

# Incentive Contract Or Tenure Reform in Managing Forest Resources:

Understanding the Transition of Forest Management in China

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( Very Preliminary and working in progress)

## Abstract

*Should the forest be privatized or owned by the government? This is an important policy question given the fact that deforestation has become a global concern, especially in developing countries where a substantial amount of forests are government owned or open access. In the context of China's forest transition, we analyze this issue by setting up a regulatory game in which the government has the option to choose some proportion of the land to privatize or own and contract out to management teams. The results show that it is rational for the government to take the relative importance of environmental benefits and resource rents, and the ability to manage the forest into consideration when making the decision of tenure reform or incentive contract approach. We find that with the possibility to share the economic rent from the logging activity under the state owned regime, the bureau as the regulator would have less incentive to decentralize the public forest land and more incline to capture the larger share of resource rent when the resource rent increases. The rent capturing and environmental concern hypothesis of the decision to choose tenure reform or incentive contract approach are confirmed from the data in Chinese forest sector.*

*JEL: Q15 ;Q28;P21.*

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## 1. Introduction

Starting from 1978, China began the reform of its economic system from centralized and planned economy to the decentralized and market economy. Along the two decades economic transition, the management regime in the forest sector also experienced a remarkable change. The pre-reform forest management system relied on command and control to implement the central government's forest sector plan and did not rely on prices to create incentives for producers to allocate products efficiently. The reform initiated liberalizing the timber market and allocating the use right to the household. Even though, in some areas, especially southern area in China, more than half of forest lands have been allocated to rural households, there are substantial forest lands still owned by the government at various levels. The ongoing policy debate among politicians concerns whether the government should own the forest land or not. If the answer is yes, under what conditions and how much should they own?

The answer to the question above might be trivial to some people given the fact that privatization has become a key part of economic policy in many countries. The last two decades witnessed the great wave of privatizing the public sectors. Since its introduction by Britain's Thatcher government in the early 1980s, privatization now appears to be accepted as a legitimate tool of statecraft by governments around the world. The privatized sectors range from competitive industry sectors to the so called strategic sectors such as steel and defence industries. The government owned forests experienced a rapid deforestation in the last two decades. It has been claimed for a long time that the insecurity of land right contributes to the deforestation process. Based on the stylized fact and existing experience, it would be easy to conclude that to privatize forestlands is the better alternative than the government ownership.

However, privatizing forest lands is not the only policy tool available to the government, the incentive contract approach has also been prevail in managing forest lands for quite a long time. The most common form of the incentive contract approach is the forest concession policy. Under this policy, the forest owner, mostly the government designs a contract with the other party where the later has a permit to harvest the timber and/ or manage the forest resource from a specified area in a given period. The forest utilization and forest management services contract has been found in many countries. For example, in Gabon, logging concessions cover 11.9 ha, and 56 percent of the forest area in the country; in Cameroon, it account for 76 percent of the forest area and in Indonesia, the active concessions in 1998 covered 52.3 million ha and account for 56 percent of the total harvest of wood (Gray, 2000).

It is not clear, to economists which of these two arrangements, i.e incentive contracts and ownership is more relevant. The importance of property rights to improve economic efficiency is highly emphasized in the modern economic theory (Coase, 1937; Williamson, 1985; Grossman and Hart, 1986; and Hart and Moore, 1990). On the other hand, Bardhan and Roemer (1992) claim that contracts can provide sufficient incentives for socialist firms to become as efficient as their capitalist counterparts. From the experience in managing socialist state-owned

enterprises (SOEs), Bardhan and Roemer (1992, p. 102) argue that “...(as far as) the key incentive and agency problems in the management of a public firm have to be addressed; we claim that privatization is not the only or even a better way of handling those problems.”

The issue is even more complicated for the forest has public goods properties and provides substantial ecological services. Forests contain over half of the world’s species, sequester a large amount of carbon and play an important role in soil conservation, the clearing of these forests would have a significant impact on the earth’s genetic diversity, climate change and agricultural productivity. In China, a lot of government owned forests are located at the upriver of Yangtze, Yellow and other important River, which are environmentally vulnerable and important. One of the main arguments from the supporter for government ownership of forests is the importance of environmental services.

The economic literature on deforestation is lacking systematic investigation whether the government should contract out or privatize the land and by how much. The recently growing literature seems more focus on the topic of tenure security, and fairly extensive (Kaimowitz and Angelsen 1999). Mendelsohn (1994) develops partial equilibrium models suggesting that insecure ownership will lead to land use decisions that reduce forest cover. Deacon (1994) examines evidence on deforestation and the rule of law, he further gave a strong theoretical link between resource use and property rights (Bonning and Deacon, 2002). Alston, Libecap, and Schneider (1996) show that adjudicated land claims enhance incentives for agricultural investments in Brazil and caused deforestation.

China provides an interesting case study. The increase of income creates the demand for environmental services from forest. The government responds with their struggling for the balance between the government ownership and decentralized management. In this paper we document the main process of China’s forest transition and develop a multi-task principal-agent model to analyze this issue. We investigate an economy where the government can use both the incentive contract and tenure reform as policy tools to manage the forest resource. We find that the ability of private agents to manage forest lands and relative importance between environmental benefits and economic rents of the forest affect the decision of the government. In particular, for the land of which the environmental benefit is higher, it is rational for the government to impose the logging ban, and it doesn’t matter for the government to choose how large the share of the rent. However, if resource rents dominate the environmental benefit, the government will set the share of the rent based on the proportion of the land privatized and the relative importance between environment benefits and economic rents. Specifically, with less public forest lands or the more important environmental benefit, the government will consider taking more economic rent and give management team lower share of total profits. In both cases, the subsidy to the private agent for their preserving effort will depend on the environmental relevance of the forest and their capability to monitor the forest preservation effort.

The crucial decision for the government is to choose whether they should privatize some specific land. The analytical results reveal that for the land with

different environmental benefits and economic profitabilities, it would be more beneficial for the government to privatize the land with less environmental benefits or resource rents. If the rent from the timber or the environmental benefit is low enough, the government would privatize the land. As it becomes easier to monitor the management team, the government is less opt to decentralization.

The empirical part of this paper links the theoretical conclusion with the data from China. Using the price of timber as the proxy for resource rents and the variable whether the forest is located in the environmental vulnerable area as the measurement of environmental benefits, we investigate the impact of resource rents and environmental importance on the process of tenure reform. The empirical results show that the incentive for the government to allocate forest lands to rural households will decrease if the resource rent from the land is high or the environmental benefit is important.

Section 2 gives a brief survey about the process of transition of forest management regime in China. In section 3, we develop a model in which the economy is endowed with some forest lands and the government faces the decision whether they should privatize the land. In Section 4, the main proposition and corollary about how the ability to manage the forest land, the environmental benefit and the economic rent will affect the structure of incentive contract and the decision of the tenure reform are established; the choice between the incentive contract and the tenure reform is also discussed in the subsequent part of this section. The empirical evidence is documented in section 5. The last section concludes.

