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Incentives and Forest Reform: Evidence from China

Yuanyuan Yi

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In loving memory of my father
To my mother and my daughter, Yingzhuo

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Yuanyuan Yi
Gothenburg, May 2017

Contents

1 Introduction

In the past two decades, the world's forests had a net loss of 129 million hectares, though the rate of forest loss is declining (FAO, 2015). An increasing number of developing countries have recognized local ownership and control over forests. Meanwhile, governments adopted forest tenure reforms by devolving control of forests to (indigenous) community management, or by a further step, to household management. And some governments maintain their forests as public. By 2015, 76 percent of the world's total forests of 3,999 million hectares were under public ownership and less than 20 percent were under private ownership. The existence of such reforms, legislation or regulations, however, is not always coupled with effective enforcement and forest conservation (FAO, 2015; RRI, 2014). Meanwhile, governments in general, in spite of concerns with environmental protection and climate change mitigation, are more focused on economic development, food security and political stability. The overriding concerns of sustainability, efficiency and distribution in forest devolution reforms and forest management systems have never been higher.

China, as one of the world's recent "economic development miracles", has a total forestland area of over 208 million hectares as of 2014, and is ranked fifth in terms of percentage of the world's total (FAO, 2015). China's forests are categorized into two ownership types: village collective-owned and state-owned. The collective forests consist of 60 percent of the national forest area and 32 percent of the forest stock volume; the state forests account for 40 percent of the national forest area and 68 percent of the forest stock (State Forestry Administration, 2011).

In this context, the thesis explores the extent and depth of recognition of rights to forest land and resources in the two types of forest in China, and investigates the relationship between managerial incentives and associated environmental outcomes. The first two chapters focus on collective forests and evaluate the impacts of the devolution of forest tenure rights from villages to households. The third chapter shows how the institutional setting for state-owned forests, in which the actual forest manager is an agent to two principals – the central government and jurisdictional (local) government – leads to deforestation. The findings show that devolution of forest rights to households improves households' investment and the efficiency of forestland reallocation among households, as well as household welfare and forest biomass. With respect to state-owned forests, however, the research shows that forests are being depleted because local governments strongly incentivize the forest manager to maximize revenue, while the central government provides only limited incentives to protect the environment. These findings contribute substantially to the knowledge base for the forest policy sector.

2 Collective Forests and Household Management

Whether devolution (decentralization) brings about deforestation is a question that is ceaselessly asked. An increasing number of countries have devolved forests to the community level in forest-rich areas of Asia, Africa, and Latin America, where more than 27 countries had the total forest area under local community management increased from 383 million hectares to 511 million hectares in 2002-2013 (RRI, 2014). A large body of literature has been devoted to studying the effect of this step of devolution on forest conditions, but the findings are inconclusive (e.g., Kaimowitz et al., 1998; Foster et al., 2002; Baland et al., 2010; Coleman and Fleischman, 2012). A key question, then, is whether to take a further step, by devolving forest management to the household level. China made an early move.

Given the history of unsuccessful village collective management, a wave of forest devolution reform was announced soon after the millennium, starting in Fujian province, and featuring the devolution of forest management rights to households. The main measures include reallocation of village collectively-owned forestland, formal acknowledgement of household property rights to these forest plots, in particular by forestland certificates with legalized tenure terms, and encouragement of forestland transfer (rental) markets. This was very successful and encouraged the central government to implement a few more pilots starting in 2003 (State Council, 2003) and finally to promulgate the policy document "*Collective Forest Tenure Reform in the Southern Collective Forest Areas in China*" in 2008. This promulgation reflects both the recognition by the benefits of devolution by the highest legislation and the extent and the depth of the government's ambition to devolve forest tenure rights. During that period, any decision and implementation of the reform required village-level democratic consensus.

The Collective Forest Tenure Reform in China is the most extensive devolution of communal forests to households ever seen. By 2008, the reform had devolved 62 million hectares of the total 100 million hectares of the forests from collective ownership to individual households (Xu et al., 2010). The reform has involved 600 million people in rural areas in more than twenty provinces of China (State Forestry Administration, 2011).

My **Chapter I**, *Forest Devolution Reform in China: A Trigger for Investment or Deforestation?* (single authored), evaluates the impact of the Collective Forest Tenure Reform on households' investment in forestland. I also investigate the effect of household management on forest resource conditions. Specifically, the investment analysis is based on a panel dataset of a two-round survey of 3,000 households in eight provinces before and after the implementation of the forest devolution reform. The identification strategy exploits the variations in villages' decisions to select the reform and in households' forest investment across time. Using a difference-in-difference propensity score matching model, I find that the devolution reform resulted in more investment per area unit of a forest plot, in terms of annual labor input days and value of silvicultural treatments. The analysis on resource conditions is based on satellite imagery on forest cover and vegetation during 2001-2012. At the county level, where more forestland is under household management, improved forest conditions are found soon after the reform. As the channels for the investment effect, I investigate the following two: (i) the effect of tenure security, i.e., holding a forestland certificate and (ii) the reallocation effect from obtaining more forestland during reform. The effects of devolution and improved tenure on increased private investment and resource conditions provide evidence that well-defined and protected property (tenure) rights for households offer an effective alternative to common-pool resources management in small-scale forestry in China.

In **Chapter II**, *Allocative Efficiency or Agglomeration? The Emergence of Forestland Rental Markets and the Forest Devolution Reform in China* (single authored), I focus on the emerging forestland rental markets. I investigate whether the devolution reform of forestland to household management had an effect on allocative efficiency and household welfare through households' participation in forestland rental markets. Using a household panel dataset from three Chinese provinces, I find that the emerging forestland rental markets improved allocative efficiency, using an indicator of factor equalization. Based on multinomial logit model estimates for households that chose among renting out their forestland, renting in forestland, and not participating in the rental market, I find that, with the reform, forestland is transferred (rented) from forestland-rich, labor-constrained households to forestland-constrained, labor-rich households. I also find that forestland is transferred to households with higher levels of productivity in forestry. I do not find any evidence for agglomeration of forestland to households that were already land-rich, nor to wealthier or politically powerful households. Furthermore, I compare the differences in welfare between the no-renters and renting households of similar characteristics, based on a propensity score matching approach. I find participation in forestland rental markets increases household per-capita income and decreases the likelihood of having an income below the poverty line.

3 State-owned Forests and State Forest Enterprises

The state-owned forest sector presents a different system from that in the villages' collective forests. In the state forest areas, forests are owned by the state (i.e., the central government on behalf of the state). These forests are managed by state-owned forest enterprises (SFEs). A manager of an SFE has obligations to the central government on sustainable use of forests. Meanwhile, he or she also signs a contract with the jurisdictional sub-national government on revenue sharing and other societal goals such as job creation, payment of pension benefits, provision of schooling and health care.

In the past thirty years, China's annual growth rate of gross domestic product (GDP) was remarkable, at almost 10 percent. However, the fast speed of economic growth has come at a tremendous cost to the environment, with inefficient, excessive resource use and high levles of pollution (Liu and Diamond, 2008). In this process, state-owned enterprises inextricably make an enormous contribution, given that 80 percent of the total national value of gross industrial output came from state-owned enterprises by the end of the 1970s and they accounted for 70 percent of the total national assets (NBSC, 1999). During the current decade, state-owned enterprises still account for 40 percent of the total national assets (NBSC, 2015).

The fast rate of GDP growth has been attributed to the so-called Chinese-style federalism (Montinola et al., 1995; Xu, 2011). A key feature of this type of federalism is that it combines fiscal decentralization with performance-based personnel control. The decentralization of fiscal authority, combined with a fiscal transfer system, allows regional governments (provincial, municipal, county and township level governments) to have primary control over economic issues, including firms in their jurisdiction, while the central government typically owns natural resources and possesses the right to set pollution targets. In this system, short-term economic growth is rewarded with promotions of the eligible people at each level of the political hierarchy; by contrast, longer-term environmental issues such as resource degradation and pollution do not negatively affect the likelihood of being promoted.

In **Chapter III**, *Managerial Incentives for Environmental Protection in Chinese-Style Federalism* (with Wolfgang Habla and Jintao Xu), we explain the strategic consequences of a manager of an SFE in this context, as an agent who faces two principals – the jurisdictional sub-national government that is in charge of the state-owned enterprise, and the State Forestry Administration on behalf of the central government, which is the owner of the forests that the agent manages. Career concerns by managers of state-owned enterprises that manage natural resources, and asymmetric information between managers and their superiors regarding the enterprises' environmental performance, are sources of environmental degradation. As well as needing to meet ecological targets imposed by the national government, a manager wants to be promoted into the ranks of the sub-national government. We develop three hypotheses based on a theoretical model with two principals and one agent. We then empirically test these hypotheses for the case of China's northeastern state-owned forests, combining satellite imagery data on deforestation with economic survey data. Our findings suggest that managers of state-forest enterprises that have a larger area are more difficult to monitor with respect to ecological targets, log more timber, and are more likely to deforest. The same holds true for managers who share a larger percentage of profits with the local government. We find that the latter increases the likelihood that the managers will get promoted.

4 Policy Implications

The results of this thesis have important policy implications along at least three dimensions. First, the two papers on the Chinese second-order devolution reinforce the importance of focusing on the quality of resource management reforms. The quality of reforms depends on deepening the recognition of tenure rights, as well as the in-depth knowledge of a great number of factors that determine individual managerial incentives, so that managers of devolved forest will not "fell and run". The effects of devolution and improved tenure on increased private investment and short-run forest conditions enhance our understanding that the effectiveness of devolution relies on well-defined and protected property rights for households. Emerging forestland rental markets are facilitating forestland allocation among households. The households that need more forestland, and that manage forests efficiently, rent in more land. A long-run, comprehensive effect on sustainable forest management will benefit from policy efforts that intensify tenure rights – in particular, transferability rights to more households – and that strengthen the protection of tenure rights and households' perception of tenure security.

Second and more specifically to China, although the results in Chapter II alleviate concerns about agglomeration of forestland to wealthy or powerful households or those already are large landholders, follow-up policies should still be vigilant on fighting consolidation to households of these kinds in the long run. Yet, agglomeration to more efficient users is not bad. In particular, rapid urbanization and transformation from rural to urban economic activities have demanded more rural-to-urban labor migration. More and easier factor mobilization is required. In this case, strengthening local institutions to improve farmers' access to factor resources and credit is necessary to address these considerable constraints. In parallel, policies to improve rural households' knowledge and skills in forest management, and to help build transparent, well-functioning forestland exchange platforms/markets that are easily accessible by villagers, could reduce transaction costs and encourage forestland rental market development.

Finally, the findings about the lack of managerial incentives to protect the environment call for systematic change. The scale of China's forests already makes it difficult for national or regional environmental authorities to measure and monitor forest depletion; an additional challenge comes from the fact that forest managers and local governments have a mutual interest in maximizing revenue from forests. The latter worsens the problem of deforestation even more, because of local governments' "protective umbrella" effect. Policy suggestions are directed toward making the measurement of forest activities easier – for example, by using monitoring technologies such as real-time satellite imagery. More systematic solutions include transferring authority over forests to local governments and basing promotions on the performance of environmental protection as well as revenue generation, or designing contracts for SFE managers that make their interests compatible with both the local governments and the central or regional environmental authority.

To reiterate, as of 2015, the world's total forests still have 76 percent under governmental ownership (FAO, 2015). Potential policy reforms, when it comes to forest management, can be both bottom-up and top-down. In addition, there are a number of potential steps from well-functioning government management to individual or private or household management. Increasing evidence reveals a great deal of interest in reform by the customary owners of their land and resources in African, Latin American, and Southeastern Asian countries where deforestation is still problematic. It is my hope that this thesis – and the data and analyses – will make a small contribution to increased awareness of this global trend of devolution, and to our understanding of policy options for effective natural resource management.

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Chapter I

Forest Devolution Reform in China: A Trigger for Investment or Deforestation?*

Yuanyuan Yi†1

1Department of Economics, University of Gothenburg, Sweden

Abstract

I investigate whether and how the devolution of forestland to households in China triggered investment in forestland, and its effect on forest resource conditions. The investment analysis is based on a panel dataset of a two-round survey of 3,000 households in eight provinces before and after the implementation of the forest devolution reform, while the analysis on resource conditions is based on satellite imagery on forest cover and vegetation during 2001-2012. Using a difference-in-difference propensity score matching model, I find that the devolution reform resulted in more investment, in terms of annual labor input days and value of silvicultural treatments per area unit. At the county level, more forestland under household management is found to improve forest conditions during the time period studied. I also investigate the investment effect through two channels: (i) the effect of tenure security, i.e., holding a forestland certificate and (ii) the reallocation effect from obtaining more forestland resources. The effects of devolution and improved tenure on increased private investment and resource conditions provide evidence that well-defined and protected property rights for households offer an effective alternative to common-pool resources management in small-scale forestry in China.

JEL **Classification:** O13, Q23, Q24, Q58

Keywords: forest devolution; household management; forest investment; deforestation; China

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†Vasagatan 1, SE-405 30 Gothenburg, Sweden, Email: yuanyuan.yi@economics.gu.se

1 Introduction

Devolution of forestland management and its implications for deforestation have concerned both economists and policy-makers for a long time. Devolution means a transfer of the control over a resource from the central government to lower levels such as communities or households. First-order devolution in forest management means transferring full responsibility for state forests to local collective management, while second-order devolution means a transfer to household management. The overall question is whether or not devolution of authority over natural resources is an efficient policy. Many proponents argue that devolution to communities or households is a good idea because they have better knowledge of local conditions and the unique characteristics of the resource. In addition, internalizing protection costs and reducing transaction costs increase efficiency (Baland and Platteau, 1996; Agrawal and Ribot, 1999; Whitaker and Time, 2001; Kelleher and Yackee 2004; Hyde, 2015). Yet, one main concern with devolution is that recipients of devolved rights might simply cut down the forest for short-run profit. There are also concerns about equality and distribution of welfare, in that local actors may be ill-equipped and lack capabilities to respond to local needs (Kenyon and Kincaid, 1991; Peterson, 1996) or the poorest residents may not benefit from devolution. The literature provides no consistency in empirical findings regarding the effects of forest devolution on user investments and forest conditions and focuses mostly on forest devolution of the first-order. For example, in a selection of Asian and African countries as well as South America, positive evidence is found by Köhlin and Amacher (2005), Engel and Palmer (2006), Bray et al. (2008), Qin and Xu (2013), Holden et al. (2013a, 2013b), Yi et al. (2014), and Xie et al. (2016), and inconclusive findings are found by, e.g., Kaimowitz et al. (1998), Baland et al. (2010), and Coleman and Fleischman (2012).

In this study, my interest is to empirically evaluate the second-order devolution of forest management. This has been in place in rural China since 2003 through the Chinese Collective Forest Tenure Reform (State Council, 2003). This devolution reform allows villages to reallocate village-owned forestland to rural households' management and certifies the households' rights. The expectation has been that a local forest owner's decision would incorporate long-term forest returns so that investment in forestland is incentivized, rather than clear-cutting trees and changing land use to a less sustainable use.[1] The incentives influencing the land-use decisions by households are crucial for the outcome of forest cover and quality. With devolved forestland and secure tenure,

[1] In this study, I use "owners" to represent those who possess tenure rights during the contract period. I do not distinguish between the concepts of property rights and tenure rights, because in China all land is owned collectively or by the country as a whole, while management/tenure rights are guaranteed by China's Property Law.

forest owners could: 1) conserve the standing forests by waiting and not harvesting, 2) invest in the forestland by undertaking silvicultural treatments such as thinning and gap-filling, and 3) replant trees after harvest. All of these are examples of forest investments. However, if owners are uncertain of the long-term stability of the reform, they could immediately reap the "windfall" timber benefits of the mature forest stand and convert it into other land uses such as cropland, or even abandon the land.

I provide a microeconomic perspective on the impact of second-order devolution on a forest owner's propensity to invest or deforest, and forest growth or decline as a consequence. This reform was implemented by formally devolving forestland to household management, issuing forestland certificates, and reallocating more village-owned forestland to households. I use two rounds of survey data from 2,940 randomly selected households in eight Chinese provinces from south to north, covering the period 2000-2010. I analyze a total of 10,860 forest plots managed by farmer households. They are located in 258 villages, where the village committees decided on whether and how to implement second-order devolution. To assess the devolution effect on investment, the forest plots are divided into the treated group and the control group. The control group comprises forest plots with no reform before 2010, and the treated group comprises the plots reformed between 2006 and 2010. The reform is not completely exogenous to the villages, the forest plots, or the households, because villages self-selected into the reform and made many decisions related to implementation.

I adopt a difference-in-difference matching approach based on propensity scores. This approach controls for the fact that villages self-selected into the reform, and for the pre-existing observed and unobservable heterogeneity between the treated and the control groups of forest plots, to identify the average treatment effect of the devolution reform on investment. Investment is measured by days of labor input and annual silvicultural investments (in Chinese Yuan, or CNY) for per area unit of each plot. I find a large and statistically significant effect of forest devolution on both labor input and value of investment. Next, I match the satellite MODIS land cover and the Enhanced Vegetation Index (EVI) data with the 44 counties involved in the surveys. By instrumented fixed effects (FE-IV) models, I find short-run positive impacts of devolution on forest cover and forest quality. In addition, I investigate two channels through which the devolution reform triggered investment, i.e., the tenure security effect (through holding a forestland certificate) and the reallocation effect of obtaining more forestland during the reform.

The remainder of the paper is structured as follows. Section 2 reviews the literature on forest devolution and identifies main problems of the mixed findings in previous studies. Section 3 introduces the history of forest management institutions in China, and generates two main hypotheses to test. Section 4 describes the data and Section 5 presents the empirical strategy to test the hypotheses. Section 6 discusses the results and the final section concludes.

2 Evidence of Devolution and Forest Conditions

An increasing number of countries have adopted first-order devolution in forest management. In Asia, these include India (Somanathan, 1991; Agrawal, 2001; Foster et al., 2002; Köhlin and Amacher, 2005; Behera and Engel, 2006), Indonesia (Engel and Palmer, 2006), Vietnam (Meyfroidt and Lambin, 2008a; Meyfroidt and Lambin, 2008b), Nepal (Nagendra et al., 2008), and the Philippines (Dalmacio et al., 2000). In Africa, these include Uganda (Coleman and Fleischman, 2012), Tanzania (Meshack et al., 2006; Robinson and Lokina, 2011); in Latin America, Mexico (Antinori and Rausser, 2007; Bray et al., 2008), Bolivia (Kaimowitz et al., 1998; Andersson 2004; Coleman and Fleischman, 2012) and others (Lynch and Talbott, 1995; Andersson 2004; Agrawal et al, 2008). However, the effects of such first-order devolution on whether forest is more sustainably managed are inconclusive in the literature.

For example, in Bolivia, where forest management was devolved to local municipal governments in the mid-1990s, some studies find no evidence that either the forest or indigenous people benefited from devolution (Kaimowitz et al., 1998; Coleman and Fleischman, 2012). Other studies find that effective forest devolution depends on the connectivity amongst actors and local politicians' interests in forestry (Andersson, 2004; Andersson et al., 2006). Palmer and Engel (2007) investigated logging and forest cover in forest-dependent communities in Indonesia before and after decentralization in 1999. They found logging significantly increased, but they did not evaluate the effect on forest quality. Foster and Rosenzweig (2003) and Baland et al. (2010) both investigated Indian communities but the results are different. Foster and Rosenzweig (2003) used national census data and 1971-99 satellite images and found that the effect of common ownership is positive on forest area and negative on biomass. Baland et al. (2010) found community forest management leads to no improvements in either forest area or biomass. Coleman and Fleischman (2012) assessed the effects of forest devolution on forest conditions in Bolivia, Kenya, Mexico, and Uganda, and found that community management was effective only in Mexico, with insignificant impact in the others.

Given the inconclusive effectiveness of the first-order forest devolution, a key issue is whether to take a further step, by devolving forest management to the household level. A large body of research has provided evidence on the success of second-order devolution of agricultural land ownership, tenure or use; see, for example, Holden et al., 2013a; Jacoby et al., 2002; Feder et al., 1988; Bandiera, 2007; Rozelle and Swinnen, 2004; Goldstein and Udry, 2008. Though the success of the devolution reforms in cropland tenure or titling is not universal, lessons include how the establishment and maintenance of land use rights are arranged (Besley, 1995; Carter and Olinto, 2003; and Deininger and Jin, 2006). Moreover, the devolution of agricultural land in China in 1978 doubled agricultural productivity in a period as short as six years and led to a five-fold increase in rural household income in real terms in two decades (NBS, 2014).

Little evidence exists on second-order forest devolution and its effect on forest cover, and that evidence points in different directions. For example, Meyfroidt and Lambin (2008a, 2008b) found in Vietnam that first-order devolution of forestland before 1994 had no effect on forest regrowth, but second-order devolution post-1994 was positive and statistically significant. Nagendra (2007) qualitatively studied a portion of Nepal's Chitwan Valley district and compared forest changes among community, government and private ownership, using Landsat satellite-image data for 1989 and 2000. Community forests were found more stable than the other two, and the privately owned forestland was cleared or had fragmented forests.

There are several reasons for the inconclusive findings. First of all, many papers are case studies, or studies with small sample size and a narrow geographical focus. Second, reforms are often endogenous to local circumstances and devolution tends to emerge when local forests become degraded (Baland et al., 2010). This in turn brings about a greater level of forest improvement than in previously less-degraded forests.[2] Third, except for satellite imagery data, regional-level or subjective estimates on forest conditions may suffer from systematic measurement error and inconsistencies in definitions across contexts, or extrapolations from outdated surveys, or other dubious estimation techniques (Rudel et al., 2005). The fourth reason lies in the lack of focus on individual behavior. The regional outcome is an aggregation of behaviors at the micro level. Any variation among the following could affect the impact of devolution on good forest management: the actors involved in the devolution process and their new powers, the powers and resources transferred, the accountability of local authorities, the amount of information, financial and human resources, and the degree of public participation (Agrawal and Ribot, 1999; Etoungou, 2003; Andersson, 2004; Andersson et al., 2006; Ribot and Agrawal, 2006).

More recently, studying the same forest devolution reform that is of interest in this paper, Qin and Xu (2013), Holden et al (2013b), Yi et al. (2014), Huang (2015) and Xie et al. (2016) documented the reform's effectiveness in increasing owner investment and village-level forestation. However, these studies rely on regional data and most of them

[2] In the cases where financial aid is available, this positive effect can be expected to be very significant, because this is usually a companion to devolution to communities and local governments, with the purpose of protecting forests.

focus only on Fujian province. My paper uses a panel dataset of comprehensive, two-round household and village surveys in eight provinces from south to north China. The data allows me to address the aforementioned problems. To my knowledge, this paper is the first study analyzing forest-plot-level panel data from a large-scale household survey to evaluate the impacts of a second-order forest devolution reform in terms of private investment and resource conditions. It will provide evidence on how well-defined and protected property rights for households can be an effective alternative to common-pool resources management.

3 The Chinese Collective Forest Tenure Reform

The collective forest tenure reform that I study in this paper is the most extensive devolution of communal forests to households ever seen. By 2008, the reform had devolved 62 million hectares of the total 100 million hectares of forests from collective village ownership to individual households (Xu et al., 2010). The reform has involved 600 million people in rural areas in more than twenty provinces of China (State Forestry Administration, 2011). In this section, I review the background to this reform, and the features of the reform compared to earlier institutional changes in forest management in this context.

Since 1954, when all private forests were collectivized, China's collective forests have undergone a number of tenure system reforms. What followed in the early 1960s was returning trees around homesteads to individual households' control. In the early 1980s, inspired by the successful Household Responsibility System reform, which contracted agricultural land to households in the late 1970s, the tenure rights of collectively owned forests were allowed to be devolved to villagers within the village communities on a large scale. This is known as the "Three Fixes" policy, in the policy document "*Resolution on Issues Concerning Forest Protection and Development*", announced by the State Council of China in 1981.

By 1986, roughly 60-70 percent of collectively owned forests was under household management (Xu et al., 2010). The "Three Fixes" had three characteristics – the forests were still under collective ownership, there was a lack of clearly defined borders and use rights, and the implementation was uneven. Excessive timber harvest and extensive deforestation were perceived as rampant outcomes, especially in association with the Chinese government's attempts to liberalize trade control in the mid-1980s. By 1987, the government increased its control over forest management again, along with a logging quota system. In the 1990s, villages took back forestland from households and put it under collective control. In the meantime, some forestland was subject to market transactions through, for example, auction of use rights. This marketization process created opportunities for large-scale private forest management, but the large poor rural population could not afford to participate in this market and still had no full property rights to claim returns from the community forests (Hyde et al., 2003).

Soon after the millennium, a new wave of forest tenure reform was initiated in Fujian province. This time, the focus was on devolution of forest management rights to households. The main features of the devolution were reallocation of village collectively owned forestland to households, and formal acknowledgement of household tenure rights to these forest plots. This was very successful and encouraged the central government to implement a few other pilot cases starting in 2003 (State Council, 2003). The reform spread to other provinces quickly, and was finally promulgated by the central government in the policy document "*Collective Forest Tenure Reform in the Southern Collective Forest Areas in China*" in 2008.

This round of forest devolution had the following features. First, based on votes in the village – via village assembly or representative meetings – the village committee decided on the implementation of forest reallocation. Second, ambitious measures were adopted to strengthen tenure security. Forestland certificates for each forest plot, with clearly specified contract terms, were issued to owners. For instance, the tenure for plots previously called "family plots" was given a clear duration in this round of reform, ranging from 30 to 70 years, and some of these plots received certificates with a "long-term" contract duration. The terms specified in the certificates were more complete compared to the earlier, simpler contracts. Furthermore, the new certificates often extended the rights to include production and harvest decisions, such as rights to convert forestland to cropland, select tree or plant species, interchange different forest types, harvest non-timber forest products, and even abandon plots, as well as transferability rights to other villagers or outsiders, and the right to use forestland as collateral. Third, forestland rental/transfers markets were encouraged in the new devolution reform. The rights to transfer forestland to people within or even outside villages, and to mortgage forestland as collateral, were acknowledged, which was unprecedented. The transferability rights and rental markets are expected to mobilize production factors and also to provide incentives for owners to invest in forestland in order to transfer it with a higher price.

With these features, the devolution reform aimed to incentivize forest owners to make long-term decisions on forestland uses. According to the policy documents, the expectations included increases in investment and reforestation. Investment can take one of the following forms: (i) waiting a longer period before harvesting,[3] or (ii) un-

[3] Waiting for a longer period before harvesting is regarded as an investing behavior in an asset with expectation of future interest.

dertaking silvicultural treatments, such as thinning trees and reforesting after harvest. Such investments protect the forest and foster forest growth. As discussed earlier, the opposite could also occur, where households would reap the "windfall" timber benefits of the mature forest stand and convert it into other land uses, such as cropland, or even abandon the land.

Given the mixed evidence in the literature on the impacts of devolution in other countries, and the past challenges in devolving forest management in China, I am interested in analyzing the impact of the collective forest tenure reform in terms of investment and forest quality. In order to assess these outcomes of the reform, I will test the following hypotheses:

Hypothesis 1. *Forest investment increases due to the devolution reform.*

Hypothesis 1a. *The devolution reform increases forest investment through enhanced tenure security.*

Hypothesis 1b. *The devolution reform increases forest investment through reallocation of forestland.* That is, households that receive more forestland during the reform conduct more forest investment per area unit.

Hypothesis 2. *More forestland devolved to household management contributes to better forest conditions.*

4 Data and Descriptive Statistics

The data used in this study come from two sources. Data regarding forest investments come from a unique, comprehensive two-round survey of households and villages in eight Chinese provinces, conducted by the Environmental Economics Program in China, based at Peking University. After a pilot survey in two counties in Fujian, the first-round survey was conducted in 45 other counties during the period from March 2006 to August 2007. These counties are located in eight provinces: Fujian, Jiangxi, Zhejiang, Anhui, Hunan, Liaoning, Shandong, and Yunnan. A stratified random sampling rule was applied to survey 10-20 households in each of the 258 villages from 128 townships in the 45 counties. The second-round survey, in 2011, revisited the same households. Figure 1 depicts the distribution and survey time of the samples.[4]

In each round, a household level questionnaire collected information on the past year on forestland management practices for each forest plot, as well as households' farming activities, with costs and outputs, and non-farm work and income. Village

[4] Two counties in Fujian province were selected for pilot surveys in March 2006, so in the second round of survey they were not followed up. The pilot samples are thus excluded from the analysis in this paper. In total, 45 counties were included in the analysis. In the second survey, some observations are missing because the houshold representative could not be surveyed due to temporary absence such as being in the hospital, or busy at work, or long-term absence because of migration or death, etc.

leaders were asked about the decision-making and implementation of the Collective Forest Tenure Reform and the community socio-economic characteristics during the period 2000-2010.

< Figure 1 here >

To measure forest conditions, i.e., forest cover rate and forest quality, the second data source is spatial data – the MODIS land cover (MOD12Q1) and the Enhanced Vegetation Index (EVI) data (in MOD13Q1) from satellite images of NASA's Terra spacecraft. The data provides spatial resolution up to 250 meters and covers the period from 2001 to 2012. I match them for the 45 counties with two year lags to the survey, i.e., in 2002, 2007, and 2012, to allow for the forest management decisions to be better captured in the satellite images.[5] Figures 2 and 3 illustrate the changes in forest cover and EVI of China as an overview from the satellite.

< Figures 2 and 3 here >

Variable Definitions and Descriptive Statistics

I drop the forest plots that were already reformed in 2005, because of no data about them prior to the reform. The samples in the pilot survey are also excluded because they were not followed-up. In order to compare the investment change in the reformed forest plots with those not reformed, I divide the sample into control and treated groups: the control refers to forest plots with no reform before 2010, and the treated group includes the plots reformed between 2006 and 2010. Table 1 summarizes the investment and reform variables for each group and period.

