

The Social Cost of Fiscal Federalism and the Depletion of China's Native Forests

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Abstract

China's key forested region is located in the northeast and consists of state forest enterprises which manage forest harvesting and reforestation. Deforestation is a major problem there and has resulted in several central government reforms. We develop a framework for assessing the social cost of state forest enterprise deforestation. We first develop a two-principal, one-agent model that fits the federalistic organization of state forests, in that state forest managers make (potentially hidden) decisions under influence of provincial and central government policies. This model is used to derive an expression of the social cost of these hidden actions. We then use panel data from a survey conducted by Peking University to compute social welfare losses and to formally identify the main factors in these costs. A sensitivity analysis shows that, interestingly, command and control through lower harvesting limits and a more accurate monitoring system are more important to lowering social welfare losses than conventional incentives targeting wages of forest managers. Through regression analysis we also find that the more remote areas with a higher percentage of mature natural forests are the ones that will always have the highest social welfare losses.

Keywords: Deforestation, Two-principal-one-agent model, Social welfare loss, Fiscal federalism

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1 Introduction

China's key forested region is located in the northeast and encompasses the Heilongjiang, Jilin, and Inner Mongolia provinces. This region has been the most important source of wood supplies since the 1950s and remains the most important wood basket of the country, producing over 20 million cubic meters of lumber per year, accounting for more than one half of the national total (Xu 2013). It has also been an area of historic and unprecedented degradation, where harvesting and high grading of forest stocks and lack of reforestation have been the rule for decades (Jiang et al. 2014).

Forest harvesting decisions within the Northeast Region are the responsibility of managers for state forest enterprises (SFEs). These are de facto government-owned entities and are managed by a director who receives wages and continued appointments from both local (provincial) and central governments based on harvest income generation. However, the director is, in theory, required to generate this income while staying within central government quotas on harvesting and reforestation. Meeting these quotas implies reduced tax revenue to local governments, less income to the SFE manager, and less regional economic growth.

Central government quotas were instituted during the market reforms of the 1980s to prevent further degradation of Chinese state forests. Despite their promise, deforestation has remained a constant concern, and state forest enterprises have been blamed for encouraging illegal logging and not meeting required reforestation targets for decades (Xu et al. 2004). One often cited reason for this is that, in the mid-1980s, SFEs faced resource and financial crises, and by the 2000s, ninety percent of state forests had almost depleted their mature forests (Xu 2013). The National Forest Protection Program (NFPP) was formally implemented in 2000 to address this deforestation; the NFPP required cessation of commercial harvesting on 670 million hectares of state-owned forest and increased SFE employee average annual income by over 300% or 4,400 USD.¹ The purpose was to reduce incentives for these SFE managers to generate income through illegal harvesting.

Despite these new reforms, strong incentives remained for SFE managers to deviate from central government quotas. These continue to represent a lingering feature of a now decentralized market economy but a continued centralized political system. The most important reason for the disincentive is that the salaries of SFE managers still depend in part on provincial governments. Provincial governments value harvesting for local economic growth, and as a result it is very likely that central and local governments do not have perfect incentives to cooperate. Local governments impacted by SFEs have incentives to pressure directors to increase harvesting and contribute to local economic growth and tax revenues. The central government, however, principally has sought to promote lower harvest quotas with at least some objective of conservation in mind. This incentive incompatible problem has been discussed many times in the literature and blamed for significant continued forest loss and lack of reforestation (Xu et al. 2004, Yi et al. 2017).

The incentive problems inherent in Chinese state forestry represent both an unusual type

¹The first phase of NFPP is from 2000 to 2010 and the second phase is from 2011 to 2020.

of mechanism design problem and a more classical problem of fiscal federalism in economics. Federalism is a consequence of the fact that central and local governments serve different constituents and face different revenue constraints. Additionally, the incentive problems do not fit into a standard hidden actions problem in mechanism design, which assumes a single principal attempting to control the performance of an agent using various instruments. The Chinese forestry problem is much more complex. Not only do SFE managers answer to the central government, but they also generate revenues for their local government. Both central and local governments impact the income of SFE managers through continued appointments and harvest revenue sharing. This type of problem is a two-principal, one-agent mechanism where actions of the SFE are hidden from one of the principals (central government). Thus, while the classic mechanism design problem leads to straightforward rules about using policy instruments to achieve first best outcomes, the impact of policies by any one government in the Chinese forestry case may not lead to a first best result.

In this paper, we determine the increase in social costs, and the factors affecting this increase, when a second best (federalistic) outcome arises in Chinese state forest management compared to a theoretical first best (perfect coordination) outcome. We use a two principal/single agent approach that reveals incentive problems inherent in the failures of local and central governments to coordinate with respect to SFE management. The consequences of these failures to deforestation and the choice of policies are also examined. Although our basic approach is static, we incorporate aspects of the dynamic problem where important, such as SFE manager income streams; our problem is also consistent with the observation that many policies, such as quotas or local taxes, are set and forget investments by governments. This allows focus on the incentive problems that the Chinese SFE system creates, as these would be present in similar fashions in more dynamic treatments of the problem. The importance of allowing for two governments who control policies and impact SFE managers differently is more important than the growth of the forest over time to the results. Moreover, the incentives we model would also not change in a more dynamic problem.

The problem of SFEs and deforestation has already been argued to be a case of Chinese-style fiscal federalism (Montinola et al. 1995; Qian and Weingast 1997; Xu 2011), but this work does not consider incentive problems among SFE managers. It has also been argued that hidden actions of SFE managers will always be present given that monitoring costs of the scale required of state forests is prohibitively high, making it impossible for the central government to receive a perfect signal of SFE practices (Xu et al. 2004). There is only one closely related article to our study that considers incentives of SFE managers in a two-principal, one-agent model (Yi et al. 2017). Yi et al. found that deforestation is more likely to happen in larger forest areas, as the monitoring cost is higher or profit sharing is higher. Their model focuses mainly on the decision making of the SFE manager. We add utility functions for the provincial government and the central government to analyze their decision making as well, and most importantly we develop an expression that represents the social costs of these interactions. We also investigate factors that influence these costs using data from SFEs in the Northeastern Region. Our analysis will therefore inform future discussions concerning the best instruments to achieve deforestation limits in China that are incentive

compatible.

Our work also contributes more broadly in three ways. First, environmental studies in China have found that pollution emissions are positively correlated with fiscal decentralization (Zhang et al. 2011). Hong et al. (2019) found that local government officials in China have a powerful motivation to ease environmental regulations for economic growth. Our paper shows the same motivation of prioritizing economic growth over forest protection in northeast state forests, but we also quantify this by computing social costs associated with poorly used policies. Second, this paper contributes to the general regulatory federalism literature, which has established that inefficiencies of imperfect coordination vanish when governments share revenues. In the forestry problem, the inefficiency occurs not only from coordination failures but also from hidden actions inherent in forest harvest monitoring, and the fact that forest stock can be thought of as a public good.² In the environmental literature, uniform standards are proposed to reduce interjurisdictional competition. However, regulation of SFEs are already based on a uniform standard system set by China’s State Forest Agency (SFA). The SFA has incomplete information on actual harvesting due to a high monitoring cost. As we will show, decentralization of the right to set harvest standards may actually be a solution for this incomplete information problem given that SFEs are fixed and cannot “move” across provinces.

The paper is structured as follows: Section 2 sets the theoretical framework of the model and introduces the idea of social cost in this context. In Section 3, we describe our data, calculate the social cost; and perform a sensitivity analysis of our results. A regression analyses of social cost factors is presented in Section 4. Our concluding comments are given in Section 5.

2 Theoretical Model

In this section we model differences in incentives of the SFE managers and the principals (local and central governments). We also develop a social cost function that depends on various policy and natural resource factors. Later we calculate social costs and study their determinants using data on multiple SFEs in Northeast China between 1980-2008.³

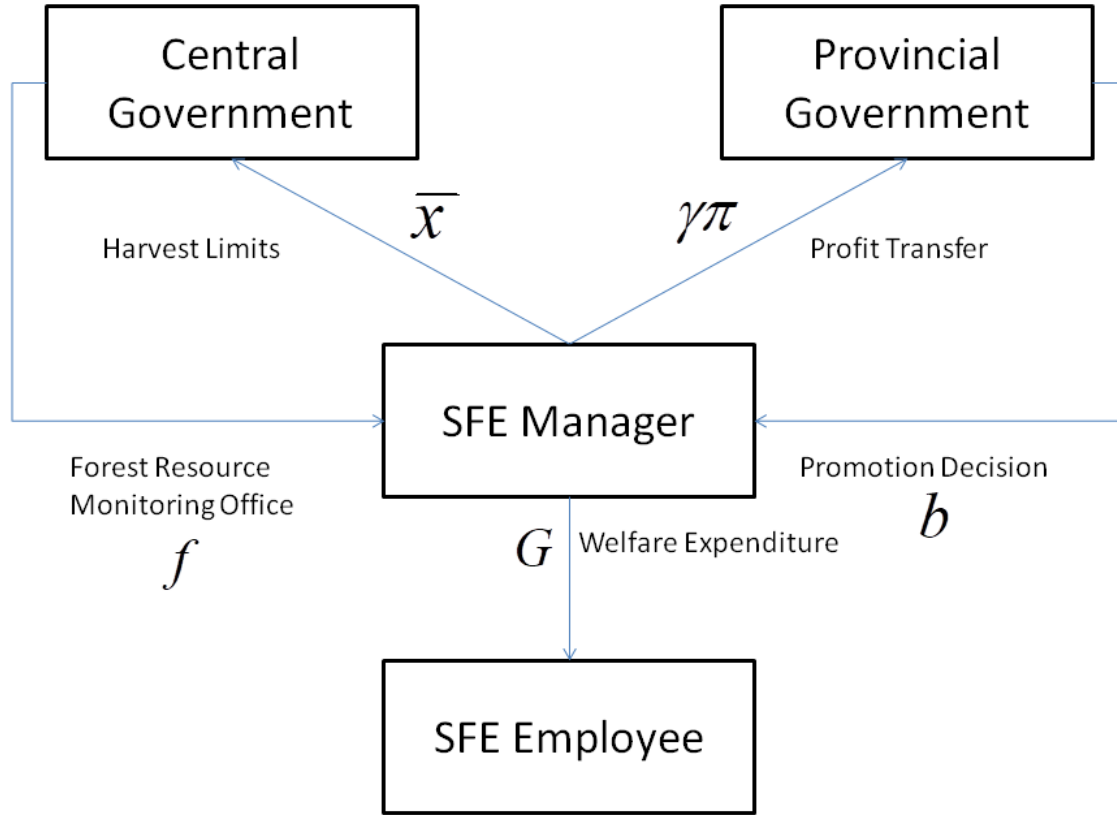


Figure 1: Two principal, one agent model of Chinese State Forest Enterprises

2.1 Two principal, one agent model

Figure 1 describes the organization of Chinese government forest management and the way in which transfers and harvesting decisions are made by the SFE manager and the provincial and central governments in practice. The agent is the SFE manager, serving two principals: the central government and the provincial government. The central government sets harvesting limits (quotas) (\bar{x}) to prevent negative forest growth rates (see Xu et al. (2002) for a

²Amacher (2002) previously showed that revenue sharing can actually create incentives of increasing public harvesting in a simple federalism model of U.S. national forest management.