## **2. Institutional Changes in Chinese Forest**

The changes in Chinese forest sector started in the middle of 1980. Before the reform, the harvesting and non-harvesting activities such as replanting were completely on the basis of the plan. The goal of timber producers was to meet the production target. They couldn't sell the timber in the market, wasted a lot of residues and had little incentive to protect the forest in terms of harvesting operation methods. The afforestation and replanting goals weren't successful neither even though the government put enormous efforts. The original intention of the government to reform the existing regime is to promote more efficient use of forest resources and improve the incentives in afforestation and replanting. Three policies are especially worth discussion along the process: the timber market liberalization, land tenure reform and state owned forest farms reform.

### **2.1. Timber Market and Price Reform**

At the beginning of the reform, the market was under the firmly control of the government. The government prohibited the entry of new buyers and procured the specified amount of timber from the forest farm at a price set by them, and allocate the timber to state owned timber processing firms according to their quota. The tight financial constrain and the lack of incentive made the system very inefficient. As the marketization and decentralization in China's economy

proceeds, it became more and more costly for the government to maintain the uniform procurement and selling system, and the system began to collapse.

To increase the incentive to supply timber and promote the efficient use of forest resources, in 1985 the government opened the free market and allowed the participation of existing forest farms and timber processing firms after fulfilling their mandated targets. In order to enhance the market to work, the government even coordinated the transaction of timber by organizing the meeting and inviting suppliers and demanders. The new dual track system for the timber changed the market structure, and the incentive of existing participants substantially. The timber price in the free market started to increase and in most cases, the timber price in the free market was higher than the quota price set by the government. The arbitrage opportunity encouraged the entry into the market and made the market very active. The farmer with their own forest lands could respond to price and adjust their logging behavior according their expectation about the timber price in the market. The possibility to sell the above quota timber in the free market created the incentive to save the residue from the logging and made the efficient farm produce more timber.

## **2.2. Forest Land Tenure Reform**

The delegation of the user right from the government to local farmers was largely encouraged by the great success of household responsibility system in agriculture sector, and triggered by land tenure disputes among local governments and farmers. The decollectization of Chinese rural communes and adoption of household responsibility system was a remarkable reform in rural sector. It created the incentive for rural households and enabled the growth of output by 7.7 percent in the early eighties(Lin, 1994). The agricultural reform made people express serious doubts about the legitimacy of communes under the old ideology, and enabled reformists in the government to gain larger support. It became straightforward for reformists to adopt similar approach in the forest sector.

Land tenure disputes among local people triggered the process of decollectization and accelerated the adoption of forest household responsibility system. Before the reform, the regional authorities thought the household operation were too small to support long-run forest development activities and denied households rights to forest land. The fact that the state had very strong power enabled the entrenchment of the state forest. These two conflicts were caused by the old regime where there were no clear definition and enforcement of property rights. The conflict was so serious that in some cases, the participant even engaged in a large scale of fighting and they had to resort to the central government to resolve the disputes. The central government made their decision to solve the problem by initializing a profound reform with its aim to solve the disputes and define the ownership. In order to achieve the goal, the central government defined the property right of unsettled forest land along the boundary of different regions, allocated some of the land within regions to farmers as self keeping plots, and contracted the use right of some of the land to farmers, which was the famous “three confirmation” policy in Chinese forest sector.

The “three confirmation” policy was implemented at the beginning of the reform period in the managed forest area, mainly in southern and northern China. In southern China, the government promised that whoever planted the tree in their contracted land would own the property right of the tree for at least 50 years, the farmer also could transfer or sell the use right of forest land under the permission of existing rules. In the middle of 1980, the total amount of land accounted to 69 percent of the total forest land in Southern China. In the northern China, there were very few natural forests, but some ecological trees planted by the government to protect the environment. The government allocated the land to farmers. Whoever owned the land also had the access to the tree. they could transfer the right by selling the land.

### **2.3. State Owned Forest Reform**

Historically the forest resource is environmentally and economically important in Northeastern and Southeastern China, where the forest resource accounts to 53.4 percent of total area in China. Before the reform, these forest were under the control of government and the management of these forest is delegated to state owned forest farms. These farms are better named bureaucracies rather than companies. Their objective was to meet the government’s production, afforestation and other protection targets, not to pursue economic profits and environmental sustainability.

Contrasting to defining property rights and adopting household responsibility forest management system in northern and southern China, the reform strategy of the government is to delegate the management to state owned forest farms, to reconstruct and strengthen the incentive to the state owned forest farms(China Forest Yearbook, 1949-1986). In order to foster their incentive and enhance the cost-benefit perception of the farms, the government changes the accounting system and charges the farms for their usage of the capital invested by the government. The government also decentralized the decision and gave more autonomous decision rights to the management team, who was allowed to harvest and sell timber in the free market and could retain some share of profits to invest or increase the welfare of workers. These changes gave much stronger incentive for the management team to save the cost and harvest efficiently. However, they do not provide any incentive for the firm to protect the forest and manage the forest in a sustainable way. To make sure the manager will make efforts in replantation, the subsidy from the government to the farms for their preservation effort and replanting activities is a very common practice in the regulation scheme.

## **3. The model**

In the model, we consider an economy, where there are some forest land, the government and the private agent. To simplify the notation, the amount of land is normalized to one unit. The land could be owned either by the government or the private agent. It could also be the case that parts of the forest land is owned

by the government and the rest is owned by the private. The ownership status of the land is represented as  $\delta$ , where  $\delta \in [0, 1]$ .  $\delta = 1$  means that the land is privatized, while  $\delta = 0$  implies that the government owns the land. The real value between 0 and 1 can be understood as the probability of the government to privatize a specific piece of public forest land, or as the proportion of the total public forest land in the country that is privatized.

The prevailing institutional arrangement and ownership structure to the forest land identify a set of boundaries within which all economic activity takes place. If the government owns the forest land, the important institutional structure for timber operations are contracts between the government and the industrial firms, or the concessionaires, that log and process the timber resource where in China's context, the concessionaires are state owned forest farms. The other important institutional structure for smallholder management and use of the forest resource is the smallholder's resource tenure. Tenure may be established for land with trees or for the trees themselves. It may be held singly by individual persons, or communally in accordance with specialized set of local rules or customs. We are interested in forest household responsibility system in which the use right of forest land is owned by the household for a very long time with the possibility to transfer.

To model the economy, we have to capture the key feature of the institutional arrangement and ignore other aspects. If the forest land is owned by the government, the government can't manage the land by themselves and has to contract out them to the private agent. In such a regime, it is assumed here that they share the rent from the logging activity and subsidize the management team for their effort in preserving the forest. All these objectives can be approached by designing a contract specifying the proportion of the rent shared with the management team and providing the incentive for the management team to plant the forest. The government can also choose to privatize the land. Once the forest land is privatized, they give up their right to claim the rent from the logging and the rent from the logging activity will be kept solely by the private agent. The representative private agent with some their own land and the land from the government fulfills their task in the fire controlling, profit mandate and afforestation.