< Table 1 here >

Forest investment is represented by yearly days of labor input in taking care of the forestland and the CNY value of other investments such as silvicultural treatments or/and regeneration efforts. The reformed forest plots have higher levels of investment in 2010, in both per-plot and per-*mu* terms.[6] The difference seems to exist as early as 2005, but not to the same level as in 2010. Interestingly, in 2010 a larger share of plots have positive investment in the treatment group compared with the control

[5] Huang (2015) evaluated the same reform's effect on forest conditions using village shapefiles. In their study, half of the village maps were not available, so the author created buffers based on the coordinates of village centers and village land areas. In this paper, I use the administrative county maps to improve the accuracy and variation in forest cover and quality.

[6] *Mu* is an area unit used in rural China, with 1 *mu* equal to 1/15 hectare.

group, while the opposite was true in 2005, suggesting a positive effect of the reform on investment.

In the treated group, 58 percent of the plots received their forestland certificates and 72 percent were in households that obtained more forestland during the reform. Whether a household received a certificate was due to administrative time and financial constraints, and variations in resource endowments. I also observe that 27 percent of the plots in the control group were rented in, so that their households' access to forestland increased, too.

< Table 2 here >

Table 2 lists the characteristic variables of households, forest plots and villages that affect investment incentives. The mean values of demographic characteristics such as household size, household head's age, gender, and education are not different between the two groups in either period. However, differences exist in other household, plot, and village characteristics between the treated and control groups. The differences indicate a methodological concern that the pre-treatment differences should be taken into account, and also suggest differences in characteristics that may correlate with a village selecting the reform, households' incentives to invest, and the consequences for forests.

In general, the treated group has wealthier households than the control group, given by their higher livestock value, per capita income, and value of house(s). Furthermore, these households have easier access to credit by closer distance to a local bank, and better connections to village leadership. The forest plots in the treated group are located farther from households' homes and from the closest paved main road, and are larger in size, with flatter slope and worse irrigation conditions, less timber and more so-called "economic" forests such as fruit trees and medicine plantations. The resource status of the stands looked similar in 2005 in the control and treated groups, i.e., 3.94, implying near-mature forests. In 2010, the reformed forest plots looked better, with 4.17, meaning closer to maturity, than 3.85 in the comparison group. So, if better forestland is reformed first, this fact rather than the reform could drive the change in investments. Therefore, I control for these factors in the identification.

Importantly, harvesting activities reflect how forest owners realize their property (or tenure) rights, even though they may harvest due to poor tenure in the short run. In 2005, around 7 percent of the forest plots were harvested. In 2010, almost 20 percent of the plots were harvested, with a higher percentage in the treated group than in the control group. Harvest with improved tenure should differ from harvest because of poor tenure (e.g., insecurity), in that the former would be carried out with regeneration efforts, such as replanting trees or nurturing the harvested plots. I will look at this by comparing the difference in investment between harvested and non-harvested plots in the treated group, and the difference in investment in the harvested plots between the treated and the control groups.

In addition, in parallel with the influence of harvest on investment incentives and forest outcomes, there is a small number of forest plots with a special role. These are the forest plots involved in the Sloping Land Conversion Program (SLCP), which are 5 percent of the sample.[7] These plots were converted from cropland to forestland, based on households' decisions. They accepted governmental payment and in return promised to protect and not harvest the standing trees. Although the SLCP is independent of the forest tenure reform, I take into account any spillover effect to the new round of devolution reform with respect to reform decisions and household investment.

At the village level, population, income, and commercial timber price increased over time, as well as average precipitation and the number of households with telephones (an indicator of development). The labor market became more developed, as measured by the percentage of labor engaging in off-farm work. The overall changes in the economy are relevant to the increased interest in forestry, possibly driving a village to reform.

In contrast to the control group, the villages that implemented the reform are located in somewhat more remote areas, farther from paved roads and from the closest county center. In those respects, they were less developed, but they grew quickly, as indicated by the population having telephones and the increasing timber prices. They were larger in size (in terms of the total number of households), had higher per capita income, and were endowed with more forestland. By contrast, the villages that decided not to reform had a smaller share of forestland, and households already managed over 80 percent of the forestland in 2005, though without legal acknowledgement. Also, villages with a less developed labor market, in terms of a smaller proportion of off-farm labor out of the total labor force, were more likely to select the reform; specifically, less than 30 percent of labor was engaged in off-farm work in the reform villages, compared to 61 percent in villages with no reform.

$<$ Table 3 here $>$

For the county-level analysis on forest conditions, Table 3 reports the summary statistics of the variables of interest for the years 2000, 2005 and 2010. From the National Geomatics Center of China, I obtain the 44 administrative maps for the 45

[7] The Sloping Land Conversion Program in China is one of the first and most ambitious payment for ecosystem services programs in China (Bennett, 2008). The program started in 1999. It encourages farmers to convert cropland to forests and uses a public payment scheme. The farmer households participating in this program are obliged to take care of the converted forests and are limited in harvest.

counties involved in our survey.[8] Forest conditions are computed using the MODIS products data of 2002, 2007 and 2012. I use two dependent variables – one for forest cover and one for forest quality.

The forest cover indicator includes evergreen (deciduous) needle leaf (broad leaf) forests and mixed forests, as defined in the IGBP classification of land cover types in the standard MODIS product MCD12Q1, at 500 meter spatial resolution in a sinusoidal projection. The dependent variable, forest cover, is the percentage of land in a county that is covered by forests, and it is observed to rise in this 10-year period, from 32 to 38 percent.

The forest quality variable is the average value of the vegetation index for each pixel in the polygon that represents a county region, using the Enhanced Vegetation Index (EVI) at 250 meter resolution in the MOD13Q1 product data. Overall, I observe a rise in vegetation indices from 2002 to 2007, and then a decline to a level lower than in the beginning in 2012.

The county socio-economic variables are generated as the county mean of the surveyed villages weighted by village land area out of the county total. The representativeness of this approach is justified by the stratified randomness of sampling at each level of the survey. The degree of forest devolution in one county is measured by the percentage of area of forestland managed by households. This percentage increased from 36 to over 43 in the study period. In addition to the institutional dimension – forest devolution – I take the following factors of economic and social development into account: per capita income, commercial timber price, daily labor wage, average village size, and population having telephones.

Finally, the weather data come from the China Meteorological Data Sharing Service System (CMDSSS) on daily precipitation and temperature.[9] Matching with the closest weather station recorded by the CMDSSS, I compute for each county the annual rainfall average and its variability. For temperature, because of its nonlinear effect on plants (Schlenker and Roberts, 2009), I use two aggregates for trees: the effective growing-degree days of 0-35 degrees Celsius (GDD) and the harmful degree days of >35 degree Celsius (HDD).[10] In this decade, effective GDD is stable but the rainfall average and variation and the HDD all increased. For example, the average precipitation increased by 20 percent, from 37.4 mm to 44.9 mm during 2000-2010.

[8] In total, 44 counties are matched, because two counties (Taierzhuang and Shanting Districts) belonged to the same polygon as one county in Zaozhuang City of Shandong province.

[9] http://data.cma.cn/

[10] GDD is a measure of effective cumulative heat for days with 0-35 degree Celsius (°C). $\boldsymbol{GDD = \sum_i^N T_{i,a} - T_{i,base}}$, where $\boldsymbol{T_{i,a}}$ is the daily average temperature for day $\boldsymbol{i}$, and $\boldsymbol{T_{i,base}}$ is the base temperature below which vegetation ceases to be biologically active (here, $\mathbf{0\,^{\circ}C}$ is selected for trees). HDD measures harmful cumulative heat for the days with temperature higher than 35 °C, calculated by $\boldsymbol{HDD = \sum_i^N (T_{i,max} - 35\,^{\circ}\mathrm{C})/T_{i,max}}$, where $\boldsymbol{T_{i,max}}$ is maximum temperature for day $\boldsymbol{i}$.

5 Empirical Strategy

5.1 Estimating the Impact of Devolution on Forest Investment

To test Hypothesis 1, I estimate the impact of the forest devolution reform on owners' investments in forestland. As a natural experiment, a valid measure of impact evaluation should compare outcomes in the plots that received the reform to what the outcomes would have been if there were no reform. But two challenges exist in the identification of such an impact. One is that the counterfactuals are unobservable, while a difference-in-difference estimator compares the outcomes based on observable differences. The other challenge is induced by unobserved characteristics that drive targets to self-select into the experiment and also correlate with the outcome of interest, thus biasing the impact estimate even if the pre-experiment characteristics are controlled for (Heckman, 1990; Heckman et al., 1998; Heckman and Navarro-Lozano, 2004).

Because villages self-selected into the reform, village resource endowments and socio-economic development might drive these reform decisions and also correlate with households' incentives to invest. However, the fact that the panel data consist of both a control group with no reform and a treated group before and after the reform allows me to apply the difference-in-difference propensity score matching approach. With this approach, I first construct a plausible comparison group by matching the reformed plots with similar non-reformed ones, based on a rich set of covariates. The covariates include the plot-, household- and village-level characteristics that potentially influence reform status and investment incentives. Second, taking advantage of the panel data setting, changes in investments before and after the reform in the treated group are compared to the change in investments in the sample of controls between periods. This process removes possible unobserved time-constant differences between the treated and the control group (Heckman et al., 1998; Heckman and Navarro-Lozano, 2004). These differences include household risk and time preferences that are believed to be stable in the long run and may influence incentives for forest investment.

For this approach, I follow the procedures formalized in Heckman et al. (1997, 1998), Smith and Todd (2001, 2005), and Gilligan and Hoddinott (2007), and estimate the average impact of the treatment on the treated (ATT) with the panel dataset:

$$\begin{aligned}
\boldsymbol{ATT} &= \boldsymbol{E(\Delta|X, D=1)} \\
&= \boldsymbol{E(Y^1 - Y^0|X, D=1)} \\
&= \boldsymbol{E(Y^1|X, D=1) - E(Y^0|X, D=1)} \\
&= \boldsymbol{E(Y_t^1 - Y_\tau^1|X_\tau, D=1) - E(Y_t^0 - Y_\tau^0|X_\tau, D=1).}
\end{aligned} \tag{1}$$

where the superscripts $\mathbf{1}$ and $\mathbf{0}$ stand for "treatment" status, with $\mathbf{1}$ if the village adopted the reform between 2006 and 2010, and $\mathbf{0}$ if the village did not adopt the Reform by 2010. $\boldsymbol{Y^1 = Y_t^1 - Y_\tau^1}$ is the outcome, i.e., change in investment, from 2005 ($\boldsymbol{\tau}$) to 2010 ($\boldsymbol{t}$), of a forest plot receiving the reform between 2006 and 2010, and $\boldsymbol{Y^0 = Y_t^0 - Y_\tau^0}$ is the change in investment if the forest plot did not receive the reform. Investment ($\boldsymbol{Y}$) is measured by annual, per-mu labor days or the CNY value of silvicultural investment conducted on each plot. $\boldsymbol{X_\tau}$ is a vector of covariates, including forest plot, household and village characteristics. $\boldsymbol{D}$ is an indicator that an observation is in the "treatment" group, equal to $\mathbf{1}$ if in the treated group and $\mathbf{0}$ if in the control group.

Because only $\boldsymbol{Y^1}$ or $\boldsymbol{Y^0}$ can be observed for each observation, $\boldsymbol{E(Y_t^0 - Y_\tau^0 | X_\tau, D = 1)}$ is not observable. The propensity score matching method allows me to match a number of similar non-treated to the treated, and to estimate the counterfactual outcome for the treated observations (Rosenbaum and Rubin, 1983). To match, I let $\boldsymbol{p(X_\tau) = Pr(D = 1 | X_\tau)}$ be the probability of a forest plot being in the treated group, so that a reform recipient plot is statistically matched to a group of non-reformed forest plots with similar values of $\boldsymbol{p(X_\tau)}$. To put it differently, the propensity scores, $\boldsymbol{p(X_\tau)}$, are obtained as the fitted values from estimating the likelihood of receiving the reform, by using a probit model that includes pre-reform observable characteristics, $\boldsymbol{X_\tau}$. $\boldsymbol{X_\tau}$ include potential determinants of a village selecting the reform and factors affecting forest investment. Based on the propensity scores, I match the treatment and control observations using kernel-based matching (KBM), which matches all treated observations with a weighted average of all controls. The weights in KBM are inversely proportional to the distance between the propensity scores of treated and control groups. Then, the average of the differences of each matched pair is computed as $\boldsymbol{ATT}$. The standard errors for the impact are estimated by a bootstrap strategy.

The validity of this approach stands on two assumptions: the "conditional mean independence" (CIA) and common support condition. The former requires that $\boldsymbol{E(Y^0 | X, D = 1) = E(Y^0 | X, D = 0)}$, implying that, conditional on the covariates, the observations in the control group have the same mean outcomes as the treated observations would have had if they had not been treated. The latter condition, $\boldsymbol{0 < p(X_\tau) < 1}$, requires that valid matches of $\boldsymbol{p(X_\tau)}$ can be found for all values of $\boldsymbol{X_\tau}$.

Next, in order to test Hypotheses 1a and 1b, regarding how the reform triggered investment through tenure security and through reallocation, I estimate two separate treatment effects of the reform, interacted with improved tenure security and with reallocation, respectively. In other words, I regard a household's perception of security of tenure over a specific forest plot due to the reform as one treatment, and a household receiving more forestland during the reform as another treatment. As discussed in Section 3, the tenure security effect may occur because the household received a forestland certificate or formal acknowledgement of tenure rights. In addition, households could receive more forestland from the administrative reallocation by village committees or from the forestland rental markets that have been encouraged by the reform. Investments are therefore expected to be incentivized because of increased access to more production assets, and through stronger tenure security and resulting gains-from-trade (Deacon, 1994; Mendelsohn, 1994; Besley, 1995).

5.2 Estimating the Effect of Devolution on Forest Conditions

To test Hypothesis 2, I assess the impact of devolution on forest cover and quality in a reduced-form regression model:

$$\boldsymbol{F_{it} = \alpha + \theta_1 s_{it} + \theta_2 P_{it} + \theta_3 V_{it} + \omega_i + \mu_t + \varepsilon_{it}}. \tag{2}$$

where $\boldsymbol{F_{it}}$ is forest cover or EVI index of county $\boldsymbol{i}$ at time $\boldsymbol{t}$; $\boldsymbol{s_{it}}$, extent of forest devolution, i.e., percentage of forest under household management, see Table 3; and $\boldsymbol{P_{it}}$ and $\boldsymbol{V_{it}}$, respectively, are vectors of prices of input factors (e.g., timber price and off-farm labor wage) and observed geographical and socio-economic characteristics. These factors drive forest degradation through economic and population growth, and agricultural expansion, that increase the demand for forest products. In spite of this, forest could rehabilitate and increase in area and quality via increased output price because of forest scarcity and/or reduced agricultural expansion, due to increased labor moving to off-farm work (Foster and Rosenzweig, 2003; Rudel, 1998; Rudel et al., 2005). $\boldsymbol{\omega_i}$ represent the unobservable, time-invariant factors; $\boldsymbol{\mu_t}$ is year trends, and $\boldsymbol{\varepsilon_{it}}$ is the error term.

The extent of forest devolution, $\boldsymbol{s_{it}}$, may be endogenous because some unobservable factors in the error term, $\boldsymbol{\varepsilon_{it}}$, may correlate with both $\boldsymbol{s_{it}}$ and $\boldsymbol{F_{it}}$. These factors may be time-constant or varying. Let me take the exogenous geographical conditions first, as in $\boldsymbol{\omega_i}$. Their influences can be controlled by panel fixed effects (FE) models, assuming there are permanent differences, such as soil conditions, between villages adopting and not adopting the reform. However, some other unobservable, time-varying influences cannot be removed by FE estimations. They stem from historical resource changes and regional socio-economic development and structure. Such influences – including the regional reliance on forestry, forestland productivity or ability factors, and villagers' overall bargaining power in calling for the reform – could lead to the variation in reform implementation amongst villages and counties. To put it simply, these factors explain why a region is endowed with better institutions and more sustainable resource management. Omitting them in FE estimations would result in biased point estimates.

Therefore, I use 2SLS fixed effects (FE-IV) estimators. The following instrumental variables (IVs) are used: average and standard deviation of rainfall, the helpful and harmful cumulative heat measures (GDD and HDD), and the population share with telephones. Weather conditions may correlate with the general environment for forestry and forestland productivity. A larger population with telephones suggests better information access and social development, so that villagers may have stronger bargaining power in calling for the reform and thus more forest may be devolved.[11] Therefore, the IVs are relevant ($\boldsymbol{Cov(IV, s) \neq 0}$), and in the meantime they do not directly affect forest cover, fulfilling the exclusion restriction ($\boldsymbol{Cov(IV, \varepsilon_{it}) = 0}$). In addition, because vegetation depends on weather conditions as trees grow, I remove the weather variables from the excluded instruments and include them in the second-stage estimation.

6 Results

The empirical results of impact evaluation involve two sets of estimations: the matching difference-in-difference estimators of the investment effect of the reform, and the fixed-effects estimators of the impact of devolution on forest cover and quality.

6.1 The Investment Effect of the Forest Devolution Reform

The impact analysis of the reform is preceded by a specification of the propensity scores for the treatment variables used to match the treatment recipients and non-recipients. I analyze three treatments specifically: the reform and its two possible triggers, which are the enhanced tenure security effect and the forestland reallocation effect. A probit model is regressed on a broad set of covariates (for 2005) for each treatment variable to predict the probability of being treated, the results of which are presented in Table 4. The selection of the covariates is based on the desirability of over-parameterizing the probit model for the best possible match, conditional on factors highly associated with the treatment variable and the outcome. Also, the individual parameter estimates from the model should not possess a causal interpretation, but only association (Heckman and Navarro-Lozano, 2004; Lee, 2013).

$<$ Table 4 here $>$

By a series of t-tests on the covariates across the treated and control groups, I check that the CIA condition is satisfied and the groups are well balanced. Figure 4 distributes

[11] Access to the phone grid can also be an indicator of cohesion and political clout, which would affect tenure reform.

the propensity scores between the treated and control observations for each treatment. Each figure shows that the common support condition is well satisfied by the substantial overlap of the density distributions of the estimated propensity scores for the treated and control groups. On the propensity to be treated, the significant coefficients provide evidence that the reform decisions are associated with socio-economic development and natural conditions in a village, as well as plot and household characteristics. Column 2 shows that, as expected, receiving a forestland certificate and a higher score of perceived tenure rights are significantly and positively associated with more secure perception of ownership of a forest plot.[12] In Column 3, the significant estimates suggest that, in addition to village selection into the reform, household characteristics such as work experience in a forestry department, as well as plot conditions, correlate with the likelihood of receiving more forestland during the reform.

< Figure 4 here >

Given the proper matches based on the distribution of the propensity scores, the effect of the reform and its two triggers on forest owner's investment is estimated with a KBM algorithm with 0.01 bandwidth. Table 5 reports the estimates of the average impacts of the reform on investments (in Columns 1-3). As in Equation (1), the level of investment, in terms of annual per-*mu* labor-days or CNY value of silvicultural investment, is $Y^1 = ln(Y^1_{2010}/Y^1_{2005})$ for the treated forest plots and $Y^0 = ln(Y^0_{2010}/Y^0_{2005})$ for the control plots. The results reveal a large and statistically significant effect of the reform on forestland owners' investment, both in terms of labor input and value of investments. Investments increase over time in both the treated and the control groups, but the increase in the treated group is higher. The ATT estimates for the reform treatment, 0.119 and 0.328, imply that the reform increases both labor inputs and investment in a forest plot. The effect is equivalent to a 13 percent increase in the ratio of average forest labor investment in the reformed plots to that in the matched non-reformed plots over this period, and a 39 percent increase in the CNY value of investment in the reformed plots compared to the controls. These findings support Hypothesis 1.

< Table 5 here >

In Columns 2 and 3, the ATT estimates represent strong average impact of the reform through enhanced tenure security and through more forestland reallocated. Lack of protection for ownership (or tenure) is a common problem in developing countries

[12] The nine tenure rights are: production rights such as converting forestland to cropland, selecting tree or plant species, interchanging different forest types and different land use purposes, using non-timber forest products, and gains-from-trade rights such as forestland transfers, inheritance, and mortgaging.

that jeopardizes the incentives of landowners to invest. Many economists see security as a prerequisite to successful forest investment (Deacon, 1994; Mendelsohn, 1994; Besley, 1995). In addition to legal acknowledgement of private tenure and rights, the Chinese forest devolution reform issued forestland certificates, which strengthened tenure security as perceived by forestland owners, as found in Column 2 of Table 4. Evidently supporting Hypothesis 1a, the statistically significant estimates (0.348 and 0.526) suggest that perception of security of future ownership encourages a 42 percent increase in labor input and a 69 percent increase in the CNY value of investment.

Besides the devolution of ownership and improved tenure, the reform encourages reallocation of village-owned forestland to households and participation in forestland rental markets. Increased access to production assets enables a household to conduct more investment. In Column 3, the *ATT* estimates show that the reform's reallocation effect is sizable too: 0.246 (0.294), implying a 28 percent (34 percent) increase in the labor (value) of investment on a forest plot where its owner received more forestland during the reform than if it had not been received, supporting Hypothesis 1b.

Further Exploration: Forest Investment as Regeneration Efforts after Harvest

As discussed previously, the right to harvest empowers owners to realize their rights to claim returns on investment. There also exists opposition to forest devolution, with the fear that harvest would be conducted without regeneration efforts such as nurturing and replanting. Due to this concern, I check whether harvesting brought about forest investment in reformed forest plots (Column 4 of Table 5). The investment variables (labor input and CNY value of investment) allow us to check this because they are aggregated, excluding those associated with harvesting activities. The labor and other investments associated with harvesting are more often regarded as harvest costs. By contrast, for the variable, an investment increase in plots where harvest was carried out in the study period reflects post-harvest regeneration efforts or investments. So, I also compare the difference in investment in the harvested plots between the treated and the control groups (Column 5).

First of all, as shown in Columns 2 and 3 of Table 4, previous harvests do not undermine households' perception of tenure security, but may encourage them to acquire more forestland. On the other hand, harvest activities on the reformed plots are an outcome of self-selection, where an owner may invest more because he or she wants to harvest, given the perception of tenure security and other household and resource characteristics. So, I use harvest as a treatment variable and the same set of covariates for the first-stage propensity estimation and then report the second-stage *ATT* estimates in Column 4 of Table 5. The *ATT* estimates show that the difference in investment increase between the devolved plots harvested and the matched, devolved non-harvested plots is statistically significant. The increase in labor input will be 8 percent higher on a forest plot after harvest than if no harvest activities were undertaken, and the value of investment will be 35 percent higher. These findings alleviate the concern that harvest would be carried out without regeneration efforts on devolved forestland. Furthermore, in Column 5, the estimated difference in investment between the matched pairs of harvested plots with the reform and the harvested plots with no reform is negative for labor and positive for investment value, though statistically insignificant.[13]

6.2 Forest Devolution and Forest Conditions

In light of the evidence supporting Hypotheses 1, 1a and 1b, devolution of forest management to households increases forest investment, including regeneration efforts. As a result, reduced deforestation and better forest outcomes can be anticipated. Table 6 reports the FE and FE-IV estimation results of Equation (2), on the impact of devolution on forest cover and forest quality (EVI). Columns 1-2 and 4-5 are FE estimators, where year trends are included in Columns 2 and 5. Adding the year dummies influences the estimate of devolution on forest volume change, as expected, as forest foliage naturally grows with time in all regions. Following the earlier discussion on the endogeneity of the degree of devolution, the variable of percentage of household-managed forestland in the FE-IV estimates in Columns 3 and 6 are instrumented separately for forest cover and EVI. The first-stage results are reported in the last column. The significant coefficient of the population share having telephones and the strong F-statistic satisfy the condition that the selected instruments are correlated with the endogenous variable. The Sargan test cannot reject the null that all instruments are uncorrelated with the error term, satisfying the exclusion restriction.

< Table 6 here >

The FE estimates in Columns 2 and 4 suggest that all forestland devolved to household management from communal management will lead to an increase of 23 percentage points in forest cover, and of 6 percentage points in vegetation volume, *ceteris paribus*. This effect indicates that households of the average levels of characteristics in the samples, in the case of obtaining 100 hectares of forestland, will enlarge the regional forest cover by 23 hectares of forest. By waiting a longer period before harvesting, they will

[13] I also employ a simple probit model to investigate the factors that explain why a forest plot had no investment after harvest. I find plots with stronger tenure rights, greater household wealth and credit access, and less time spent on off-farm work, are more likely to have post-harvest investment. Plot characteristics seem to drive post-harvest investment, e.g., plots with fruit trees are more likely to have post-harvest investment than those with timber trees. The results are not reported in the paper but are available upon request.

also improve forest conditions by undertaking more silvicultural treatments; as an expected result, forest volume will be improved, with a 6 percentage point increase in vegetation index values.

The difference in the FE versus FE-IV estimates suggests a downward bias of the FE estimates of devolution's impact on forest conditions. The FE-IV estimate of the devolution variable in Column 3 of Table 6 indicates that full devolution from completely collective management will lead to a 51.8 percentage points increase in forest cover. Vegetation will have an increase of 7 percentage points from the mean level. In other words, taking the 2010 sample mean of devolution rate (0.431, in Table 3) for example, an increase in devolution by one standard deviation (0.194) will lead to an increase in forest cover by 0.100 (or 26.7 percent of the mean level of forest cover, 0.377) and an increase in vegetation by 0.014 (or 5.7 percent of the mean indexed vegetation, 0.245). These findings support Hypothesis 2 by suggesting a short-term impact of forest devolution on forest cover and quality, given that the variables of forest conditions are measured in two years.

I acknowledge that the devolution effects on forest conditions are identified only for forestland under household management, instead of the overall marginal effect of the new round of reform. Household management in the studied area comes from two sources – the new round of devolution reform and the earlier Sloping Land Conversion Program.[14] I also recognize that the forest cover and EVI are constructed as averages of the pixels inside a county and do not exclude urban land; therefore, the estimates may be taken as a lower bound effect on forest conditions.

I also find interesting evidence on economic development and forest increase in area. Economic growth would be expected to bring about forest decline due to increased demand for forest products, but would also promote tree-planting because of forest scarcity (Rudel, 1998; Foster and Rosenzweig, 2003; Rudel et al., 2005). I find, on the one hand, that timber price increases would drive more deforestation to supply more timber products and thus reduce forest cover, but the effect is nonlinear. On the other hand, income growth increases forest cover and the increasing effect slows down as income grows higher, though the marginal effect estimated by both the FE and FE-IV models is trivial. A high labor wage attracts rural labor to engage more in off-farm work; thus, less labor would be spent on enlarging forest cover and taking

[14] Due to data availability, I cannot exclude the influences on forest increase of the Sloping Land Conversion Program starting from 1999, which compensated farm households that converted agricultural land into forest plots and refrained from cutting standing trees before they are mature. Some counties, in particular in Shandong province, followed the devolution trend by allowing villages to devolve forest plots with ecological forests, with the aim of encouraging better forest management by devolution. In these two cases, the owners of forest plots promise not to cut the standing trees, at least before the trees are mature. Though the earlier investment analysis controlled for the SLCP effect, the estimates of household management effect on forest conditions would encompass the SLCP's contribution to forest increase.

care of forests, and, as a result, forests would decline in both area and quality. Thus, I do not find similar evidence as in Rudel et al. (2005) that the labor market moves rural labor from agricultural expansion by a higher wage, which eases the pressures on forests, allowing for their spontaneous regeneration.

7 Conclusion

In spite of natural disasters, forest degradation is more often caused by human activities such as cattle ranching, logging, mining and oil extraction, construction of dams and roads, and so on. Population and economic growth have been identified as two main underlying driving factors of forest decline by a number of regional and country-level studies, e.g., Rudel (1998) and Rudel et al. (2005), Barbier and Burgess (2001a, 2001b), Foster and Rosenzweig (2003), and Coleman and Fleischman (2012). Weak institutions and market failures due to non-existing prices for forest goods or services and bad policies also contribute to forest degradation. For instance, centralized land ownership, thence poorly defined or non-existing ownership and land tenure arrangements, are the institutional factors of governance weakness leading to forest declines (Ostrom, 1990; Deacon 1994; Mendelsohn, 1994).

The trends encouraging privatization and devolving collaborative resource management emerged from the concern about the prediction of the tragedy of the commons by Garrett Hardin (1968). Ostrom (1990) contributed to collective action and common-pool-resources institutions with her famous eight design principles. Practically, the findings on the first-order devolution effect on forest conditions are largely mixed in the existing literature. The second-order devolution, to household management, has undeniably improved the welfare of the local population compared to the previous system of collective management of forestland in China (Xu et al., forthcoming). China started devolution due to previously weak institutional management of public assets, where non-cooperation and forest degradation were generally observed under collective management.

This paper provides evidence of the positive effects in terms of investment and forest cover of the Chinese second-order devolution, implying that private management of forests can be an alternative to common-pool resource management. I studied households' behaviors as responses to the devolution of forestland management. I combined repeated household surveys and satellite imagery data. The econometric results indicate that privatizing forest management to households triggered more investment, and had a positive impact on forest conditions. But we have to also keep in mind that there does not exist a unique institutional arrangement that fits all. For China, the success of forestland devolution can to a large degree be attributed to the reallocation of forestland and improved tenure security. By reallocation of forestland, farmers' access to resources and production factors is improved. With forestland certificates being issued to farmer households, the contract terms are clearly specified. Ownership security is strengthened to a degree unprecedented in China, which guarantees the right to claim future returns on investments. Moreover, private ownership of forests has a longer history in industrial countries, where private property rights have been well protected by institutions and rules of law. For developing countries, the path to forest transitions from deforestation and degradation is still long.

