambda(a)$ is decreasing, we need $\lambda(0) \leq 1$ only. That is, $C \geq \delta$. Hence, we need the following condition to ensure $0 \leq \lambda(a) \leq 1$:

$$\delta \leq C \leq \delta_n - \frac{1}{1-\theta} \int_0^{a^*} \frac{dc(\tau)}{f(\tau, k^*)}.$$

Such a C exists if and only if condition (6) is satisfied. In other words, as long as the time preference δ of the N-holder satisfies (6), we can identify a proper $\lambda(a)$ to induce a^* . The end result is an efficient market-based firm.

If the marginal cost of effort is constant and is small relative to output, then any N-holder with $\delta < \delta_n$ will be enticed by the reform program to improve the firm. In a large economy with $n \rightarrow \infty$, we have $\delta_n \rightarrow 1$, implying that virtually any N-holder has enough incentive to improve the firm.

Finally, we can simply take $C = \delta$. Then, although unnecessary, we can choose the following λ_0 to ensure continuity of $\lambda(\cdot)$:

$$\lambda_0 = \lambda(a^*) = \frac{\ln \delta_n - \ln \left[\delta + \frac{1}{1-\theta} \int_0^{a^*} \frac{dc(\tau)}{f(\tau, k^*)} \right]}{\ln(\delta_n/\delta)}.$$

Proof of Proposition 2

Given the profit function in (11), with $k = k^*$, we have

$$\pi'_N(a) = [1 - \beta \sigma^2 f(a, k^*)] f_a(a, k^*) (1 - \theta) \delta^{\lambda(a)} \delta_n^{1-\lambda(a)} \\ + [1 - \beta \sigma^2 f(a, k^*)] f(a, k^*) (1 - \theta) \lambda'(a) \delta^{\lambda(a)} \delta_n^{1-\lambda(a)} \ln \left(\frac{\delta}{\delta_n} \right) - c'(a).$$

Consider a general lockup policy $\lambda(a)$ of the following form:

$$\lambda(a) = \begin{cases} \lambda(a) & \text{if } a < a^*, \\ \lambda_0 & \text{if } a \geq a^*. \end{cases} \quad (21)$$

For $a \geq a^*$, $\lambda(a)$ can take any constant $\lambda_0 \in [0, 1]$. Then, we have

$$\pi'_N(a) = f_a(a, k^*)[1 - \beta\sigma^2 f(a, k^*)](1 - \theta)\delta^{\lambda_0}\delta_n^{1-\lambda_0} - c'(a).$$

Since $\pi'_N(a^*) < 0$ and $\pi_N(a)$ is concave in a , we have $\pi'_N(a) < 0$ for all $a \geq a^*$. This means that, in $[a^*, \infty)$, the N-holder will choose a^* .

On the other hand, for $a < a^*$, we need $\pi'_N(a) > 0$ or

$$f_a(a, k^*) + \lambda'(a)f(a, k^*)\ln\left(\frac{\delta}{\delta_n}\right) > \frac{c'(a)}{(1 - \theta)[1 - \beta\sigma^2 f(a, k^*)]\delta^{\lambda(a)}\delta_n^{1-\lambda(a)}},$$

or

$$\lambda'(a) < \frac{1}{f(a, k^*)\ln(\delta/\delta_n)} \left[\frac{c'(a)}{(1 - \theta)[1 - \beta\sigma^2 f(a, k^*)]\delta^{\lambda(a)}\delta_n^{1-\lambda(a)}} - f_a(a, k^*) \right]. \quad (22)$$