### 3.1. The government

The payoff structure of the government under the two regimes shares similar characteristics and also differs from each other. The government cares about both the economic benefit from logging and the environmental service from the standing forest. Under the contracting system, the government receives the shared profit from the management team, and subsidizes the afforestation of state owned enterprises. However, they receive no profit from the privatized land and give no subsidy once they allocate the land to the private agent.

Under the contract out regime, the government to manage the forest reflects the dual objectives of the forest bureau to obtain economic profits from logging while at the same time to preserve the forests so as to generate long-term economic and ecological benefits. To simplify our analysis, the payoff under the

linear incentive scheme between the government and the management team is

$$(1 - \alpha)\pi + (\lambda - \beta)(V_t - V_{t-1}) - \alpha_0 \quad (1)$$

, where  $\pi$  is the economic rent from logging;  $\alpha_0$  is a fixed payment to state forest farms to ensure their subsistence;  $\alpha$  is the share of profit allocated to the agent, i.e the management team;  $\beta$  is the incentive provided by the government as the forest regulator to the state forest enterprise for its sustainable operation which can be understood either as the reward to forest farms for its preservation efforts, or the penalty for under-providing preservation efforts;  $V_t - V_{t-1}$  is the increase of the volume of standing timber; and  $\lambda$  is the parameter transforming the standing forest into environmental and ecological benefits measured in the monetary metric equivalent. The profit is obtained directly from selling the logged timber, which is  $p \cdot x$ , where  $x$  is the amount of timber logged and  $p$  is the resource rent, or stumpage value per unit of timber, equal to the difference between the price and the extraction and delivery costs for the logs. The increase of forest volume measuring assets and environmental services value  $V_t - V_{t-1}$ , which can be described as<sup>2</sup>

$$V_t - V_{t-1} = \theta V_{t-1} - x + e \quad (2)$$

where the logging  $x$  will decrease the volume and value of forest; the forest in the last period will increase the stock in the current period;  $\theta$  is the growth rate of the standing forest, which describes the growth pattern of the forest; the preservation effort and afforestation activity  $e$  will increase the stock of the forest. Under the privatized regime, the government is assumed to receive no monetary revenue from and give no subsidy to the private agent. However, the logging activity by the private agent will contribute to the loss of the environmental benefits, which is  $\lambda \cdot x$ .

The last part of the cost comes from the information rent or the agency cost caused by the information asymmetry. It is costly for the government to observe and verify the amount of the rent the private agent gets from the logging and the effort they put in preserving the forest. It is assumed here that the cost to observe the fire is trivial since it is very hard for the private agent to claim there is no fire once the fire outbreaks. The cost of observing the afforestation activity is increasing with the size of the public forestland since it's found that with the larger size of the concession, it is more difficult for the government to supervise. For our analytical simplicity, we assume the total agency cost for observing newly planted trees is  $\rho(1 - \delta)$ , where  $\rho$  measures the capability of the government to audit the concession operation in plantation. The agency cost of observing the resource rent, or the cost for the government to monitor the amount of timber logged in the economy is assumed to be  $M(x, t)$ , where  $t$  measures the monitoring technology. The difficulty of observing the logging

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<sup>2</sup>The function form assumes that the forest grows at an exponential rate, which is not a necessary condition for the following conclusion. If it is assumed here that the forest grows at a logistic way, the conclusion still holds. In order to simplify the notation, we stick to the exponential rate here.



activity is increasing with the amount of timber and decreasing with the better monitoring technology. We assume  $M'_x(x, t) > 0$ ,  $M'_t(x, t) < 0$ ,  $M''_{xx}(x, t) > 0$  and  $M''_{xt}(x, t) < 0$ .

Considering the benefits and costs from both the contracted out land and the privatized land, the total payoff of the government can be written as

$$a(1 - \delta)[px + \lambda(\theta V_{t-1} - x + e)] + a \cdot \delta \cdot \lambda \cdot (-x) - \rho(1 - \delta) - M(x, t) - \alpha_0 - a(1 - \delta)[\alpha \cdot px + \beta(\theta V_{t-1} - x + e)] + \mu U \quad (3)$$

where  $a$  is the probability of bad states, such as the fire or insect outbreak;  $\mu$  is the weight of the representative agent's utility in the social welfare function and  $U$  is their utility. It is assumed that  $\mu \in [0, 1)$  due to the dead weight loss of the transfer and because of the government's preference for their direct payoff.

### 3.2. The private agent

In the economy, there is one representative agent, or a group of people, who can act as the private people managing the privatized land or the management team. The amount of land leased by the government to them is  $1 - \delta$ , while the amount of the private owned land is  $\delta$ .

The revenue for the representative agent contains two parts either from the contracted land or from their own land. Without any other risk, the management team will receive the shared profit and the subsidy from the government under the contracting regime, which is

$$(1 - \delta)[\alpha \cdot px + \beta(\theta V_{t-1} - x + e)]. \quad (4)$$

However, as widely known, the risk of extreme event, such as fire or insect outbreak is especially important in the management of forest resource. The outbreak of fire or insect will destroy the forest and it will take substantial time for the forest to regenerate. In some countries, the management team will be heavily punished in case of fire or insect break. The people managing the forest has to put substantial effort in preventing the forest from the outbreak of extreme event. It is reasonable to claim that the more effort is put in the preservation, the less probable the extreme event will break out. To catch the economic idea and simplify the analysis, we assume the probability of outbreak is a linear function of effort in preserving the forest which can be expressed as following

$$P(\text{extreme event}) = 1 - a, \quad (5)$$

where  $a$  is the effort in fire control, and  $a \in [0, 1]$ . If the fire outbreaks, the manager gets nothing. So the expected monetary revenue for the contracted out land is

$$a(1 - \delta)[\alpha \cdot px + \beta(\theta V_{t-1} - x + e)] . \quad (6)$$

However the expected revenue from the private land is assumed to depend only on selling timber, which is  $a \cdot \delta \cdot px$ .

Apart from the monetary payment from the action taken by the agent, they also suffer the disutility from the effort. To measure these effects, we take the conventional approach, and use  $\frac{1}{2}c_e e^2$  and  $\frac{1}{2}c_a a^2$  to represent the monetary measured disutility from the effort in afforestation and fire controlling respectively, where  $c_e$  and  $c_a$  measures the ability or skill levels of the agent in afforestation and preservation. For example, the manager with more experience in fire control has lower cost implementing the same task, the manager with more human capital or knowledge in afforestation has low cost planting the same seedlings. More specifically, the less  $c_e$  and  $c_a$ , the more able they are in afforestation and controlling fire. So, the overall objective function of the representative private agent can be written as

$$U = \alpha_0 + a(1 - \delta)[\alpha \cdot px + \beta(\theta V_{t-1} - x + e)] - \frac{1}{2}c_e e^2 - \frac{1}{2}c_a a^2 + \delta \cdot a \cdot px \quad (7)$$

where  $\alpha_0$  is the fixed payment to the private agent to assure their participation in the contract, or the survival due to the limited liability<sup>3</sup>.