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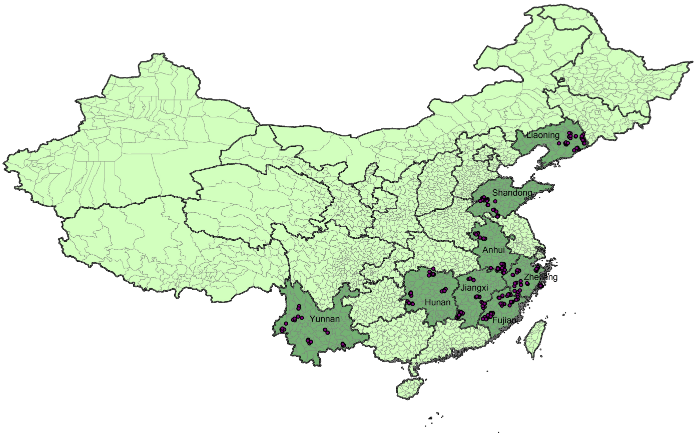
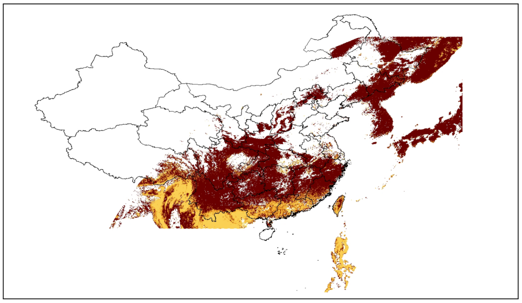
Figure 1: Distribution of survey samples.



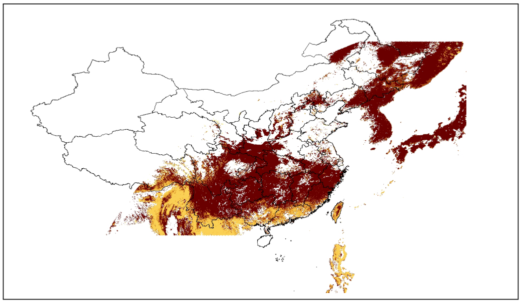
Survey Time	Province	County	Township	Village	Household	Forest plots
March-April 2006	Fujian	8	23	46	419	1385
June 2011		8	24	46	281	1013
May 2006	Jiangxi	5	15	30	279	884
March 2011		5	15	30	195	771
Oct-Nov 2006	Zhejiang	6	18	34	299	1339
July 2011		6	18	35	286	1739
April 2007	Anhui	5	15	30	283	1067
July 2011		5	15	30	249	1526
April 2007	Hunan	5	15	27	105	105
May-June 2011		5	15	29	202	689
May-June 2007	Liaoning	5	15	29	263	642
July 2011		5	14	28	254	756
May-June 2007	Shandong	5	15	30	263	482
August 2011		5	15	30	236	573
August 2007	Yunnan	6	12	30	485	1391
August 2011		6	12	30	502	1942
1st round	Total	45	128	256	2396	7295
2nd round		45	128	258	2205	9009

Notes: The figures in the table exclude the two counties surveyed as pilots in Fujian province, because they were not followed up in the second round of surveys, nor are the pilots included in the analysis. The increase in the number of villages was because some administrative villages split during the research period. Other missing samples were due to temporary absence, such as being in a hospital, being at work, migration or death, etc. The first round survey skipped over 2006 and 2007 due to the unavailability of financial resources.

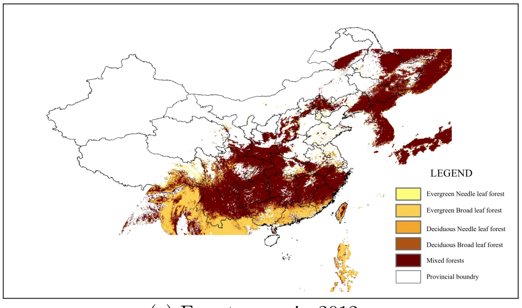
Figure 2: Forest cover in China, 2002-2012.



(a) Forest cover in 2002



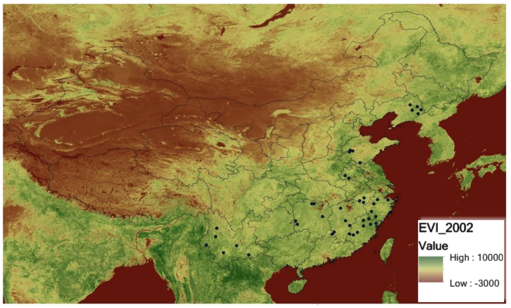
(b) Forest cover in 2007



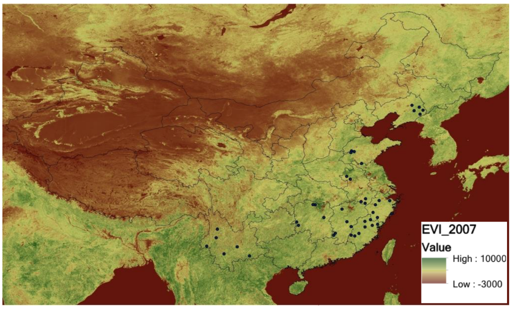
(c) Forest cover in 2012

Source: Channan et al. (2014); Friedl et al. (2010) − MODIS land cover type data

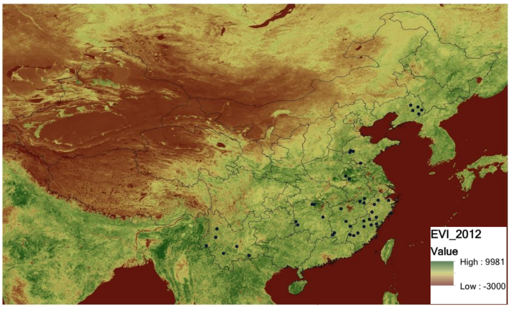
Figure 3: Trend in the Enhanced Vegetation Index (EVI), China, 2002-2012.



(a) EVI in 2002



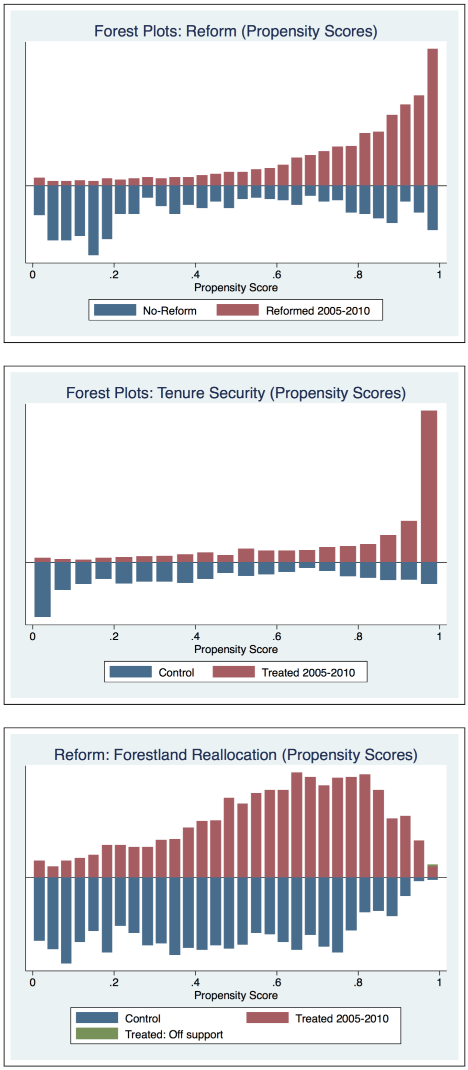
(b) EVI in 2007



(c) EVI in 2012

Source: Channan et al. (2014); Friedl et al. (2010) − MODIS land cover data on EVI

Figure 4: Propensity score distribution and common support for difference-in-difference propensity score matching estimation.



Notes: “Reformed (Treated) 2005-2010”, indicated by the red bars, means the observations in the treated group that have a suitable comparison in the “No-Reform (Control)” – the blue bars. “Treated: Off support”, indicated by the green bars, means the observations in the treated group that do not have a suitable comparison.

Table 1: Summary statistics for investment and reform measures

	2005		2010	
	Control	**Treated**	**Control**	**Treated**
Labor input, days				
Labor input on *plot* (days)*	13.89	20.10	11.53	19.89
	(29.89)	(38.23)	(17.51)	(41.38)
Labor input per *mu* (days)*	5.54	7.25	5.95	7.99
	(9.13)	(11.73)	(9.63)	(13.62)
If labor input is nonzero (1 if >0; 0 if otherwise)	0.547	0.491	0.414	0.461
	(0.498)	(0.500)	(0.493)	(0.499)
Value of investment, CNY				
Value of investment on *plot* (CNY)*	725.49	698.79	549.80	855.87
	(1650.99)	(1484.64)	(1444.26)	(1855.36)
Value of investment per *mu* (CNY)*	166.29	170.94	213.45	342.00
	(251.82)	(234.94)	(386.44)	(709.47)
If investment is nonzero (1 if >0; 0 otherwise)	0.308	0.271	0.285	0.290
	(0.462)	(0.444)	(0.452)	(0.454)
Reform dummy, 1=yes, 0=no	0	0	0	1
	(0)	(0)	(0)	(0)
Received Forestland Certificate, 1=yes, 0=no	0	0	0	0.581
	(0)	(0)	(0)	(0.493)
Obtained more forestland, 1=yes, 0=no	0	0	0.271	0.722
	(0)	(0)	(0.445)	(0.448)
Number of observations	406	4229	649	5854

Notes: * The values are sample means among plots with nonzero labor input and nonzero investment, respectively. *Mu* is a land area unit used in rural China, with 1 *mu* equal to 1/15 hectare. The control group is defined as the forest plots with no reform in the village before 2010; the treated group includes forest plots where the village selected the reform between 2006 and 2010. The table summarizes differences in investments between the two groups of forest plots.

Table 2: Sample mean: household, forest plot, and village characteristics

	2005		2010	
	Control	**Treated**	**Control**	**Treated**
Household characteristics				
Household size	4.877	4.342	4.143	4.249
Gender of household head (1=male, 0=female)	0.953	0.966	0.959	0.951
Age of household head	51.61	48.97	53.21	52.23
Household head education, years	5.488	5.971	5.550	5.890
Household head is Communist (1=yes, 0=no)	0.155	0.208	0.251	0.213
Household head is village leader (1=yes, 0=no)	0.0788	0.102	0.0647	0.0699
Work experience in forestry department (1=yes, 0=no)	0.00739	0.0175	0.0709	0.0687
Credit access (distance to local bank, km)	9.713	8.414	15.50	11.48
Per-labor nonfarm work days	108.4	103.1	112.9	112.7
Per capita cropland size (in *mu*)	1.849	2.113	1.709	1.636
Household livestock value (CNY)	789.3	1,585	1,491	3,970
Per capita income (CNY)	5,820	6,595	9,770	12,038
House value (10,000 CNY)	4.443	4.923	12.35	13.77
Forest plot characteristics				
Forest plot size, *mu* [a]	4.191	10.42	4.495	8.381
Distance to home, km	0.971	1.862	0.987	1.769
Distance to main road, km	1.271	1.593	0.804	1.194
Irrigation condition, 1-4 [b]	3.246	3.579	2.928	3.301
Slope (1: <25°; 2: 25-45°; 3: >45°)	2.151	1.595	2.066	1.520
Sloping Land Conversion Program (1=yes, 0=no)	0.0123	0.0419	0.0139	0.0516
Timber forest (1=yes, 0=no)	0.727	0.452	0.750	0.648
Economic forest (1=yes, 0=no)	0.0985	0.167	0.106	0.293
Bamboo forest (1=yes, 0=no)	0.0911	0.106	0.159	0.125
Current resource status (1-6) [c]	3.946	3.945	3.849	4.175
If harvested (1=yes, 0=no)	0.0813	0.0641	0.173	0.190
Bundle of rights score, 0-9 [d]	6.628	6.088	5.581	5.676
Perception of ownership risk (1=secure)	0.919	0.955	0.871	0.953
Village characteristics				
Village distance to paved road, km	0.610	6.914	0.277	1.487
Village distance to closet county center, km	26.64	36.32	30.85	35.58
Village total forestland area, ha	5,043	16,685	5,241	18,004
Village forestland area share	0.561	0.709	0.572	0.703
Proportion of village forest managed by household	0.869	0.804	0.836	0.769
Village total population	1,278	1,503	1,082	1,601
Village size, number of households	283.2	383.7	276.6	425.5
Village average per capita income (CNY)	2,146	2,588	3,467	3,859
Proportion of households having telephone	0.779	0.724	0.871	0.930
Development of labor market (Off-farm labor/total)	0.311	0.292	0.610	0.257
Commercial timber price, CNY	500	422	580	579
Precipitation: annual average, mm	36.87	35.32	39.81	44.29
Precipitation: standard deviation, mm	113.4	93.33	111.6	108.3
Effective cumulative heat, 0-35°C	6,101	5,871	5,953	6,014
Harmful cumulative heat, >35°C	8.137	4.472	8.859	5.037
Number of observations	406	4229	649	5854

Notes: [a]: 1 *mu* =1/15 hectare.
[b]: Irrigation condition takes four values: 1 means the best and 4 means no irrigation.
[c]: Current resource takes 6 values, 1 if scattered trees, 2 if very young trees, 3 if young trees, 4 if near-mature forest, 5 if mature or old forest, and 6 if bamboo, or other "economic" forest such as fruit trees and medicine plantations.
[d]: The rights scores are summed from the nine rights: production rights such as converting forestland to cropland, selecting tree or plant species, interchanging different forest types and different land use purposes, using non-timber forest products; and gains-from-trade rights such as forestland transfers, inheritance, and mortgaging.

Table 3: Summary statistics of forest conditions and county characteristics

	2000		2005		2010	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Forest cover in 2 years	0.321	0.239	0.355	0.252	0.377	0.257
Forest quality (EVI) in 2 years	0.261	0.156	0.266	0.159	0.245	0.147
Proportion of village forest of household management *	0.359	0.195	0.418	0.201	0.431	0.194
Per capita income, CNY *	1,217	695.0	1,592	1,044	2,372	1,469
Commercial timber price, CNY *	193.8	102.4	256.4	123.5	523.9	601.3
Forestland as percentage of village land area *	0.150	0.102	0.154	0.102	0.162	0.105
Labor daily wage, CNY *	19.95	10.76	27.75	15.57	44.40	26.40
Average village population *	865.5	607.2	902.7	662.4	974.2	698.4
Household size *	2.426	1.134	2.374	1.124	2.296	1.010
Population share with telephone *	0.186	0.114	0.455	0.202	0.595	0.245
Precipitation: annual average, mm	37.44	11.86	38.40	11.84	44.90	15.25
Precipitation: standard deviation, mm	100.3	25.28	109.4	34.10	118.0	30.63
Growing degree-days (GDD, 0-35°C)	6,036	1,174	6,098	1,191	6,141	1,241
Harmful degree-days (HDD, >35°C)	2.861	3.072	5.396	5.566	6.241	6.527
Number of observations	44		44		44	

Notes: Forest cover includes evergreen (and deciduous) needle leaf (and broad leaf) forests and mixed forests, as defined in the IGBP classification of land cover types in the standard MODIS product MCD12Q1. Forest quality is computed as the average value of the Enhanced Vegetation Index (EVI) in the MOD13Q1 product data for each county, and the values are divided by 1000 for scaling purpose.

*: Variables are generated as mean of sample villages for each county.

Table 4: Probit estimates of the propensity to treatment

	Treatment 1 Reform	Treatment 2 Security	Treatment 3 Reallocation
Log village population	0.229***	0.268***	0.131*
	(0.081)	(0.073)	(0.068)
Log village average income	0.174	0.165	-0.134
	(0.221)	(0.171)	(0.170)
Proportion of households having telephone	2.946***	2.721***	2.375***
	(0.835)	(0.577)	(0.732)
Development of labor market (Off-farm labor/total)	-1.269***	-0.541	-1.277***
	(0.406)	(0.343)	(0.339)
Log village total forestland area	0.006	0.004	-0.002
	(0.045)	(0.040)	(0.039)
Proportion of village forest managed by household	-0.567*	-0.630***	-0.070
	(0.307)	(0.225)	(0.227)
Log distance to closet county, km	0.017	-0.015	0.009
	(0.119)	(0.085)	(0.089)
Log timber price	0.142	-0.047	-0.007
	(0.158)	(0.121)	(0.119)
Precipitation: annual average, mm	0.026***	0.012*	0.025***
	(0.009)	(0.007)	(0.007)
Precipitation: standard deviation, mm	-0.001	-0.002	-0.002
	(0.005)	(0.004)	(0.003)
Effective cumulative heat, 0-35°C	0.000***	0.000***	0.000**
	(0.000)	(0.000)	(0.000)
Harmful cumulative heat, >35°C	-0.033	-0.039**	-0.008
	(0.022)	(0.018)	(0.018)
Log household size	-0.395***	-0.376***	-0.071
	(0.110)	(0.108)	(0.132)
Gender of household head (1=male, 0=female)	-0.204*	-0.028	-0.274**
	(0.113)	(0.181)	(0.138)
Household head age	0.880***	0.637***	0.408***
	(0.133)	(0.134)	(0.133)
Household head education years	0.141**	0.133**	0.040
	(0.059)	(0.053)	(0.062)
Household head is Communist (1=yes, 0=no)	-0.262***	-0.209***	-0.228***
	(0.075)	(0.074)	(0.088)
Household head is village leader (1=yes, 0=no)	-0.272***	-0.125	-0.188*
	(0.089)	(0.095)	(0.102)
Work experience in forestry department (1=yes, 0=no)	0.669***	0.365***	0.600***
	(0.158)	(0.123)	(0.140)
Log per-labor nonfarm work days	-0.068	-0.054	-0.005
	(0.052)	(0.040)	(0.052)
Log per-capita cropland size	0.046	0.056	0.073
	(0.094)	(0.065)	(0.091)
Log household livestock value	0.071***	0.052***	0.055***
	(0.011)	(0.011)	(0.009)
Log per-capita income	0.173***	0.129***	0.135***
	(0.031)	(0.029)	(0.028)
Log house value	0.251***	0.154***	0.187***
	(0.037)	(0.032)	(0.035)
Log distance to local bank	0.018	0.073	0.015
	(0.092)	(0.067)	(0.072)
Log distance to home	0.071	0.026	0.053
	(0.065)	(0.061)	(0.069)

continued on next page

Table 4 continued

Log distance to main road	-0.205***	-0.235***	-0.202***
	(0.056)	(0.055)	(0.063)
Irrigation condition	-0.118***	-0.108***	-0.107***
	(0.026)	(0.024)	(0.024)
Slope (1: <25°; 2: 25-45°; 3: >45°)	-0.087**	0.009	-0.044
	(0.037)	(0.032)	(0.039)
Sloping Land Conversion Program plot (1=yes, 0=no)	-0.032	-0.165	0.001
	(0.115)	(0.110)	(0.108)
Timber forest (1=yes, 0=no)	0.267***	0.129*	0.158***
	(0.075)	(0.068)	(0.055)
Economic forest (1=yes, 0=no)	0.355***	0.170**	0.264***
	(0.100)	(0.086)	(0.077)
Current resource status	0.005	-0.016	-0.003
	(0.027)	(0.021)	(0.022)
If harvested (1=yes, 0=no)	0.407***	0.311***	0.277***
	(0.088)	(0.078)	(0.080)
Bundle of rights score, 0-9	-0.006	-0.038***	-0.008
	(0.014)	(0.014)	(0.012)
Perception of ownership risk (1=secure; 0 otherwise)	0.803***	2.169***	0.512***
	(0.183)	(0.225)	(0.171)
Receiving forestland certificate		1.861***	
		(0.134)	
Observations	10,860	10,860	10,860
Log Lik	-4310	-3486	-5121
Pseudo R-squared	0.427	0.536	0.292

Notes: The probit models regress on all village and household variables of 2005. Robust standard errors in parentheses. Significance is denoted: *** p<0.01, ** p<0.05, * p<0.1

Table 5: DID estimates of the impact of the Reform on forestland owner investment

	(1) Treatment 1 The Reform	(2) Treatment 2 Tenure Security	(3) Treatment 3 Reallocation	(4) Reformed: Harvest vs. No harvest	(5) Harvested: Reform vs. No reform
Labor input per *mu*, days					
Average in the treated	0.492	0.514	0.581	0.508	0.449
Average in the control	0.373	0.166	0.335	0.427	0.470
Difference in average outcomes (ATT)	0.119*	0.348***	0.246***	0.081*	-0.020
	(0.070)	(0.043)	(0.038)	(0.045)	(0.122)
Value of investment per *mu*, CNY					
Average in the treated	0.942	0.977	1.065	1.058	0.988
Average in the control	0.614	0.450	0.771	0.76	0.812
Difference in average outcomes (ATT)	0.328***	0.526***	0.294***	0.298***	0.176
	(0.117)	(0.100)	(0.077)	(0.082)	(0.247)

Notes: Column 4 reports the ATT estimates of post-harvest investment in the reformed plots, by comparing the difference in investment between the matched, harvested plots and non-harvested plots using the treated group. Column 5 reports the ATT estimates of the reform's effect on investment if harvested, by comparing the difference in investment between the matched pairs of harvested plots with the reform and the harvested plots with no reform. Standard errors of the ATT estimates are in parentheses, bootstrapped using 200 replications. Significance is denoted: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 6: Devolution impact on forest conditions (FE and FE-IV estimators)

	Forest Cover			Forest Quality (EVI)			IV 1st Stage
	(1) FE	(2) FE	(3) FE-IV	(4) FE	(5) FE	(6) FE-IV	% devolved
Proportion of household-managed forestland	0.243***	0.233***	0.518***	0.061**	0.025	0.070*	
	(0.053)	(0.058)	(0.125)	(0.023)	(0.024)	(0.041)	
Household size	-0.022	-0.018	-0.010	0.023**	0.025**	0.023**	0.045
	(0.025)	(0.025)	(0.027)	(0.011)	(0.010)	(0.010)	(0.051)
Commercial timber price	-0.750*	-0.831**	-0.427	-0.016	0.014	-0.014	-1.094
	(0.405)	(0.407)	(0.430)	(0.178)	(0.164)	(0.162)	(0.792)
Timber price squared	2.661**	2.892**	2.308*	0.130	0.080	0.137	1.899
	(1.268)	(1.271)	(1.363)	(0.556)	(0.513)	(0.508)	(2.481)
Labor daily wage	-0.001	-0.001	-0.002**	-0.000	-0.000	-0.000	0.003*
	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.002)
Labor wage squared	0.000	0.000	0.000	-0.000	0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Average village population	-0.000	-0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Population squared	0.000	0.000	0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Per capita income	0.000***	0.000	0.000***	-0.000	-0.000	-0.000	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Per capita income squared	-0.000**	-0.000	-0.000***	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Forestland share	-0.039	-0.086	-0.574	-0.257*	-0.234*	-0.273**	1.280**
	(0.294)	(0.295)	(0.380)	(0.129)	(0.119)	(0.134)	(0.542)
Rainfall: average	0.001	0.001		-0.001	-0.000	-0.001	0.001
	(0.001)	(0.001)		(0.000)	(0.000)	(0.000)	(0.002)
Rainfall: variation	0.000	0.000		0.000	-0.000	0.000	0.000
	(0.000)	(0.000)		(0.000)	(0.000)	(0.000)	(0.001)
GDD	0.000	-0.000		-0.000***	-0.000***	-0.000***	-0.000
	(0.000)	(0.000)		(0.000)	(0.000)	(0.000)	(0.000)
HDD	0.003*	0.002		0.001	0.000	0.001*	-0.004
	(0.002)	(0.002)		(0.001)	(0.001)	(0.001)	(0.003)
Population share with telephone		0.014			0.011**		0.342***
		(0.013)			(0.005)		(0.068)
Year trends	NO	YES	NO	NO	YES	NO	NO
Observations	132	132	132	132	132	132	132
R-squared	0.574	0.588	0.380	0.445	0.547	0.444	0.540
IV validity (LM-statistic)			26.15			22.77	25.49
Sargan statistic P-value			0.2518			/	/

Notes: Instrumented: Proportion of forestland devolved to household management. Excluded instruments: population share possessing telephones, for both forest cover and EVI estimation (Column 3 and 6); average and deviation of precipitation, effective and harmful cumulative heat variables (GDD and HDD) are instrumented only in Column 3. Results of the first stage are reported in the last column.
The LM-statistic of IV(s) rejects the null hypothesis that excluded instruments are orthogonal, implying the instruments are relevant. The overidentification test on multiple instruments in Column 3 (Sargan statistic) cannot reject the joint null that all instruments are valid, i.e., uncorrelated with the error term, and that the excluded instruments are correctly excluded from the estimated equation.
Standard errors are in parentheses, bootstrapped with 100 replications. Significance is denoted: *** p<0.01, ** p<0.05, * p<0.1.

Chapter II

Allocative Efficiency or Agglomeration? The Emergence of Forestland Rental Markets and the Forest Devolution Reform in China*

Yuanyuan Yi†[1]

[1]Department of Economics, University of Gothenburg, Sweden

Abstract

This paper evaluates whether the devolution reform of forestland to household management had an effect on allocative efficiency and household welfare through participation in forestland rental markets. Using a household panel dataset from three Chinese provinces, I find that the emerging forestland rental markets improved allocative efficiency in terms of factor equalization. With the reform, forestland is transferred to forestland-constrained and labor-rich households, and to households with higher levels of productivity in forestry. I do not find any support for agglomeration of forestland to land-richer, wealthier, larger or powerful households. Participation in forestland rental markets increases household per-capita income and decreases the likelihood of having an income below the poverty line.

JEL **Classification:** D61, O12, Q15, Q23

Keywords: allocative efficiency, household welfare, forestland rental markets, collective forest tenure reform, China

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†Vasagatan 1, SE-405 30 Gothenburg, Sweden, Email: yuanyuan.yi@economics.gu.se

1 Introduction

Land reform, by means of changing land tenure arrangements, is an institutional instrument for reallocation of factors of production to and among farm households. Property (tenure) rights are an important precondition for economic growth (North, 1981; Barro, 1991; Besley, 1995). In China, the Household Responsibility System (HRS) in 1978 successfully transformed collectively owned agricultural land to household tenure. Following that reform, agricultural production increased by 225 percent in six years and rural household income increased five-fold in real terms by 2000 (NBS, China, 2014). Following the success of the HRS reform, in the early 2000s the Collective Forest Tenure Reform started to formally devolve forestland owned by village collectives to individual households (hereinafter, the Reform). As in earlier land reforms, the Reform applied an egalitarian rule to reallocate forestland on a per capita basis, leading to concerns that fragmented and small operational sizes of forest plots might result (Wen, 1989). As an attempt to address potential problems in fragmentation of land, the Reform encourages forestland rental markets by giving formal transfer rights to the households to which forestland was devolved, with the aims of sustainable management of collective forests and growth of forestry productivity and household income.[1] The reform also allocated more forestland to household management and improved tenure security. The combination of increased land resources under private management, secure tenure, and transfer rights, in the presence of heterogeneity in managerial ability, allows households to maximize the value of forestland by providing both willing out-renters and in-renters for land markets (Zimmerman and Carter, 1999).

In light of Besley (1995)'s seminal work on the link between investment and property rights, a land owner with property rights is incentivized to invest more when given transfer rights, which makes it easier to rent (or sell) land. Earlier in Chapter I of this thesis, I investigated the impact on investment when households obtained tenure rights to forestland. The objectives of this chapter are to explore whether the Reform also encouraged forestland rental markets to emerge and improved the allocative efficiency of forestland; and to assess the impact of renting on household welfare. More productive farmers are expected to rent in forestland, and less productive farmers to rent it out. In case of an equal level of managerial ability, households with a larger area of forest are expected to be willing to rent out, and those in the opposite situation to rent in. In addition, farmers may use forestland as collateral, making it easier to obtain credit for investment purposes. Opportunity costs are important to rural households; those who rent out forestland due to relatively lower ability in forest management and

[1] The overall objectives were stated in the State Council's announcement of "*The Promotion of the Collective Forest Tenure Reform*" on June 8, 2008. (http://www.gov.cn/jrzg/2008-07/14/content_1044403.htm)

higher ability in off-farm jobs would be able to obtain more income through engaging in off-farm work. Hence, participating in the rental market could improve household welfare and meanwhile, facilitate rural structural transformation by shifting rural labor to nonagricultural sectors.

This is the first study that uses empirical data to assess the performance of forestland markets in a context where forest management is individualized. The Reform involved two-thirds of the total forestland area of China (i.e., 62 million hectares of the total 100 million hectares) and 70 million rural households, though forestland markets are thin (Xu et al., 2010; Siikamäki et al., 2015). In the literature on agricultural land use and rental markets, small operational size is likely to affect investment incentives and sustainable management (Rozelle et al., 2002). Inefficiency in land markets concerns both policy makers and development economists, in that small farmers and land-scarce or landless workers tend to be rationed out, so that land is agglomerated into the hands of richer and more powerful people, or those who already are large landowners (Otsuka, 2007). In addition, rapid growth of off-farm industries is fostering rural-urban labor migration, which calls for a flexible system for facilitating factor and resource reallocation. Farm households in places like rural China could benefit from a land rental system, not only through optimizing factors allocation, but also by holding forestland as a safety-net asset. Forestland is different from farmland in that standing trees store wealth, require less intensive labor, and are subject to a greater extent of uncertainty and production risk because forests growth takes a longer time than crops on farmland. As a unique model of forest devolution – private management accompanied by forestland markets – the lessons of China will provide options for effective common-pool resources management in other contexts.