³There are some examples that have considered multiple principals and agents in different contexts. Groenendijk (1997) used a two principal one agent model to describe corruption. In their model, one principal is corrupted and the other is not. A multi principal, one agent model is used in Delacote et al. (2014), who showed that the existence of multiple principals reduces information rents in a spatial game. Larsen (2007) used a two principal and one agent model for European Union trade negotiations involving South Africa for a different purpose than our work.

discussion of this policy in practice).⁴

The central government must employ costly monitoring of the SFE. If an SFE is found to be harvesting more than the limit, then a fine of f is imposed. The local government makes a promotion decision concerning the SFE manager. If promoted, the present value sum of all the future salary increases is assumed to equal b . To increase the chance of promotion, the SFE manager retains enough profit from harvesting to cover the welfare (wages plus benefits) expenditure (G) for SFE employees and transfers the remainder ($\gamma\pi$) to the provincial government. This creates incentives of over harvesting in that the SFE managers will likely pursue short-term profits.

The fact that provincial governments benefit from exploiting resources has support in related environmental literature for China. For example, Zhang et al. (2011) found that pollution emissions for local firms are positively correlated with fiscal decentralization, while Li and Chan (2016) found that small and medium state-owned enterprises spend less on pollution abatement. These studies support the fact that provincial governments are likely to act on their own and cooperate with state-owned enterprises to generate higher profits.

2.2 Solution of the two principal, one agent model

Yi et al. (2017) considered only the utility function of the SFE manager. We adjust the utility function to a quasilinear form and add the utility functions for the provincial and central governments. We use quasilinear specification because the financial part comes in a linear way, while the impact of harvesting and the harvesting limit come in nonlinearly. This is consistent with lots of utility functions in forest resources (Koskela and Ollikainen 1997; Amacher et al. 2002; Ovaskainen et al. 2006) including the Hartman problem used in rotation analysis (Hartman 1976).

2.2.1 Agent: SFE

We model wages in present value terms following Boskin (1974) and Menchik and Martin (1983). Thus, \bar{w} is the present value sum of all future wages for the SFE manager. The term b is the present value sum of all future wage increases if the manager is promoted. This term captures the present value of the net benefits of promotion. We assume that the manager is promoted with probability $(1 - \frac{1}{\gamma\pi})$. This probability increases in the rate of profit shared with the provincial government (γ) and the profit of the enterprise (π). The larger the profit transfer $\gamma\pi$ is, the more likely the manager will be promoted.

SFE profit depends on forest harvesting revenue and costs:

$$\pi = (1 - \tau)(Px - C(x)), \quad (1)$$

where x is the harvest amount chosen by the SFE manager, P is an exogenous price, $C(x)$ is the cost of harvesting⁵, and τ is a tax levied by the provincial government on harvesting

⁴There are documented examples where SFE managers have harvested significantly over these limits, however (e.g., Economy 1997; Alford and Shen 1997; Brandt and Zhu 2000).

⁵In our data, the cost function could in principle be different across SFEs.

profit. In addition to harvesting level, the SFE manager chooses γ , which defines the transfer of net profit π to the provincial government. A higher γ increases the chance of promotion.

The present value of the fine imposed by the central government if they catch the manager harvesting over the limit \bar{x} is $f \in (0, +\infty)$. Due to the high cost of perfect monitoring, the central government observes an imperfect signal of this harvesting level given by:

$$x^s = \mu(x) + \epsilon, \quad \epsilon \sim \mathcal{N}(0, \sigma^2). \quad (2)$$

In equation (2), the term $\mu(x)$ is a fraction of the actual harvesting level x , the term ϵ is a normally distributed random variable with mean 0 and standard deviation σ .

The cost function for monitoring is $m(\sigma)$ with $m'(\sigma) < 0$, thus, in order to receive a more accurate signal, the monitoring cost paid must be higher. The probability of the enterprise being fined is then defined by $(1 - e^{\bar{x} - x^s})$. Thus, and reasonably, the larger the gap of the harvest signal and the quota, the more likely an SFE will be caught and fined. This fits with previous literature suggesting that larger SFEs with higher harvesting levels are more likely to overharvest.

With the building blocks above, the SFE is represented by the manager who has an expected utility function given by:

$$EU = E \left[\bar{w} + b \left(1 - \frac{1}{\gamma\pi} \right) - f (1 - e^{\bar{x} - x^s}) \right]. \quad (3)$$

In what follows we will use the rule $E[e^{k\epsilon}] = e^{\frac{k^2\sigma^2}{2}}$, and therefore rewrite equation (3) as:

$$EU = \bar{w} + b \left(1 - \frac{1}{\gamma\pi} \right) - f \left(1 - e^{\bar{x} - \mu(x) - \frac{\sigma^2}{2}} \right). \quad (4)$$

The agent (SFE manager) maximizes their expected utility function by choosing γ and x . The first order conditions for this problem are:

$$\frac{b}{\gamma^2\pi} > 0; \quad (5)$$

$$\frac{b}{\gamma\pi^2}(1 - \tau)P - \frac{b}{\gamma\pi^2}(1 - \tau)C'(x) - f\mu'(x)e^{\bar{x} - \mu(x) - \frac{\sigma^2}{2}} = 0. \quad (6)$$

First, notice that equation (5) cannot be binding. Therefore the manager will choose the transfer γ to be as large as possible. Intuitively, the manager would like to transfer as much profit as possible to the provincial government in order to guarantee the highest possible chance of promotion.

The constraint on γ is $(1 - \gamma)\pi - G \geq 0$, where G is the welfare expenditure for the employees in the enterprise. The manager chooses a transfer rate that makes the enterprise's income cover its expenditure (in welfare terms).⁶ That is,

$$\gamma = 1 - \frac{G}{(1 - \tau)(Px - C(x))}. \quad (7)$$

⁶By law in China, SFEs provide social services for their localities (e.g., see Groves et al. 1995). This includes wages, housing, education, health care and pension benefits.

In equation (6), the SFE manager equates the marginal benefit of an additional unit of harvesting (first term) to the marginal cost of harvesting one more unit (second and third terms). From equation (6) and (7), the manager then solves for the optimal level of harvesting x^0 and transfer γ^0 .

Assuming as is convention that this maximization problem is concave, that is $\beta = \frac{\partial^2 EU}{\partial x^2} < 0$, we have the following comparative static results:

$$\frac{\partial x}{\partial b} = \frac{-(1 - \tau)(P - C'(x))}{\gamma\pi^2\beta} > 0; \quad (8)$$

$$\frac{\partial x}{\partial f} = \frac{\mu'(x)e^{\bar{x} - \mu(x) - \frac{\sigma^2}{2}}}{\beta} < 0; \quad (9)$$

$$\frac{\partial x}{\partial \bar{x}} = \frac{f\mu'(x)e^{\bar{x} - \mu(x) - \frac{\sigma^2}{2}}}{\beta} > 0; \quad (10)$$

$$\frac{\partial x}{\partial \sigma} = \frac{-f\sigma\mu'(x)e^{\bar{x} - \mu(x) - \frac{\sigma^2}{2}}}{\beta} > 0. \quad (11)$$

A higher promotion net benefit b increases the SFE manager's incentive to choose greater harvesting. A higher fine for exceeding the harvesting limit, if caught, leads to less harvesting. A more lenient harvesting limit obviously leads to increased harvesting because costly monitoring by the central government is less effective. Similarly, if the central government receives a less accurate signal (i.e., one with a higher variance), then there are also incentives for the SFE manager to increase harvesting and deforestation.

These results show the power of the disincentives involved in this problem, but also the critical parameters that the central government must consider in trying to achieve a better outcome that reduces social costs. Any parameter change that increases harvesting will, as we will show later, increase social costs through greater deforestation than is optimal relative to achieving the first best outcome.

2.2.2 Principal 1: the Provincial Government

Using backward induction, the provincial government knows x^0 and γ^0 , and uses these to solve for their best response, determining the net promotion benefit for the SFE manager, b . This can also be interpreted without loss as continued appointment of the manager. The provincial government's utility function is;

$$U_p = \gamma\pi + \tau(Px - C(x)). \quad (12)$$

Equation (12) includes two parts: $\tau(Px - C(x))$ is the tax paid by the SFE and $\gamma\pi$ is the profit transfer. The provincial government solves for the optimal b according to the following first order condition:

$$\frac{\partial U_p}{\partial b} = \frac{\partial \gamma^0}{\partial b}\pi^0 + \tau(1 - \gamma^0)(P\frac{\partial x^0}{\partial b} - C'(x^0)\frac{\partial x^0}{\partial b}) > 0, \quad (13)$$

where $\pi^0 = (1 - \tau)(Px^0 - C(x^0))$.

Equation (13) suggests that the provincial government wants to set b as large as possible, and thus so $b = \bar{b}$ (\bar{b} is the upper bound for b).