Under the condition when the government can't observe the amount of effort in afforestation and fire control put by the private agent, the private agent can always choose the effort to maximize their utility. First order conditions for the agent are then

$$(1 - \delta)[\alpha \cdot px + \beta(\theta V_{t-1} - x + e)] + \delta \cdot px - c_a a = 0, \quad (8)$$

and

$$a(1 - \delta)\beta - c_e e = 0. \quad (9)$$

The economic intuition for the first order condition is straightforward. The first equation indicates that the representative agent will increase efforts in preserving forest until the marginal benefit contributed by the decrease of the likelihood of extreme event including the benefit from the contracted land  $(1 - \delta)[\alpha \cdot px + \beta(\theta V_{t-1} - x + e)]$  and the benefit from the private land  $\delta \cdot px$ , equals the marginal disutility  $c_a a$ . At the mean time, the representative agent will choose the amount of effort in afforestation at the margin where the expected marginal subsidy from afforestation activity  $a(1 - \delta)\beta$  equals the marginal disutility from the effort  $c_e e$ .

#### 4. The structure of incentive contract and the choice of tenure reform

As discussed above, the programming problem for the government, as the regulator is to choose the proportion of land to privatize, allocate the logging

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<sup>3</sup>Since the benefit and cost of private owned forest land only contains harvest and fire control decisions, we do not model the afforestation decision of private agent, which is believed to be very important in the long run (Hyde, Amacher, and Magrath, 1996).

quota and design the structure of incentive contract to maximize their payoff, which is the weighted average of the welfare of the representative agent and the direct welfare of the government including the economic, and environmental benefits, the agency cost, the expense paid to the private agent.

$$\begin{aligned} & a(1 - \delta)[px + \lambda(\theta V_{t-1} - x + e)] + a\delta\lambda \cdot (-x) - M(x, t) - \rho(1 - \delta) \\ & - \alpha_0 - a(1 - \delta)[\alpha \cdot px + \beta(\theta V_{t-1} - x + e)] + \mu U \end{aligned} \quad (10)$$

However, the contract designed by the government has to ensure the private agent's survival or participation in the game, otherwise they would quit from the contract and find some other opportunities, that implies the programming as to fulfill the following individual rationality constraint,

$$U = \alpha_0 + a(1 - \delta)[\alpha \cdot px + \beta(\theta V_{t-1} - x + e)] - \frac{1}{2}c_e e^2 - \frac{1}{2}c_a a^2 + \delta \cdot a \cdot px \geq 0 \quad (11)$$

The unobservability of the actions taken by the private agent due to the information asymmetry implies the decision of the government facing the constrain (8) and (9).

**Lemma 1,** The individual rationality constrain (11) has to be binding for the programming problem of the government.

**Proof:**

Suppose that the constrain (11) is not binding under the optimal contract chosen by the government. By designing a new contract with less fix payment  $\alpha'_0$  and the same subsidy  $\beta$  and sharing scheme  $\alpha$ , where  $\alpha'_0$  is such that the constrain (11) still holds, the government can increase its payoff by  $(1 - \mu)(\alpha'_0 - \alpha_0)$ , that is contradictory to the assumption that the original contract is optimal. QED

From Lemma 1, after Substituting for  $\alpha$  and  $\beta$ , and rearranging the equation, the problem is equivalent to the following decision problem,

$$\begin{aligned} Max_{(a, x, \delta, e)} \Omega(y, \tau) &= a(1 - \delta)[px + \lambda(\theta V_{t-1} - x + e)] + a \cdot \delta \cdot x \cdot (p - \lambda) \\ &\quad - \rho(1 - \delta) - M(x, t) - \frac{1}{2}c_e e^2 - \frac{1}{2}c_a a^2 \end{aligned} \quad (12)$$

Assuming interior solution, the first order conditions for the programming problem above are,

$$\frac{\partial \Omega}{\partial a} = (1 - \delta)[px + \lambda(\theta V_{t-1} - x + e)] + \delta x(p - \lambda) - c_a a = 0 \quad (13)$$

$$\frac{\partial \Omega}{\partial x} = a(1 - \delta)(p - \lambda) + a\delta(p - \lambda) - M'_x(x, t) = 0 \quad (14)$$

$$\frac{\partial \Omega}{\partial e} = (1 - \delta)a\lambda - c_e e = 0 \quad (15)$$

$$\frac{\partial \Omega}{\partial \delta} = -a(px + \lambda(\theta V_{t-1} - x + e)) + ax(p - \lambda) + \rho = 0 \quad (16)$$

**Lemma 2:** If  $p \leq \lambda$ , then  $x^* = 0$ .

**Proof:**

Since

$$\frac{\partial \Omega}{\partial x} = a(p - \lambda) - M'_x(x, t)$$

, if  $p \leq \lambda$ ,  $\Omega$  must be a decreasing function of  $x$ . From the assumption that  $x$  belongs to  $[0, \infty)$ , we have that the optimum point located at  $x^* = 0$ .

Lemma 1 says that if the total economic benefits from the timber can't compensate the environmental and ecological loss from the logging, it would be better to stop logging from the government point view.

**Proposition 1:**  $\Omega$  is a supermodular function in  $(a, x, -\delta, e)$  on the domain where  $p > \lambda$ ; if  $p \leq \lambda$ ,  $\Omega$  is a supermodular function in  $(a, -\delta, e)$  at  $x^* = 0$ .

**Proof:**

From the theorem 6 in Milgrom and Shannon(1994), we can conclude that if for the twice differentiable function  $\Omega(y, \tau)$ ,

$$\Omega''_{y_i y_j} \geq 0$$

for any  $i \neq j$ , then  $\Omega(y, \tau)$  is a supermodular function in  $y$ . So, what we need is to check the cross derivatives of  $\Omega$  over  $y$ . If  $p \leq \lambda$ , from lemma 1, we have  $x^* = 0$ , so in this case, we only have to check the cross derivatives of  $\Omega$  with respect to  $(a, -\delta, e)$ . The confirmation of the nonnegative sign of the cross derivatives when  $p \leq \lambda$  and  $p > \lambda$  can be found in the appendix I.QED

The supermodular function has some nice properties in generating comparative statics results, which are very important in the empirical part for testing the hypothesis. The comparative statics results are summarized in the next proposition.

**Proposition 2:**  $(a, x, -\delta, e)$  are monotone nondecreasing in the parameters  $(p, -c_e, -c_a, t, -\rho, \theta, V_{t-1})$  if  $p > \lambda$ ; and  $(a, -\delta, e)$  are monotone nondecreasing in the parameters  $(p, -c_e, -c_a, \lambda, t, -\rho, \theta, V_{t-1})$  given  $p \leq \lambda$ .