The analysis uses a panel dataset of 1,192 randomly surveyed households in three Chinese provinces: Fujian, Jiangxi, and Yunnan. These provinces were the earliest adopters of the forest devolution reform, and data is available as a panel with two waves. The data include households' farming and non-farming work and income, in particular forestland management activities in 2005 and 2010; villages' socio-economic characteristics, resources, and natural conditions; and whether, when and how the Reform was implemented in 2000, 2005 and 2010. Controlling for the fact that village characteristics correlate with the adoption of the forest devolution reform, I examine the determinants of forestland rental participation, i.e., how a household chooses among rent-in, rent-out, and no-rent. I focus on two factors: a household's endowment of forestland per unit of labor and managerial ability in forestry. The managerial ability is obtained as a composite residual term from a Cobb-Douglas forestry production function for each household. A multinomial logit model is applied on the determinants of forestland rental participation. I then analyze the welfare effects of rental participation in terms of income and poverty by propensity score matching (PSM) methods because the renting decision is not random.

I find positive effects of forestland rental market participation on household factor equalization, income and poverty reduction, suggesting efficiency and household welfare improvement. Forestland is transferred from land-rich, labor-constrained households to households with relatively abundant labor and less forestland and to more productive households. Little evidence is found for agglomeration in forestland to richer households, households that already have large landholdings, or more politically powerful households. Consequently, participation in forestland rental markets increases household per-capita income and reduces the likelihood of absolute poverty. The results are highly consistent with alternative estimation procedures (multinomial logit and tobit models and PSM with a number of matching algorithms).

The rest of this article is structured as follows. Section 2 reviews a selection of the literature related to allocative efficiency, rural land institutions, and land rental/sales markets. Section 3 introduces the background and emerging forestland rental markets in China. Section 4 discusses a conceptual model, followed by four testable hypotheses and the associated methodological approach in Section 5. Section 6 describes the data, and the next section presents the estimation results. Finally, I conclude with policy implications in Section 8.

2 Studies on Agricultural Land Rental Markets and Efficiency

This chapter focuses on the performance of forestland rental markets with regard to allocative efficiency and rural household welfare. Standard economic theory started with very strong assumptions – an identical, constant-returns-to-scale production function for all households, with clearly defined and perfectly functioning markets – says that the initial resource endowment should not be important for allocative efficiency (Bliss and Stern, 1982; Feder, 1985; Bardhan and Urdy, 1999; Deininger 2003). Under these assumptions, managerial ability does not differ, land-labor ratios will be efficiently allocated across farm households, and output per factor unit will be optimized. However, these assumptions are often not fulfilled in reality, and, particularly in developing countries, the outcome of a rental market could be that land or other forms of resources are prevalently captured by a small group of people. Moreover, parts of the markets might be imperfect or missing, due to the presence of transaction costs such as lack of access to credit.

Imperfect land rental markets and transaction costs have long been recognized in the literature. In addition to unclear ownership, one main source of transaction costs arises from asymmetric information between renting partners in the process of making transactions. Such costs might include searching, bargaining, enforcing bargains, and monitoring tenants (Alston et al., 1984; Otsuka and Hayami, 1988; Carter and Yao, 2002; Holden et al., 2009; Kimura et al., 2011). Another type of transaction costs include varying degrees of regulation on land transfer rights, which result in missing and imperfect labor, credit and insurance, and land markets (Skoufias, 1995; Deininger and Jin, 2005; Pender and Fafchamps, 2006; Deininger et al. 2008).[2] The overall conclusion is that these costs cause the discrepancy between optimal and actual transactions, and the latter systematically agglomerate land to wealthier, land-rich, or powerful households (Deininger and Jin, 2008).

Empirical evidence on the performance of rental markets is mainly about farmland, with a considerable variation in geographical and cultural conditions, and with mixed findings. For example, the following studies found evidence for inefficient farmland markets: Andre and Platteau (1998) in Rwanda, Zimmerman and Carter (1999) in Burkina Faso, and Deininger et al. (2011) and Holden et al. (2011) in Ethiopia. The others, such as Migot-Adholla et al. (1994) in Ghana, Gavian and Fafchamps (1996) in Niger, Yamano et al. (2009) and Jin and Jayne (2013) in Kenya, Lunduka et al. (2009) in Malawi, Deininger and Mpuga (2009) and Nkonya et al. (2009) in Uganda, Deininger et al. (2008) in India, Deininger and Jin (2008) in Vietnam, and Carter and Yao (2002), Deininger and Jin (2005), and Kimura et al. (2011) in China, found that farmland markets equilibrate factor ratios among households. A key factor determining rental participation is, according to many studies, transaction costs.

Forestland markets differ from farmland markets in a number of aspects. First of all, the nature of forests means longer-term uncertainty, and the public benefits provided by standing trees mean that forest plots often are undervalued. Moreover, relatively larger land size, compared to farmland, requires a considerable amount of rental payment. Because of these two facts, cash constraints and credit access would be associated with imperfect forestland rental markets, raising the costs of rental contracts of forestland and thus reducing households' willingness to rent. On the other hand, forestland functions as a safety-net asset, with standing trees which store wealth with merely a small amount of labor, so that renting-out makes it easier for rural labor to engage in off-farm work while still enjoying the benefits of owning the forestland. Given all these features and the large scale of the Reform[3], this study adds to the literature

[2] Pender and Fafchamps (2006) find that transaction costs do not necessarily affect rental market participation and efficiency in a negative way in Ethiopia.

[3] In Chapter I of the thesis, a review was presented in Section 3. According to government statistics, the reform had devolved 62 million hectares of the 100 million hectares of forests from village-owned to household tenure, involving 600 million people in rural areas in more than twenty provinces of China (Xu et al., 2010; State Forestry Administration, 2011).

as one of the first empirical evaluations of forestland markets in terms of determinants of participation and consequences on household welfare.

3 China's Forest Devolution Reform and Emerging Forestland Rental Markets

China's forestland tenure system started to reform as early as 1954. However, it underwent privatization and collectivization, revoking privatization and then redistributing forestland through contracts to households in the late 1980s and 1990s (Xu et al., 2010). By the end of the 1990s, all the forestland in southern collective forest areas was legally owned by village collectives. The success of the agricultural HRS reform in the late 1980s provided lessons for improving agricultural productivity and the welfare of the rural population, and for the introduction of devolution of forestland management to rural households. Eventually, since the beginning of the 2000s, village committees, on the basis of majority voting in village assemblies or representative meetings, decided on whether to implement the reform.[4] In mid-2003, a state council resolution (Document No. 9, *The Resolution on the Development of Forestry*) was issued, formally calling for deeper reform in the collective and state forest sectors.

In villages adopting the Reform, the village committees decided on whether and how much of the village-owned forestland to devolve to household management by means of administrative reallocation. Measures were taken to strengthen and secure tenure rights. These included formally documenting rights in production, transferability and use as collateral, and issuance of forestland certificates. Besides forest devolution, together with local institutional support on land value assessment, for example, efforts have been directed toward reducing transaction costs in the forestland transfer market, with the hope of encouraging rental transactions.

Land reforms by the Chinese government are based on egalitarian rules for equity purposes. The administrative reallocation of forestland is not an exception. Land was thus distributed amongst village members on a per capita basis. Earlier studies have shown that this type of reallocation results in land fragmentation and small household operational size (e.g., Wen, 1989). Small-scale management dis-incentivizes land investment because of the low level of expected returns. Fragmentation hampers acquisition of timely information about markets because of the large cost of acquiring

[4] The village committee is the lowest administrative organization in China, elected by member households in both administrative and natural villages. (Natural villages mean villages in place for a long period as village clusters, which trace their history back in time to at least before 1949. Administrative villages refer to a structural integration of neighboring villages during the early Mao years, and comprise two or more natural villages.) Village committee membership ranges from 3 to 7 people, as required by China's *Organic Law of Villagers Committees.*

information relative to the small quantity of goods produced on a small plot. Therefore, the egalitarianism in land (re)allocation has been subject to problems of inefficiency and high transaction costs. In addition, attributed to concentrated power in the hands of village leaders, it may create rent-seeking opportunities and preferences for friends and relatives (Rozelle et al., 2002; Deininger and Jin, 2005). Moreover, forest fragmentation concerns enviornmental scientists due to potential negative impacts on forest quality such as biodiversity (Hill et al., 2011). With an aim to address fragmentation concerns, the Reform was designed to also encourage forestland holders to participate voluntarily in the land rental market. The main purpose in this paper is to explore how the recipients of devolved rights to forestland respond in reallocating forestland among themselves.

The rural population in collective forest areas lives on agricultural, forestry, and livestock production, as well as off-farm income. Their heterogeneous skills in (forest) land management and off-farm occupations call for a flexible system that optimizes the allocation of resources and factors. In China, the rapid growth of off-farm industries has induced rural-to-urban labor migration, resulting in a need to reallocate land resources among rural households (Deininger et al., 2014). Well-functioning land rental markets bring land to more productive users, and allow owners working off-farm to continue enjoying the benefits of owning land (Otsuka and Hayami, 1988; Jin and Deininger, 2009).

Agricultural land rental transactions increased nationwide following the HRS reform, with 2.3 percent of the total number of households renting out in 1992. By 2013, the total rented area of agricultural land accounted for 26 percent of agricultural land in the nation. Still, compared to other developing countries, this number is very low (Otsuka, 2007; Deininger and Jin, 2005). In the meantime, along with the recent forest devolution reform, forestland rental transactions are emerging among households. The three provinces studied in this paper – Fujian, Jiangxi and Yunnan – were among the earliest adopting the Reform. In these provinces, the percentage of households engaged in the forestland rental market increased from 4 percent in 2005 to 12 percent in 2010, as shown in Table 1.

< Table 1 here >

Forestland rental participation increased over the period: the percentage of households renting in forestland increased from 2.1 to more than 7 in 2005-2010; the more than threefold increase mainly comes from households that were affected by the Reform during the study period. The percentage of households renting out forestland increased from 2.9 to 5.5 in the same period. Pre-rental, households affected by the Reform had a larger mean area of forestland compared to non-Reform households. Among households not subject to the Reform, 4.4 percent had informal forestland transfers in 2005, implying lax regulation in some villages. When villages implemented the Reform, former informal rental contracts for forestland, if still valid, were presented to the leaseholders and tenants for their re-assessment of whether to rent again or keep the forestland for own use. So, the 4.42 percent of the non-reform households who rented out in 2005 do not necessarily appear among the 5.58 percent of the rent-out households with the Reform in 2010. In addition, compared to the non-reformed households, the reformed households had a larger area of forestland rented-in, and their rented-in forest plots accounted for a larger proportion of the endowment level of forestland.

4 A Conceptual Model of Forestland Rental Market Participation

A representative household in the study area is endowed with some size of forestland area ($\bar{\boldsymbol{A}}$), family labor ($\boldsymbol{L}$), managerial ability ($\boldsymbol{\alpha}$), household characteristics such as risk preferences ($\boldsymbol{\rho}$), and credit and cash constraints ($\boldsymbol{C}$). Other household characteristics ($\boldsymbol{H}$) include age and years of education of the household head, who is usually the decision-maker in a rural household, as well as the household head's professional knowledge of forestry. In household forestry, the optimal size of the operational forestland area, $\boldsymbol{A^*}$, is a function of the household's forestry managerial ability ($\boldsymbol{\alpha}$), its characteristics ($\bar{\boldsymbol{A}}$,$\boldsymbol{L}$,$\boldsymbol{\rho}$,$\mathbf{C}$,$\mathbf{H}$), and village-level exogenous factors ($\boldsymbol{V}$), such as natural and social endowments, market access, precipitation and temperature. The household's utility is maximized when the difference between the household's actual and desired land size is minimized.

This utility maximization can be achieved through rental market participation, taking transaction costs into account. When a forestland rental market exists but there are transaction costs ($\boldsymbol{T}$), the household decides to participate in the rental market based on the rental payment and opportunity cost of rental participation ($\boldsymbol{R}$), e.g., potential income from managing cropland, off-farm work, and livestock. That is, the household finds itself in one of the three rental states:

$$\begin{aligned} \text{Rent-out } (\boldsymbol{A^*} < \bar{\boldsymbol{A}}) \text{ if } \boldsymbol{MB}(\bar{\boldsymbol{A}}) + \varepsilon_i \leq \boldsymbol{R} - \boldsymbol{T^{out}}; \\ \text{No-rent } (\boldsymbol{A^*} = \bar{\boldsymbol{A}}) \text{ if } \boldsymbol{R} - \boldsymbol{T^{out}} < \boldsymbol{MB}(\bar{\boldsymbol{A}}) + \varepsilon_i < \boldsymbol{R} + \boldsymbol{T^{in}}; \\ \text{Rent-in } (\boldsymbol{A^*} > \bar{\boldsymbol{A}}) \text{ if } \boldsymbol{MB}(\bar{\boldsymbol{A}}) + \varepsilon_i \geq \boldsymbol{R} + \boldsymbol{T^{in}}. \end{aligned} \tag{1}$$

where $\boldsymbol{MB}(\bar{\boldsymbol{A}}) + \varepsilon_i$ stands for the marginal benefit or marginal value of the forest and non-forest production of managing an additional area unit of forestland. The marginal returns are evaluated at the level of forestland endowment, and depend on $\boldsymbol{\alpha}$,$\boldsymbol{\rho}$,$\mathbf{C}$,$\mathbf{R}$,$\mathbf{T}$,$\mathbf{H}$ and $\mathbf{V}$. $\boldsymbol{\varepsilon_i}$ is an error term containing non-observable factors and is assumed to follow a standard normal distribution.

One type of transaction cost arises from imperfect factor markets, resulting in credit constraints for some households. Firstly, the lack of finance for rental payments, and, secondly, the possibility that wealthier farmers will have the opportunity to monopolize land, greatly impede market transactions in rural areas of developing countries, as in Skoufias (1995), Rozelle et al. (2002), Deininger and Jin (2005), and Deininger et al. (2008). Rozelle et al. (2002), Deininger and Jin (2005) and Deininger et al. (2008) also found that varying degrees of regulation on land transfer rights result in high transaction costs that reduce the efficiency of land rental markets. Deininger and Jin (2005) developed a model for transaction costs affecting rental decisions, so I follow them to denote $\boldsymbol{T^{in}}$ and $\boldsymbol{T^{out}}$ as the transaction costs associated with rent-in and rent-out transactions. In the study area, the rights to rent forestland to any other villagers and to any outsiders, the right to use a forest plot as collateral, and the right to change forest type, i.e., among timber, fruit, bamboo, and other types of trees, vary across villages.

In the forest tenure reform in China, a household's ownership of one specific forest plot is guaranteed for 30 to 70 years, and in some cases even longer ("long term" or "forever"). The length of ownership is clearly specified in the forestland certificate for each forest plot. Thus, a rental contract for any forest plot can be as long as the length of the ownership. Besides the security brought by a certificate, the household's attitude towards production risk and future ownership risk, reflected by the perception of risk of losing the plot, factors into the household's willingness to participate in the rental market. In addition, a cash-constrained household, with cropland size too small to meet its own consumption needs, may rent out some forestland to obtain some cash.

5 Testable Hypotheses and Empirical Strategy

According to the conceptual model, a rural household's decision to rent in, rent out, or do neither, and the implications of its decisions for allocative efficiency, are driven by factor endowment and managerial ability in forestry, *ceteris paribus.* To improve the understanding of the Reform's impact on forestland rental markets and the determinants and welfare effects of household participation, I am interested in testing four hypotheses, as follows. I take three steps in the empirical analysis. The identification strategies are explained later in this section, taking into account the factors of ownership and tenure security, policy restrictions on transfer rights, and market access.

Hypothesis 1. *The forest devolution reform improves allocative efficiency through forestland rental markets, which contribute to the equalization of forestland-labor ratios among rural households.* In other words, forestland is transferred from households with less labor and more forestland to households with more labor and less forestland, holding other factors constant.[5]

Hypothesis 2. *Forestland rental markets improve allocative efficiency by transferring forestland from less productive to more productive households.*

Hypothesis 3. *Rental market participation has a positive income effect on rent-in households through higher production value in forestry, and on rent-out households through more income from off-farm work.*

Hypothesis 4. *Rental market participation has a positive impact on poverty alleviation.* That is, participating in forestland rental market reduces the likelihood of household per capita income falling below the absolute poverty line.

5.1 Household Forestry Production and Managerial Ability

First, I estimate a measure of a household's managerial ability in forestry, which is not directly observable. To obtain the measure, for each household, I compute an annual incremental value of household forestry production – the value of marginal benefit of leaving the trees to grow for an extra year – from standing timber, economic forests (including fruit trees, herbal medicine and seedling nursery plantations), or bamboo forests on each forest plot,[6] and then aggregate a Cobb-Douglas forestry incremental

[5] A focus on equalization of factor ratios is warranted if the quality of factor inputs are homogenous or at least similar. While this is commonly assumed, I try to keep closer to reality by controlling for households' different quality of labor (managerial skill). This means that equalization of forestland-labor ratios is only an indication of allocative efficiency. In agriculture it is therefore more common to analyze changes in actual productivity. But in my case it is too early after the reform to analyze that (particularly for timber outputs). Given earlier research and an assumption of not too different within-household managerial skill in land and labor (in agricultural production, e.g., Gavian and Fafchamps, 1996; Deininger and Jin, 2005), I therefore focus on forestland-labor ratios.

[6] This value of marginal benefit of leaving the standing trees to grow for an extra year is computed in a manner similar to the decision to invest the stumpage for an interest return: for timber forest, the self-estimated standing timber volume is multiplied by the village-reported timber price and annual interest rate; for economic forests – fruit trees, herbal plantations, etc. – it is the annual production value; and for bamboo forest, the value is a summation of annual production value of bamboo shoots and the bamboo fiber volume times output price and interest rate. I acknowledge that this value function differs from the forest valuation function in which the (discounted) present value of forest rent is maximized based on a decision of optimal rotation in the long run. One major issue is the unavailability of precise data from the surveys on optimal (or household perceived optimal) rotation years for all the tree species. So the current measure for *forest plot productivity*, by using the annual incremental value, is not able to evaluate a longer-term impact of the forest tenure reform on *forest (forestry) productivity*. In addition, it is still too early for us to assess that, due to the lack of knowledge about the recently planted trees – the rotation decisions and long-run uncertainty, for example. So this paper is devoted to the short-term effects on the responses of forestland owners, how they adapt to improved tenure and transfer rights in small-scale forest management, and whether their responses would imply more efficient forest production overall.

value function for a household $\boldsymbol{i}$ in village $\boldsymbol{j}$ at time $\boldsymbol{t}$, as in Equation (2).

$$\boldsymbol{logy_{ijt} = \gamma_1 logL_{ijt} + \gamma_2 logA_{ijt} + \gamma_3 logK_{ijt} + \gamma_4 X_{ijt} + \eta_t + \vartheta_j + \vartheta_{jt} + \mu_i + \epsilon_{ijt}.} \quad (2)$$

where $\boldsymbol{y_{ijt}}$, $\boldsymbol{L_{ijt}}$, $\boldsymbol{A_{ijt}}$, and $\boldsymbol{K_{ijt}}$ are, respectively, annual incremental value of household forestry production, family labor, total forestland area, and value of inputs. $\boldsymbol{X_{ijt}}$ is a set of household control variables $(\boldsymbol{\rho, C, R, H})$ that could potentially affect households' forestry production. Time trend $(\boldsymbol{\eta_t})$, province and village fixed effects $(\boldsymbol{\vartheta_j})$ and village year effects $(\boldsymbol{\vartheta_{jt}})$ are controlled for. $\boldsymbol{\vartheta_{jt}}$ is expected to also capture a few particular events. First, some provinces and villages were affected by the 2008 global financial crisis, and these effects might have lasted until 2010. Second, in the year when villages implemented the Reform, there might have been some immediate effects encouraging efforts in production.

Equation (2) is estimated by a household-level fixed effects linear regression (FE) model on a two-period panel dataset. I obtain the measure of forestry managerial ability, $\boldsymbol{\alpha_i}$, as the composite term of the time-invariant constant $(\boldsymbol{\mu_i})$ and the stochastic error $(\boldsymbol{\epsilon_{ijt}})$: $\boldsymbol{\hat{\alpha_i} = \hat{\mu_i} + \hat{\epsilon_{ijt}}}$. Including the latter takes into account the randomness of, for example, weather and social influences in the productivity of a piece of land with standing trees, which is a feature of the measurement of total factor forestry productivity. Therefore, the measure of $\boldsymbol{\alpha_i}$ differs from several previous studies of agricultural land that use only the household fixed effect $\boldsymbol{\mu_i}$ (Deininger and Mpuga, 2009; Jin and Deininger, 2009; Jin and Jayne, 2013; Chamberlin and Ricker-Gilbert, 2016).

5.2 Determinants of Forestland Rental Market Participation

In the next step, I use the derived estimate of total factor forestry productivity, $\boldsymbol{\hat{\alpha}}$, as an explanatory variable in a model of the determinants of forestland rental market participation in Equation (3):

$$\boldsymbol{\tau_{ijt} = \delta_1 \hat{\alpha}_i + \delta_2 (\frac{A}{L})_{ijt} + \delta_3 FTR_{jt} + \delta_4 T_{ijt} + \delta_5 X_{ijt} + \delta_6 V_{jt} + \varepsilon_{ijt}.} \quad (3)$$

$\boldsymbol{\tau_{ijt} < 0}$ when $\boldsymbol{A^* < \bar{A}}$ (so the household rents out forestland), $\boldsymbol{\tau_{ijt} > 0}$ when $\boldsymbol{A^* > \bar{A}}$ (so the household rents in forestland), and $\boldsymbol{\tau_{ijt} = 0}$ when $\boldsymbol{A^* = \bar{A}}$ (so the household does not rent). I will treat $\boldsymbol{\tau_{ijt}}$ in the following two ways. First, I use a categorical response of $\boldsymbol{\tau_{ijt}} \in \boldsymbol{\{0, 1, 2\}}$ to indicate $\boldsymbol{\{}$Rent out, No rent, Rent in$\boldsymbol{\}}$, with the category 0 representing a case when $\boldsymbol{A^* < \bar{A}}$, category 1 representing a case when $\boldsymbol{A^* = \bar{A}}$, and category 2 representing a case when $\boldsymbol{A^* > \bar{A}}$. Second, $\boldsymbol{\tau_{ijt}}$ also can be continuous, meaning the difference between the desired and the endowed forestland, $\boldsymbol{A^* - \bar{A}}$, which is the amount of rented area. The three variables – the household's managerial ability in forestry ($\hat{\boldsymbol{\alpha}}_{\boldsymbol{i}}$), the pre-rental area of forestland per unit of labor ($(\frac{\boldsymbol{A}}{\boldsymbol{L}})_{\boldsymbol{ijt}}$), and the length of time with the Reform ($\boldsymbol{FTR_{jt}}$) – allow me to test Hypotheses 1 and 2 by the signs and marginal effects of the coefficients $\boldsymbol{\delta_{1\sim3}}$.

$\boldsymbol{FTR_{jt}}$ estimates the Reform's effect in encouraging rental transactions. An immediate effect is expected to be an increase in $(\frac{\boldsymbol{A}}{\boldsymbol{L}})_{\boldsymbol{ijt}}$ once a village decided to reform and reallocate some its forestland. Furthermore, forestland rental participation might increase over time with the Reform.[7] To identify the effect of the Reform, potential endogeneity has to be addressed, because the reform decision, driven by village natural endowments and socio-economic characteristics, may also correlate with households' willingness to rent forestland. In particular, the villages with more forestland involved in informal transfers may be more likely to reform. I define $\boldsymbol{FTR_{jt} = z_j \xi' + v_{jt}}$, where $\boldsymbol{z_j}$ includes a vector of village characteristics before the Reform ($\boldsymbol{z_{j0}}$) and in the current period ($\boldsymbol{z_{jt}}$). $\boldsymbol{\varepsilon_{ijt} = \beta v_{jt} + e_{ijt}}$ leads to a biased estimate of the Reform's effect on forestland rental participation, i.e., $\boldsymbol{\delta_3}$ in Equation (3). I use the control function (CF) approach to correct the selection bias. Then, Equation (3) is adjusted to:

$$\boldsymbol{\tau_{ijt} = \delta_1 \hat{\alpha}_i + \delta_2 (\frac{A}{L})_{ijt} + \delta_3 FTR_{jt} + \delta_4 T_{ijt} + \delta_5 X_{ijt} + \delta_6 V_{jt} + \beta \hat{v}_{jt} + e_{ijt}.} \tag{4}$$

and $\boldsymbol{\hat{v}_{jt} = F\hat{T}R_{jt} - z_j \hat{\xi}'}$ as a first-stage step to estimate Equation (4). The two main advantages of using the CF approach are that (1) the null of the endogeneity of $\boldsymbol{FTR_{jt}}$ can be tested simply by the statistical significance of the parameter $\boldsymbol{\beta}$ and (2) the average partial effects are easy to compute when Equation (4) is estimated by a nonlinear (and multinomial response) model (Petrin and Train, 2006; Wooldridge, 2010).

In interpreting $\hat{\boldsymbol{\alpha}}_{\boldsymbol{i}}$ and its parameter estimate $\boldsymbol{\delta_1}$, I follow several other studies such as Jin and Jayne (2013), and acknowledge that $\hat{\boldsymbol{\alpha}}_{\boldsymbol{i}}$ also captures some other things that do not vary with time, for example, soil quality. Soil quality of plots with standing trees is believed to be even more stable, that is, time-invariant, than that of plots with crops. Given the assumption that a household is more likely to rent out (forest) land with lower soil quality than to maintain such land for its own use, $\hat{\boldsymbol{\delta}}_{\boldsymbol{1}}$ is more likely to be downward biased than to over-estimate the effect of productivity on renting in or out forest plots.

$\boldsymbol{X_{ijt}}$ is the same set of household-level factors as in Equation (2), including perceptions of risk ($\boldsymbol{\rho}$), cash constraints and credit access and ability to obtain credit ($\boldsymbol{C}$), opportunity costs of managing more forest ($\boldsymbol{R}$) (reflected by cropland size, income

[7] For example, it takes time to arrange forestland transfers; to obtain professional services, such as the assessment of the value of land with standing trees, which is important for establishing market rates; and to develop information platforms. Further, owners' confidence in tenure security may take time to develop.

from off-farm work, and livestock production value), and other household characteristics ($\boldsymbol{H}$): household head's gender, age, education, political connections, and experience working in a forestry department.

$\boldsymbol{T_{ijt}}$ is a vector of variables representing transaction costs affecting rental decisions. Two examples in the vector include holding a forestland certificate, which guarantees the security of tenure rights, and the perceived rights to change forest types, to transfer forestland to other villagers and outsiders, and to mortgage forestland, which are based on policy regulations. More forestland transactions at an earlier time may imply better-functioning markets and lower transaction costs. Other village-level characteristics in $\boldsymbol{V_{jt}}$ include demographic and resource endowment, and distances to cement-paved road, to closest county center, and to local bank. Precipitation and temperature are controlled for because they are important for forest growth.

Equation (4) is estimated by multinomial logit regressions on farmers' choices among rent-in, rent-out, and no-rent, using the same two-period panel data. I also unravel the determinants of the extent of rental participation by random effects tobit models, where the dependent variables are continuous – the amount of area and the percentage of forestland rented-out (rented-in) compared to the pre-rental level. Tobit estimators allow us to account for the corner solution for a large number of households that do not participate in the forestland rental market. The results of the binary response of rent-out (rent-in) estimated by probit models are similar to the results of multinomial logit models and are not reported in the paper. Standard errors are bootstrapped for models, including the two estimates $\hat{\boldsymbol{\alpha}}_{\boldsymbol{i}}$ and $\hat{\boldsymbol{v_{jt}}}$ that are generated from the two-step estimation process.

5.3 Welfare Impacts of Forestland Rental Market Participation

The third step of the empirical analysis is to quantify the impact of rental participation on household welfare, in terms of income and income distribution, in order to test Hypotheses 3 and 4. I estimate a set of models on the average treatment effect of rental participation on a set of welfare indicators: i) a household's per capita income; ii) household's income share from off-farm work; iii) household's income share from forestry; and iv) probability of income falling below the poverty line. The treatment, a household's renting-in (renting-out) forestland ($\boldsymbol{D_i}$ in Equations (5) and (6)) is not randomly assigned. Some factors driving households to self-select to renting may also correlate with their welfare outcomes. Propensity score matching (PSM) methods correct the self-selection bias so as to identify the causal impact of renting, based on the observable pre-treatment differences between the treated and the control groups. I elaborate the conceptual foundation and procedure of the PSM method as follows.

Following Becerril and Abdulai (2010), a random utility framework is used to model the difference between the utility from renting (in or out) ($\boldsymbol{U_1}$) and the utility from not renting ($\boldsymbol{U_0}$), defined by a latent variable, $\boldsymbol{D_i^*}$. $\boldsymbol{D_i}$ is observed as households' actual forestland rental behavior given a set of observable household and forestland characteristics ($\boldsymbol{Z_i}$) according to the decision function (5):

$$\boldsymbol{D_i^* = g(Z_i) + u_i, D_i = \begin{cases} 1 & \text{if } D_i^* = U_1 - U_0 \geq 0 \\ 0 & \text{if } D_i^* = U_1 - U_0 < 0 \end{cases}.} \tag{5}$$

Because $\boldsymbol{D_i}$ is by self-selection instead of random assignment, I use the following welfare Equation (6) to illustrate how PSM is carried out to identify the average renting effects:

$$\boldsymbol{I_i = p(Z_i) + \theta D_i + \sigma_i.} \tag{6}$$

where $\boldsymbol{I_i}$ refers to one of the aforementioned welfare indicators. $\boldsymbol{p(Z_i) = Pr[D_i = 1 \mid Z_i] = F\{h(Z_i)\}}$ and $\boldsymbol{F\{\cdot\}}$ can be normal or logistic cumulative distribution; $\boldsymbol{\sigma_i}$ is a normal error term. As suggested by Rosenbaum and Rubin (1983), counterfactual situations for those who rented (i.e., the treated, if $\boldsymbol{D_i = 1}$) will be statistically matched with those who did not rent (i.e., the control, $\boldsymbol{D_i = 0}$) and who had the same probability of assignment to the treatment, $\boldsymbol{p(Z_i)}$. Conditional on the propensity score, $\boldsymbol{p(Z_i)}$, the coefficient of rental participation $\boldsymbol{\hat{\theta}}$, will be unbiased and estimated as the average treatment effect on the treated (ATT). The average welfare effect of forestland rental participation is given by Equation (7):

$$\boldsymbol{\theta = ATT = E\{E[I_{i1} \mid D_i = 1, p(Z_i)] - E[I_{i0} \mid D_i = 0, p(Z_i)] \mid D_i = 1\}.} \tag{7}$$

The estimation of the treatment effects using propensity score matching requires two assumptions. First, the Conditional Independence Assumption (CIA) assumes that, for a given set of covariates, participation is independent of potential outcomes. Second is the condition that the ATT is only defined within the region of common support. The propensity scores, $\boldsymbol{p(Z_i)}$ are conditional on a vector of observable pre-treatment characteristics, suggesting that the selection of the $\boldsymbol{Z_i}$ covariates is crucial for the matching. My selection of $\boldsymbol{Z_i}$ includes all the observed covariates determining a household's forestland rental status, as used in the estimation of Equation (4).