If we take $A(a) \equiv [\delta^{\lambda(a)}\delta_n^{1-\lambda(a)}]^{-1}$, then $\lambda(a) = \frac{\ln[\delta_n A(a)]}{\ln(\delta_n/\delta)}$. Hence, inequality (22) becomes

$$\frac{A'(a)}{A(a)} < \frac{1}{f(a, k^*)} \left[f_a(a, k^*) - c'(a) \frac{A(a)}{(1 - \theta)[1 - \beta\sigma^2 f(a, k^*)]} \right], \quad (23)$$

which is satisfied if

$$\frac{A'(a)}{A(a)} = - \frac{c'(a)}{f(a, k^*)} \frac{A(a)}{(1 - \theta)[1 - \beta\sigma^2 f(a, k^*)]},$$

which implies

$$(1 - \theta)dA^{-1} = \frac{dc(a)}{f(a, k^*)[1 - \beta\sigma^2 f(a, k^*)]},$$

implying

$$A^{-1}(a) = C + \frac{1}{1 - \theta} \int_0^a \frac{dc(\tau)}{f(\tau, k^*)[1 - \beta\sigma^2 f(\tau, k^*)]},$$

where C is a free parameter. Since

$$\lambda(a) = \frac{\ln \delta_n - \ln A^{-1}(a)}{\ln(\delta_n/\delta)},$$

we have

$$\lambda'(a) = - \frac{1}{\ln(\delta_n/\delta)} \frac{[A^{-1}(a)]'}{A^{-1}(a)} = - \frac{1}{(1 - \theta)\ln(\delta_n/\delta)} \frac{c'(a)}{f(a, k^*)[1 - \beta\sigma^2 f(a, k^*)]} \frac{1}{A^{-1}(a)} < 0.$$

Hence, this lockup policy is downward sloping.

Although this C can be arbitrary, we do need to restrict it to ensure $0 \leq \lambda(a) \leq 1$. To have $\lambda(a) \geq 0$ for all $a \leq a^*$, since $\lambda(a)$ is decreasing, we need $\lambda(a^*) \geq 0$ only. That is, $A^{-1}(a^*) \leq \delta_n$, or

$$C \leq \delta_n - \frac{1}{1 - \theta} \int_0^{a^*} \frac{dc(\tau)}{f(\tau, k^*)[1 - \beta\sigma^2 f(\tau, k^*)]}.$$

To have $\lambda(a) \leq 1$ for all $a \leq a^*$, since $\lambda(a)$ is decreasing, we need $\lambda(0) \leq 1$ only. That is, $A^{-1}(0) \geq \delta$, i.e., $G \geq \delta$. Hence, we need the following condition to ensure $0 \leq \lambda(a) \leq 1$:

$$\delta \leq C \leq \delta_n - \frac{1}{1-\theta} \int_0^{a^*} \frac{dc(\tau)}{f(\tau, k^*)[1 - \beta\sigma^2 f(\tau, k^*)]}.$$

Such a C exists if and only if (12) is satisfied. In other words, as long as the time preference δ of the N-holder satisfies (12), we can identify a proper $\lambda(\cdot)$ to induce a^* . We can simply take $C = \delta$. Then, we can choose the following λ_0 to ensure continuity of $\lambda(\cdot)$:

$$\lambda_0 = \lambda(a^*) = \frac{\ln \delta_n - \ln A^{-1}(a^*)}{\ln(\delta_n/\delta)} = \frac{\ln \delta_n - \ln \left\{ \delta + \frac{1}{1-\theta} \int_0^{a^*} \frac{dc(\tau)}{f(\tau, k^*)[1 - \beta\sigma^2 f(\tau, k^*)]} \right\}}{\ln(\delta_n/\delta)}.$$

Proof of Proposition 3

Given the profit function in (15), with $k = k^*$, we have

$$\begin{aligned} \pi'_N(a) &= f_a(a, k^*)(1-\theta)\delta^{\lambda(a)}\delta_n^{1-\lambda(a)} \\ &\quad + [f(a, k^*) - \beta\sigma^2](1-\theta)\lambda'(a)\delta^{\lambda(a)}\delta_n^{1-\lambda(a)} \ln\left(\frac{\delta}{\delta_n}\right) - c'(a). \end{aligned}$$

Consider a general lockup policy $\lambda(a)$ of the following form:

$$\lambda(a) = \begin{cases} \lambda(a) & \text{if } a < a^*, \\ \lambda_0 & \text{if } a \geq a^*. \end{cases} \quad (24)$$

For $a \geq a^*$, $\lambda(a)$ can take any constant $\lambda_0 \in [0, 1]$. Then, we have

$$\pi'_N(a) = f_a(a, k^*)(1-\theta)\delta^{\lambda_0}\delta_n^{1-\lambda_0} - c'(a).$$

Since $\pi'_N(a^*) < 0$ and $\pi_N(a)$ is concave in a , we have $\pi'_N(a) < 0$ for all $a \geq a^*$. This means that, in $[a^*, \infty)$, the N-holder will choose a^* .