**Proof:**

According to the theorem 6.1 from Topkis(1978) or the theorem 5 from Milgrom and Shannon(1994), it follows that if  $\Omega(y, \tau)$  is a supermodular function in  $y$  and has nondecreasing difference in the variables  $(y, \tau)$ , then

$$\operatorname{argmax}_{y \in Y} \Omega(y, \tau)$$

is monotone nondecreasing with respect to  $\tau$ . Since the nondecreasing difference in  $(y, \tau)$  is equivalent to  $\Omega''_{y_i \tau_j} \geq 0$  for  $i = 1, \dots, n; j = 1, \dots, m$  for the twice differentiable function, we only need to prove the nonnegative sign of  $\Omega''_{y_i \tau_j}$ . From lemma 1 if  $p \leq \lambda$ ,  $x^* = 0$ , we only need to consider the case when  $y = (a, -\delta, e)$ . The rest of the proof is left in the Appendix II. QED

To discuss the intuition behind this proposition, suppose resource rents increase and let's check its effect on the decision of the government and the agent. The agent's incentive to control fire will increase due to the immediate increase of marginal benefits following the rise of resource rents. The agent can take two actions in response to the increase of resource rents: to exert less efforts in afforestation so that the subsidy from environmental benefits will be reduced and subsequently the marginal benefit will decrease, or to put more effort in controlling fire so that the marginal cost of controlling fire will increase. Since to reduce the effort in afforestation is not in the interest of the agent, he will choose to exert more efforts in controlling fire to increase his utility<sup>4</sup>. How would the government adjust their policy parameters? As the effort in afforestation and fire control increases, it becomes less preferable for the government to allocate more land to the agent since the marginal revenue from privatizing public forest lands is negative now. They will hold larger proportion of forest lands to compensate the effect of the price increase on the effort in afforestation and fire control.

The effect of environmental importance of forests on the decision to log timber, to plant forests and to privatize is slightly different. When the environmental benefit is higher than the resource rent, the amount of timber harvest will be set to be zero. In this case, the marginal revenue to allocate the land to private agents will be less than zero as the environmental benefit increases, that creates the incentive to reduce the amount of private forest lands. The marginal benefit of afforestation will become larger than its marginal cost with less private lands and larger environmental benefits, in respond to that the private agent could either reduce their effort in controlling fire or increase their effort in afforestation. However, it is not a rational response to reduce their effort in controlling fire since such a response will create positive margin to control fire<sup>5</sup>.

<sup>4</sup>To see why this is true, we can substitute the effort in afforestation,  $e$  in equation (9) into equation (8) and cancel out  $e$ , that leads to the following equation  $(1 - \delta)[\alpha \cdot px + \beta(\theta V_{t-1} - x)] + \delta \cdot px - [c_a c_e - (1 - \delta)^2 \beta^2]a/c_e = 0$ . From the second order condition to maximize (7), we conclude that  $c_a c_e - (1 - \delta)^2 \beta^2 > 0$ , so the effort in controlling fire,  $a$  will increase. From equation (9), obviously  $e$  must also increase simultaneously and it is not in the interest of the agent to reduce the effort in afforestation.

<sup>5</sup>Since  $(1 - \delta)\lambda$  will increase following the rise of environmental benefits, if the private agent reduce the effort in fire control,  $a$  the marginal revenue to control fire,  $(1 - \delta)\lambda\theta V_{t-1} - [c_a c_e -$

When the resource rent is higher, the incentive to own more public forest lands by the government and allocate larger logging quota will increase and it is not in the interest of the government any more to impose logging ban. However, the effect on the effort in afforestation and fire control is ambiguous since we can't tell whether the marginal benefit to control fire increases or not. If the amount of timber logged is small or the forest stock increase is large so that the marginal benefit will rise, then both the effort in fire control and afforestation will increase. If on the other hand, a large amount of timber is harvested and the forest grows very slow, then the private agent will reduce their effort in fire control and afforestation.

**Proposition 3:**  $\beta = \lambda$  and if  $p > \lambda$ , then  $1 - \alpha = \frac{\delta\lambda}{p(1-\delta)}$ .

**Proof:**

From the incentive compatible conditions, we have

$$a(1 - \delta)\beta - c_e e = 0 \quad (17)$$

. The optimization problem for the government implies one of the necessary conditions,

$$\frac{\partial \Omega}{\partial e} = (1 - \delta)a\lambda - c_e e = 0 \quad (18)$$

. From the two equations, it immediately follows  $(1 - \delta)a\lambda = (1 - \delta)a\beta$ . The first order condition for incentive compatible contracts implies

$$(1 - \delta)[\alpha \cdot px + \beta(\theta V_{t-1} - x + e)] + \delta \cdot px - c_a a = 0 \quad (19)$$

. Check the necessary condition for the optimization problem of the regulator, we can get

$$(1 - \delta)[px + \lambda(\theta V_{t-1} - x + e)] + \delta x(p - \lambda) - c_a a = 0. \quad (20)$$

The two equations imply

$$(1 - \delta)[(1 - \alpha)px + (\lambda - \beta)(\theta V_{t-1} - x + e)] = \delta\lambda x. \quad (21)$$

The left hand side of the equation is the marginal expected benefit of fire control from the government owned land, while  $\delta \cdot \lambda \cdot x$  is the marginal gain of fire control from the privatized land. The equation says that the implanted effort in controlling fire has to equalize the marginal expected benefit from the land owned by the government and the marginal gain from the privatized land. Given that  $x \neq 0$ , it follows that  $p(1 - \delta)(1 - \alpha) = \delta\lambda$ . From Lemma 1, the sufficient condition for  $x \neq 0$  is that  $p > \lambda$ . QED

Proposition 3 determines how the subsidy for the afforestation effort should be set for the government owned forest. The agent will increase their effort until

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$(1 - \delta)^2 \lambda^2]a/c_e$  will become positive, which means that reducing effort in fire control will not be rational since the utility will decrease.

her marginal cost equals the marginal benefit which is the subsidy she gets. If the subsidy is set higher than environmental benefits, the agent will exert more effort in afforestation. Since it is costly for the regulator to compensate the agent for its effort and he will choose the most preferred effort which equalize its marginal benefits  $(1 - \delta)a\lambda$  with its marginal cost  $c_e e$ . It would be beneficial for the regulator to reduce the subsidy and induce less effort in afforestation.

How large should the share of resource rents be kept by the government? Since the contract was set such that the marginal benefit of controlling fire including the shared resource rent from sold timber and subsidy from the government from the public forest and the profit from logging from the private forest for the representative private agent equals the social benefit of controlling fire which is total resource rent minus the benefit from environmental services. Given that the subsidy to the preservation is set to marginal social benefits of preservation efforts, the share of resource rent have to be set such that the loss of environmental benefits caused by the logging in the private forest will equal the resource rent the government get from the public forest.

**Corollary 1:**

$\alpha$  is monotone nondecreasing in the parameters  $(p, -c_e, -c_a, t, -\rho, \theta, V_{t-1})$ .