The last step is to match the "neighbors" of a rent-in (or rent-out) household with a propensity score very close to the propensity scores of the no-rent households. I apply the most commonly used matching methods: the nearest neighbor (NNM) and the kernel-based (KBM) matching. The NNM and KBM differ in that the former matches each treated observation with the control observation that has the closest propensity score. The latter matches all treated observations with a weighted average of all controls. The weights in KBM are inversely proportional to the distance between the propensity scores of treated and control groups. Then, the average of the differences of each matched pair is computed as the $\boldsymbol{ATT}$ ($\boldsymbol{\theta}$).

6 Data

I use a two-period panel dataset from over 1,000 randomly surveyed households in three Chinese provinces: Fujian, Jiangxi, and Yunnan. The survey team, from the Environmental Economics Program in China at Peking University, collected household data on demographic and social-economic characteristics, labor allocation, agricultural production, forest management activities at plot level, income and assets, basic social relationships, and (forest) land use practices and rights, in the years 2005 and 2010. The village-level data is for three years (2000, 2005 and 2010) and covers natural and resource endowments, socio-economic characteristics, and whether, when, and how the Reform was implemented in the village. The survey is nationally representative, in eight provinces with collective forests from the south to north of China. In 2006, 10-20 households were selected in one village in each county following a stratified random sampling rule, and were revisited in 2011. The three provinces are included in this study because the surveys in the other five did not ask about rent-in and rent-out of forestland plots in 2005. More importantly, the provinces included were the earliest to adopt the Reform, and thereby provide a better understanding of the emergence and evolution of forestland rental markets.

The analysis focuses on the 1,192 and 967 households who were interviewed in 106 villages in the two waves, respectively.[8] This gives an attrition rate of 19 percent. The variables used in the analysis are defined in Tables 2 and 3, for the surveyed households in reformed and non-reformed villages in both periods and their village characteristics in 2000-2010. The Reform had been implemented in 58 percent of the households in 2005 and 98 percent in 2010. As Table 2 shows, sizeable differences exist between the reformed and non-reformed households in landholdings, tenure rights, and ownership security. Households in reformed places had a larger average size of per labor forestland as an endowment than in non-reformed places (18 vs. 12 and 17 vs. 5 *mu* in 2005 and 2010, respectively). In general, households with the Reform

[8] The first wave surveyed 480, 300, and 600 households in Fujian, Jiangxi and Yunnan respectively (1,380 in total). In the second wave, 325, 228, and 528 households were available to be re-surveyed (1,081 in total). The sample size for the analysis comes to 1,192 and 967 excluding observations with missing and bad quality data. The reason for attrition is that the respondent was not available. I believe this is not systematic and will not affect the analysis. My reasoning is discussed below.

perceived stronger rights to change forest type and to transfer forestland within and outside the village. The households receiving forestland certificates in reformed places increased from 19 to 65 percent during 2005-2010, while the 2005 non-reform households already perceived that they were secure about the risk of ownership/production. Other household characteristics will be discussed later in Table 4 with regard to different rental participation status.

< Table 2 here >

Table 3 reports the village characteristics of social, economic, geographic and weather conditions during 2000-2010. Among the sampled villages, 4 villages where forestland accounted for 90 percent of the total land area, decided, in a spontaneous and informal way, to reform in 2000 and devolved 43 percent of their collective forests to households. In 2005, when the central government officially announced its encouragement to proceed with the Reform, 73 villages followed. Villages with better forest endowment, in terms of larger size and percentage of the village total land area, seem to be the first-movers of reform. Also, the Reform was more likely to be selected by villages with smaller population size and fewer households, those with higher average income, and those facing a higher price of commercial timber. By 2010, the 105 reformed villages had devolved on average 62 percent of the collective forests to households. The higher percentage of forestland transfers in reformed villages suggests better rental markets in villages with the Reform than in those without in 2000 (10 vs. 5 percent), 2005 (8 vs. 2 percent) and 2010 (almost 10 percent vs. 0).

< Table 3 here >

Weather data on rainfall and temperature is obtained from the China Meteorological Data Sharing Service System (CMDSSS). The CMDSSS records daily minimum, maximum and average temperatures, precipitation, and solar radiation in 820 weather stations (with exact coordinates) distributed across all of China. Using village center coordinates taken by the survey team with GPS devices, I match each village with the closest weather station. As shown in the bottom of Table 3, I calculate average and standard deviation of annual precipitation. Because temperature effects are non-linear, a higher level of effective cumulative heat (0-35 degree Celsius, °C) is good for plants, whilst the influence by harmful cumulative heat (>35 degree Celsius, °C) is the opposite (Schlenker and Roberts, 2009). The reformed villages had higher average rainfall and rainfall variation, as well as higher levels of both heat measures, than the non-reformed at all times.

To illustrate the extent to which the hypotheses on forestland markets are borne out, Table 4 presents key variables by household's forestland rental status – rent-in, rent-out, or no-rent – and by reform status and time. On average, in both 2005 and 2010, the rent-in households with the Reform were endowed with a smaller area of forestland per unit of labor (17.61 and 12.88 *mu*) and the households who rented out had a larger endowment (38.15 and 43.34 *mu*). Among the non-reformed households, the gap is bigger, with 79.76 *mu* of forests in rent-out households and only 6 *mu* of forests in rent-in households in 2005. In 2010, none of the 18 sampled households in the only non-reformed village rented any forestland. The comparison between the endowed level and the currently managed level of forestland per unit of labor among the three groups suggests that rental participation decreases the gap in landholdings. Furthermore, this gap is smaller in households with the Reform than in those without. In 2010, the gap almost disappeared, when each member of the family available for labor managed about 34 *mu* of forestland in both rent-in and rent-out households. These facts imply a direction in which forestland markets transferred land from households richer in per labor forest-landholdings to those with less forestland per labor unit.

< Table 4 here >

The rent-in households had the highest value of investment in forestry, compared with the rent-out and no-rent households. As expected, the annual value of all forest and non-forest products on plots is higher than that of the no-rent or the rent-out households. Labor work time in off-farm jobs does not differ much by rental status. Off-farm income was the highest in the rent-out households and the lowest in the rent-in households in 2005, but in 2010 the rent-in households surpassed those renting out. The difference in per capita income suggests a higher level of income achieved by households who participated in forestland rental markets than by the no-renters.

I also observe that forestland is transferred from households with older heads to those with younger heads. The renters had easier credit access (by the distance to closest local bank) and stronger ability to obtain credit than the no-renters had.[9] The other variables, such as regulations on forestland use and transfer rights, do not differ in a meaningful way, except that the rent-in households perceived stronger rights to mortgage forestland to obtain loans. Note that the rent-in households are never the richest, nor are the rent-out households the poorest, based on values of house and livestock, for example. Further, the household head's Communist Party membership and village committee service do not indicate a consistent difference among the three rental states. So, forestland agglomeration into the hands of wealthy and powerful people should not be a major concern based on the descriptive evidence so far. The

[9] Ability to obtain credit is measured by the answer to whether a surveyed household could successfully borrow 500 CNY within one week's time. 500 CNY is roughly the wage income of two weeks of off-farm work in rural areas in the three provinces.

next section exploits econometric methods to control for endogeneity and other factors affecting rental decisions, and examines the agglomeration or the allocative efficiency effect in household forestry via rental markets.

Potential Attrition Bias

The second wave survey lost 225 observations (19 percent attrition) because of household heads' temporary absences for business, sickness, or migration. Concerns exist about potential attrition bias if the reasons that households were not re-surveyed are non-random exist with respect to their forestland rental market participation. To correct the bias, I use the inverse probability weighting (IPW) method introduced in Wooldridge (2010, p. 837). I first estimate a household's probability of being re-surveyed on their first-period observable characteristics ($Pr_{i,2010} = \Phi(X_{i,2005})$), and then use the inverse predicted probabilities as weights ($IPW_i = 1/Pr_{i,2010}$) for each variable of 2010 in the estimation of Equation (4). The coefficient estimates from the IPWs-adjusted specifications do not differ much from the basic results, suggesting that attrition bias should not be a major concern, so I report the main results in which IPWs are not included.

7 Results

In this section, I present results for three sets of regressions: first, a Cobb-Douglas production function of household forestry, via a household FE model, aiming to derive the measure of forestry productivity; second, the multinomial logit and tobit models on determinants of forestland rental participation, with implications for allocative efficiency and agglomeration concerns; and, finally, the welfare impacts of renting forestland, estimated by the PSM method.

7.1 Household Forestry Productivity

Table 5 presents the FE estimates of the Cobb-Douglas production function. Results indicate that the annual incremental value of household forestry is significantly higher in households with larger forest landholding, higher value of investment, easier access to credit (with shorter distance to local bank), farther distance from urban population pressure (with longer distance to closest county center), and higher product price (proxied by commercial timber price, due to unavailable prices for all products).[10] Lower average and higher variation of rainfall, more days with temperature between 0 and 35 °C, and less days warmer than 35 °C are statistically significantly related to a higher level of forestry production.

< Table 5 here >

As discussed previously, I use the time-invariant and the stochastic terms from these results as a measure of forestry productivity: $\hat{\alpha_i} = \hat{\mu_i} + \hat{\epsilon_{ijt}}$ for each household i. The distribution of household forestry productivity is plotted in Figure 1. Overall, household forestry productivity shows a normal distribution in all subsamples of provinces in each year, but with various degrees of dispersion in different provinces and times. Active rental markets and better factors mobility are believed to contribute to a more concentrated normal distribution of managerial ability towards a zero mean; however, more spikes and larger dispersion of the distribution of productivity would be due to inactive land rental markets and less off-farm or migration opportunities, which impede factors mobility. Similar to what Deininger and Jin (2005) found for household farming ability, a more dispersed productivity distribution is found in Yunnan than in the other two provinces due to less-developed factor markets.

< Figure 1 here >

7.2 Forestland Rental Market Participation and Allocative Efficiency

Table 6a reports the estimation results on the determinants of forestland rental market participation (Equation (4)). I apply multinomial logit models with three rental states: rent-out, no-rent, and rent-in (the reference case is no-rent), with standard errors clustered at the household level. I estimate them firstly on pooled data (in column-set 1) and then for 2005 and 2010 samples separately (in column-sets 2 and 3). The results include the two generated regressors – $\hat{\alpha_i}$ representing the household forestry productivity and $\hat{\upsilon_{jt}}$ representing the endogeneity of reform selectivity to rental participation, with p-values based on 200 iterations of bootstrapping the standard errors. Omitting $\hat{\upsilon_{jt}}$ and then also $\hat{\alpha_i}$ yields results very similar to other coefficient estimates (not shown and available upon request), indicating robustness to the addition. The coefficient of $\hat{\upsilon_{jt}}$ is statistically significant, and the model corrects the estimation bias of the reform's time effect.

[10] The quadratic terms of family labor, forestland area and input value are added to investigate the non-linearity of scale and investment increments, as well as that of education and price of timber. None of the quadratic terms has significant coefficients. The coefficient of the quadratic term of endowed forest landholdings is negative, suggesting the returns to scale could be diminishing. Results are available upon request.

< Table 6a here >

The coefficient estimates in Table 6a are consistent with previous literature in agricultural land rental markets regarding the implications for welfare, in terms of allocative or productive efficiency (e.g., Deininger and Mpuga, 2009; Jin and Deininger, 2009; Jin and Jayne, 2013). In all specifications, household pre-rental, per-labor forestland has a positive and statistically significant effect on the likelihood of renting out, and a negative and significant effect on the likelihood of renting in. Stated otherwise, holding other factors equal, households with a larger amount of forestland per unit of labor are more likely to rent out, and those with a smaller amount of forestland per unit of labor are more likely to rent in. The forestry productivity variable has positive and statistically significant coefficients in all "rent-in" columns, suggesting that relatively productive households are more likely to rent in forestland. A longer period with the Reform in place increases the likelihood of renting in forestland, and, for 2005, increases the likelihood of renting out. The findings support Hypotheses 1 and 2 that, via forestland rental markets, the forest devolution reform improves allocative efficiency. The other covariates that significantly explain the variation in forestland rental participation have the expected signs. Their marginal effects are evaluated at the sample means and presented in Table 6b, on the likelihood of rent-out, no-rent, and rent-in, respectively.

Holding other factors constant, for a household where per labor forestland is 100 percent higher than the average (of 15 *mu*), the probability of the household renting out some forestland will be 2.2 percentage points higher; the likelihood of renting in will decrease by 1.9 percentage points. Given that the average percentage of renting-out households is 7 and that of renting-in households is 5.4 (in 2010), the effects are sizeable – about one-third. Hypothesis 1 is supported by the evidence that rental markets transfer forestland from the forestland-rich, labor-constrained households to the labor-rich, forestland-constraint households. This points toward the equalization of forestland-labor ratios among households. An increase in productivity, from the bottom to the top in the sampled households, is estimated to increase the likelihood to rent in by 9.5 percentage points. Households with younger (older) heads are more likely to rent-in (rent-out), and they rent in more forestland, implying a net transfer from less able to more able households. These findings suggest a productive efficiency effect through the forestland rental market that transfers forestland from less productive to more productive households, supporting Hypothesis 2.

< Table 6b here >

To examine the extent of rental participation – the determinants of amount and percentage of rented forestland relative to the endowment level, I employ random effect tobit models. Results for renting-in and renting-out are presented in Table 7. The negative (positive) coefficients of the per-labor forest landholding, accompanied by the positive (negative) coefficients of household forestry productivity in the area rented in (rented out) are evidence of the allocative efficiency effect of these rental markets.

Little evidence is found on agglomeration in forestland to a specific kind of landholders, by either the size of household landholdings, political connections, or wealth. Political connections such as membership in the Communist Party or village committee, or work experience in forestry departments, have no statistically significant impact on rental market participation. An exception is that members of village committees were less likely to rent forests out in 2005. Households with a higher asset value of, e.g., houses, are more likely to rent in forests. But this does not necessarily mean agglomeration to the rich, because there is no significant effect suggesting that poorer households are more likely to rent out.

< Table 7 here >

In addition to forest landholdings and owner productivity, I find that access to credit and ability to obtain credit affect forestland rental participation, as expected. Households with a shorter distance to local banks are more likely to participate in forestland rentals. Softened credit constraints, i.e., ease of borrowing 500 CNY within a week, increases the likelihood of forest rental transactions (in Tables 6a and 6b), but there is no significant effect on rental amount (in Table 7). As a tenure security effect, households' stronger perception of secure ownership or rights to production is found to significantly encourage renting in forestland in 2005, while those perceiving a bigger chance of losing plots were more likely to rent out.

Timber price, as the proxy variable for the price of forest products, indicates the value of a forest plot on rental markets. A price increase would drive the market supply up; thus, more rental transactions would be anticipated. As expected, I find the likelihood and magnitude of renting out, and the area rented in, increasing with an increase in timber price. Another important factor that would make the expected returns to land differ is a restriction on forestland use – the right that allows owners to change forest type amongst timber, bamboo, and economic forests.[11] This right enables owners to rationalize their use in order to maximize the profits from a forest plot. Controlling for the right does not affect the driving effects of factor endowment and productivity. Nevertheless, this right seems to have an encouraging effect on renting in, as shown by the positive signs.

[11] It is usually forbidden to change forestland to other uses, such as cropland or for construction. In places with this right, any restrictions on harvest would be non-binding.

A household's opportunity costs in view of agricultural and livestock production and off-farm work do not have a statistically significant impact on rental participation. Note that households with a smaller amount of per capita cropland tend to rent out some forestland (significantly in 2005), probably due to cash constraints and the need to fulfill their own consumption of food. As Table 7 shows, households with greater per-capita cropland are more likely to rent in a larger amount of forestland, indicating the complementarity of agricultural and forestry production. This is also supported by the evidence that renting in and renting out are more likely in villages with a larger share of cropland.

One more year with the Reform is estimated to increase the rent-in likelihood by 2.7 percentage points, and also the likelihood to rent out in 2005. Apart from the effect of perceived tenure security, other sources of transaction costs related to rental markets, such as regulations, earlier transactions and forestland certificates, have little statistical power. An exception is that the right to mortgage forestland is found to encourage renting in (for 2005) and a stronger transfer right (the ability to rent forestland to outsiders) encourages renting out (in 2010). Finally, households in villages with a larger area of forests are more likely to rent. Larger population and social-economic development, represented by average income, percentage of population having telephones, and development of off-farm labor markets, entail high pressures on forests, and are found to discourage households from participating in rental markets. Weather conditions, on which forests are very dependent for growth, affect rental participation in a significant way. Households are more likely to rent out forestland, and to rent out a greater amount of forestland, in places with lower average rainfall and greater variation, and are more likely to rent in where rainfall is higher on average but varies less and where there are more days between 0 and 35 degrees Celsius.

7.3 Impact of Forestland Rental Participation on Household Welfare

Table 8 shows the differences in the main welfare indicators between the no-renters (Column A), the rent-in households (Column C), the rent-out households (Column D), and the households rented (Column B). Compared to the no-renters, the rent-in and rent-out households have higher annual per capita income, ranging from 1,930 to 2,448 CNY, and more than 10 percent lower probability of income falling below the absolute poverty line. The poverty line is defined as 2000 CNY for 2005 and 2300 CNY for 2010, in accordance with the World Bank's global poverty standard, i.e., 1.25 Purchasing-Power-Parity (PPP) U.S. dollars a day in 2005. Households participating in forestland rental markets have more off-farm income than the no-rent households, by 1,766-2,758 CNY a year. The difference in products value of per-*mu* forestland does not significantly differ by rental status. This suggests that the average forestry productivity of the incumbent managers is satisfactory. In support of this point of view, I also find that, compared to the no-renters, the rent-out households have 6 percent less income from forestry production, and this difference is statistically significant.

< Table 8 here >

In the light of the significant mean differences in welfare indicators, I undertake the following procedures to identify average treatment effects for each treatment – renting (including either rent-in or rent-out), rent-in and rent-out separately. The propensity to be treated, i.e., $p(Z_i)$, is estimated on the basis of the observables from the earlier results on rental market participation.[12] In the estimation of a treatment effect, I use a common support, assuming the treated and the control are distributed in the same domain. Figure 2 provides a visual inspection of the density of the distribution of the estimated propensity scores for the treated group and the control group, for each treatment. The substantial overlap in the distribution of the propensity scores for each treatment indicates that the common support condition is satisfied.

< Figure 2 here >

Table 9 presents the estimates of the average treatment effect of rental participation, rent-in and rent-out, using the Epanechnikov kernel estimator (KBM) with a bandwidth of 0.06. Standard errors of the estimated ATT are bootstrapped with 200 replications. For sensitivity analysis, other matching algorithms, of KBM with bandwidth 0.1, and nearest neighbor matching (NNM) with 1, 5 and 10 neighbors, are also applied and produce similar results (not shown and available upon request).

Renting in forestland could increase household income through forestry production, and renting out land could release labor for greater engagement in off-farm work. As expected, participation in forestland rental markets has a positive impact on household annual per-capita income, of more than 1,500 CNY, and reduces the probability of income falling below the poverty line, by 9 percentage points, for either renting in or renting out forestland. These results support Hypotheses 3 and 4 – namely, rental market participation has positive impacts on household income and poverty alleviation.

I find that renting out forestland leads to higher off-farm incomes, with an average treatment effect of 1,646 CNY a year, and 7 percent more income from off-farm work.

[12] The logit models for propensity scores have Pseudo-R^2 values of 0.133, 0.177 and 0.183. These values are similar to the levels in recent literature using the PSM strategy, e.g., Becerril and Abdulai, 2010; Kassie et al., 2011. By contrast, significant parameter estimates (t-test) or goodness-of-fit measures like Pseudo-R^2 can be misleading (Heckman and Navarro-Lozano, 2004; Lee, 2013). They only show association and are used to balance the observed distribution of covariates across the treated and the control groups, in order to provide good matches for the estimation of ATT.

The findings lend support to my contention that renting out forestland enables family labor to engage better in off-farm jobs, given that off-farm working days per household labor do not differ across rental status, as observed in Table 4.

Renting in forestland seems not to increase forestry production value in a statistically significant way. Renting out forestland significantly reduces household forestry production, by an average value of 78 CNY per *mu*, and reduces income from forestry by almost 5 percent, compared to the case if the household does not rent out. Results indicate that the no-rent households are doing well as forest managers, so that they are willing to maintain the forestland for their own use rather than rent it out.

< Table 9 here >

8 Conclusion

I analyzed panel survey data and found that, through allowing more productive households to access forestland and equalize factor ratios, rental markets improve allocative efficiency and household welfare. The number of transactions of forestland transfers is still very small compared to the rental transactions in agricultural land. Obviously, the devolution in agricultural land to households started twenty years earlier than the devolution in forest management. With the experiences and lessons from agriculture, policy makers anticipate the same efficiency gains as were achieved with forestland markets.

The main findings include the importance of factor endowment and managerial ability, which determine productivity in forestry, in driving the direction of resource allocation. Policies should improve rural households' knowledge and skills in forest management, and should facilitate more productive individuals in obtaining their optimal operational size of forestland. Transparent, well-functioning land exchange platforms/markets have been put in place at the municipal level by the Chinese central government. Policies that promote the inclusion of forestland in these markets and the extension of such exchange platforms to counties and communities could encourage forestland rental market development.

I also propose that policies should be devoted to address constraints and strengthen local institutions to improve farmers' access to factor resources and credit. Effective efforts should include securing property rights to forestland. I find, and so have previous studies, that households' perceptions on property rights (or tenure security) drive their decisions on management and transfer. However, in 2010, seven years after the formal announcement of the Collective Forest Tenure Reform, only two-thirds of households had received forestland certificates in the earliest reformed provinces.

Finally, the current low participation rate in forestland rental markets implies potential for a future market. Although no evidence was found of agglomeration of forestland to larger, wealthier, or more powerful landholders, follow-up policies should still be vigilant on avoiding consolidation among such households. On the contrary, forestland agglomeration to more efficient users is not bad, especially in the context where the growth of rural migration would demand reallocation of factor resources in rural areas. Given the results that rental participation enables households to better engage in off-farm work, forestland could provide a household not only with a safety-net asset but also with improved off-farm ability. From an integrative perspective, a shift of labor to the manufacturing and service industries may play an underpinning role in fostering the structural transformation of rural development in China.

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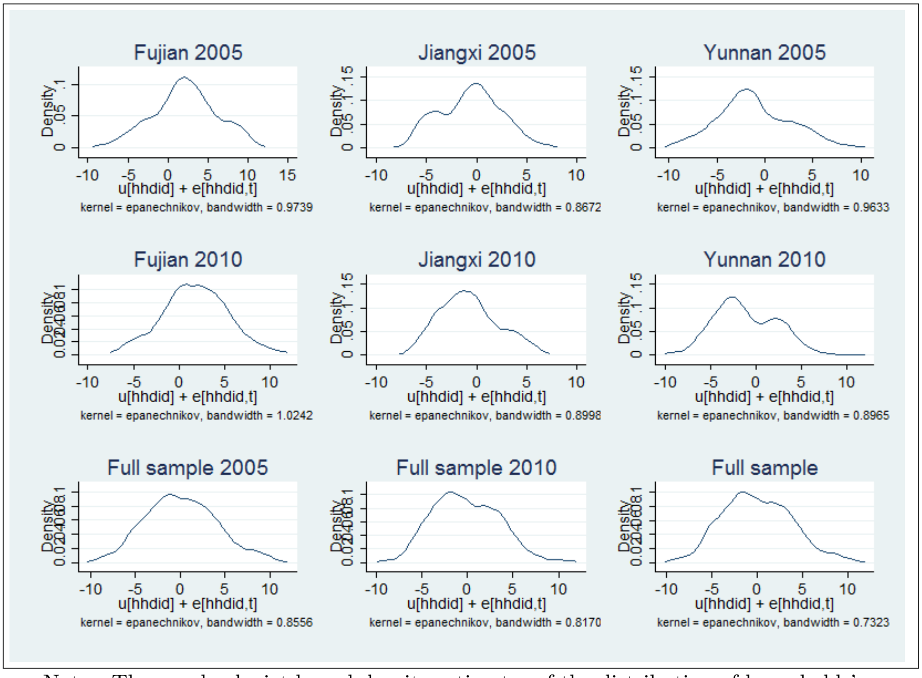
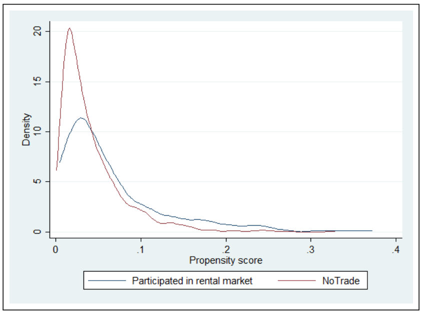
Figure 1: Distribution of household forestry productivity in three provinces

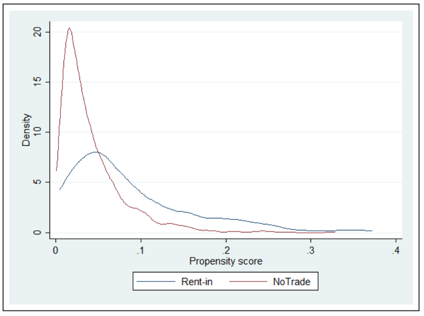


Notes: The graphs depict kernel density estimates of the distribution of households' forestry productivity as predicted from the household fixed-effects Cobb-Douglas forestry production functions.

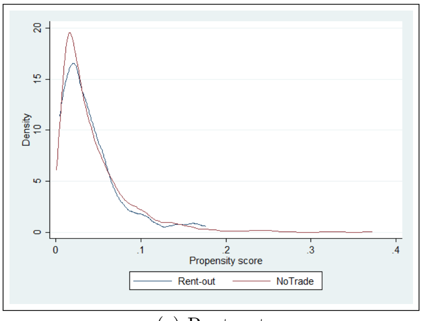
Figure 2: Propensity score distribution and common support for propensity score estimation



(a) Rental Participation



(b) Rent-in



(c) Rent-out

Notes: For each of the three treatments: "rental participation" in (a), "rent-in" in (b), and "rent-out" in (c), all treated observations have common support. That is, all the "Treated" observations, i.e., each of the 180 rental participating households, each of the 93 renting-in households, and each of the 87 renting-out households, has a suitable comparison.

Table 1: Emerging forestland rental market, sample mean, by reform and time

	2005			2010		
	All	*No-Reform*	*With-Reform*	*All*	*No-Reform*	*With-Reform*
Total forestland area (*mu*)*, endowment	48.99	36.59	57.89	52.21	12.43	52.97
% of households renting-in	2.10	1.41	2.59	7.03	0	7.17
% of households renting-out	2.85	4.42	1.73	5.48	0	5.58
Rented-in forestland, area (*mu*)*	0.854	0.274	1.269	4.229	0	4.309
Rented-out forestland, area (*mu*)*	2.070	4.189	0.549	2.146	0	2.186
Rented-in forestland, % to endowment	1.18	0.673	1.54	4.10	0	4.17
Rented-out forestland, % to endowment	1.32	1.84	0.942	1.99	0	2.03

Notes: * 1 *mu*=1/15 hectare.

Author's computation based on representative survey data of 2005 and 2010 in Fujian, Jiangxi and Yunnan provinces of China, conducted by the Environmental Economics Program of China at Peking University, China.

Table 2: Household characteristics by reform and time (Mean)

	2005			2010		
	All	*No-Reform*	*With-Reform*	*All*	*No-Reform*	*With-Reform*
Demographic characteristics:						
Number of household members	4.758	4.721	4.784	4.851	5.611	4.837
Number of labor equivalents	3.398	3.239	3.512	3.347	3.556	3.344
Household head age (years)	47.74	44.70	49.91	50.82	54.67	50.75
Household head gender (1=male, 0=female)	0.949	0.920	0.970	0.946	0.667	0.952
Household head is Communist (1 if yes, 0 if no)	0.153	0.114	0.180	0.174	0.111	0.175
Household head is village leader (1 if yes, 0 if no	0.0629	0.0562	0.0677	0.0558	0	0.0569
Average education (years)	5.280	5.029	5.460	5.557	6.897	5.531
Work experience in forestry department (1=yes, 0=never)	0.0201	0.0141	0.0245	0.0496	0	0.0506
Forestland, cropland, assets and incomes:						
Mu of forestland per labor	16.13	12.47	18.75	17.24	5.331	17.46
Mu of forest endowed to household	48.99	36.59	57.89	52.21	12.43	52.97
Capital investment in forestry (CNY)	647.9	796.7	541.1	1,353	706.7	1,365
Annual value of forestry production (CNY)	3,851	1,356	5,642	859.9	6.624	876.1
Mu of cropland per capita	1.644	2.037	1.361	1.931	0.552	1.957
Off-farm work days per labor	106.7	78.24	127.2	110.9	139.9	110.3
Total off-farm income (CNY)	12,257	8,197	15,171	25,879	28,067	25,838
Total livestock value (CNY)	1,358	2,450	574.7	3,829	343.3	3,895
Total house value (10,000 CNY)	3.379	3.244	3.476	11.48	44.69	10.85
Income per capita (CNY)	4,134	3,109	4,870	8,772	7,256	8,801
Risk perception, credit constraint, and restriction on forestland:						
Holding a forestland certificate (1 if yes, 0 if no)	0.110	0	0.189	0.635	0	0.647
Ability to obtain credit[a]	0.787	0.772	0.797	0.948	1	0.947
Credit access (distance to local bank, km)	8.209	10.63	6.475	9.165	0.311	9.333
Perception of ownership/production risk[b]	0.690	0.951	0.504	0.931	0.889	0.932
Right to change forest type (1 if yes, 0 if no)	0.878	0.867	0.885	0.807	0.556	0.811
Right to transfer forestland within village	0.693	0.645	0.727	0.687	0.500	0.690
Right to transfer forestland to outsiders	0.617	0.581	0.642	0.609	0.333	0.614
Right to mortgage forestland	0.430	0.406	0.447	0.309	0.361	0.308
Number of observations	1192	498	694	967	18	949

Notes: 1 *mu*=1/15 hectare.
[a] Ability to obtain credit measures household ability to obtain credit, with value equal to 1 if they can successfully borrow 500 CNY within a week, 0 if not.
[b] 1 if secure, 0.5 if unsure or do not know, 0 if insecure.