On the other hand, for $a < a^*$, we need $\pi'_N(a) > 0$ or

$$f_a(a, k^*) + \lambda'(a)[f(a, k^*) - \beta\sigma^2] \ln\left(\frac{\delta}{\delta_n}\right) > \frac{c'(a)}{(1-\theta)\delta^{\lambda(a)}\delta_n^{1-\lambda(a)}},$$

or

$$\lambda'(a) < \frac{1}{[f(a, k^*) - \beta\sigma^2] \ln(\delta/\delta_n)} \left[\frac{c'(a)}{(1-\theta)\delta^{\lambda(a)}\delta_n^{1-\lambda(a)}} - f_a(a, k^*) \right]. \quad (25)$$

If we take $A(a) \equiv [\delta^{\lambda(a)}\delta_n^{1-\lambda(a)}]^{-1}$, then $\lambda(a) = \frac{\ln[\delta_n A(a)]}{\ln(\delta_n/\delta)}$. Hence, inequality (25) becomes:

$$\frac{A'(a)}{A(a)} < \frac{1}{f(a, k^*) - \beta\sigma^2} \left[f_a(a, k^*) - c'(a) \frac{A(a)}{1-\theta} \right]. \quad (26)$$

Assume $f(a, k^*) > \beta\sigma^2$ for all $a \in [0, a^*]$; if this is not satisfied, the output has no social value. Equation (26) is satisfied if

$$\frac{A'(a)}{A(a)} = - \frac{c'(a)}{f(a, k^*) - \beta\sigma^2} \frac{A(a)}{1-\theta},$$

implying

$$(1 - \theta)dA^{-1} = \frac{dc(a)}{f(a, k^*) - \beta\sigma^2},$$

implying

$$A^{-1}(a) = C + \frac{1}{1 - \theta} \int_0^a \frac{dc(\tau)}{f(\tau, k^*) - \beta\sigma^2},$$

where C is a free parameter. Since

$$\lambda(a) = \frac{\ln \delta_n - \ln A^{-1}(a)}{\ln(\delta_n/\delta)},$$

we have

$$\begin{aligned} \lambda'(a) &= -\frac{1}{\ln(\delta_n/\delta)} \frac{[A^{-1}(a)]'}{A^{-1}(a)} = -\frac{1}{(1 - \theta) \ln(\delta_n/\delta)} \frac{1}{A^{-1}(a)} \frac{c'(a)}{f(a, k^*) - \beta\sigma^2} < 0, \\ \lambda''(a) &= \frac{1}{(1 - \theta) \ln(\delta_n/\delta)} \frac{1}{A^{-1}(a)} \\ &\quad \cdot \left[\frac{c'(a)}{f(a, k^*) - \beta\sigma^2} \frac{[A^{-1}(a)]'}{A^{-1}(a)} - \frac{c''(a)[f(a, k^*) - \beta\sigma^2] - c'(a)f_a(a, k^*)}{[f(a, k^*) - \beta\sigma^2]^2} \right]. \end{aligned}$$

Hence, the lockup policy $\lambda(a)$ is decreasing. If the marginal cost is constant, $\lambda(a)$ is also convex.