**The choice among the incentive contract and tenure reform:**

We discuss the interior solution for the choice of land property rights status above. It only deals with the situation where the government will allocate parts of forest land to private people. It would be possible for the government to privatize all the forest land or own all the forest land. We discuss the corner solution in the next proposition.

**Proposition 4.** *There exists a locus  $(p^*, \lambda^*)$ , such that if  $p < p^*$ ,  $\delta = 1$ ; and if  $p > p^*$ , then  $\delta = 0$ ; under the condition  $p \leq \lambda$ , if  $\lambda > \lambda^*$ , then  $\delta = 0$ ; and if  $\lambda < \lambda^*$  then  $\delta = 1$ .*

**proof:**

From the first order condition, we have  $a\lambda - c_e e = 0$ . The sufficient condition for  $\delta = 1$  is that

$$-a(px + \lambda(\theta V_{t-1} - x + e)) + ax(p - \lambda) + \rho > 0 \quad (22)$$

which is equivalent to  $-c_e e^2 - c_e \theta V_{t-1} e + \rho > 0$ . Let  $e^*$ , such that  $-c_e e^{*2} - c_e \theta V_{t-1} e^* + \rho = 0$ , then

$$e^* = \frac{\sqrt{(\theta c_e V_{t-1})^2 + 4c_e \rho} - \theta c_e V_{t-1}}{2c_e}. \quad (23)$$

Since  $-c_e e^2 - c_e \theta V_{t-1} e + \rho$  is a decreasing function in  $e$ , if  $e(\tau) < e^*(\rho, \theta, c_e, V_{t-1})$ , then  $\delta = 1$ . The rest of the proof is easily concluded from the proposition 2. QED

Proposition 4 says that the government decision whether or not to privatize a specific piece of forest land depends on the economic profitability and the

environmental importance. Given the same environmental service two pieces of forest land provide, once the economic profitability of one land is little enough, the government will allocate it to the private, however, if the economic profitability is bigger enough, they will keep the land. The same is true if the forest provides different environmental service and has similar economic profitability.

## 5. Empirical Analysis

### 5.1. Hypothesis and Econometric Model

It is concluded in the proposition above that the resource rent and environmental benefit will have very significant effect on the decision whether the government will privatize public forest lands. As the resource rent increases, the government is less opt to privatize the land and tends to have hold more public forest lands. However, if the environmental importance of the land decreases, the government will have the incentive to allocate the land to the private agent. These conclusions are very much consistent with the overall management regime change in China's forest sector over the last two decades. In the initial stage of the reform, a large amount of forest lands, especially the barren land previously owned by the government were allocated to the household. However, the price of timber increased a lot as the reform proceeded, the Chinese government claimed that the price increase would cause the household to harvest timber, which would lead to a large scale of deforestation. So they slowed down, and even stopped the process of allocating the use right to households and implementing the decollectization, in some area, they even took back the forest land which has already been managed by households. Until now, the government still owns a very large proportion of forest lands, among which most are economic profitable and some of them are located in environment sensitive areas.

To test the hypothesis implied from the proposition and the story above empirically, we set up the following linear econometric equation:

$$y_{it} = \alpha_0 + \alpha_1 * p_{it} + \alpha_2 * \lambda_{it} + \gamma' x_{it} + v_{it} \quad (24)$$

where  $y_{it}$  measures the property right status of forest lands,  $p_{it}$  measures the resource rent,  $\lambda_{it}$  represents the environmental importance and  $x_{it}$  are a set of control variables. Our primary interest is to check the significance and sign of the parameter  $\alpha_1$  and  $\alpha_2$ .

We use the proportion of forest lands managed by households as the measurement for  $y_{it}$ . Among these forest lands, there are two different kinds of forest: managed forest and natural forest. We construct three measures for  $y_{it}$ : the proportion of managed forest lands, natural forest lands and all forest lands managed by households. As discussed in the second section, the property right of forest lands managed by households is much more secure than that of state owned forest lands since the household holds the use right of their land for a very long time, up to 50 years and with the possibility to transfer and high priority to continue their right, however, the contract between the management



and the government to manage the state owned forest is subject to frequent negotiation and termination.

We use the information on the price of timber, i.e, the nominal price<sup>6</sup> divided by the cost of living index and the quality of forest as proxies for resource rents  $p_{it}$ . The price reflects the scarcity of timber, and has direct impact on the revenue of the agent. Definitely, it will convey the information on the stumpage value per unit of timber. However, since the resource rent is equal to the difference between the price and the extraction and delivery costs for the logs, one has to be aware of its imperfection as a proxy. Another proxy for resource rents in the regression for over all forest is the ratio of natural forest land among the total forest land. Since the quality of managed forest is much lower than the natural forest, the ratio measures the quality of forest, hence provides the information on the profitability of the forest<sup>7</sup>.

To measure the environmental importance  $\lambda_{it}$ , we use two variables i.e, the location of forest and the income per capital. The location of the forest is an important determinant of its environmental benefits. Whether the forest is located in the environmental vulnerable area has been one of the main concerns for the government's decision. We use the dummy variable whether the forest is located in the upper basin of Yangtze or Yellow river as the measurement of its environmental importance. Since with the increase of income per capital, the demand for the environmental service from forest will increase, the environmental service of forest will become more important. We expect that the government will have less incentive to allocate the use right of forest land to rural households as the demand for environmental services increases.

Other control variable in the model include the process of rural household responsibility in the agricultural sector. The process of the adoption of household responsibility system in the agricultural sector has been one of the main impetus for the similar reform in the forest sector. We expect that it has significant positive impact on the tenure reform in the forest sector.

## 5.2. The Data

The empirical analysis uses data from various sources. The main source of data for our empirical analysis comes from China's National Forestry Census data. The forestry census contains information of state forest area and timber volume with the information about tenure. The data has been used by some researchers in analyzing Chinese forest resource dynamics, and has been found to be one of the few consistent data about Chinese forest. There are several reasons that it might be true. Firstly, the primary aim to conduct the censuses is to aid the government to evaluate the country's state forest status, instead of as an evaluation criterion for the performance of local officials. Second, aware of the misreporting from the local state forests, the Chinese government has implemented five rounds of independent national forest resource

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<sup>6</sup>Since the price for timber largely depends on the quality and varieties of timer, we use the price index for timber in our calculation.

<sup>7</sup>We don't include this variable in the regression of managed forest and natural forest since we are not able to find good arguments for the ratio of natural forest containing the information to the managed or natural forest.

censuses across 28 provinces in the mid of 1970s (QGSLZYTJ 1976), late 1970s to early 1980s (QGSLZYTJ 1983), mid to late 1980s (QGSLZYTJ 1989), early 1990s (QGSLZYTJ 1994) and late 1990s (QGSLZYTJ 1998). Third, these National Forestry Censuses relied on direct observation techniques and sampling the same permanent sites in each census, and the survey results did not pass through the governmental hierarchy, which is very often a big concern for the researcher using the Chinese official data. We then match the forestry data with provincial social and economic characteristics. Our data on the price is from China Market Yearbook (CRSY) at various years. The data on income per capital and the process of the adoption of rural household responsibility are from China Statistical Yearbook (SSB) and China Rural Statistical Yearbook at various years respectively.