Table 3: Villages characteristics by reform and time (Mean)

	2000		2005		2010	
	No-Reform	*With-Reform*	*No-Reform*	*With-Reform*	*No-Reform*	*With-Reform*
Length of period with the Reform (years)	0	1	0	2.195	0	6.581
Number of households in village	349.3	152.5	536.4	300.1	867	413.3
Population	1,504	642.8	2,457	1,224	2,471	1,650
Average per capita income (CNY)	1,640	2,800	1,290	2,374	3,213	3,022
Distance to paved road (km)	0.601	0	1.517	0.0629	0	0.541
Distance to closest county center (km)	36.08	65.75	39.76	36.08	0	35.03
Population share possessing telephones	0.286	0.497	0.583	0.751	1	0.928
Development of labor market[a]	0.185	0.0724	0.211	0.284	0.731	0.301
Village cropland area share	0.111	0.0512	0.121	0.0884	0.0434	0.125
Village forestland area share	0.700	0.904	0.751	0.715	0.957	0.654
Village total forestland area (*mu*)	15,587	21,185	23,092	13,267	10,080	16,420
Proportion of household-managed forestland area[b]	0.525	0.427	0.546	0.608	0.00645	0.617
Proportion of forestland involved in transfers	0.0556	0.105	0.0159	0.0793	0	0.0958
Commercial timber price (10,000 CNY)	0.0269	0.0310	0.0406	0.0469	0.0208	0.0816
Annual precipitation: average (mm)	44.32	45.24	32.63	50.35	27.12	51.03
Annual precipitation: standard deviation (mm)	107.2	107.3	81.10	137.1	70.90	125.5
Effective cumulative heat, 0-35°C, GDD[c]	6,687	7,606	6,403	6,962	5,281	6,888
Harmful cumulative heat, >35°C, HDD[c]	2.794	6.352	0.00701	6.544	0	5.580
Number of villages	102	4	29	77	1	105

Source: Author's computation based on representative survey data of 2005 and 2010 in Fujian, Jiangxi and Yunnan provinces of China, conducted by the Environmental Economics Program of China at Peking University, China; the village-level data on 2000 is recalled. Weather data is obtained from the China Meteorological Data Sharing Service System (CMDSSS).

Notes: [a] Development of labor market is measured by the ratio of number of off-farm workers to the total labor force in village.

[b] In 2000, the variable refers to the ratio of forestland area accessed by households over the village total forest area.

[c] Effective cumulative heat, or growing degree days (GDD), is a generated measure of days with 0-35°C. Harmful cumulative heat, or harmful degree days (HDD), is generated for days with temperature higher than 35°C. $GDD = \sum_i^N T_{i,a} - T_{base}$, where $T_{i,a}$ is the daily average temperature for day i, and T_{base} is the base temperature below which vegetation ceases to be biologically active (here we select 0°C for trees). $HDD = \sum_i^N (T_{i,max} - 35°C)/T_{i,max}$, where $T_{i,max}$ is maximum temperature for day i.

Table 4: Household characteristics by rental and reform status in 2005 and 2010 (Mean)

	2005						2010			
	No-Reform			*With-Reform*			*No-Reform*	*With-Reform*		
	Rent-out	No-rent	Rent-in	Rent-out	No-rent	Rent-in	No-rent	Rent-out	No-rent	Rent-in
Demographic characteristics:										
Number of household members	5.364	4.695	4.429	4.750	4.810	3.833	5.611	4.604	4.836	5.029
Number of labor equivalents	3.955	3.213	2.714	3.833	3.526	2.778	3.556	3.283	3.326	3.603
Household head age (years)	45.73	44.67	43.57	51.83	50.09	42.22	54.67	53.67	50.68	49.35
Household head gender (1=yes, 0=never)	0.909	0.921	0.857	1	0.968	1	0.667	0.887	0.954	0.971
Household head is Communist (1=yes, 0=never)	0.182	0.111	0.143	0.0833	0.182	0.167	0.111	0.189	0.171	0.206
Household head is village leader (1=yes, 0=never)	0	0.0576	0.143	0	0.0708	0	0	0.0566	0.0531	0.103
Average education (years)	6.284	4.988	3.897	6.093	5.445	5.581	6.897	4.896	5.546	5.844
Work experience in forestry department (1=yes, 0=never)	0.0455	0.0107	0.143	0	0.0256	0	0	0.0755	0.0471	0.0735
Forestland, cropland, assets, and incomes:										
Mu of forestland per labor, endowed	79.76	9.412	6.224	38.15	18.43	17.61	5.331	43.34	16.18	12.88
Mu of forestland per labor, currently managed	44.67	9.412	13.18	28.07	18.43	35.72	5.331	33.31	16.18	34.64
Capital investment in forestry (CNY)	481.0	803.2	1,353	525	515.8	1,487	706.7	819.1	1,265	3,005
Annual value of forestry production (CNY)	69.47	1,272	11,014	2,486	5,569	10,436	6.624	915.8	732.6	2,593
Mu of cropland per capita	2.433	1.995	3.641	0.789	1.370	1.432	0.552	1.473	2.034	1.393
Off-farm work days per labor	75.73	78.41	74.88	110.1	127.9	112.9	139.9	111.5	109.2	123.4
Total off-farm income (CNY)	13,965	7,973	5,097	27,278	15,042	11,847	28,067	29,726	24,565	38,310
Total livestock value (CNY)	1,907	2,489	1,509	300.8	592.0	118.9	343.3	2,807	4,118	2,037
Total house value (10,000 CNY)	3.725	3.251	1.294	2.563	3.512	2.749	44.69	10.98	10.21	18.53
Income per capita (CNY)	4,478	3,037	3,679	8,087	4,800	5,306	7,256	9,340	8,632	10,443
Risk perception, credit constraint, and restriction on forestland:										
Holding a forestland certificate (1 if yes, 0 if no)	0	0	0	0.167	0.185	0.333	0	0.811	0.644	0.559
Ability to obtain credit[a]	0.909	0.762	1	0.833	0.794	0.889	1	1	0.942	0.971
Credit access (distance to local bank, km)	3.159	10.97	10.79	4.208	6.478	7.861	0.311	7.323	9.721	6.168
Perception of ownership/production risk[b]	0.886	0.953	1	0.500	0.504	0.500	0.889	0.943	0.930	0.941
Right to change forest type (1 if yes, 0 if no)	0.773	0.870	1	0.833	0.889	0.778	0.556	0.755	0.810	0.868
Right to transfer forestland within village	0.273	0.663	0.643	0.854	0.726	0.667	0.500	0.689	0.683	0.787
Right to transfer forestland to outsiders	0.250	0.598	0.500	0.688	0.642	0.611	0.333	0.660	0.603	0.706
Right to mortgage forestland	0.114	0.416	0.643	0.500	0.442	0.583	0.361	0.236	0.305	0.397
Length of period with the Reform (years)	0	0	0	2.667	2.197	2.833	0	6.245	6.010	6.941
Proportion of forestland involved in transfers in 2000	0.0146	0.0153	0.0447	0.163	0.0702	0.0614	0.0585	0.0790	0.0684	0.104
Number of observations	22	469	7	12	664	18	18	53	828	68

Note: In 2010, none of the 18 sampled households in the non-reformed village rented any forestland.
1 *mu*=1/15 hectare.
[a] Ability to obtain credit measures household ability to obtain credit, with value equal to 1 if they can successfully borrow 500 CNY within a week, 0 if not.
[b] 1 if secure, 0.5 if unsure or do not know, 0 if insecure.

Table 5: Household forestry: Cobb-Douglas production function (FE estimates)

	Coefficient	Std.Err. (*P*-value)
Log labor equivalents	0.139	(0.343)
Log forestland endowment (*mu*)	0.225	(0.120)*
Log value of investment in forestry (CNY)	0.180	(0.0412)***
Log household head age (years)	0.807	(0.731)
Household head gender (1=yes, 0=never)	-0.261	(0.427)
Household head is Communist (1=yes, 0=never)	-0.184	(0.549)
Household head is village leader (1=yes, 0=never)	0.417	(0.379)
Average education (years)	0.0346	(0.0779)
Work experience in forestry department (1=yes, 0=never)	0.141	(0.555)
Log cropland per capita (*mu*)	0.160	(0.251)
Log off-farm work days per labor	0.109	(0.0508)**
Log total livestock value (CNY)	0.00103	(0.0278)
Log total house value (10,000 CNY)	0.182	(0.114)
Holding a forestland certificate (1 if yes, 0 if no)	0.191	(0.308)
Ability to obtain credit (1=can borrow 500 CNY in a week)	0.0568	(0.286)
Perception of ownership/production risk (1 if secure)	0.467	(0.492)
Log distance to local bank (km)	-0.748	(0.121)***
Log distance to closest county (km)	0.769	(0.0692)***
Log timber price (CNY)	0.263	(0.105)**
Annual precipitation: average (mm)	-0.236	(0.0325)***
Annual precipitation: standard deviation (mm)	0.064	(0.00706)***
Effective cumulative heat, 0-35°C, GDD	0.00239	(0.00134)*
Harmful cumulative heat, >35°C, HDD	-0.0595	(0.0205)***
R-squared		0.394
Number of households		1,266
Number of observations		2,155

Notes: Table shows coefficient estimates from household fixed effects regression. The dependent variable is log of the annual incremental value of forestry. Model includes year, province year and village year dummies (not shown). Standard errors are robust to clustering at the village level. Significance is denoted by *** p<0.01, ** p<0.05, * p<0.1.

Table 6a: Determinants of forestland rental market participation
(Multinomial Logit Model estimates)

	(1) Full sample		(2) 2005 samples		(3) 2010 samples	
	Rent-out	Rent-in	Rent-out	Rent-in	Rent-out	Rent-in
$\hat{\alpha}$ (forestry productivity)	0.017	0.172***	-0.063	0.214**	0.058	0.195***
	(0.051)	(0.054)	(0.082)	(0.100)	(0.070)	(0.060)
Log forestland endowment	0.609***	-0.524***	0.673***	-0.579**	0.471***	-0.573***
	(0.132)	(0.186)	(0.196)	(0.281)	(0.167)	(0.173)
Log household head age	0.019*	-0.027**	0.016	-0.064***	0.023	-0.017
	(0.011)	(0.012)	(0.023)	(0.023)	(0.014)	(0.016)
Household head gender (1=male)	-0.501	0.043	1.073	-0.940	-0.775	0.616
	(1.155)	(2.010)	(0.894)	(0.853)	(0.537)	(0.730)
Household head is Communist (1=yes)	0.023	-0.229	-0.203	0.560	0.258	-0.347
	(0.396)	(0.428)	(0.568)	(0.715)	(0.445)	(0.421)
Household head is village leader (1=yes)	-0.514	0.354	-13.887***	-1.224	-0.227	0.774
	(3.004)	(0.467)	(0.555)	(1.335)	(0.802)	(0.561)
Average education (years)	-0.120	0.024	0.054	0.026	-0.227***	0.048
	(0.074)	(0.063)	(0.146)	(0.111)	(0.072)	(0.072)
Work experience in forestry department (1 if yes)	0.152	0.361	0.252	0.638	-0.019	0.199
	(0.637)	(1.293)	(0.880)	(1.161)	(0.688)	(0.544)
Log cropland per capita	-0.370	-0.152	-1.314**	0.548	-0.218	-0.161
	(0.303)	(0.305)	(0.627)	(0.597)	(0.282)	(0.324)
Log off-farm work days per labor	0.076	-0.019	0.025	-0.013	0.106	-0.034
	(0.084)	(0.075)	(0.120)	(0.140)	(0.096)	(0.087)
Log total livestock value	0.017	-0.014	0.117*	0.001	-0.026	-0.025
	(0.042)	(0.041)	(0.070)	(0.090)	(0.048)	(0.045)
Log timber price	0.638**	0.304	0.572	0.196	0.557**	0.231
	(0.281)	(0.267)	(0.471)	(0.533)	(0.248)	(0.269)
Right to change forest type (1 if yes)	-0.185	0.138	0.370	0.170	-0.277	0.380
	(0.331)	(0.412)	(0.518)	(0.719)	(0.380)	(0.472)
Log total house value	0.029	0.276*	-0.346	-0.172	0.184	0.382**
	(0.158)	(0.164)	(0.281)	(0.384)	(0.170)	(0.164)
Ability to obtain credit	0.982	0.630	0.023	1.156*	14.963***	-0.109
	(2.416)	(2.855)	(0.721)	(0.699)	(0.651)	(0.875)
Credit access (km to local bank, log)	-0.593***	-0.680***	-1.516*	-0.794**	-0.559*	-0.735***
	(0.212)	(0.214)	(0.839)	(0.398)	(0.295)	(0.225)
Risk perception (1=secure)	-0.950	1.687	-4.689***	28.410***	-0.100	1.433
	(0.836)	(1.294)	(1.393)	(2.515)	(0.747)	(1.069)
Holding a forestland certificate (1 if yes)	0.546	0.360	-1.052	0.274	0.758	0.374
	(0.437)	(0.370)	(1.107)	(0.644)	(0.480)	(0.372)
Right to transfer forestland within village	-0.706	-0.211	0.099	-0.687	-1.304	-0.060
	(3.241)	(0.572)	(1.031)	(0.997)	(0.676)	(0.593)
Right to transfer forestland to outsiders	0.605	0.024	-0.111	0.217	1.165*	0.161
	(3.209)	(0.525)	(1.055)	(0.907)	(0.705)	(0.529)
Right to mortgage forestland	-0.081	0.343	0.138	1.087**	0.036	0.128
	(0.321)	(0.290)	(0.547)	(0.515)	(0.432)	(0.315)
Earlier transfers in village (%)	0.154	0.028	3.542	-1.557	-0.602	0.269
	(1.070)	(1.032)	(2.183)	(3.142)	(1.171)	(0.963)
Distance to paved road (km, log)	-0.086	0.184	-1.327	0.216	0.103	0.203
	(0.217)	(0.276)	(0.826)	(0.667)	(0.224)	(0.250)
Distance to closest county center (km, log)	-0.057	-0.482*	-0.690	0.336	0.263	-0.581**
	(0.217)	(0.249)	(0.446)	(0.647)	(0.304)	(0.269)

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Table 6a continued

Village total forestland area (*mu*, log)	0.428*	0.613***	0.859	1.132***	0.326	0.757***
	(0.226)	(0.229)	(0.615)	(0.422)	(0.210)	(0.245)
Village cropland area share (%)	4.194***	2.915*	11.975**	5.070	2.766**	3.212***
	(1.557)	(1.644)	(5.191)	(3.689)	(1.253)	(1.235)
Log number of households in village	-0.808	-1.023	-4.088	-4.603***	-2.104	0.183
	(1.552)	(1.088)	(3.110)	(1.413)	(2.339)	(1.377)
Log village population	0.329	-0.242	2.584	3.373	1.417	-1.621
	(1.512)	(0.980)	(2.826)	(1.362)	(2.378)	(1.285)
Log village average pc income (CNY)	-0.890	-1.259**	-2.504***	0.163	-1.143	-1.593***
	(0.560)	(0.584)	(0.906)	(1.301)	(0.739)	(0.516)
Village income growth	0.149	-0.236	-1.125	-1.699	0.482	0.042
	(1.019)	(0.774)	(1.048)	(1.064)	(0.485)	(0.685)
Population share possessing telephones	-2.201	-3.767***	-4.589	-0.578	-2.436	-4.244***
	(1.390)	(1.452)	(3.051)	(3.519)	(1.739)	(1.342)
Development of labor market (%)	-1.200	-0.439	-3.572*	-0.956	-0.754	-0.998
	(1.301)	(1.005)	(1.835)	(3.583)	(1.897)	(1.119)
Annual precipitation: average (mm)	-0.140***	0.019	-0.265***	0.335**	-0.126***	-0.008
	(0.042)	(0.054)	(0.097)	(0.136)	(0.048)	(0.046)
Annual precipitation: standard deviation (mm)	0.036***	-0.007	0.035	-0.091**	0.040**	0.003
	(0.013)	(0.014)	(0.036)	(0.041)	(0.016)	(0.014)
Effective cumulative heat (days 0-35°C)	-0.000	0.001**	-0.000	0.002***	0.000	0.001**
	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)
Harmful cumulative heat (days >35°C)	-0.036	-0.016	-0.155	-0.072	-0.021	-0.011
	(0.032)	(0.040)	(0.095)	(0.089)	(0.044)	(0.048)
Length of period with the Reform (years)	0.251	0.805**	1.644**	0.531	-0.192	0.685**
	(0.320)	(0.314)	(0.678)	(0.690)	(0.363)	(0.279)
$\hat{v_{jt}}$ (Reform selectivity)	-0.223	-0.578**	-1.190**	-0.533	0.088	-0.461*
	(0.251)	(0.263)	(0.492)	(0.574)	(0.307)	(0.241)
Number of observations	2,151	2,151	1,187	1,187	964	964
Log Lik	-567.5	-567.5	-171.4	-171.4	-339.6	-339.6
Pseudo R-squared	0.230	0.230	0.367	0.367	0.236	0.236

Notes: The first-stage regression of length of period with the Reform is on a set of village characteristics for 2000 and a set in the current year. F-statistic reports 57.92, and adjusted R-squared is 62%. Second-stage MNL regressions include year trends, province fixed effects and province year effects (not shown because of insignificance). Robust standard errors are in parentheses, using a bootstrapped method with 200 iterations in model 1, and household-clusters adjusted in models 2 and 3. Significance is denoted: *** p<0.01, ** p<0.05, * p<0.1.

Table 6b: Determinants of forestland rental market participation
(Marginal effects from Multinomial Logit Model, Delta-method)

	Rent-out		***No-rent***		***Rent-out***	
	dy/dx	Std. Err.	dy/dx	Std. Err.	dy/dx	Std. Err.
$\hat{\alpha}$ (forestry productivity)	0.029	0.168	-0.618***	0.236	0.588***	0.168
Forestland endowment (mu, 1%)	2.159***	0.394	-0.262	0.674	-1.896***	0.555
Household head age (years)	0.070*	0.036	0.025	0.057	-0.095**	0.045
Average education (years)	-0.415*	0.237	0.311	0.310	0.103	0.211
Total house value (1%)	0.054	0.461	-0.997	0.654	0.944**	0.466
Ability to obtain credit ($0-1$)	3.247*	1.867	-5.254**	2.500	2.008	1.925
Credit access (km local bank, 1% farther)	-1.912***	0.632	4.153***	0.885	-2.240***	0.651
Risk perception ($0-1$)	-3.509*	2.024	-2.440	4.114	5.949*	3.599
Timber price (1%)	2.126**	0.834	-3.067***	1.136	0.941	0.769
Village total forestland area (mu, 1%)	1.361*	0.664	-3.400***	1.001	2.038***	0.707
Village cropland area share (%, $0-1$)	13.825***	3.885	-23.164***	6.161	9.338**	3.696
Earlier transfers in village (%, $0-1$)	0.522	2.954	-0.595	4.014	0.073	2.989
Village average pc income (1%)	-2.831*	1.633	7.014***	2.183	-4.183***	1.492
Distance to closest county (km, 1%)	-0.118	0.655	1.766*	0.950	-1.648**	0.691
Population share possessing telephones (%, $0-1$)	-6.895*	3.826	19.483***	5.516	-12.588***	4.020
Annual precipitation: average (mm)	-0.479***	0.125	0.392**	0.184	0.087	0.146
Annual precipitation: standard deviation (mm)	0.124***	0.041	-0.093*	0.053	-0.031	0.037
Effective cumulative heat (days 0-35°C)	-0.001	0.001	-0.002	0.001	0.003***	0.001
Length of period with the Reform (years)	0.726	0.939	-3.452***	1.282	2.726***	0.901

Notes: Table shows marginal effects of a selection of variables evaluated at sample means, based on the estimation results of model 1 in table 6a. Delta-method is used for computation. Significance is denoted: *** p<0.01, ** p<0.05, * p<0.1.

Table 7: Determinants of forestland rent-in and rent-out (Random Effect Tobit Model)

	Area		**% of Endowment**	
	Rented-out	*Rented-in*	*Rented-out*	*Rented-in*
$\hat{\alpha}$ (forestry productivity)	-7.346	9.698**	-0.030	0.053**
	(5.502)	(3.775)	(0.022)	(0.024)
Log forestland endowment	100.460***	-45.187***	0.270***	-0.440***
	(13.156)	(10.906)	(0.055)	(0.073)
Log household head age	0.591	-2.754***	0.003	-0.015**
	(1.142)	(0.947)	(0.005)	(0.006)
Household head gender	-19.290	19.454	-0.177	0.110
	(46.567)	(56.747)	(0.184)	(0.346)
Household head is Communist	-18.995	2.018	-0.042	0.062
	(33.916)	(25.083)	(0.139)	(0.160)
Household head is village leader	14.301	7.446	-0.240	0.079
	(53.989)	(35.224)	(0.250)	(0.221)
Average education years	3.201	5.434	-0.017	0.011
	(6.464)	(4.650)	(0.026)	(0.029)
Work experience in forestry department	-64.985	44.009	-0.237	0.143
	(55.705)	(39.048)	(0.239)	(0.254)
Log cropland per capita	-39.573	30.966*	-0.257**	0.152
	(28.189)	(18.200)	(0.119)	(0.116)
Log off-farm work days per labor	-4.093	-2.088	0.007	-0.000
	(6.405)	(5.089)	(0.027)	(0.032)
Log total livestock value	7.083*	0.467	0.022	0.006
	(3.725)	(3.059)	(0.015)	(0.019)
Log timber price	207.751	78.108*	0.853	0.530**
	(170.712)	(43.815)	(0.539)	(0.266)
Right to change forest type	-13.210	24.213	-0.109	0.109
	(30.223)	(26.143)	(0.119)	(0.160)
Total house value	-1.703	11.930	-0.029	0.041
	(13.416)	(9.442)	(0.054)	(0.060)
Ability to obtain credit	38.435	19.397	0.244	0.297
	(46.191)	(34.202)	(0.189)	(0.222)
Credit access (km to local bank, log)	30.106	-60.184	0.378	-0.434
	(80.594)	(55.697)	(0.293)	(0.340)
Risk perception	-182.293***	106.762	-0.618**	0.533
	(65.340)	(71.560)	(0.268)	(0.434)
Holding a forestland certificate	-23.710	39.042	-0.013	0.161
	(45.903)	(25.472)	(0.172)	(0.162)
Right to transfer forestland within village	-6.160	-33.379	-0.104	-0.262
	(47.162)	(39.701)	(0.197)	(0.241)
Right to transfer forestland to outsiders	40.768	40.259	0.167	0.180
	(46.920)	(35.783)	(0.197)	(0.221)
Right to mortgage forestland	-8.161	26.027	0.004	0.141
	(28.406)	(19.667)	(0.114)	(0.122)

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Table 7 continued

Earlier transfers in village	-337.277**	110.926	-1.199*	0.530
	(164.589)	(151.280)	(0.612)	(0.887)
Distance to paved road (km, log)	40.378	2.413	0.184	0.074
	(49.687)	(31.115)	(0.196)	(0.193)
Distance to closest county center (km, log)	-1,182.138*	-180.106*	-4.261*	-1.102*
	(608.678)	(105.869)	(2.201)	(0.630)
Village total forestland area (*mu*, log)	-174.739	-211.777*	-0.359	-1.308*
	(169.389)	(124.114)	(0.553)	(0.756)
Village cropland area share	-538.202	-45.326	-0.030	-0.244
	(1,287.811)	(185.803)	(4.355)	(1.215)
Log number of households in village	-242.241	152.191	-0.682	0.892
	(379.638)	(185.403)	(1.373)	(1.119)
Log village population	-2,091.388*	501.198	-6.695	3.618
	(1,228.247)	(458.668)	(4.533)	(2.833)
Log village average pc income	-219.599	-75.460	-0.589	-0.354
	(167.966)	(61.154)	(0.690)	(0.362)
Village income growth	48.631	-6.638	0.188	-0.209
	(59.590)	(59.716)	(0.239)	(0.381)
Population share possessing telephones	141.047	-117.632	0.463	-0.930
	(228.755)	(123.791)	(0.833)	(0.751)
Development of labor market	-920.215*	-57.267	-3.012*	-0.480
	(535.685)	(161.956)	(1.714)	(0.930)
Annual precipitation: average (mm)	-48.438*	6.259	-0.168*	0.035
	(26.257)	(7.881)	(0.088)	(0.048)
Annual precipitation: standard deviation (mm)	14.159**	-1.363	0.052***	-0.007
	(5.751)	(2.133)	(0.019)	(0.013)
Effective cumulative heat (days 0-35°C)	-0.992	0.240	-0.004	0.001
	(0.689)	(0.357)	(0.003)	(0.002)
Harmful cumulative heat (days >35°C)	83.899**	-4.846	0.321**	-0.080
	(36.139)	(14.063)	(0.132)	(0.085)
Length of period with the Reform	-39.218	230.954***	-0.015	1.567***
	(144.038)	(88.390)	(0.426)	(0.536)
$\hat{\upsilon_{jt}}$ (Reform selectivity)	-27.266	-25.929	-0.143	-0.140
	(32.337)	(20.332)	(0.126)	(0.124)
Observations	2,151	2,151	2,151	2,151
Number of households	1,264	1,264	1,264	1,264
Log Lik	-662.3	-684.3	-208.0	-236.1

Notes: Robust standard errors in parentheses, adjusted for clustering effect at the village level. Province, village and year dummies and the interaction between year and province are included. *** Significant at 1%; ** significant at 5%; * significant at 10%.

Table 8: Differences in welfare indicators across no-rent, rent-in, rent-out households (Sample mean)

Variable	No-rent households (A)	Renting households (B)	**Difference** (B-A)	Rent-in households (c)	**Difference** (C-A)	Rent-out households (D)	**Difference** (D-A)
Per capita income, CNY	6007.6	8455.2	2447.6 ***	8939.5	2931.9 ***	7937.4	1929.8 **
Poverty: likelihood under poverty line	0.305	0.156	-0.149 ***	0.129	-0.176 ***	0.184	-0.117 **
Off-farm income per capita, CNY	3495.5	5773.7	2278.2 ***	6253.3	2757.8 ***	5261	1765.5 ***
Off-farm income share	0.514	0.568	0.054 **	0.572	0.058 *	0.564	0.05
Forestry production, CNY/mu	162.4	92.6	-69.8	171.9	9.5	7.7	-154.7
Forestry production share	0.101	0.07	-0.031 **	0.098	-0.003	0.04	-0.061 ***
Number of observations	1979	180		93		87	

Notes: Author's own computation. Column (B) includes both the rent-in households and rent-out households. Poverty line is defined as 2000 CNY for 2005 and 2300 CNY for 2010, in accordance with the 1.25 Purchasing-Power-Parity (PPP) U.S. dollars a day in 2005 as the World Bank's global poverty standard. Significance is denoted: *** p<0.01, ** p<0.05, * p<0.1.

Table 9: Welfare effects of forestland rental participation, PSM estimates

	Average Treatment Effects (ATT, θ)					
Welfare indicator	*Renting*	Std. Err.	*Rent-in*	Std. Err.	*Rent-out*	Std. Err.
Income per capita	1538.36	(657.10) **	1318.91	(973.18)	1849.48	(986.91)*
Absolute poverty	-0.093	(0.027) ***	-0.093	(0.040) **	-0.088	(0.051) *
Off-farm income per capita	1445.30	(600.73) **	1423.21	(974.94)	1645.87	(812.37) **
Proportion of income from off-farm	0.035	(0.028)	0.027	(0.040)	0.070	(0.040) *
Forestry incremental value per *mu*	1.47	(78.25)	76.86	(150.72)	-77.85	(16.57) ***
Proportion of income from forestry	-0.020	(0.014)	0.020	(0.023)	-0.047	(0.022) **

Notes: Table reports results of average treatment effect in the treated (ATT) using the matching algorithm − the Epanechnikov kernel estimator (KBM) with bandwidths 0.06. Standard errors, in parentheses, are bootstrapped with 200 iterations. Significance is denoted: *** p<0.01, ** p<0.05, * p<0.1.