2.2.3 Principal 2: the Central Government

The central government's utility function is:

$$U_c = f(1 - e^{\bar{x} - \mu(x) - \frac{\sigma^2}{2}}) + S - \mu(x) - m(\sigma). \quad (14)$$

Equation (14) includes three parts: the fine income $f(1 - e^{\bar{x} - \mu(x) - \frac{\sigma^2}{2}})$, the forest stock benefit $S - \mu(x)$, and the monitoring cost $m(\sigma)$. The term $f(1 - e^{\bar{x} - \mu(x) - \frac{\sigma^2}{2}})$ is the expected income from using the fine.

The term $S - \mu(x)$ is the central government's utility function as a function of the forest stock, where S is the initial forest stock and $\mu(x)$ is the observed signal of SFE harvesting by the central government. They must use $\mu(x)$ in their utility function as they have incomplete information about actual harvesting. The term $m(\sigma)$ is the monitoring cost, where $m'(\sigma) < 0$; thus, a more accurate signal costs more for the central government to acquire.

The central government has the following choices here: the fine f , the harvesting limit \bar{x} , and indirectly the monitoring accuracy σ . The central government chooses f , \bar{x} and σ according to the following first order conditions:

$$1 - e^{\bar{x} - \mu(x^0) - \frac{\sigma^2}{2}} - \mu'(x^0) \frac{\partial x^0}{\partial f} = -f e^{\bar{x} - \mu(x^0) - \frac{\sigma^2}{2}} \mu'(x^0) \frac{\partial x^0}{\partial f}; \quad (15)$$

$$f e^{\bar{x} - \mu(x^0) - \frac{\sigma^2}{2}} \mu'(x^0) \frac{\partial x^0}{\partial \bar{x}} - f e^{\bar{x} - \mu(x^0) - \frac{\sigma^2}{2}} - \mu'(x^0) \frac{\partial x^0}{\partial \bar{x}} = 0; \quad (16)$$

$$f e^{\bar{x} - \mu(x^0) - \frac{\sigma^2}{2}} (\mu'(x^0) \frac{\partial x^0}{\partial \sigma} + \sigma) - m'(\sigma) = \mu'(x^0) \frac{\partial x^0}{\partial \sigma}. \quad (17)$$

In equation (15), the left hand side is the marginal benefit of a higher fine. This includes a higher direct fine income and the utility of forest stock by a more severe punishment. The right hand side is the marginal cost of a higher fine; a higher fine decreases SFE harvesting levels as we showed earlier, thus the possibility of catching a SFE violating the limits is lower.

In equation (16), the first term is the marginal benefit of a higher harvesting limit: a higher limit means more harvesting and an increased likelihood of catching the SFE in violation and collecting the fine. The second term is the marginal cost of a higher limit. A higher limit also means more harvesting and less forest stock. This is represented as a cost to the government in the third term.

In equation (17), the left hand side is the marginal benefit of a larger signal variability. Larger variation means the monitoring result can be higher or lower. If the result is higher, the chance of catching the cheating SFE and the resulting fine payment are greater. This

is the benefit to the central government in the first term. An inaccurate signal (higher variability) also costs less, and this is represented as a benefit in the second term. The right hand side is the marginal cost of a larger signal variation, as a lower monitoring accuracy provides an incentive for the SFE to increase harvesting and lower the forest stock, all of which represent a social welfare loss to the central government.

2.3 Social welfare losses in the second best outcome

If central and provincial governments and the SFE manager do not perfectly coordinate, which we have shown would not happen in general, then the situation is the two principal, one agent model we solved above. This represents the best second-best outcome achievable in the Chinese forestry problem. We now define the corresponding second best social welfare function and eventually compare it with the theoretical first best social welfare. This comparison allows us to derive an expression for the social cost of federalism and hidden actions with respect to SFE harvesting. Later in the empirical-based simulation we compute this using data for a range of small and large SFEs in northeastern China.

The social welfare function consists of the utility of the SFE manager, the provincial government's utility, the central government's utility, and finally the utility of the SFE employees.⁷

$$SW(S^0) = \bar{w} + \bar{b}(1 - \frac{1}{\gamma^0(1-\tau)(Px^0 - C(x^0))}) + Px^0 - C(x^0) + S - \mu(x^0) - m(\sigma_0), \quad (18)$$

where γ^0 and x^0 are the solutions of equation (6) and (7), and σ_0 is solved from equation (15) to (17). The term $\bar{w} + \bar{b}(1 - \frac{1}{\gamma^0(1-\tau)(Px^0 - C(x^0))})$ is the wage income of the SFE manager, and $Px^0 - C(x^0)$ is the SFE profit. The term $S - \mu(x^0)$ is the forest stock benefit, and $m(\sigma_0)$ is the total monitoring cost.

2.4 First best social welfare

Now we can discuss the first best outcome and the resulting social welfare. This is a situation where the central government has perfect information about actual harvesting on the SFE, and all levels of governments perfectly cooperate to maximize the social welfare. The two principal governments can therefore structure instruments to achieve the first best outcome. The social welfare function in this case is:

$$SW = \bar{w} + b(1 - \frac{1}{\gamma(1-\tau)(Px - C(x))}) + Px - C(x) + S - x. \quad (19)$$

Notice that we now have x instead of $\mu(x)$ for the forest stock benefits and we drop the monitoring cost $m(\sigma)$ because there is perfect information. Social welfare consists of the

⁷We consider the fourth part as SFE employees; they enjoy the SFE profit that is not transferred to the provincial government, $(1 - \gamma^0)(1 - \tau)(Px^0 - C(x^0))$, as their welfare expenditure.

SFE manager wage income ($\bar{w} + b(1 - \frac{1}{\gamma(1-\tau)(Px-C(x))})$), SFE revenue $Px - C(x)$, and the public forest stock benefit $S - x$. More harvesting increases the SFE manager wage income and SFE revenue. However, it decreases the forest stock benefit. We solve for the optimal level of harvesting.

The central government maximizes SW by choosing b , γ and x . The necessary conditions suggest that the first best solution requires γ and b to be as large as possible:

$$\gamma = 1 - \frac{G}{(1-\tau)(Px-C(x))}; \quad (20)$$

$$b = \bar{b}. \quad (21)$$

The first order condition for x is:

$$\frac{b}{\gamma(1-\tau)(Px-C(x))^2}(P-C'(x)) + P-C'(x) = 1. \quad (22)$$

In equation (22), the left hand side is the marginal benefit of additional harvesting. This induces a greater promotion chance for the SFE manager (the first term) and higher profit for the SFE (the second term). The right hand side is the marginal social cost of additional harvesting due to the forest stock decrease.

Solving equation (20) and (22), we have a solution for the pair x^* and γ^* . We can now define first best social welfare using the first best solution pair as:

$$SW(S^*) = \bar{w} + \bar{b}(1 - \frac{1}{\gamma^*(1-\tau)(Px^*-C(x^*))}) + Px^* - C(x^*) + S - x^*. \quad (23)$$

Comparing this to the second best social welfare function derived above, we have a term that represents the social welfare loss (i.e., social cost) of federalism and hidden actions for the Chinese state forestry problem. This social welfare loss is therefore defined formally as:

$$SWL = SW(S^*) - SW(S^0) = \bar{b}(\frac{1}{\gamma^0(1-\tau)(Px^0-C(x^0))} - \frac{1}{\gamma^*(1-\tau)(Px^*-C(x^*))}) + Px^* - C(x^*) - (Px^0 - C(x^0)) + \mu(x^0) - x^* + m(\sigma_0), \quad (24)$$

where γ^0 , x^0 , γ^* , x^* and σ_0 are solved from the corresponding equations. Social welfare losses therefore consist of the lost forest stock benefit due to over-harvesting $\mu(x^0) - x^*$ and the saved monitoring cost $m(\sigma_0)$. However, this is offset by the higher profits $Px^* - C(x^*) - (Px^0 - C(x^0))$, and the greater promotion chance for the SFE manager $\bar{b}(\frac{1}{\gamma^0(1-\tau)(Px^0-C(x^0))} - \frac{1}{\gamma^*(1-\tau)(Px^*-C(x^*))})$ in an over-harvesting situation.

There is one additional case to consider. There are some arguments in the regulatory literature that fines or emissions tax revenues should not be part of any government's welfare function (Hettich 1998; Parry and Bento 1999; Murray and Rivers 2015).

Suppose the central government does not include SFE fine income in their utility function. The interpretation is that the central government is purely concerned with the utility of

forest conservation (a public good). Again, as above, we define the second best outcome under hidden actions and federalism, and the first best perfect coordination outcome with no cheating on the part of the SFE. The social welfare loss function can then be derived from the difference of these functions.

The second best decisions for the SFE and provincial government stay the same and do not depend on removal of fine revenue from social costs. The central government's problem is different, however. The central government's utility for the second best case becomes:

$$U_c = S - \mu(x^0) - m(\sigma). \quad (25)$$

The first order condition for \bar{x} is:

$$-\mu'(x^0) \frac{\partial x^0}{\partial \bar{x}} = 0. \quad (26)$$

This is not possible as $\frac{\partial x^0}{\partial \bar{x}} > 0$, and $\mu'(x^0) > 0$. The central government wants the target \bar{x} to be as small as possible, as a smaller target means less harvesting. However, there should be a lower bound for \bar{x} , denoted as \bar{x}^0 .

The first order condition for σ is:

$$-\mu'(x^0) \frac{\partial x^0}{\partial \sigma} - m'(\sigma) > 0. \quad (27)$$

This suggests σ should be as large as possible. As the central government does not care about the fine revenue in this case, it seeks only to minimize the cost of monitoring. Therefore, the central government will not do any monitoring, and as a result $\sigma = \sigma_0$, where σ_0 is the largest value for σ .