The descriptive statistics for the main variables in our regression are presented in table 1. Since the first survey doesn't contain any tenure information, we only analyze the data for 28 provinces over later four periods, which contains 112 observations. Table 1 shows that the mean value of the percent of managed forest, natural and over all forest allocated to household are 68%, 57% and 60%. To have some further information about the forest coverage in China, a more disaggregate result for two typical areas in China is presented in table 2. From table 2, the general pattern of forest cover change can be observed (1) in northeastern China, the natural dominates the forest and the government owns most of the natural forest, however, the percent of either managed or natural collective<sup>8</sup> forest is growing, (2) in southern China, the forest is mainly managed by households, which leaves the magnitude of change very small.

#### 5.4. The result

Table 3 and table 4 report results for the regression of the percent of forest land decentralized to households and communities for managed forest, natural forest and over all forest. We run OLS regression first and the results are presented in table 3. The concern for possible regional heterogeneities leads us to include regional dummies in the equation and run similar regressions, and the results are presented in table 4<sup>9</sup>. Given the limited number of observations for our sample, the high overall fitness for regressions are quite unexpected. The overall fitness for natural forest and overall forest is especially high, and more than half of the variation of natural forest and overall forest tenure change can be explained in some of the regressions.

The significance of the variable, location holds under most specifications except the case when regional dummies are included in the regression and the

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<sup>8</sup>the term "collective" in China means that the use right of forest is allocated to and managed mainly by households.

<sup>9</sup>The coefficients for dummies are not included in our table due to limited space. One of the reasons why we use the regional dummies instead of provincial dummies is that once we include the provincial dummies in the regression equation, the measure for environmental importance will be canceled out. Another reason is that in the panel regression, the measure error will exacerbate the variance so that the t-statistics are underestimated. We do run a regression with fixed effects, from which we find that the sign of coefficients doesn't change, however, most of coefficients become insignificant.

proxy for tenure reform is the percent of managed forest allocated to households or communities, and the coefficient of log (income per capital) is also significant under a number of specifications, which suggest that the association is quite robust. The larger magnitude of the two coefficients and the stronger significance of the impact in the OLS regression suggest the need for the concern of heterogeneity. We will mainly refer to table4, especially column (1), (2) and (4) when we explain the results. The negative significant relationship between the location and the measure for tenure reform implies that in the environmental vulnerable area, the government will allocate less forest land to households or communities due to the larger concern for social benefits of environmental services from forest. Specifically, the government will allocate 8.8% less managed forest, 31.5% less natural forest and 26.3% less total forest to households or communities. The increasing willingness to pay for environmental services due to the increase of income per capital also requires the government to keep more public forest. If the income per capital doubles, the percent of overall public forest will increase by 6.8%. These results confirm our hypothesis of tenure reform process.

The impact of timber price on government decision to privatize the forest is significant both for natural and total forest, and the forest quality also has significant impact on the tenure reform process. These findings support the rent capturing hypothesis during the reform process. If the real price of timber increases by 1%, the government will have less incentive to decentralize the management of forest and allocate 0.065% less of natural forest and total forest to households or communities. The incentive to capture resource rents will lead the government to privatize 0.232% less when the forest quality is high.

The econometric results also suggest that the success of rural reform in the agricultural sector indeed has a strong and significant spillover effect on the reform in the forest sector. The relationship is significant in all the specifications. In the province where the agricultural reform proceeds faster in the early period of the reform, the government also implemented a faster and wider tenure reform in the forest sector. The coefficient of 0.21 in column4 of table4 implies that the government who adopted 1% higher of the agricultural household responsibility in agricultural sector will allocate 0.21% more of forest to households or communities.

Overall, the results in this subsection suggest that the proxies for environmental benefits and resource rents have significant effect on the process of tenure reform. Specifically, the government will allocate less forest land to local people when the environmental concern are more urgent, however, they will privatize more land if the economic benefits from the land are lower. The conclusions are quite robust under a number of specifications.

## 6. Conclusion

This paper analyzes the issue whether the government should privatize the forest land or use the contracting approach to manage the forest resource. These two regimes reflect key institutional features in some developing countries, i.e.,

the household based property rights and the state owned or concessioned forest. In the context of Chinese management transition, we develop a model of the regulatory game where the government has two policy options and the private has multitasks. The analytical results confirm the basic intuition that the relative importance between the environmental benefit and the economic rent of the forest affects the decision of the government in a great deal. As the resource rent increases, the government is less opt to privatize the land and tends to have hold more public forest lands. However, if the environmental importance of the land decreases, the government will have the incentive to allocate the land to the private agent. For the land with different environmental benefits and economic profitability, it would be more beneficial for the government to privatize the land with less economic rents and less environmental benefits. The share of the resource rent kept by the government is based on the proportion of the land privatized and the relative importance between the environment benefit and the economic rent. Specifically, with less public forest lands or the more important environmental benefit, the government will capture larger share of economic rents. For the land of which the environmental benefit is higher, it is rational for the government to impose the logging ban. The government as the regulator may also select the more able people with high ability to manage forest lands as a substitute tool for the privatization.

Both the rent capturing hypothesis and environmental concern hypothesis are confirmed in our empirical analysis by using the data from China, which implies that the main conclusions from our theoretical part are very much consistent with the overall management regime change in China's forest sector over the last two decades. In the initial stage of the reform, a large amount of forest lands, especially the barren land previously owned by the government were allocated to the household. However, as the price of timber increased a lot following the reform, the Chinese government claimed that the price increase would cause a large scale of deforestation. So the process of household responsibility reform, i.e., allocating the use right to households in forest sector was slowed down, and even was stopped in a number of areas. The variation of reform process in different places also reflects the government's concern for environmental benefits. In the area where the environment is vulnerable and the demand for environmental service is high, the government allocate less forest to households.

Appendix I:

$$\begin{aligned} \frac{\partial^2 \Omega}{\partial a \partial x} &= p - \lambda; \frac{\partial^2 \Omega}{\partial a \partial e} = (1 - \delta)\lambda; \frac{\partial^2 \Omega}{\partial a \partial (-\delta)} = \lambda(\theta V_{t-1} + e); \\ \frac{\partial^2 \Omega}{\partial e \partial x} &= 0; \frac{\partial^2 \Omega}{\partial (-\delta) \partial x} = 0; \frac{\partial^2 \Omega}{\partial (-\delta) \partial e} = a\lambda \geq 0. \end{aligned}$$