Chapter III

Managerial Incentives for Environmental Protection in Chinese-Style Federalism*

Yuanyuan Yi†1, Wolfgang Habla‡2 and Jintao Xu§3

[1]Department of Economics, University of Gothenburg, Sweden
[2]Center for European Economic Research (ZEW), Mannheim, Germany
[3]National School of Development, Peking University, China

Abstract

China's fast economic growth has come at the expense of environmental quality and the degradation of natural resources such as forests. In this paper, we identify career concerns by managers of state-owned enterprises that manage natural resources, and asymmetric information between managers and their superiors regarding the enterprises' environmental performance, as sources of environmental degradation. A manager of such an enterprise is the agent of two principals: national and sub-national governments. As well as needing to meet ecological targets imposed by the national government, a manager wants to be promoted into the ranks of the sub-national government. We develop three hypotheses based on a theoretical model with two principals and one agent. We then empirically test these hypotheses for the case of China's northeastern state-owned forests, combining satellite imagery data on deforestation with economic survey data. Our findings suggest that managers of state forests that have a larger area and volume, and are thus more difficult to monitor with respect to ecological targets, log more timber and are more likely to deforest. The same holds true for managers who share a larger percentage of profits with the local government. In turn, we find that sharing more revenue with the local government increases the likelihood of getting promoted.

JEL **Classification:** H77, O13, O44, Q23, Q56

Keywords: managerial incentives; environmental protection; deforestation; state-owned forests; state-owned enterprises; Chinese-style federalism; two-principal, one-agent model

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†Vasagatan 1, SE-405 30 Gothenburg, Sweden, Email: yuanyuan.yi@economics.gu.se

‡L7 1, DE-68161 Mannheim, Germany, Email: habla@zew.de

§No.5 Yiheyuan Rd., Beijing 100871, China, Email: xujt@pku.edu.cn

1 Introduction

China's remarkable economic growth has come at a tremendous cost to the environment, with inefficient, excessive resource use and high levels of pollution (Liu and Diamond, 2008). The growth and environmental consequences are closely linked to so-called Chinese-style federalism (Montinola et al., 1995; Xu, 2011). A key feature of this type of federalism is that it combines fiscal decentralization with performance-based personnel control. The decentralization of fiscal authority and a fiscal transfer system allow regional governments (provincial, municipal, county and township level governments) to have primary control over economic issues, including firms in their jurisdiction, while the central government typically owns natural resources (through various agencies) and sets pollution targets. In this system, short-term economic growth is rewarded with promotions; by contrast, longer-term environmental issues such as resource degradation and pollution do not negatively affect the likelihood of being promoted.

In this paper, we argue that a systematic cause for the neglect of the environment is the fact that authority over the environment lies with the central government, while local governments are interested in economic performance and use this as the basis for promoting managers of state-owned enterprises (SOEs) to local government positions.

During the economic reforms of the 1970s and 1980s, SOE ownership was decentralized from the central to sub-national governments at all levels. SOEs have enormous importance to local governments: they provide public goods such as schools and hospitals, and they are also a considerable source of revenue. In addition to tax payments, the managers of SOEs can transfer part of their profits to the local government to increase their chances to be promoted into the ranks of the local government. At the same time, SOEs are monitored by central government agencies in terms of their environmental performance. For instance, the Ministry of Environmental Protection is in charge of environmental regulation and its enforcement. Responsibility for natural resources is with the Ministry of Land Resources, the Ministry of Water Resources, and the State Forestry Administration (SFA). If managers are found to fail to meet ecological targets, they can be fined. Although the central government authorities have sub-level bureaus responsible for the enforcement of their respective ecological targets, these local bureaus are not superior to local governments but work independently. Overall, the managers' incentives to protect the environment seem to be outweighed by their career concerns.

We focus on state-owned forest enterprises (SFEs), which are owned by local governments but whose forests are owned and monitored by the central government through the SFA. In this context, the difficulty of monitoring the SFEs' and their managers' environmental performance is due in part to the size and volume of the managed forests. We interpret the complex relationship between an SFE manager, the local government and the SFA as a two-principal, one-agent framework, in which the SFA has only limited information on the manager's environmental performance and the manager cares about being promoted. Establishing a simple political career concern model with asymmetric information, we derive three hypotheses. First, a larger degree of asymmetric information between the SFA and the SFE, as measured by the forest area and volume, as well as the area and volume share of the natural forest, increases the amount of logging and thus leads to more deforestation. The reason that these variables are correlated with the degree of asymmetric information between the SFA and the SFE is that it is more difficult, and also more costly, to conduct inspections in larger forest areas and in areas with more forest in terms of volume. Furthermore, in natural forests, the application of selective logging makes it harder to detect whether too much cutting has been done. Second, if a manager transfers a higher percentage of profits to the local government, the logged volume increases (or decreases) and thus induces more (or less) deforestation. The intuition for why this effect is ambiguous in sign is that, on the one hand, a higher transfer rate directly increases a manager's chances of getting a promotion (an assumption we confirm with the next hypothesis), which makes cutting more attractive to the manager. On the other hand, if a manager transfers a higher percentage to the local government, cutting can be reduced. This will, of course, decrease profits but the corresponding drop in the chance to get promoted is offset by the higher transfer rate. Third, the likelihood of an SFE manager getting promoted increases with the share of profits transferred to the local government as well as with the absolute amount of transferred profits. The last hypothesis sets out to test the assumptions that we have made in the theoretical model.

Using data on state-owned forest enterprises (SFEs) in Northeast China over the period 1980-2009 and combining it with satellite imagery data on vegetation growth as a measure of deforestation, we test these hypotheses. We find support for the first hypothesis and show that the logged volume increases with a higher rate of transfers from the SFE to the local government (second hypothesis). Finally, we find evidence in support of the first part of the third hypothesis (that the share of profits is a determinant of a manager's likelihood of getting promoted) but not in support of the second part (that the absolute amount of transferred profits has a significant and positive effect on this likelihood). Our results suggest that the information asymmetry with the SFA is exploited by SFE managers and that higher transfers to local governments go hand in hand with more deforestation. On the other hand, our findings also suggest that it is rational for SFE managers to transfer a higher percentage of profits to the SFE's owner – the local government – as this does indeed increase their likelihood of getting promoted.

This paper highlights the managerial incentive problem regarding environmental protection in this Chinese-style fiscal federalism. It aims to explain how, in such Chinese-style federalism, the SOE managers lack incentives to protect the environment. The paper draws extensively on the growing literature on managerial incentives and their impact on performance and societal welfare (e.g., Besley and Coate, 1997, 2003; Acemoglu and Johnson, 2005; Xu, 2011). It also draws on the Chinese fiscal federalism literature (Qian and Xu, 1993; Lin and Liu, 2000; Maskin et al., 2000; Jin et al., 2005; Xu, 2011), in that career concerns not only motivate government officials to compete among each other but also motivate the managers of SOEs to over-harvest resources or to over-pollute.

The impact of fiscal federalism on economic growth has been studied intensively, but not sufficiently with respect to the impact on environmental quality and resources. Zhang et al. (2011) study this relationship for China, using provincial data on carbon emissions from 1998 to 2008. They find that pollution is positively correlated with fiscal decentralization. Li and Chan (2016) compare firms of different ownership types and find that SOEs spend less on pollution abatement, but they do not find different environmental consequences among SOEs and private or foreign-funded firms. Indeed, the incentives that SOE managers face are very similar to those in Western corporations (Murphy and Zimmerman, 1993; Weisbach, 1988). The most closely related paper is Groves et al. (1995), who show that local governments rely mostly on economic performance criteria for the selection of SOE managers.

Overall, we add to the large body of literature on managerial incentives and a variety of principal-agent models (e.g., Tirole, 1986; Thomas and Worrall, 1990; Holmstrom and Milgrom, 1991, 1994; Fehr and Schmidt, 2004; Ward and Filatotchev, 2010; Delacote et al., 2014) with a dual-principal, one-agent model with asymmetric information between one principal and the agent, with the agent possessing information that one of the two principals does not have.

The paper proceeds as follows. Section 2 introduces Chinese-style federalism, the importance of state-owned enterprises, the system of environmental authority, and the implications for the state forest sector. Our empirical analysis is grounded on this sector. In Section 3, we outline a simple theoretical framework that captures the complex relationship between an SFE manager, his jurisdictional government and the SFA (we use male gender because all managers in our surveyed SFEs are males). Section 4 formalizes testable hypotheses based on the theoretical predictions and specifies econometric models. Section 5 describes the construction of the data sets and Section 6 presents the econometric results. Section 7 concludes.

2 Background

In the following sections, we explain the features of "Chinese-style" federalism, the importance of state-owned enterprises, the system of the environmental policy-making and enforcement, and the implications for the state forest sector.

2.1 Chinese-style Federalism

China's economic reforms, which began in 1978, transformed China from a highly centralized to a decentralized, market-oriented economy (Montinola et al., 1995; Xu, 2011). In the 1980s, authority over jurisdictional economies was decentralized to local governments. In this process, sub-national governments – at provincial, prefecture, county and township levels – were endowed with control rights over land, firms, financial resources, energy, raw materials, etc. At the same time, all sub-national governments obtained full fiscal autonomy, which secured tax revenues from "grabbing-hand" upper-level governments.[1] Based on this autonomy, a fiscal transfer system was established which allows each sub-national government to contract with the next higher level.[2]

The decentralization in China is different from other countries for two reasons. First, typical elements of Western federalism are absent: the protection of individual rights; strong and explicit constitutional foundations; political freedom; and the right of representation and democratization (Montinola et al., 1995; Qian and Weingast, 1997; Xu, 2011). Second, despite decentralization in economic terms, there is strong political centralization by means of personnel control. Through control over promotion decisions, the central government provides provincial officials with incentives to adhere to centrally proclaimed goals but, also, because promotion decisions are taken mainly based on economic performance, with incentives to compete as if they were in a tournament. However, as we will argue below, personnel control applies not only to officials but also to the managers of state-owned enterprises, who can be promoted into the ranks of local government officials. It has been argued that this "Chinese-style" federalism is one of the key determinants of China's economic success (Qian and Weingast, 1997).

[1] This stands in stark contrast to some post-Soviet Eastern European countries, in which the central authorities retained discretionary authority over the firms' profits and bailed out firms with deficits; see Montinola et al., 1997.

[2] The fiscal contract system (1980-1993) and revenue assignment system (since 1994) allow each sub-national government to contract with the next level up. They decide on the remittance amount (or share) of tax and revenue for a certain number of years. The lower level keeps the rest and enjoys sole discretion to allocate the retained revenues (World Bank, 1993).

2.2 Importance of State-Owned Enterprises

State-owned enterprises (SOEs) have played an important role in China's development. By the end of the 1970s, SOEs accounted for 80 percent of the total national value of gross industrial output (NBSC, 1999). In 1998, SOEs managed almost 70 percent of the total national assets, and in the 2010s this number is still at 40 percent (NBSC, 2015).

The SOEs were initially established to fulfill development and construction needs, such as the production of timber, coal, cement and steel, agricultural machinery, automobiles and tractors (Xu and Zhuang, 1998). Managers were initially appointed by government officials of, e.g., industrial bureaus. Prior to the economic reforms in 1978, the central and regional planning commissions controlled the entire industrial system. Managers of the SOEs had to follow the orders of the (upper level) political leaders and to provide services to the government (Groves et al., 1995). Because the areas in which the SOEs were located were sparsely populated, the SOEs were also obliged to supply social services, such as housing and schooling, health and child care, and pension benefits, to employed families.

In the 1980s, enterprise reforms, accompanied by various price and market reforms, introduced material incentives for SOE management. Simultaneously, SOE ownership was decentralized from the central to sub-national governments at all levels. Managerial contracts now commit the managers to specific performance targets, such as profitability. After transferring taxes and an agreed-upon share of profits to the local government (which is prescribed for the duration of the contract), managers enjoy extensive autonomy in using the retained profits for firm investments and capacity expansion (Nolan and Wang, 1999). They may also transfer more than the contractually required amount to the local government in order to signal their ability. We will, later on, assume that the managers can freely choose the amount to transfer. The contracts effectively link managers' rewards and careers to firm performance. The contracts generally have a duration of three or five years (Groves et al., 1995).

SOEs have enormous importance to local governments: they provide public goods such as schools and hospitals, and they are also a considerable source of revenue. Nevertheless, SOEs often are very pollution-intensive and depleting natural resources, because they mostly belong to the industrial sectors of iron and steel, machinery construction, mining, automotive, and manufacturing, as well as the processing of wood, leather and chemical products.

2.3 Environmental Protection: Authority and Enforcement

This section reviews the system of environmental authority and enforcement in which SOEs operate. First of all, the enviornmetnal legal framework is well-developed in China, including 22 laws and over 44 regulations, 500 standards and more than 600 other legal documents addressing pollution control, natural resource protection and environmental regulation of consumer products.[3] As mentioned in the introduction, the authority regarding the environment lies with the central government and is delegated to several distinct ministries. The Ministry of Environmental Protection (MEP) is in charge of environmental regulation, while the Ministry of Land Resources (MLR), Ministry of Water Resources (MWR) and State Forestry Administration (SFA) are in charge of natural resources, which are mostly owned by the central government. Their sub-level bureaus are designed to work independently and undertake monitoring and inspection activities to make sure that SOEs and other firms comply with the environmental regulations.

In the National Pollutant Discharge Reporting and Registration Program, as an example, each firm reports its input uses of raw materials, its pollutant discharges, and its environmental management. Using the self-reported data, local environmental protection bureaus aggregate the data and submit it to the MEP to compile a national pollution register. In reality, monitoring is very incomplete, and few environmental agencies have accurate data on firms' actual emissions and use of natural resources or raw materials. Likewise, in the Pollutant Discharge Standard, the pollution charges on 65 kinds of water pollutants and 44 kinds of air pollutants (MEP, 2003) are set by the central government (i.e., the MEP), but, in practice, the actual payments by enterprises are limited, not only by difficulties in measurement and monitoring, but also by the "protective umbrella" of local governments (OECD, 2009).[4]

2.4 Implications for the State Forest Sector

This section introduces the empirical context of our analysis: the state-owned forest sector and its SOEs. State forests make up 42 percent of China's total forest area and 68 percent of the total national forest stock.[5] Since the 1950s, 135 SFEs have been

[3] See, for example, the website of the Department of Policies, Laws and Regulations, Ministry of Environmental Protection, P.R. China: http://zfs.mep.gov.cn/.

[4] According to anecdotal evidences, except for a small number of severe violations against criminal law, the sub-bureaus seldom disclose enforcement decisions. It also seems that they often go with the local governments' preferences regarding the trade-off between development and environment (Lo et al., 2006).

[5] Chinese forests, which are the fifth largest in area world-wide (208 million hectares), account for merely 22 percent of the total land area, which is below the 30.8 percent global average (FAO, 2016). They are unevenly distributed, with the majority located in the South (about 68 million ha) and 43 million hectares located in the Northeast, 83 percent of which are natural forests (Xu, 2013), in which no sowing or planting is allowed.

established to meet the growing demand for timber in China's development process. The SFEs manage the forest-rich regions in the Northeast, Northwest and Southwest, and their main business is timber extraction.

Before the reforms of the 1980s, the SFEs, like other SOEs, were under the control of the central government, specifically, the Ministry of Forestry. With the economic reforms in the 1990s, the ownership of the SFEs was devolved to sub-national governments, which were given great autonomy in appointing managers and making financial and production decisions.[6] In 1998, the Ministry of Forestry was downgraded to become the SFA, which still maintains authority in forest governance on behalf of the central government. The SFA thereby represents the central government as the forest owner. The monitoring bodies of the SFA are State Forest Resource Monitoring Offices (SFRMOs) for timber production and forest protection; they also implement the national forest policies. For example, the Forest Law from the mid-1980s required reforestation after commercial harvest, and a logging ban associated with the Natural Forest Protection Program (NFPP) was introduced in 1998 (Xu, 2013).

The managers of SFEs have commitments to the SFA in terms of sustainable use of forests and commitments to their jurisdictional governments based on contracts that specify revenue-sharing and social obligations. They are, of course, free to over-fulfill these targets to please the local government. The goals written in the contracts – profitability, job creation, payment of pension benefits and provision of other social benefits, and profit-sharing – are relatively easy to monitor. By contrast, the ecological targets on forest protection are more difficult to measure and do not affect human welfare immediately; the impact of over-harvesting on forest degradation is cumulative and takes a longer time. SFE managers are thus reasonable in prioritizing economic performance over natural resource protection, leading to over-harvesting and forest degradation (Xu et al., 2004).

3 Theoretical Framework

As described in the previous section, the management and monitoring of Chinese state-owned forests involves a complex interplay of three actors: the SFA, the local governments, and the SFEs, represented by their managers. The managers have career concerns and care about being promoted, while they also have to make sure that ecological targets imposed by the SFA are not violated (at least not by too much) - else, they will be fined. We interpret this complex relationship as a two-principal, one-agent relationship, with the principals being the SFA and the local government, and the agent being

[6] The SFEs were mainly devolved to provincial governments, and also to prefecture- and county-level governments.

the manager of an SFE. We will argue that one of the principals (the SFA) can only imperfectly observe the agent's effort with respect to meeting the ecological target, while the other one (the local government) decides upon his promotion.

In what follows, we characterize the relationship between a representative SFE (through its manager), the SFA and a representative local government. In particular, we describe the SFA's and local government's objectives and interests, and then turn to the description of the manager's payoffs and maximization problem. We take the agent's contract as given and will *not* characterize the optimal contract here. This would be beyond the scope of this paper.

3.1 SFA and Local Governments

As the owner of all state forests, the central government through the SFA wants to ensure that the forests are able to fulfill their ecological functions. Therefore, it sets an upper limit to the total allowable harvested volume, $\bar{x}$. Let X be each SFE's overall forest volume. Then $X - \bar{x}$ is the protected volume, which may not be logged. We assume that SFEs always log a volume x which is at least as large as $\bar{x}$, i.e., the "cap" on legally logged forest is binding. To enforce this cap, the SFA or its sub-bureaus make monitoring visits in each SFE. However, due to the large area of the forests and the huge administrative cost that a complete inspection would require, the monitoring technology is imperfect. We assume that the SFA only receives the signal x^s about the total logged volume (where the superscript "s" stands for signal):

$$x^s = \mu(x) + \epsilon \;, \quad \epsilon \sim \mathcal{N}(0, \sigma^2) \;. \tag{1}$$

μ is assumed to be twice continuously differentiable and strictly concave, and ϵ is normally distributed with mean zero and variance σ^2.

The massive floods of the Yangtze River, the Nen River, the Songhua River and the Pearl River in the summer of 1998 convinced the SFA to implement the Natural Forest Protection Program (NFPP). The main policy instrument of this program is a logging ban on most commercial logging in order to increase the capacity of the forests to absorb rainwater. However, logging is still allowed in plantation forests and for forest tending. To compensate the SFEs for the logging ban and the associated reduced profit, the SFA supports them with an annual transfer of T.

The local government gets twofold benefits from the SFE's gross profit π^G. First, it receives corporate income tax payments, which we model as a profit tax. These amount to $\tau\pi^G$, where $0 < \tau < 1$ is the tax rate. Second, it receives an additional share of the profit as a transfer from the SFE, amounting to $\gamma\pi^G$, where $0 \leq \gamma \leq 1$. Whereas the tax rate is exogenously given for the SFE, the transferred amount can be chosen by the SFE through its manager.[7]

3.2 SFEs and Managers

Each SFE cuts a volume $\boldsymbol{x}$ of timber and sells at the exogenously given price $\boldsymbol{P}$. Cutting costs are $\boldsymbol{C(x)}$, with $\boldsymbol{C'(x), C''(x) > 0}$. The profits, net of taxes and net of the transfer $\boldsymbol{T}$ received from the SFA for offsetting the financial implications of the logging ban after 1998, are given by:

$$\boldsymbol{\pi = (1-\tau)\pi^G + T} \ , \tag{2}$$

where gross profit is $\boldsymbol{\pi^G = Px - C(x)}$. From these profits, transfers to the local government can be made, and social welfare benefits $\boldsymbol{G > 0}$ to residents in the local communities of an SFE must be provided. The latter consist of unemployment benefits, health insurance, etc., and are exogenously given in our model. After transfers, taxes and the provision of social welfare benefits, the remaining profits have to satisfy:

$$\boldsymbol{(1-\gamma)\pi - G \geq 0} \ . \tag{3}$$

In other words, the transfer to the local government cannot be set so high that this inequality is violated, i.e., $\boldsymbol{\gamma}$ is always strictly smaller than unity.

The manager earns a fixed wage $\boldsymbol{\bar{w}}$. Beyond that, he may be promoted into the ranks of local government officials based on economic achievements, and may also be fined for failing to meet ecological targets. If promoted, the agent receives economic benefits from the time of being promoted until retirement (and possibly beyond). The net present value of a promotion (compared to the earnings profile of continuing to work as a manager) equals $\boldsymbol{b}$. We model the likelihood of being promoted as a continuous variable which depends on the amount of transfers that are voluntarily handed over to the local government. Either a higher share $\boldsymbol{\gamma}$ or a higher profit $\boldsymbol{\pi}$ (or both) will thus increase the agent's likelihood of receiving a promotion. The likelihood reads:[8]

$$\mathbf{Pr}\boldsymbol{(b) = 1 - e^{-\gamma\pi} \in [0,1)} \ . \tag{4}$$

If fined, the agent will suffer an income loss equal to $\boldsymbol{f}$. The likelihood of being caught cheating upon the ecological target positively depends on the deviation of the

[7] Before the manager signs a contract for a certain number of years, individual targets for the transfers are negotiated. We conjecture that managers have an incentive to over-fulfill their targets and strategically negotiate lower targets in order to be able to demonstrate their good performance.

[8] This specification of the probability function is chosen to analytically separate the variance component of the signal in the agent's payoff function.

signal from the ecological target, $x^s - \bar{x}$, and is equal to

$$\Pr(f) = 1 - e^{-(x^s - \bar{x})} \in [0, 1) \ . \tag{5}$$

The manager chooses the share of π transferred to the local government, i.e., τ, and the logged volume, x (where we assume that $x \geq \bar{x}$ always holds), so as to maximize his payoff

$$\mathrm{EU} = \mathrm{E}\left[\bar{w} + b(1 - e^{-\gamma\pi}) - f(1 - e^{\bar{x} - x^s})\right] \ . \tag{6}$$

Plugging in (1) and considering that $\mathrm{E}\left[e^{k\epsilon}\right] = e^{\frac{k^2\sigma^2}{2}}$ for any constant k when $\epsilon \sim \mathcal{N}(0, \sigma^2)$, expected utility can be written as:

$$\mathrm{EU} = \bar{w} + b(1 - e^{-\gamma\pi}) - f(1 - e^{\bar{x} - \mu(x) - \frac{\sigma^2}{2}}) \ . \tag{7}$$

The first-order conditions with respect to γ and x read as follows:

$$b\pi e^{-\gamma\pi} > 0 \ , \tag{8}$$

$$b\gamma(1 - \tau)[P - C'(x)]e^{-\gamma\pi} - f\mu'(x)e^{\bar{x} - \mu(x) - \frac{\sigma^2}{2}} = 0 \ , \tag{9}$$

which implies $P - C'(x) > 0$ at the optimum.

The first condition is never fulfilled with equality. Instead, a corner solution is chosen, i.e., γ is chosen as high as possible so that equation (3) is still satisfied. The agent thus does not gain from transferring less to the local government than $\pi - G$, which increases his chances of getting a promotion. The second condition trades off the marginal benefits of cutting more timber (first term in equation (9)) with the marginal costs of doing so (second term). The marginal benefits are the increased likelihood of receiving a promotion because profits have increased. At the same time, the agent runs a higher risk of being fined because the likelihood of being detected cheating increases with cutting (marginal costs).

In general, it cannot be shown that the maximization problem is concave for all parameter constellations. We assume that it is concave for empirically relevant parameter constellations.

Applying the implicit function theorem to equation (9), we derive the following comparative statics results:

$$\frac{\partial x}{\partial \bar{x}} = \frac{f\mu'(x)e^{\bar{x}-\mu(x)-\frac{\sigma^2}{2}}}{\Gamma} > 0 \ , \tag{10}$$
$$\frac{\partial x}{\partial T} = \frac{b\gamma^2(1-\tau)[P - C'(x)]e^{-\gamma\pi}}{\Gamma} < 0 \ , \tag{11}$$
$$\frac{\partial x}{\partial b} = \frac{-\gamma(1-\tau)[P - C'(x)]e^{-\gamma\pi}}{\Gamma} > 0 \ , \tag{12}$$
$$\frac{\partial x}{\partial f} = \frac{\mu'(x)e^{\bar{x}-\mu(x)-\frac{\sigma^2}{2}}}{\Gamma} < 0 \ , \tag{13}$$
$$\frac{\partial x}{\partial \sigma_x} = \frac{-f\sigma\mu'(x)e^{\bar{x}-\mu(x)-\frac{\sigma^2}{2}}}{\Gamma} > 0 \ , \tag{14}$$
$$\frac{\partial x}{\partial \gamma} = -\frac{b(1-\tau)[P - C'(x)]e^{-\gamma\pi}\,[1-\gamma\pi]}{\Gamma} \gtreqless 0 \ , \tag{15}$$

where $\Gamma \equiv \partial^2 \mathrm{EU}/\partial x^2 < 0$ by the assumed concavity of the maximization problem.

The interpretation of the comparative statics goes as follows: A marginal increase in the ecological target $\bar{x}$ increases the amount of logged timber due to the less binding constraint. If the transfer T from the SFA to the SFE marginally increases, the manager cuts less timber because he can maintain the same or a similar level of profits with less logging. Therefore, *ceteris paribus*, less logging does not decrease the manager's likelihood of getting a promotion. Marginally increasing b or marginally decreasing f has qualitatively the same effect: more timber will be cut.

If the signal with respect to x becomes more blurred, i.e., σ marginally increases, the agent can cut more without having to fear that he will be caught with a higher probability. Interestingly, if the transfer rate γ goes up, the reaction of x is ambiguous in sign. On the one hand, a higher γ directly increases the marginal benefits of cutting more forest because a higher transfer of funds to the local government, given a certain profit, increases the likelihood of being promoted. For this reason, the agent would like to cut more. On the other hand, profits can be decreased by cutting less trees while still having the same probability of being promoted due to a higher γ. Therefore, the agent would like to cut less.

4 Empirical Strategy

In this section, we state our hypotheses based on the predictions from the theoretical model and lay out our empirical strategy to test them. We will test the hypotheses with a focus on the northeastern state-owned forests in China.

4.1 Hypotheses

We base our empirical analysis on the following hypotheses, with two of the predictions coming from the comparative statics results above.

Hypothesis 1: Logging and asymmetric information.
A larger degree of asymmetric information between the SFA and the SFE, as measured by the forest area and volume as well as the area and volume share of the natural forest, increases the amount of logging and thus leads to more deforestation.

This hypothesis is in line with equation (14). The idea is that the larger the SFE's forest area and volume, the harder and more costly it is for the SFA and its sub-level bureaus to monitor that SFE's logging activities. This claim is also backed by the literature on public harvesting and concession contracts, as well as anecdotal evidence on Chinese SFEs (Poore, 1993; Gray, 2002; Palmer, 2000; Johnson, 2002; Xu et al., 2004). SFEs with larger areas of forests, especially natural forests, can more easily hide their operations from SFA inspectors, including logging beyond the specified quotas. Furthermore, in natural forests, in which no sowing or planting is allowed, it is less obvious how much cutting was actually done. The reason for this is that natural forests are usually less regular in their structure than plantation forests, and inspection of selective logging in mostly natural forests is useless, because largely intact canopy will not look very different from selectively logged canopy when viewed by the human eye from some distance.

Hypothesis 2.1: Logging and voluntary transfers: positive correlation.
If a higher percentage of profit is transferred to the local government, the manager of an SFE increases the logged volume $\boldsymbol{x}$ and thus induces more deforestation.

Hypothesis 2.2: Logging and voluntary transfers: negative correlation.
If a higher percentage of profit is transferred to the local government, the manager of an SFE decreases the logged volume $\boldsymbol{x}$ and thus induces less deforestation.

The above two hypotheses are obviously related. While the first one corresponds to equation (15) being positive, the second one corresponds to the same equation being negative. Because the theory does not give a clear prediction regarding the sign of this effect, we split the hypothesis into two sub-hypotheses.

Hypothesis 3.1: Likelihood of being promoted and share of profits transferred to local government.
The likelihood of an SFE manager getting promoted increases with the share of profits transferred to the local government, i.e., $\frac{\boldsymbol{\partial Pr(b)}}{\boldsymbol{\partial \gamma}} > \mathbf{0}$.

Hypothesis 3.2: Likelihood of being promoted and absolute amount of profits transferred to local government.
The likelihood of an SFE manager getting promoted increases with the absolute amount of

transferred profits, i.e., $\frac{\partial Pr(b)}{\partial \pi} > 0$.

The last two hypotheses come from our assumption about the probability function of getting promoted. We want to test whether the share and the absolute amount of transferred profits matter for the likelihood of promotion. In contrast to the other hypotheses, this will shed light on the other side of the coin: how managers' economic and environmental performance is actually evaluated by the SFEs' owners, the local governments.

4.2 The Role of Asymmetric Information in Deforestation

The first hypothesis is tested by estimating a simple reduced form relationship between information asymmetry and deforestation:

$$\boldsymbol{H} = \boldsymbol{f}(\boldsymbol{\theta}, \mathrm{V}) + \boldsymbol{u}, \tag{16}$$

where $\boldsymbol{H}$ is deforestation or the rate of change in forest vegetation from one year to the next, respectively. $\boldsymbol{\theta}$ represents the difficulty of measuring the manager's effort and thus the degree of asymmetric information between the SFA and the SFE ($\boldsymbol{\sigma}$ in the theory part). As discussed previously, as proxy variables for this asymmetry, we take the total forest area as well as the total forest stock volume, and area and volume shares of natural forest.