The second best social welfare function is:

$$SW(S^0) = \bar{w} + \bar{b} \left(1 - \frac{1}{\gamma^0(1-\tau)(Px^0 - C(x^0))} \right) - f(1 - e^{\bar{x}^0 - \mu(x^0) - \frac{\sigma_0^2}{2}}) + Px^0 - C(x^0) + S - \mu(x^0) - m(\sigma_0). \quad (28)$$

Because the central government does not care about fine revenue, we can without loss think of the fine as simply a fixed value set by the central government, so that f is some constant in our model. The term $-f(1 - e^{\bar{x}^0 - \mu(x^0) - \frac{\sigma_0^2}{2}})$ in equation (28) then defines lost utility of SFE due to the fine by the central government. We do not see this term in the second best social welfare equation when the central government considers the fine revenue in equation (18). Because the fine is a loss for the SFE but a gain for the central government and they are exactly the same, they cancel and do not impact social welfare in the case where the central government includes fine revenue. Social utility therefore is not impacted by the fine, whatever the size, because it represents a pure transfer from the SFE to the central government. However, when the central government does not consider the fine revenue in their utility function, the mechanism design problem here implies this is only a loss for the SFE but not a gain to the central government. The term is not cancelled by the same

term from the central government utility and it is still therefore present in the social welfare function.

To understand the first best case when the central government does not value fine revenue, we define the social welfare function as:

$$SW = \bar{w} + b(1 - \frac{1}{\gamma(1 - \tau)(Px - C(x))}) + Px - C(x) + S - x. \quad (29)$$

This is the perfect coordination scenario, where the central government has perfect information about the harvesting level. If the SFE harvests less than the harvesting limit, that is $x < \bar{x}$, they do not pay the fine, otherwise they will be fined. It is binary as we have perfect information now. In the first best solution, again, the harvesting level chosen by the government is such that the fine is avoided because they want to maximize the social welfare. This is the same solution as the first best case when the fine is present in the central government's utility function.

Comparing first and second best, the social welfare loss is given by the following function of relevant parameters:

$$\begin{aligned} \bar{b}(\frac{1}{\gamma^0(1 - \tau)(Px^0 - C(x^0))} - \frac{1}{\gamma^*(1 - \tau)(Px^* - C(x^*))}) + Px^* - C(x^*) - (Px^0 - C(x^0)) \\ + \mu(x^0) - x^* + f(1 - e^{\bar{x}^0 - \mu(x^0) - \frac{\sigma_0^2}{2}}) + m(\sigma_0), \end{aligned} \quad (30)$$

where γ^0 , x^0 , γ^* , x^* and σ_0 are solved from the corresponding first order conditions.

Equation (30) has one extra term $f(1 - e^{\bar{x}^0 - \mu(x^0) - \frac{\sigma_0^2}{2}})$, comparing to equation (24). This is because the central government does not consider the fine income in its utility function, as we explained above.

3 Data and Simulation Results

We now turn to examining the various cases above and social welfare losses for data related to China's Northeast collection of SFEs. This data relies on well-known and peer-published surveys designed and collected by the Environmental Economics Program in China (EEPC) at Peking University. The data set is combined with satellite vegetation coverage data from NASA to measure actual harvesting level and compare it to the central government quota for each SFE. Stated harvesting reported by SFE managers to the central government is falsely reported to equal the quota.

We simulate all decisions and choices by central and provincial governments, and the representative SFE manager. This is used to compute a value of the social cost of fiscal federalism in Northeast China by considering the loss in total social welfare under the first best case due to incentives that do not align for the SFE manager and the two principle governments that cannot perfectly observe actions of any other agent. A sensitivity analysis

is used to explore possible ways to lower the social welfare losses by understanding how various aspect of the problem change under parameter changes. And, finally, we use a regression analyses to understand the most statistically significant factors of social costs holding other parameters constant. The purpose of this regression is not as a predictive model in the classical sense, but rather to show what correlations between parameters and data are important, and to identify the direction of these correlations and magnitude of the effects for each important variable while controlling for other variables. The specification of the regression will follow the social cost definitions presented in the previous sections.

3.1 Data

Our data is from a survey conducted by the Environmental Economics Program in China (EEPC) at Peking University. This survey covers 24 randomly selected SFEs in the northeast of China. They are located in three provinces (Heilongjiang, Inner Mongolia and Jilin) shown in the following map.

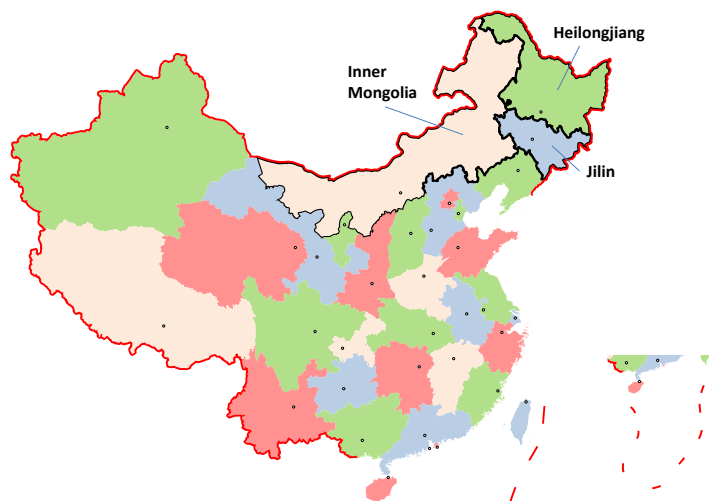


Figure 2: Jilin, Heilongjiang and Inner mongolia

The primarily harvested tree species in these provinces are Dahurian larch, white birch, Mongolian oak and spruce. The survey is collected for the period of 1980-2008. The survey consists of two waves, the first one in 2005, the second one in 2009. The data we use include SFE expenditure, timber price, primary industry production value and self-reported SFE timber harvesting level. Interviews with local officials indicated that the promotion benefits for an SFE manager averages 20 percent of wage increases. We also use inflation data for China from the World Bank for deflation in order to restate all monetary data in comparable form. Because prices are not generally available for SFE harvesting, and are not present in the Peking University survey, we use an average price of standing southern pine from Timber-Mart South 1st Quarter 2019 Vol.44 No.1 report and the cut-and-load cost

average of southern pine from Conrad and Dahlen (2019) to estimate our cost-price ratio in the simulation model as 54.11 %. We use monitoring enforcement cost report from the International Tropical Timber Organization (ITTO) to calibrate the monitoring cost in our simulation model. Finally, we use self-reported timber harvesting level as the quota for the SFE, because it is well known that they overharvest but underreport at the required limit to avoid fines.

To ensure accuracy of the data, we dropped obvious (and probably misreported) outliers, and SFEs with missing data, so that we require as little simulated data as possible. As a result, we were left with twenty SFE cases for our simulation. These cases include a range of SFE sizes and differing distances from the central government. Table 1 presents a summary of all parameters and choices in the simulation.

Table 1: Summary of parameters and choice variables in the simulation

variable	notation	range
Net promotion benefit	b	0.378 - 28.5 (1000 \$)
SFE percentage of the transfer	γ^0	To be solved in the model
Socially optimal percentage of transfer	γ^*	To be solved in the model
Tax rate for SFE	τ	0% - 1077%
Timber price	P	0.00858 - 82.5 (1000 \$)
Cost function	$C(x)$	Calibrated as $0.5411P$
Optimal harvesting level for each SFE	x^0	To be solved in the model
Socially optimal harvesting level	x^*	To be solved in the model
Central government signal of harvesting	$\mu(x)$	$0.6x$
harvesting limit	\bar{x}	8900 - 622720 (m^3)
Central government signal standard deviation	σ_0	To be solved in the model
SFE expenditure	G	0 - 17694 (1000 \$)
Upper limit for net promotion benefit	\bar{b}	Calibrated as $1.2b$
Monitoring cost function	$m(\sigma)$	Calibrated as 4.2 (1000 \$)
SFE profit	π	42 - 79182 (1000 \$)

*Ranges in parameters are explored with sensitivity analysis presented after the base simulation solutions. The range of b , τ , P , \bar{x} , G , π are from the survey data; and $C(x)$, $m(\sigma)$, \bar{b} are calibrated from other literatures and reports as mentioned above. (Exchange rate: 1 CNY = 0.15 USD)

3.2 Simulation results

To compute a value for the social cost of fiscal federalism, we solve the system of equations from the theoretical model in both first and second best cases. Then we calculate the social welfare loss according to equation (24); this is defined as the difference in the social welfare when evaluated at the first best optimal choices and the second best choices.

A summary of these results is shown in Table 2. In the table we calculated the optimal harvesting level for each SFE (x^0), the percentage of the transfer (γ^0), the socially optimal harvesting level (x^*), the socially optimal percentage of transfer (γ^*); and the social welfare loss (swl). The social welfare loss is deflated to year 2008 values.

Table 2: Simulation results for SFEs (first column) in Northeast China

SFE	year	$x^0(m^3)$	γ^0	$x^*(m^3)$	γ^*	swl (1000 \$)
Heilongjiang Dahailin	2008	799923	0.977	31381	0.573	625992
Heilongjiang Dongjingcheng	2004	860875	0.772	49935	0.095	762985
Heilongjiang Hebei	2008	331989	0.724	49992	0.100	206569
Heilongjiang Jinshantun	1990	412148	0.800	49756	0.092	703427
Heilongjiang Jinshantun	1995	222365	0.761	49756	0.095	159606
Heilongjiang Jinshantun	2000	127139	0.140	49878	0.095	45411
Heilongjiang Langxiang	2008	331989	0.351	49939	0.095	207189
Heilongjiang Qinghe	2008	182270	0.654	50000	0.100	78891
Heilongjiang Zhanhe	2000	855656	0.875	49939	0.097	810469
Jilin Linjiang	2000	253924	0.539	49878	0.094	177207
Jilin Linjiang	2008	199673	0.028	49969	0.098	94459
Jilin Wangou	1995	682967	0.967	34868	0.630	709117
Jilin Wangou	2004	568360	0.764	49939	0.097	474901
Jilin Dunhua	2000	370157	0.682	49939	0.097	295594
Jilin Dunhua	2004	272359	0.469	49939	0.096	183279
Jilin Dunhua	2008	802110	0.811	49985	0.099	584437
Jilin Tianqiaolin	2008	148905	0.895	22876	0.315	91087
Inner Mongolia Genhe	2000	935378	0.727	49616	0.060	898450
Inner Mongolia Genhe	2004	750294	0.724	49848	0.087	667033
Inner Mongolia Genhe	2008	393719	0.216	49867	0.084	262563

The term x^0 is the optimal harvesting level for each SFE; γ^0 is the percentage of the transfer; x^ is the socially optimal harvesting level; γ^* is the socially optimal percentage of transfer; and swl is the social welfare loss.