Although this C can be arbitrary, we do need to restrict it to ensure $0 \leq \lambda(a) \leq 1$. To have $\lambda(a) \geq 0$ for all $a \leq a^*$, since $\lambda(a)$ is decreasing, we need $\lambda(a^*) \geq 0$ only. That is, $A^{-1}(a^*) \leq \delta_n$, or

$$C \leq \delta_n - \frac{1}{1 - \theta} \int_0^{a^*} \frac{dc(\tau)}{f(\tau, k^*) - \beta\sigma^2}.$$

To have $\lambda(a) \leq 1$ for all $a \leq a^*$, since $\lambda(a)$ is decreasing, we need $\lambda(0) \leq 1$ only. That is, $A^{-1}(0) \geq \delta$, i.e., $C \geq \delta$. Hence, we need the following condition to ensure $0 \leq \lambda(a) \leq 1$:

$$\delta \leq C \leq \delta_n - \frac{1}{1 - \theta} \int_0^{a^*} \frac{dc(\tau)}{f(\tau, k^*) - \beta\sigma^2}.$$

Such a C exists if and only if (16) is satisfied. In other words, as long as the time preference δ of the N-holder satisfies (16), we can identify a proper $\lambda(\cdot)$ to induce a^* . We can simply take $C = \delta$. Then, we can choose the following λ_0 to ensure continuity of $\lambda(\cdot)$:

$$\lambda_0 = \lambda(a^*) = \frac{\ln \delta_n - \ln A^{-1}(a^*)}{\ln(\delta_n/\delta)} = \frac{\ln \delta_n - \ln \left\{ \delta + \frac{1}{1 - \theta} \int_0^{a^*} \frac{dc(\tau)}{f(\tau, k^*) - \beta\sigma^2} \right\}}{\ln(\delta_n/\delta)}.$$

Proof of Proposition 4

The Lagrange function for problem (18) is

$$L = f(a, k) - rk - c(a) + \mu_1 [f_a(a, k)(1 - \theta)\delta^\lambda \delta_n^{1-\lambda} - c'(a)] + \mu_2 \left[\theta f(a, k) F^{-1} \left(1 - \frac{\theta}{n} \right) - k \right].$$

The FOCs are

$$\begin{aligned}
0 &= f_a(a, k) - c'(a) + \mu_1 [f_{aa}(a, k)(1 - \theta)\delta^\lambda \delta_n^{1-\lambda} - c''(a)] + \mu_2 \theta f_a(a, k) F^{-1} \left(1 - \frac{\theta}{n} \right), \\
0 &= f_k(a, k) - r + \mu_1 f_{ak}(a, k)(1 - \theta)\delta^\lambda \delta_n^{1-\lambda} + \mu_2 \left[\theta f_k(a, k) F^{-1} \left(1 - \frac{\theta}{n} \right) - 1 \right], \\
0 &= \mu_1 f_a(a, k)(1 - \theta)\delta^\lambda \delta_n^{1-\lambda} \ln \left(\frac{\delta}{\delta_n} \right), \\
0 &= -\mu_1 f_a(a, k)\delta^\lambda \delta_n^{1-\lambda} + \mu_2 \left\{ f(a, k) F^{-1} \left(1 - \frac{\theta}{n} \right) - \frac{\theta}{n} \frac{f(a, k)}{f \left[F^{-1} \left(1 - \frac{\theta}{n} \right) \right]} \right\}.
\end{aligned} \tag{27}$$

When n is large enough, we have

$$F^{-1} \left(1 - \frac{\theta}{n} \right) < \frac{\theta}{n}.$$

Hence, we know $\mu_1 \mu_2 < 0$. By the third FOC, we know that λ must take a corner value, either 0 or 1. By (17), we have $f_a(a, k) > c'(a)$. Then, by multiplying the first FOC by μ_2 , we have

$$\mu_2 [f_a(a, k) - c'(a)] + \mu_1 \mu_2 [f_{aa}(a, k)(1 - \theta)\delta^\lambda \delta_n^{1-\lambda} - c''(a)] + \mu_2^2 \theta f_a(a, k) F^{-1} \left(1 - \frac{\theta}{n} \right) = 0.$$

Hence, we have $\mu_2 < 0$, implying $\mu_1 > 0$. Therefore, we have $\lambda = 0$.

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