Appendix II :

$$\frac{\partial^2 \Omega}{\partial p \partial a} = x \geq 0; \frac{\partial^2 \Omega}{\partial p \partial x} = a \geq 0; \frac{\partial^2 \Omega}{\partial p \partial (-\delta)} = 0; \frac{\partial^2 \Omega}{\partial p \partial e} = 0;$$

$$\begin{aligned} \frac{\partial^2 \Omega}{\partial \lambda \partial a} &= (1 - \delta)(\theta V_{t-1} - x + e) - \delta x; \frac{\partial^2 \Omega}{\partial \lambda \partial x} = -a; \frac{\partial^2 \Omega}{\partial \lambda \partial (-\delta)} = a(\theta V_{t-1} + e); \frac{\partial^2 \Omega}{\partial \lambda \partial e} = \\ &a(1 - \delta); \end{aligned}$$

$$\frac{\partial^2 \Omega}{\partial t \partial a} = 0; \frac{\partial^2 \Omega}{\partial t \partial x} = -M''_{xt}(x, t) \geq 0; \frac{\partial^2 \Omega}{\partial t \partial (-\delta)} = 0; \frac{\partial^2 \Omega}{\partial t \partial e} = 0;$$

$$\frac{\partial^2 \Omega}{\partial \theta \partial a} = (1 - \delta)\lambda V_{t-1} \geq 0; \frac{\partial^2 \Omega}{\partial \theta \partial x} = 0; \frac{\partial^2 \Omega}{\partial \theta \partial (-\delta)} = a\lambda V_{t-1} \geq 0; \frac{\partial^2 \Omega}{\partial \theta \partial e} = 0;$$

$$\frac{\partial^2 \Omega}{\partial V_{t-1} \partial a} = (1 - \delta)\lambda \theta \geq 0; \frac{\partial^2 \Omega}{\partial V_{t-1} \partial x} = 0; \frac{\partial^2 \Omega}{\partial V_{t-1} \partial (-\delta)} = a\lambda \theta \geq 0; \frac{\partial^2 \Omega}{\partial V_{t-1} \partial e} = 0;$$

$$\frac{\partial^2 \Omega}{\partial (-\rho) \partial a} = 0; \frac{\partial^2 \Omega}{\partial (-\rho) \partial x} = 0; \frac{\partial^2 \Omega}{\partial (-\rho) \partial (-\delta)} = 1 \geq 0; \frac{\partial^2 \Omega}{\partial (-\rho) \partial e} = 0;$$

$$\frac{\partial^2 \Omega}{\partial (-c_a) \partial a} = a \geq 0; \frac{\partial^2 \Omega}{\partial (-c_a) \partial x} = 0; \frac{\partial^2 \Omega}{\partial (-c_a) \partial (-\delta)} = 0; \frac{\partial^2 \Omega}{\partial (-c_a) \partial e} = 0;$$

$$\frac{\partial^2 \Omega}{\partial (-c_e) \partial a} = 0; \frac{\partial^2 \Omega}{\partial (-c_e) \partial x} = 0; \frac{\partial^2 \Omega}{\partial (-c_e) \partial (-\delta)} = 0; \frac{\partial^2 \Omega}{\partial (-c_e) \partial e} = e > 0;$$

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Table 1. Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Tenure managed <sup>1</sup>	112	0.68	0.23	0.001	0.971
Tenure natural	112	0.57	0.37	0.000	0.970
Tenure overall forest	112	0.60	0.32	0.001	0.970
HH respon system	112	0.85	0.30	0.00	1.00
Timber price	112	1.47	0.58	0.59	4.35
Income per cap <sup>2</sup>	112	13.95	15.42	2.04	114.01
Ratio of natural	112	0.65	0.26	0.001	0.97

<sup>1</sup> percent of managed forest allocated to household.

<sup>2</sup> income per capital is calculated from real GDP at 1978 price level divided by the total population.

Unit: hundred Yuan.

Table 2. The Forest Cover in China

	<i>1977-1981 Forest Inventory</i>			<i>1994-1998 Forest Inventory</i>		
	Collective	State-owned	Percent of collective	Collective	State owned	Percent of collective
All China						
Over all	38.41	52.02	0.42	67.76	57.41	0.54
Managed	8	4.74	0.63	21.55	7.62	0.74
Natural	30.41	47.28	0.39	46.21	49.79	0.48
Northeast Region <sup>1</sup>						
Over all	2.94	33.64	0.08	6.21	36.25	0.15
Managed	0.89	2.36	0.27	3.28	3.4	0.49
Natural	2.05	31.28	0.06	2.93	32.85	0.08
South Regions <sup>2</sup>						
Overall	24.14	3.52	0.87	39.8	4.9	0.89
Managed	5.3	0.94	0.85	13.03	2.52	0.84
Natural	18.84	2.58	0.88	26.77	2.38	0.92

All areas in million ha.

<sup>1</sup> Heilongjiang, Jilin, and Inner Mongolia

<sup>2</sup> Fujian, Guangdong, Guangxi, Guizhou, Hainan, Hubei, Hunan, Jiangxi, Zhejiang, and Anhui

Source: China Forestry Inventory Statistics (1977-81, 1994-98)

Table 3. OLS Regression Result<sup>1</sup>

	(1)	(2)	(3)	(4)
	managed	natural	overall 1	overall 2
household	0.324	0.328	0.310	0.388
respon system	(4.07)***	(2.98)***	(3.12)***	(4.13)***
timber price	-0.031	-0.095	-0.087	-0.096
	(0.83)	(1.81)*	(1.83)*	(2.18)**
Log (income	-0.058	-0.093	-0.080	-0.174
per capital)	(2.05)**	(2.38)**	(2.28)**	(4.44)***
location	-0.135	-0.593	-0.485	-0.452
	(2.51)**	(7.96)***	(7.21)***	(7.19)***
ratio of				-0.475
natural forest				(4.30)***
Constant	0.604	0.753	0.730	1.195
	(7.71)***	(6.95)***	(7.46)***	(8.47)***
Observations	112	112	112	112
R-squared	0.16	0.39	0.35	0.44

Absolute value of t statistics in parentheses

significant at 10%; \*\* significant at 5%, \*\*\* significant at 1%

<sup>1</sup>dependent variables: percent of forest allocated to households for various kinds of forest



Table 4. Regression Result with regional dummies included<sup>1</sup>

	(1) managed	(2) natural	(3) overall 1	(4) overall 2
household	0.188	0.176	0.192	0.210
respon system	(2.32)**	(1.90)*	(2.29)**	(2.55)**
timber price	-0.002 (0.06)	-0.065 (1.71)*	-0.057 (1.67)*	-0.065 (1.93)*
Log (income per capital)	0.002 (0.06)	-0.032 (0.79)	-0.042 (1.12)	-0.068 (1.79)*
location	-0.088 (1.54)	-0.315 (4.82)***	-0.258 (4.35)***	-0.263 (4.53)***
ratio of natural forest				-0.232 (2.36)**
Constant	0.523 (6.24)***	0.342 (3.58)***	0.416 (4.80)***	0.647 (5.01)***
Observations	112	112	112	112
R-squared	0.42	0.71	0.69	0.71

Absolute value of t statistics in parentheses

significant at 10%; \*\* significant at 5%, \*\*\* significant at 1%

<sup>1</sup>dummies are generated according to Northeast, North, Northwest, South, Southwest, East, Central and Municipality regions