In the table, we compute the value of the social costs caused by the incentive incompatible problem and we investigate factors that influence these costs in the following sensitivity and regression analyses. We see that the SFE optimal harvesting level is higher than the socially optimal harvesting level for all of the SFEs here, which highlights the hidden actions mechanism design problem and the fact that all parties do not have incentives to perfectly cooperate. The SFE percentage of transfer is higher than the socially optimal percentage of

transfer, because the social optimum requires that harvesting is lower due to benefits of the standing forest stock in the central government's social welfare function. This means SFEs always will overharvest and transfer more to the provincial government in exchange for a higher chance of promotion.

Our simulation therefore shows what has been generally known and argued in the literature, albeit without formal evidence. The table shows the social welfare losses (*swl*) due to these disincentives and the resulting second best outcome. Referring to social welfare losses, we see that they range between 45.41 million dollars to 898.45 million dollars. There are five SFEs with observations of more than one year.⁸ We see the social welfare loss decreases over time. For example, for Heilongjiang Jinshantun, the loss was 703.43 million dollars in 1990 and decreased to 45.41 million dollars in 2000. This finding confirms that state forest reforms decreased some of the social welfare loss. However, more needs to be done. The social welfare loss is higher for those larger size SFEs, such as Inner Mongolia Genhe (632424 hectares) and Heilongjiang Dongjingcheng (266310 hectares). We also see a higher loss in SFEs with the furthest distance to Beijing, such as Heilongjiang Zhanhe (1320 kilometres) and Inner Mongolia Genhe (1243 kilometres). These SFEs are far away from the central government and harder to be monitored accurately. Inner Mongolia Genhe has 23 % of mature natural forest (in terms of area) in 2000. Jilin Wangou has 12 % of mature natural forest (in terms of area) in 1995. Large percent of mature natural forests also makes it harder to perform accurate monitoring. Therefore, the SFEs harvest over the limit with a very low probability of being fined. We will show this further in the following sensitivity analysis and regressions.

3.3 Sensitivity analysis

To explore possible ways to lower the social welfare losses and to examine how parameters impact these losses, we now conduct a sensitivity analysis of key parameters. We examine each parameter with a percentage change of -20%, -10%, 0%, 10%, and 20% around our assumed or observed values (thus, 0% represents the case we used in the Table 2 results), we then solve the first and second best problems and the social welfare loss under each shift in parameters focusing on each parameter separately.

We present these results in a series Figures 3 - 12. In the figures, each of the different lines represents a different SFE in the sample and we pick five representative SFEs for illustration⁹. The x axis is the percentage changes of the variable we are conducting sensitivity analysis for, and the y axis is the social welfare loss, SFE harvesting level or SFE percentage of transfer to the provincial government depending on the figure. The patterns in the figures therefore show what happens to the Y axis variables from 20% smaller to a 20% higher value of each parameter given on the X axes. The 0 line on the Y axes refers to the base simulation case in Table 2. Thus, reading across the X axis and noting where on the Y axis each line is

⁸These are Heilongjiang Jinshantun, Jilin Linjiang, Wangou, Dunhua, and Inner Mongolia Genhe.

⁹These are Heilongjiang Dahailin 2008, Heilongjiang Jinshantun 1995, Jilin Linjiang 2008, Jilin Wangou 1995, and Jilin Dunhua 2004 from Table 2. These are representatives of all the patterns observed in SFEs for the sensitivity analyses.

located indicates how the variable of interest depends on variations in the X axis parameter.

3.3.1 Sensitivity analysis of the social welfare loss

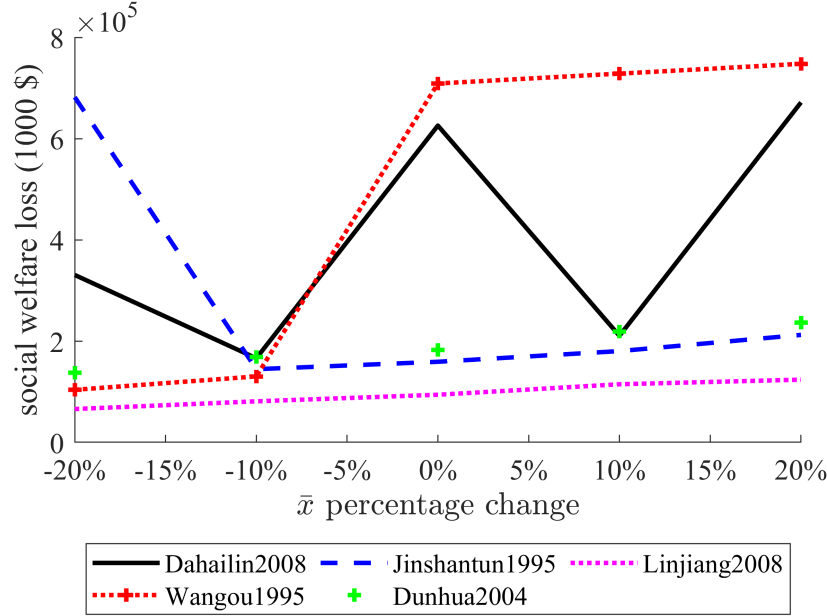


Figure 3: Sensitivity analysis of \bar{x} for the social welfare losses

Figure 3 represents the sensitivity analysis of the social welfare loss to the harvest quota, \bar{x} , which is our main focus. There is roughly an upward trend in social welfare losses as the percentage change in the harvesting limit increases. These results support the argument that an increased social welfare loss (*swl*) is always expected if the central government relaxes the quota (\bar{x}). This is intuitive, as a higher harvesting limit allows more harvesting, and this results in lost public goods values from the forest stock. The jagged nature of some of the graphs could be partially explained by the term $\bar{x} - x_s$ in the SFE utility function (equation (3)). Although SFEs typically harvest over the harvesting limits, the actual harvesting level can differ and depend on the parameters being investigated in the sensitivity analysis. Therefore, the harvesting signal x_s can be higher or lower than the harvesting limit \bar{x} . This may cause some of the jagged features in the graph.

Figure 4 considers sensitivity in the standard deviation of the monitoring signal received by the central government (σ), from equation (2). Although the trends are different for different SFEs at different percentage changes of σ , we can roughly see several upward trends reading from left to right, especially in the 0% - 20% increase part of the X axis. The social welfare loss (*swl*) increases with the monitoring signal standard deviation (σ), because it is easier for SFEs to overharvest as inaccuracies in monitoring become larger. In

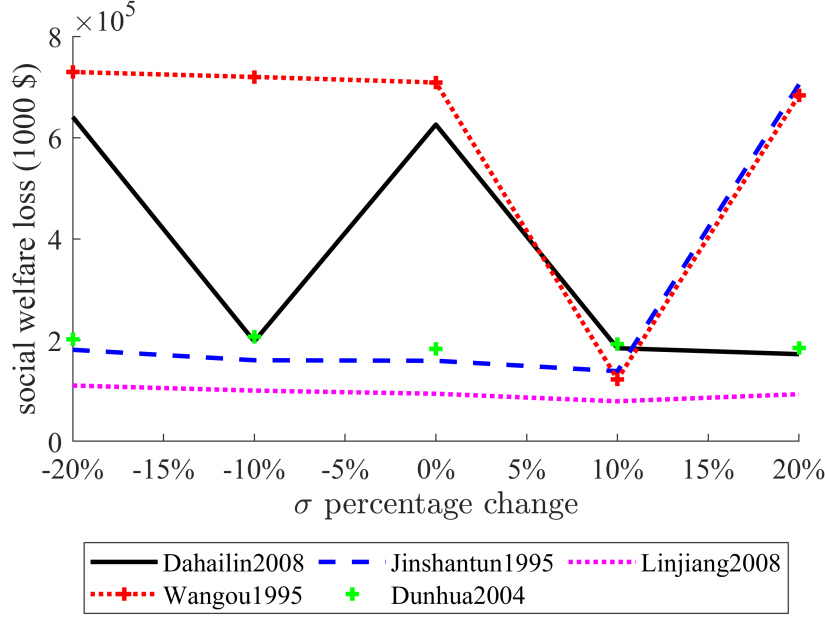


Figure 4: Sensitivity analysis of σ for the social welfare losses

terms of social welfare loss, some SFEs are not affected by the change of σ and appear as flat lines in the graph, while other SFEs have a “W” shaped trend with some upward and some downward trends at different percentage change of σ . A larger standard deviation allows the signal to be higher or lower, thus the effects differ across SFEs.

In equation (2), recall that μ is the fraction of SFE harvesting that is monitored by the central government in the harvesting signal function. Figure 5 shows our results concerning the sensitivity analysis of μ . Overall, we see that the social welfare loss (*swl*) decreases with increases in μ for several SFEs. For different SFEs, the decreasing trend happens at different percentage changes of μ . A higher μ means more harvesting can be monitored, thus the SFE harvesting level is lower and the social welfare loss is lower. This is intuitive, as the higher the monitoring accuracy is, the lower the social welfare loss must be (shown also in Figure 4).

Summarizing, from the sensitivity analyses of the social welfare loss in Figures 3 - 5, the key to lowering this loss appears to be improving the quality of monitoring and imposing stricter harvesting limits or quotas on the part of the central government. Put another way, increasing the efficiency of enforcement is clearly required to achieve incentive compatible deforestation limits in Northeast China and move the federalism outcomes closer to first best outcomes.

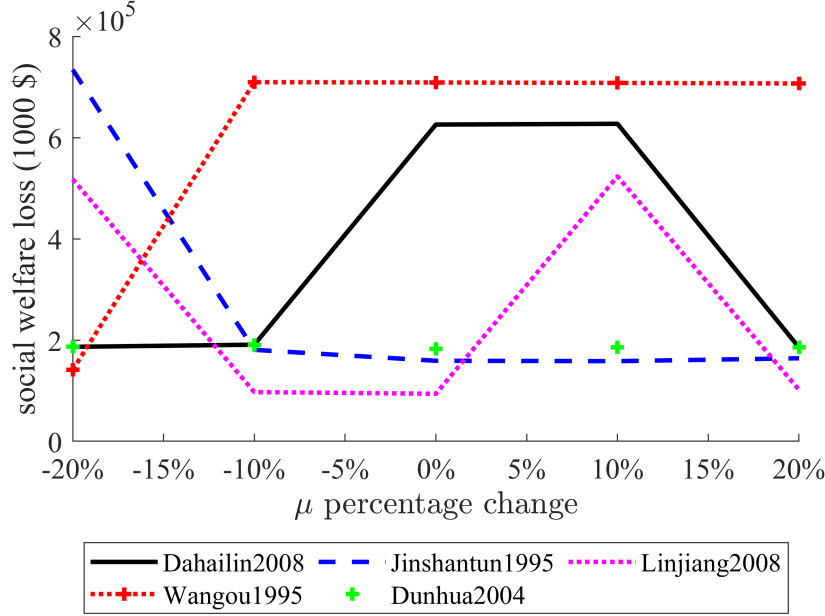


Figure 5: Sensitivity analysis of μ for the social welfare losses

3.3.2 Sensitivity analysis of the SFE harvesting level

The next decision of interest in our sensitivity analysis is that of the SFE actual harvesting level (x^0). Figure 6 presents results for the effect of the harvesting limit (quota) parameter on actual SFE harvesting. As expected the figure shows an upward trend in x^0 as the harvesting limit increases in magnitude. That is, x^0 increases with harvesting limit (\bar{x}). As we saw above, this is important to increases in social welfare as the harvesting level becomes even further above the socially optimal level when the harvesting limit is relaxed. Referring to Figure 6, the sensitivity analysis of \bar{x} for swl and x^0 have a similar trend as in Figure 3.

Figure 7 presents the sensitivity analysis of the standard deviation of the monitoring signal (σ) on SFE actual harvesting. In general, we see an upward trend of the SFE harvesting level (x^0). That is, x^0 increases with σ , especially at the 20% increase part. The increasing trends happen at different percentages for different SFEs. When σ is larger, the monitoring signal by the central government varies in a wider range, which leads to more room for harvesting over the limit without being caught. This variation can make the signal higher or lower, and explains the “W” shaped trend with some upward and some downward trend at different percentages. The sensitivity analysis of σ for swl and x^0 have a similar trend as shown in Figures 4 and 7.

Figure 8 illustrates how the fraction of harvesting that is monitored by the central government in the harvesting signal function, μ , impacts SFE harvesting. The SFE harvesting level (x^0) decreases with increasing μ . μ is the fraction of harvesting that is monitored, so

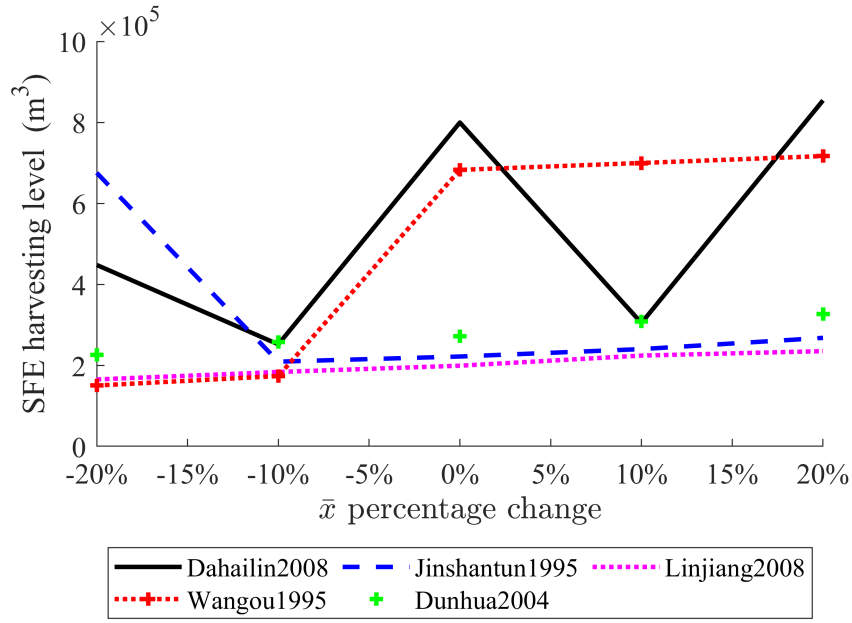


Figure 6: Sensitivity analysis of \bar{x} for the SFE harvesting level

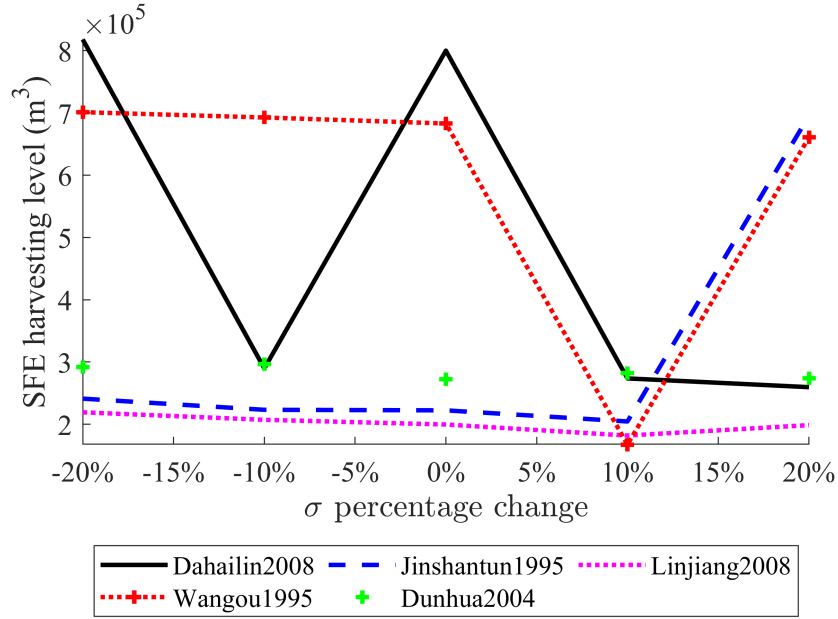


Figure 7: Sensitivity analysis of σ for the SFE harvesting level

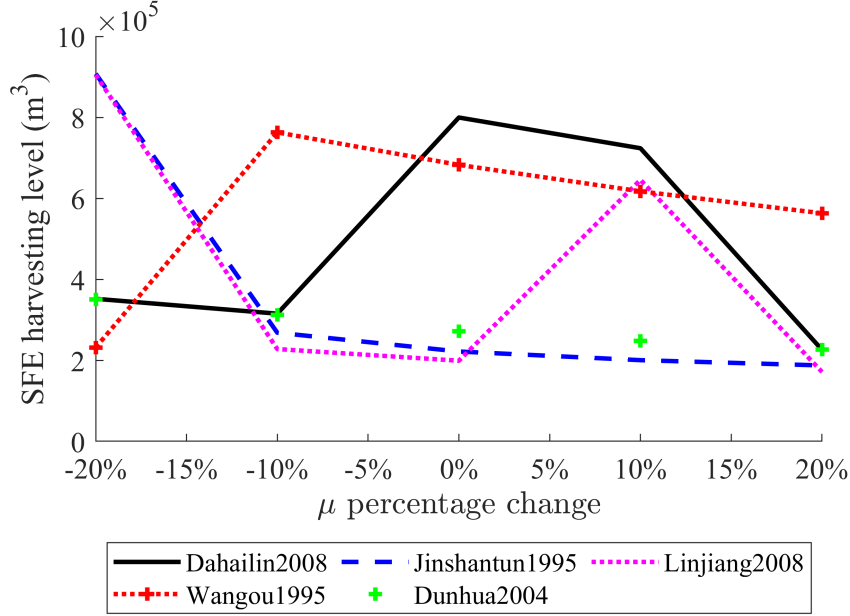


Figure 8: Sensitivity analysis of μ for the SFE harvesting level

that a higher μ means more harvesting can be monitored. Therefore, the SFE harvesting level (x^0) is lower to avoid the higher risk of being caught.

In sum, we see a similar results concerning how the SFE choice of harvesting level and the social welfare losses depend on key parameters. This also shows how SFE harvesting levels (the amount of over-logging) are key contributors to social welfare losses. The sensitivity analysis indicates that parameters related to accuracy of law enforcement are critical to abating overharvesting within SFEs in Northeast China.

3.3.3 Sensitivity analysis of the SFE percentage of transfer

The percentage transfer to the SFE manager (γ^0) is also an important variable in the model. We now illustrate the key parameters affecting γ^0 . Figures 9 - 12 illustrate sensitivity analysis for γ^0 with respect to timber price (P), expenditure (G), harvesting limit (\bar{x}) and harvesting cost (C).

Figure 9 illustrated the sensitivity analysis of the timber price (P) for the SFE percentage of transfer (γ^0). There is an increasing trend, γ^0 increases with P . The increasing trend is more significant for those SFEs with a relatively low transfer percentage. For those that have already transferred a larger percentage, there is not much room for increase. SFEs make more profit with a higher timber price. This allows them to cover their obligated expenditures for the local state enterprise community more easily and transfer more to the provincial government. The expenditure is fixed and the transfer amount is higher, thus the

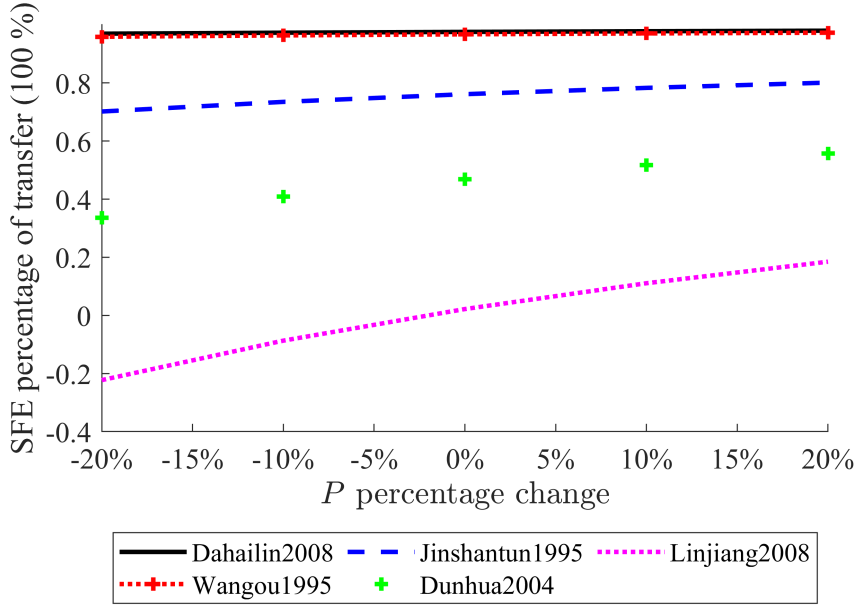


Figure 9: Sensitivity analysis of P for the SFE percentage of transfer

percentage of transfer is higher.

Figure 10 shows the importance of the SFE expenditure (G). There is a decreasing trend, with γ^0 decreasing with SFE expenditure (G). A higher G indicates SFEs expend more for the local state enterprise communities, thus transferring less to the provincial government. The percentage of transfer is lower. The decreasing trend is more significant for those SFEs with a relatively low transfer percentage, as they barely cover the expenditure. For those that have already transferred a larger percentage, the expenditure is just a small fraction of their profit and the effect is less significant.

Figure 11 shows sensitivity analysis of the harvesting limit (\bar{x}). Overall, this is an upward trend. The transfer γ^0 increases with the harvesting limit (\bar{x}). A higher harvesting limit allows more harvesting, thus SFEs have incentive to transfer more to the provincial government. The increasing trend is more significant for those SFEs with a relatively low percentage of transfer. This is consistent with our previous analysis.

Figure 12 shows the sensitivity analysis of the harvesting cost (C); γ^0 decreases with the harvesting cost. A higher C indicates SFEs have less profitable harvesting, thus providing greater incentives to transfer less to the provincial government. In the figure, this is more significant for those SFEs with relatively low transfer percentages. For those that already transfer a larger percentage to provincial governments, an increase in harvesting cost is just a small fraction of their profit and the effect is less significant.

From the sensitivity analysis of the SFE transfer to provincial governments, we have two types of results. SFEs transfer a higher percent of their profit to the provincial government

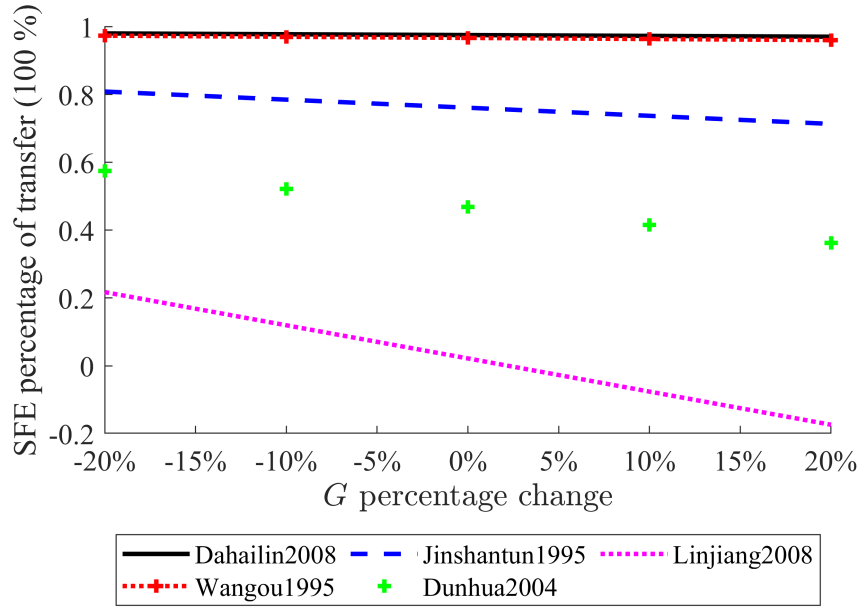


Figure 10: Sensitivity analysis of G for the SFE percentage of transfer

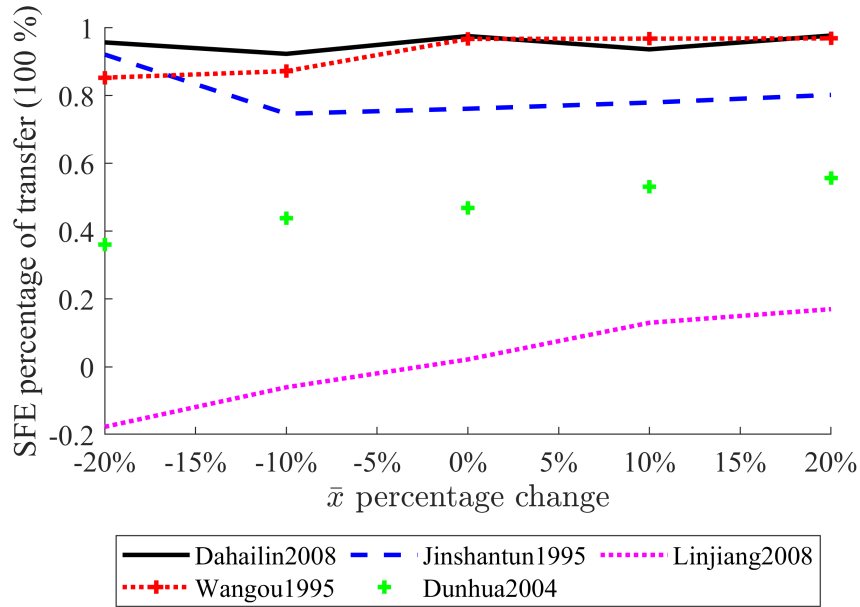


Figure 11: Sensitivity analysis of \bar{x} for the SFE percentage of transfer

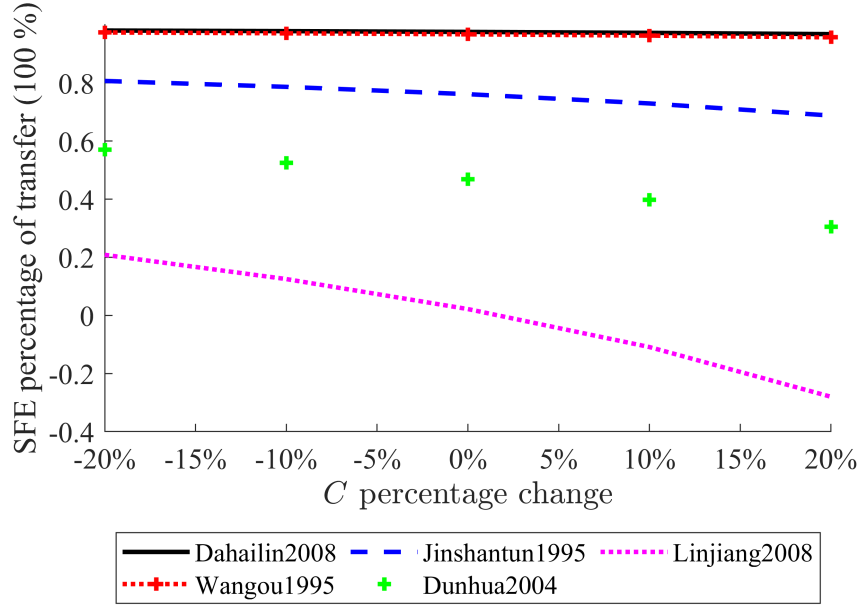


Figure 12: Sensitivity analysis of C for the SFE percentage of transfer

when their profits are higher, that is, when the timber price is higher or they are allowed to harvest more. In contrast, SFEs transfer a lower percent of their profit when their profits are lower, that is, when the harvesting cost is higher or they have greater costs to spend for the local state enterprise community.

3.3.4 Sensitivity analysis when fine revenue is part of social welfare

We briefly consider the case for social welfare losses where the central government does not include fine revenues in their utility function. We ran our simulation again and calculated the social welfare loss using equation (30). We repeated all the sensitivity analysis procedures discussed previously. In all the analyses, there are very similar results with Figures 3 - 12, The only difference worth mentioning is for the monitoring related variables μ and σ . The trends above are still the same as in Figures 3 - 4, but the magnitudes of the effect on social welfare losses are higher. Finally, we also find that the social welfare loss in equation (30) is lower than that of equation (24). Social welfare loss is lower when the central government does not value fine revenues in their utility function. This suggests that a central government who sets policy parameters based on revenue collections in the federalism case will ultimately lead to higher welfare losses following from disincentives of governments and SFE managers to perfectly coordinate.

4 Econometric Results

To investigate the significance of factors that influence social welfare losses from deforestation in SFEs, we can regress the calculated social welfare loss on other variables collected in our survey. The purpose of a regression in this case is not to create a prediction model, but rather to identify the more important influences on social welfare loss variation, holding other effects constant.

4.1 Econometric data

The data we use consist of a panel of 24 SFEs in the Northeastern China forest region from years 1980 to 2008 assembled in a stacked fashion. The social welfare loss is deflated to 2008 and recomputed in 1000s USD. This is denoted as “swl_df” and represents the dependent variable in our analysis.

Table 3 provides a summary of the descriptive statistics of all variables used in the regression. Explanatory variables are taken from parameter variables concerning the SFE managers; these includes the manager tenure experience (in years, denoted as “tenure_exp”), education level (in years, denoted as “edu”), and age (in years, denoted as “age”). The SFE manager is the key decision maker in the SFE, so their age, education level and tenure experience in the SFE affects the harvesting and transfer decision, and therefore is expected to factor into social welfare loss.

We also control for other SFE characteristics. These include the deflated SFE total social value (in 1000 USD, deflated to year 2008, denoted as “socialvalue_df”), total area (in hectares, denoted as “SFEtotalarea”) and number of SFE employees, denoted as “pop”). We also include the distance of each SFE from the central government. These are calculated using the longitude and latitude data of each SFE and Beijing (denoted as “distance”, in kilometers). Using the area data of the forests, we calculate the percentage of the natural forest (denoted as “natural forest%”) and the percentage of the planted forest (denoted as “planted forest%”) in each SFE. We also calculate the percentage of juvenile forest and mature forest for both the natural and planted forests. Therefore we have juvenile natural forest percentage (denoted as “juvenile natural% ”), mature natural forest percentage (denoted as “mature natural%”), juvenile planted forest percentage (denoted as “juvenile planted%”), and mature planted forest percentage (denoted as “mature planted%”). We also calculate these percentages both based on growth rates and based on area. Thus, for example, mature natural forest percentage calculated using growth data is denoted as “mature natural% (growth)”. The National Forest Protection Program (NFPP) was implemented in 2000 to protect the natural forest in Northeast China. Variables in the regression measuring this effect are the non-harvesting area required by the program (denoted as “non-harvesting”) and the limited harvesting area (denoted as “limited harvesting”) allowed in the forests of SFEs. These variables will measure the impact if any of this program on social welfare losses from SFE deforestation. Finally, in order to increase the sample size to a sufficient size for regression analyses, we use the inflation adjusted timber price data to make up for the missing data in

the following years. This allows more observations of the social welfare losses.

Table 3: Summary of the variables in the regression

Variable	Mean	Std. Dev.	Min.	Max.	N
swl_df	420902.673	468780.377	5399.568	3506226	99
tenure_exp	2.978	2.083	1	13	594
edu	5.397	1.709	1	9	594
age	48.554	5.381	35	62	536
socialvalue_df	65470.436	32931.458	19176.148	153445.047	42
SFEtotalarea	259500.961	169021.963	11306	766185	129
pop	35773.775	11666.914	4323	62841	151
juvenile natural%	0.202	0.159	0.004	0.813	154
mature natural%	0.177	0.163	0.004	0.787	94
mature natural% (growth)	0.242	0.215	0.005	0.924	94
juvenile planted%	0.757	0.203	0.053	1	94
juvenile planted% (growth)	0.495	0.292	0.029	1	94
mature planted%	0.021	0.052	0	0.344	50
natural forest%	0.701	0.214	0.201	1	94
planted forest%	0.126	0.103	0.002	0.47	94
non-harvesting	21.729	59.174	0.059	343.727	34
limited harvesting	17.888	25.44	0.136	96.673	32
distance	1181	149.487	909.318	1399.058	658

4.2 Regression results

Table 4 presents results by regressing social welfare losses (first row variable in Table 4) for each SFE on explanatory variables (all other rows in Table 4), and for five specifications (models 1 - 5). The number of explanatory variables vary by specification in the table, as do the number of observations. It turned out that timber price has little variation across SFEs given that markets for timber are complete in Northeast China. While stumpage price would vary based on terrain and location, the mill or gate price that we have data on would not vary over SFEs since multiple SFEs supply the same mills. Referring to the specifications in Table 4, model 1 controls for SFE characters using total value and population; model 2 adds SFE total area; in model 3 we include more SFE characteristic variables. Based on model 1, we include SFE manager tenure experience, education and age of the manager, as these factors are shown to be important by Li and Zhou (2005). We also include the distance of the SFE to the central government. Because Xu et al. (2004) found that the remote area are harder to monitor. This also tests the robustness of the positive correlation between the mature natural forest percentage and the social welfare loss in model 1. Model 4 adds SFE mature natural forest growth variables to the specification, as it is identified to be a key contributor to deforestation by Xu et al. (2004). Finally, model 5 adds juvenile planted

forest growth variables to the specification. The number of observations overchange across specifications due to dropping of missing data.

Table 4: Regression results of social welfare loss as dependent variable

	(1) swl_df	(2) swl_df	(3) swl_df	(4) swl_df	(5) swl_df
mature natural%	2115658.7** (2.85)		3220133.8* (2.68)		
socialvalue_df	-5.931* (-2.18)	-4.222 (-0.70)	-10.43 (-1.64)	-10.26 (-1.59)	-3.261 (-0.48)
pop	-6.930 (-1.09)	-0.0134 (-0.00)	-0.867 (-0.08)	1.385 (0.13)	0.0907 (0.01)
SFEtotalarea		1.214* (2.19)			
tenure_exp			70164.7 (1.32)	64731.0 (1.21)	100401.1 (1.63)
edu			-29575.5 (-0.27)	-36496.0 (-0.32)	13121.5 (0.11)
age			-13647.6 (-0.47)	-12275.8 (-0.41)	-13619.1 (-0.42)
distance			2700.3* (2.69)	3122.4** (2.93)	3515.6* (2.89)
mature natural% (growth)				2591090.6* (2.56)	
juvenile planted% (growth)					-1779740.3* (-2.27)
Constant	935579.9 (3.20)	503754.0 (1.12)	-1641452.7 (-0.86)	-2233757.2 (-1.17)	-2220517.1 (-1.09)
Observations	42	27	24	24	23

t statistics in parentheses,

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Referring to the results, we see that there is a significant positive correlation between

the social welfare loss and the mature natural forest percentage, no matter whether it is calculated by growth or area. In model 1, each one percent increase of the mature natural forest increases social welfare loss by 21 million US dollars. In model 3, each 1 percent increase of the mature natural forest increases 32 million US dollars of social welfare loss. In model 4, the percentage is calculated by growth: here, a one percent increase of the mature natural forest increases social welfare losses by 26 million US dollars. This shows robust positive correlation between the social welfare loss and an SFE mature natural forest percentage, and may indicate areas of SFEs where the government needs to monitor more heavily if reductions in social costs are to be afforded. One problem with this, and a reason for the results, is that others have argued that it is more costly and difficult for the central government to monitor in natural forested areas when they make up a larger percentage of the SFE forested area (Xu et al. 2004, Yi et al. 2017). Our new finding is that, regarding the contribution to the social welfare loss, mature forested area is especially significant and cannot be ignored moving forward.

We also find a significant positive correlation between the social welfare loss and SFE total area in model 2. One more hectare of total area results in an increase of 1214 dollars in social welfare loss. A possible explanation is the larger SFEs are harder to monitor. This is consistent with the finding by Xu et al. (2004) that the larger size SFEs have a greater reduction in forest growth rate. There is also a significant positive correlation between the social welfare loss and distance to the central government(s). This indicates that when the SFE is further away from the central government, the social welfare loss is higher. One kilometer away from the central government results in 2.7, 3.1 or 3.5 million dollars increase in social welfare loss in model 3, 4 and 5, respectively. One explanation for this is the monitoring cost is higher for these remote SFEs.

In model 5, the results show a negative correlation between the social welfare loss and juvenile planted forest percentage (calculated by growth). Planted forest has a lower monitoring cost, thus has less overharvesting.

In addition to the findings presented in table 4, we find a significant positive correlation between the social welfare loss and the SFE total social value in model 1. However, this is not robust in model 2 - 5. We also find positive correlation between social welfare loss and SFE employee structure. The employee structure is calculated using the number of employees divided by the total number of laid-off people and retired people. Finally, and interestingly, we found no significant impact of the harvesting area and limited harvesting area set by the National Forest Protection Program. This is not surprising given that this program does not address the federalism and disincentives of governments and SFE managers we have uncovered in this story.

5 Conclusions

We developed a two-principal, one-agent model to describe the incentive incompatibility problem inherent in forest harvesting decisions by state forest enterprises in Northeast China.

A key part of our approach is to characterize a social welfare loss from failures of state forest managers to coordinate with provincial and central governments, as well as the different incentives for use of state forests faced by provincial and central governments.

The model reveals key differences in first and second best harvesting outcomes that are realized in social welfare losses. These losses are social costs of harvesting outcomes that do not align incentives of the state forest enterprise manager and the two governments. The model also shows the difficulty in one principle (the central government) setting a harvesting quota and enforcement strategy to achieve the first best outcome given the importance of the lower level provincial government in state forest enterprise manager decision making. There is no work we are aware of that examines these issues for the large forest regions of China; yet continued deforestation there is of world interest.

Using our framework, we use published data to compute social welfare losses from deforestation for different sized state forest enterprises in four northeastern Chinese provinces, and we examine the sensitivity of these losses to various parameters related to financial incentives for harvesting, monitoring and enforcement costs by the central government, transfer parameters from state forest enterprises to local governments, and harvesting limits or quotas set by the central government. Finally, a regression analyses is used to assess the nature of significant factors of social welfare losses controlling for other variables.

We find that social welfare losses depend critically on state forest size, distance from the central government, and various central and provincial government policy instruments. Sensitivity analysis to investigate the major contributors to social welfare loss identifies that lower harvesting limits and a more accurate monitoring system are the two key factors to lowering these losses. Consider harvesting limits as carrot and the monitoring system as stick, this is a carrot-stick result that is common in second best problems (Balch 1980; Henderson et al. 2013; Duchelle et al. 2017). It is logical to combine lower harvesting limits with a monitoring system that reduces variability in signals of harvesting that the central government receives from state forests. Regression results are also consistent with this basic finding, indicating that the remote areas with a higher percentage of mature natural forests are the ones with the highest social welfare loss.

All our findings here suggest that monitoring is the key to lowering the social welfare loss and resolving the federalistic incentive incompatible problem that we have shown characterizes state forest harvesting in China. We present two possible solutions. The first is to decentralize the monitoring to the provincial government levels. It is also suggested by Xu et al. (2004). Although they did not examine social welfare losses, they nonetheless conclude based only on remotely sensed harvesting rates that decentralizing forest management and enforcement as much as possible reduces wedges in incentives among agent and principles. In many ways we have rigorously shown that their suggestion is correct. Because state forests are fixed entities, the monitoring cost is lower for local governments, and they also have better information on local forest stocks that can be used to set more incentive-compatible harvest standards. This would lessen the social welfare losses attributed the incomplete information problem that currently now exists. Also, decentralization would provide local governments with additional incentives to monitor and protect forests. Secondly, with regard

to monitoring, our results suggest that less costly and emerging technologies, such as drones could be highly important to lower social costs throughout China's largest wood basket.

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