$\boldsymbol{V}$ denotes control variables that affect $\boldsymbol{H}$, and $\boldsymbol{u}$ is a disturbance term. The vector $\boldsymbol{V}$ contains, first, the characteristics of natural forests, including their area and volume shares, because they constitute an important part of the total forests managed by an SFE. Given their more diversified ecosystem services, natural forests face more restrictions on cutting; in fact, higher demands are placed on the protection of natural forests because of their ecological importance. Second, the vector contains the afforested area, including areas newly afforested and reforested in the current year and their shares of the total forest land area. We include the latter variable because future vegetation will differ by the various levels of afforestation and post-harvest reforestation. Third, we include SFE characteristics such as population density and employee structure, that is, the ratio of employees to supported laid-off and retired people. Fourth, we control for manager characteristics because a manager takes actions that affect the enterprise's productivity and thus the forest stock. This includes manager age, education, and managerial experience. In addition, regional demographics and economic factors are included in $\boldsymbol{V}$, such as population and GDP, ecological pressure from agricultural and urban populations, influences from the non-farming sector, and the timber price. We also control for whether the previous manager was promoted, and whether he deforested, as well as the interaction term of these two.

We employ a linear panel fixed effects model to estimate equation (16), controlling for year trends, fixed and year effects related to upper bureaus. The panel fixed effects model allows us to capture the influence of time-invariant factors. One such important factor is historical importance, measured by the contributions to social and economic development, which might give some SFEs greater bargaining power, so that its logging activities have low probabilities of punishment. The year dummy variables control for weather changes and, in particular, for the influence of, for example, a drought year on the vegetation values. The upper bureau fixed and year effects enable us to capture time-varying factors, including changes in technology and equipment efficiency at the upper level bureaus. The upper level bureaus of the SFEs belonged to the central government prior to the economic reform and served as a government body which allocated tasks and provided equipment to the SFEs. With the economic reform, many SFEs have been delegated to the local government while their upper level bureaus still serve as their parent enterprises. These upper level bureaus are not the same sub-bureaus that are responsible for monitoring and inspection of the forests, as we introduced in Section 2.

4.3 Political Career Interest and Environmental Protection Effort

We test the remaining two sub-hypotheses by exploring the determinants of a manager's promotion into the ranks of local or upper level governments. We focus on whether or not sub-national governments in charge of selecting firm managers were driven by *both environmental protection effort* and *the voluntary transfer of profits*. We estimate the relationship between various characteristics of the incumbent manager of an SFE and his fate when his tenure as the manager was at an end (i.e., at the end of his current managerial contract):

$$\boldsymbol{Pr[Y=1|z,V]=\Phi(\alpha+\beta'\mathbf{z}+\delta'\mathbf{V}).} \tag{17}$$

The dependent variable is the likelihood of an SFE manager being promoted to the local (or upper level) government. $\boldsymbol{\Phi}$ is a standard normal cumulative distribution function. $\boldsymbol{z}$ denotes the decision variables of each SFE manager – the percentage of profits transferred, natural logs of the transferred amount, yearly average and aggregated transfers, and environmental protection efforts, i.e., the total afforestation area and the area in proportion to the total forest land area. $\boldsymbol{V}$ is a vector of manager personal and SFE characteristics, as discussed for equation (16). $\boldsymbol{\alpha}$, $\boldsymbol{\beta}$ and $\boldsymbol{\delta}$ are parameters to be estimated.

In the $\boldsymbol{V}$-vector, a manager's age, education, and expertise in management seem to be important evaluation criteria, in addition to political loyalty (Li and Zhou, 2005). Expertise is correlated with the manager's economic performance and political loyalty is reflected by the share of profits transferred to the local government. We also control for the manager's number of years to retirement and for his education in the estimation of equation (17).

Table 1 provides the definitions of all variables used in the estimation. The variables in the vector $\boldsymbol{V}$ are characteristics that may also influence $\boldsymbol{H}$ and $\boldsymbol{Pr[Y=1]}$ when we estimate the equations (16) and (17), respectively. Data sources, summary statistics, and estimation methods are described in the next section.

< Table 1 here >

5 Data

The data used for analysis comes from the economic survey data measuring various characteristics of 24 randomly surveyed SFEs and their respective managers, which are combined with satellite data measuring vegetation as a measure of deforestation.

5.1 Satellite Data Set

Given the difficulty of obtaining truthful reporting of deforestation by SFEs (Alford and Shen, 1998; Brandt and Zhu, 2000), we develop an independent measure of deforestation by using satellite imagery from two NASA satellite sensors – the AVHRR sensor carried on the Polar Orbiting Environmental Satellites (POES) and the MODIS sensor on board the Terra and Aqua satellites (Tucker et al., 2010; NASA LP DAAC, 2015). In particular, we combine the Normalized Differentiated Vegetation Index (NDVI) (1981-2002) and the Enhanced Vegetation Index (EVI) (2003-2009) to construct an annual measure of forest quality and quantity for each year. Using this measure, we are able to encompass both legal and illegal logging undertaken in the SFEs.[9]

The NDVI is the ratio of the difference in reflectance of sunlight, $\boldsymbol{\rho}$, between the near-infrared (NIR) and red bands (visible radiation), divided by the sum of near-infrared and red band radiation (Tucker 1980; Sellers 1985; Sellers et al., 1994):

$$\boldsymbol{NDVI} = \frac{\boldsymbol{\rho_{NIR} - \rho_{RED}}}{\boldsymbol{\rho_{NIR} + \rho_{RED}}}. \tag{18}$$

[9] Illegal logging includes both over-harvesting by the SFE itself and unlawful logging of forests, by the rural population, for example. An SFE is responsible for both within its management area.

Calculations of NDVI for a given pixel result in a number ranging from -1 to $+1$. No green leaves results in a value close to zero, while a value close to $+1$ indicates the highest possible density of green leaves. In other words, unhealthy or sparse vegetation implies low values of NDVI, and healthy or abundant vegetation implies high values of NDVI.

We obtain a generalized annual measure of the state of the forest in the area of an SFE by taking the mean value of the vegetation index over all pixels of size 250 by 250 meters from 1981 to 2009. Deforestation is then measured as a negative annual rate of change in vegetation values. The latter measure of deforestation differs from Burgess et al. (2012) in that we assess the forest change observed at an SFE average, while they treat a pixel inside a village as being deforested if 90% of the area is cleared. Thus, their method captures only large-scale changes such as observed clear-cutting. Selective logging, by contrast, changes the forest canopy moderately and is not captured in their estimates. Given that selective logging is a reasonable logging method and is usually adopted by forest managers over medium and large scales of forests, the average measure of forest change in our study will provide an objective estimate of an SFE manager's environmental performance.

Due to data availability, we combine the NDVI data with EVI data after 2002. EVI is an optimized vegetation index. It accounts for and reduces background and atmospheric noise. It is also more responsive to canopy structural variations, canopy type, plant physiognomy, and canopy architecture (Huete et al., 2002). In contrast to the NDVI, the EVI is computed according to the following equation:

$$EVI = 2.5 \times \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + 6\rho_{RED} - 7.5\rho_{BLUE} + L}. \tag{19}$$

where ρ_{Λ}, $\Lambda \in (NIR, RED, BLUE)$, is atmospherically-corrected or partially atmosphere-corrected surface reflectance, and L is the canopy background adjustment, which addresses non-linear, differential NIR and red radiant transfers through the canopy.

The final outputs of forest change data are values of vegetation index rescaled to be bounded between -1 and 1 for each pixel and averaged over all pixels for each SFE. We match the pixels with the maps of areas of the 24 SFEs that were surveyed; the description is in the next section. As for the years available in the survey data, vegetation change refers to the year pairs 1980-81, 1985-86, 1990-91, 1995-96, 2000-01, 2004-05 and 2008-09. Thus, the switch from NDVI to EVI in 2003 does not cause any data inconsistencies in our forest change measures because we do not compare NDVI data with EVI data – only NDVI with NDVI data and EVI with EVI data. Figure 1 illustrates the study area – maps of the 24 SFEs. Figure 2 codes the pixels with vegetation indices in Northeast China in the study period.

< Figures 1 and 2 here >

5.2 Economic Survey Data Set for State Forest Enterprises

Our data on 24 SFEs in Northeast China comes from a survey conducted by the Environmental Economics Program in China (EEPC) at Peking University. The northeastern state forests are located in three provinces (Heilongjiang, Inner Mongolia and Jilin) and are managed by 84 SFEs in total. These SFEs played an important role in the old industrial base in this area and contributed to China's growth by providing more than half of the national timber production in the past five decades. However, this enormous contribution to social and economic development has come at the expense of environmental degradation. By the beginning of the 2000s, 60 out of the 84 SFEs had almost depleted their mature forests (Xu, 2013).

To study the institutional system of state forest management and provide a roadmap for feasible reform, EEPC researchers conducted surveys in 24 randomly selected SFEs. The first wave survey was conducted from June to October 2005, and in summer 2009 the SFEs were revisited, and the earlier process of data collection was repeated. For each SFE, data was collected for the period 1980-2008 on logging and reforestation activities, employment structure, income and expenditure, and investments in other assets. The data on forest resources and the SFEs' social services, tax payments and transfers to local jurisdictional governments, as well as on the timber price, was provided by provincial forestry authorities (the sub-level bureaus of the SFA).

In addition to the average values of our constructed vegetation indices – the annual rate of change between two consecutive years and the deforestation dummy – Table 2 reports the mean values of socio-economic variables for the SFEs and the counties in which the SFEs are located, as well as the SFE managers' characteristics, during the period 1980-2008. The availability of data on the transferred amount of profits allows us to have nine observations in 1980, 13 in 1985, 15 in 1990, and around 20 for the remaining years. Overall, the observed SFEs reported a stable total land area but forest stock volumes fluctuated by more than 10 percent in the 1990s and the early 2000s. An annual deforestation rate of three to five percent was observed in 1990, 2000 and 2004 (which means that the rates of change in vegetation index values were negative in the following years). In each year, at least one to four SFEs over-harvested their forests, as shown by negative rates of change in vegetation value, and this figure rises to ten in 1990 and even more in 2000 and 2004.

In our sample, natural forests account for more than half of the forests in each SFE. They decrease in volume on average over time, while plantation forests increase in both area and volume. Following Xu et al. (2004), we use areas of forest land and of natural forest, and area and volume shares of natural forest, as proxies for the degree of asymmetric information between the SFA and the SFEs. Natural forests also differ from plantation forests in their growth rates. Plantation forests are used for timber production, and therefore fast-growing tree species are planted. Depending on climatic conditions, natural forests grow at an annual rate of about two to three percent in the SFE-managed areas. Natural and plantation forests also provide different ecological functions. Estimating equations (16) and (17), we control for the growth of natural forests in addition to their area and volume, also as a percentage of total forest.

As discussed earlier, the transfer of profits to jurisdictional local governments is unique to China. The percentage of profits transferred, the absolute amount, and the amount of timber production may signal the SFE manager's ability. They are also supposed to be among the evaluation criteria for his economic performance. We do not focus on tax payments due to the fact that these are exogenously set. The transferred amount of profits is subject to the manager's decision, and we are interested in investigating how the transfer decision determines a manager's political career at the end of his tenure as manager. The transferred amount ranges from 10 to 800 million CNY; as a share of the SFEs' disposable profit, the transfer ranges from less than ten percent to as high as 90 percent. Timber production was very high in the beginning and decreased over time, with an average of 357,463 cubic meters in 1980, and dropped by 40 percent in 1995 to 215,827 cubic meters; after the implementation of the NFPP, there was soon another 38 percent decrease, to 133,502 cubic meters in 2000, suggesting that the logging ban was effective. Nevertheless, during the period with the logging ban, the average timber production of the SFEs was still over 110,000 cubic meters in the 2000s. Because timber production is self-reported data and may be subject to measurement error and reporting fraud, our econometric estimations do not include this variable. Similar reasoning applies to the total harvested volume. Apart from transfers, the yearly afforestation area, both in absolute amount and as a percentage of the total land area, may serve as a signal for an SFE manager's effort in forest conservation. These two variables are observed to have an average decrease over time.

In addition to the above variables, a manager's personal characteristics are important. The average age of the managers is less than 50 years, varying from 34 to 60 years. The retirement age in China is 65 for males, and we conjecture that the probability of being promoted and hence the logging and transfer decisions may differ when approaching this age. Therefore, we control for the number of years for an incumbent manager until retirement age. We observe that the number of managers with higher education significantly increased over the sample period, and all the observed managers have a college education in the 2000s. Managerial experience, i.e., the number of years as the manager of an SFE, is about 3.5 years on average, varying from one to 13 years.

For each manager, the promotion status is valued 1 if he was promoted to an upper political position in a local or higher government after the tenure as manager was at an end. For promoted managers observed in two or more periods, we recode their earlier promotion status into 0 and leave only their last period of promotion equal to 1. In each observed year except 2008, one to two thirds of the managers of the northeastern state-owned forests were promoted at a later time.

Other variables that are important and may drive deforestation come from social and economic pressures to harvest forests (Hyde et al., 1996; Amacher et al., 1998; Rozelle et al., 1998; Rozelle and Huang, 2000; Foster and Rosenzweig, 2003). The sources of these pressures include SFE population and social welfare payments (because laid-off and retired employees are required to be supported by the SFE)[10], the regional endowment with land and the share of agricultural population, urban population, population growth, income growth, and changes in the timber price. Among these factors, SFE and local county population experienced first an overall increasing and then a decreasing trend (since the late 1990s), while population density at SFEs has kept rising. The social welfare payments by SFEs become less over time, as indicated by the increasing ratio of employees to supported laid-off and retired persons. The timber price during the period experienced an increasingly rising trend, due to the booming timber markets and forest resource scarcity. At the regional level, population and GDP in counties increased, and the urban populations exhibited only a slight decline. Agricultural population density was high in the 1990s and the local non-farming sector experienced small fluctuations. The growth of agricultural and urban populations may drive deforestation due to an increased need for agricultural land and higher demand for forest products. The development of the non-farming sector, e.g., the manufacturing industries, may influence forest change directly through the growth in processing related to forest and non-forest products, and indirectly by contributing to regional economic growth. Therefore, we control for the variations in these factors in the econometric estimations.

In total, we have a sample size of 24 (SFEs) for the seven year pairs for which we have vegetation data, which yields 168. From this sample, we have to drop 54 observations because of missing data on the transfers to the local government. We proceed with a sample of 114 SFEs.

< Table 2 here >

[10] The economic reform in China in the 1990s brought about a number of laid-off employees in state-owned enterprises, some of whom receive a monthly allowance for subsistence, paid by the SOEs. The retired workers are also supported by the SOEs.

6 Econometric Results

In this section, we present the econometric results of the examination of the previously stated hypotheses regarding the impact of the information asymmetry on deforestation and the role of personal interests in pursuing a future political career.

6.1 Deforestation and Information Asymmetry

Table 3 presents the estimation results of fixed-effects linear models on equation (16). The dependent variable in Columns 1 and 2 is the rate of change of the vegetation index; in Column 3, the dependent variable is the deforestation dummy. Column 1 focuses on how the rate of change is affected by various measures of asymmetric information with respect to monitoring by the central government, which is associated with different sizes of the forests managed by an SFE. The models control for an SFE's (natural) resource structure, for managerial and regional characteristics, for last year's vegetation value and for the previous manager's performance, as well as for year trends and upper bureau fixed and year effects. The parameter estimates do not have statistical power and are not reported.[11]

In support of Hypothesis 1, we find that the coefficients of the total forest land area, the forest volume and the area share of natural forests are statistically significant in Columns 1 and 2, and the total forest land area is also significant in Column 3. For Columns 1 and 2, an increase in the information asymmetry as measured by our three proxies leads to a smaller rate of change in the vegetation. This smaller rate implies that the vegetation grows less on average, and the rate might even become negative or more negative, indicating more logging activities and, as a result, deforestation. Taking the marginal effect (-0.301) of the total forest land area on the rate of vegetation change in Column 2 as an example, an SFE with a one percent larger area of forest land compared to the average (256,200 ha) will have a 30.1 percent decrease from the average rate of vegetation change in the following year (0.0183). This effect suggests that an average-sized SFE being given a 10 percent larger area will experience a decrease of 5.5 percentage points in the average rate of change in vegetation, or an annual deforestation rate of 3.7 percent in this area next year. This is a sizable effect in destroying forests. Similar correlations hold for the other two asymmetric information proxies. If we only look at SFEs that experience deforestation (Column 3), then deforestation is more likely to happen in an SFE with larger forest land area, *ceteris paribus*. This lends strong support to our Hypothesis 1, and is in line with findings by Xu et al. (2004).

In Columns 2 and 3, we add the variable of the percentage of profits transferred

[11] The complete results are available upon request.

by the SFEs to the jurisdictional sub-national governments. The parameter estimate of the variable does not have statistical power in explaining the variation in the rate of change of the vegetation index in Column 2. However, it is statistically significant at the 5 percent level when we look at the binary variable deforestation as the dependent variable in Column 3. Column 3 is estimated by a linear probability model with SFE fixed effects. The parameter estimate (0.963) implies that, when evaluated at the avearge, an SFE manager whose transfer rate to the local government increases by one standard deviation (0.288) leads to a stronger likelihood of having an overall negative rate of change of the vegetation in his area by 0.277. This effect is equivalent as 58 percent of the mean deforesatation rate (0.474). This finding provides support for Hypothesis 2.1 but not for Hypothesis 2.2. While a higher transfer rate does, on average, increase logging, it makes it more likely that forests are being degraded.

$<$ Table 3 here $>$

6.2 Political Career Interest and Environmental Protection

The above analysis assumes that the jurisdictional sub-national governments are happier with more transfers and thus are more likely to promote the responsible manager into the ranks of a government official. We now examine the determinants of an SFE manager's probability of getting a promotion to sub-national governments as a result of these transfers, which we interpret as a better political relationship. Table 4 reports the maximum likelihood estimation results of a probit model on equation (17) on the promotion status of the incumbent SFE managers in the observed years.[12] To allow for heterogeneity across observations and control for SFE fixed effects across years, we estimate the probit model with the SFE dummy variables and with the robust standard errors option – adjusted at SFE level.

While no detailed evidence is available on how the local governments evaluate and select SFE managers, we conjecture that a manager's evaluation may depend on multiple-year averages of transfers or cumulative performance rather than simply on annual performance. In Table 4, the first three columns report the results of regressions with the percentage of SFE profits transferred to local government, controlling in Columns 1-3 for different variables that signal the manager's performance and ability: the natural log of the total transferred amount in the current observational year, the multiple-year average transfer and the aggregated amount of the transfer. By doing this, the effect of past performance is incorporated into the analysis of the determi-

[12] A manager who had a tenure for five years or longer appears at least twice in our observations. This is why we control for the number of years in office as a proxy for managerial experience.

nants of personnel promotion. Column 4 computes the marginal effects of a selection of coefficients in Column 1 at sample means.

Consistent with Hypothesis 3.1, the percentage of transferred profits has a positive impact on the probability of being promoted. The sign of the coefficient is positive and significant at the 5 percent level in all columns. Moreover, the marginal effect of the percentage of profits shared with the local government on a manager's promotion probability is reasonably large. When evaluated at the mean of the independent variables, it is 0.941, suggesting that, when an average-level manager increases the transfer rate by one standard deviation (0.29) from the mean (0.288), his probability of promotion will increase by 0.273 or 66 percent of the average promotion probability (0.412).

We do not find evidence supporting a positive relationship between the amount of transferred profits and the probability of promotion and thus we reject Hypothesis 3.2. For this, we consider current year and past average and cumulative transfers of the same incumbent manager. In Columns 1 and 2, the coefficients of the transferred amount are insignificant and have ambiguous signs; in Column 3, the cumulative amount has a negative impact on the promotion probability at the 10 percent level of statistical significance. One plausible interpretation for this result is that a bigger cumulative amount, aggregated from past performance, would signify larger quantities of logging and potentially cause trouble for the manager from environmental authorities. Overall, this suggests that it is not the absolute amount of transfer that matters for the promotion decision but rather the transfer rate. No matter the size of the cake, a manager who hands over a larger share of the cake is more likely to get promoted. It seems that the transfer rate is a better signal to the local government of the manager's ability than the absolute amount of the transfer.

Interestingly, an SFE manager's efforts in environmental protection – measured by the yearly afforestation area (log) and its share of the total forest land area – do not have a positive effect on promotion as one might expect. First, a larger afforested area has no significant effect in increasing an SFE manager's promotion probability, given the statistically insignificant coefficient in all columns. Second, however, in the cases where the afforested area accounts for more than three percent of the total SFE forest land area (sample mean), a standard deviation (seven percent) increase in the total afforested and reforested area as a share of the total forest land area decreases the probability of promotion for the manager by 0.296 or 71 percent of the average promotion probability. It seems that afforestation and reforestation are not appreciated by the manager's superiors – on the contrary, more afforestation/reforestation may be a bad signal to the local government because it shows that there must have been a lot of deforestation previously.

Additionally, the point estimates are not influenced by adding manager characteristics and the importance of the SFE, which is why we only report the table with all controls. For the importance of an SFE, we consider the management scale in terms of land area and population and the volume share of its natural forests. With these variables controlled for, the regressions take into account various scales, where some managers just need to do a little and can be easily promoted because the scale determines the importance of the position of the SFE in the local economy and society. Total land area and natural forest volume have the positive and significant impact on promotion that we expected. Other economic and environmental efforts of the manager equal, a manager with a one percent larger area than the average is more likely to be promoted, by 3.3 percentage points (8 percent of the mean promotion probability of 0.412). Similarly, if the natural forest volume as a share of the total forest volume is one percentage point higher than the average, the manager's promotion is increased by 6 percentage points (15 percent of the mean probability of 0.412).

Among the manager characteristics of age, education and managerial experience, we find that the younger a manager is, the more likely he is to get a promotion. This effect is significant at the one percent level. The marginal effect of this is, however, small in absolute value. Given that the mean age of the managers is 48, the mean number of years to the retirement age of 65 is 17 years. One year less from this mean (17) increases his promotion likelihood by 0.072, or 17 percent of the average probability of promotion. This result is consistent with other studies on political promotion of personnel from the local level of governments in China, e.g., Li and Zhou (2005). Equally or more important than the incumbent manager's own characteristics is the performance of his predecessor, which has a significant impact on his promotion probability. In particular, the promotion of one's predecessor significantly decreases one's promotion probability, at the one percent level in all three columns of Table 4. The marginal effect of the predecessor's promotion on the incumbent manager's promotion is -0.857. This number means that, if the predecessor was promoted, this may raise the standard for the incumbent manager to be promoted. It might become harder for the subsequent manager to outperform his predecessor if the latter got promoted. By contrast, the predecessor's environmental performance in terms of deforestation, and the condition that the predecessor both deforested and was promoted, do not always influence the incumbent manager's promotion probability in a statistically significant way, except in Column 1. One plausible interpretation for this result is that earlier deforestation may impede the incumbent's performance due to the lack of resources available for logging; however, a manager's efficiency, especially in difficult situations like this, could also be valued highly and considered in sub-national governments' evaluation criteria.

In summary, our empirical findings lend support to the notion that: 1) an SFE manager (the agent) utilizes the information asymmetry with the central government (principal 1) to over-use natural resources; and 2), he satisfies the jurisdictional sub-national government (principal 2) with a higher percentage of profits, which indeed benefits his personal political career.

< Table 4 here >

7 Conclusion

In this paper, we identify a new channel through which natural resources such as forest stocks get degraded. We establish a theoretical model to show that, in this two-principal, one-agent relationship, managers of state forest enterprises take advantage of the asymmetric information between the SFE and the SFA to increase logging and thereby maximize profits and further their own careers. Their jurisdictional local governments are driven by their own economic and career concerns. The principal-agent relationship between the local government and the SFE manager drives the latter to share a larger proportion of his profit cake with the former. This might even add to the difficulty for the other principal – the SFA – to monitor its target if the local government is able to protect an SFE from the SFA's influence, which is suggested by anecdotal evidence, as reported in Xu et al. (2004). For both the local government and the SFE manager, environmental degradation plays a minor role because authority over the environment does not lie with the local governments and the SFA has difficulties in monitoring the exact amount of logged forest.

Our empirical analysis focuses on the state-owned forests in northeastern China, using economic survey data and satellite imagery. We find that the rate of forest change decreases and the likelihood of deforestation increases with the scale of forests, due to the difficulty of measuring and monitoring. We also find that a larger share of the cake to local government positively impacts the likelihood of deforestation. Futhermore, we find that it is the share of the cake, not the size of the cake or the environmental protection effort, that determines an SFE manager's political promotion. We suggest that the degree of information asymmetry can be reduced through better monitoring technologies such as real-time satellite imagery, by transferring authority over forests to local governments, which will then also be in charge of conservation, or simply by designing incentive-compatible contracts for SFE managers with both of their principals.

Our theoretical model not only applies to the two-principal, one-agent relationship in the state forestry sector but also to other sectors, e.g., the industrial SOEs which have emissions as a by-product of output. In that case, x needs to be interpreted as output, which is normalized in such a way that one unit of output causes one unit of emissions, and thus $\bar{x}$ is the maximum permissible level of emissions. However, it is more difficult to develop an objective measure of emissions because satellites cannot capture a factory's emissions.

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Figure 1: The study area: maps of 24 SFEs

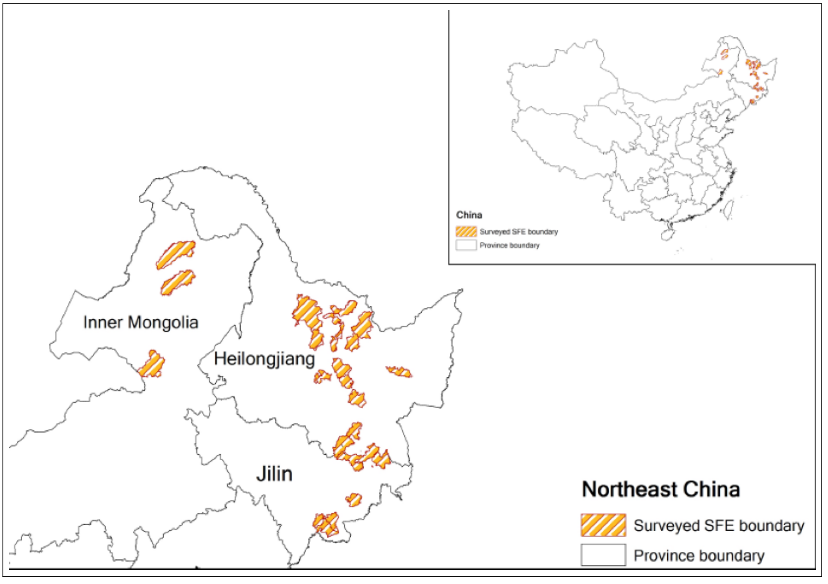
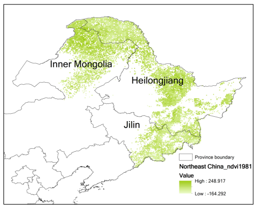


Figure 2: Forest change in Northeast China, 1981-2009



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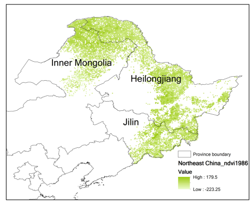

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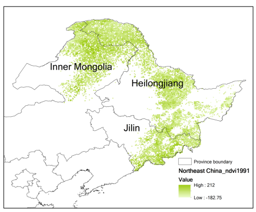

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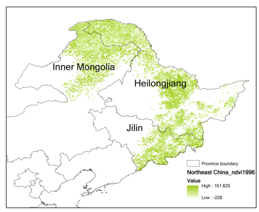

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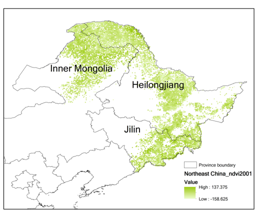

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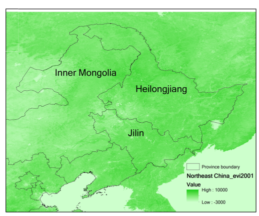

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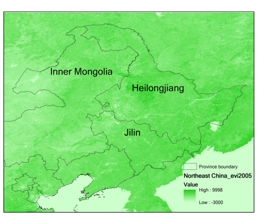

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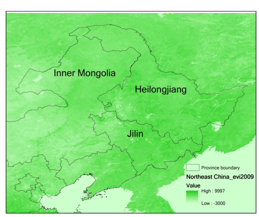

(h) EVI 2009

Data sources: Tucker et al., 2010; NASA LP DAAC, 2015

Table 1: Definitions of variables

Variable:	Definition and unit of measurement
Measure of deforestation:	
Annual rate of change of vegetation index	Annual rate of change of NDVI/EVI values for an SFE-managed forest land area
Deforestation	Binary, =1 if negative annual rate of change of vegetation index, =0 otherwise
Difficulty in evaluating the SFA's target:	
Total forest land area	Total forest land area managed by an SFE (ha)
Total forest volume	Total forest living stock volume managed by an SFE (1000 m^3)
Area share of natural forest	Natural forest area as a share of the total land area in an SFE
Volume share of natural forest	Natural forest volume as a share of the total forest living stock volume in an SFE
Area share of plantation forest	Plantation forest area as a share of the total land area in an SFE
Volume share of plantation forest	Plantation forest volume as a share of the total forest living stock volume in an SFE
Profits transferred to local government	Amount of an SFE's profits transferred to the jurisdictional government (10000 CNY)
Proportion of profits transferred	Percentage of an SFE's profits transferred to the jurisdictional government
Control variables:	
Annual growth rate of natural forest volume	Average annual growth rate of timber volume in natural forests of an SFE
Share of yearly afforestation area	Total afforested and reforested area at time t as a share of total forest land area in an SFE
Log of yearly afforestation area	Natural log of yearly afforestation area (ha)
Population	Population size of an SFE
Population density	Persons per hectare in an SFE
Ratio of employees to the supported laid-off and retired	Ratio of the number of employees to the number of supported laid-off and retired persons
County population	Total population size in the county where an SFE is located
County GDP per capita	Annual GDP in the county where an SFE is located (CNY)
County urban population share	Urban population as a share of total population in the county where an SFE is located
County agricultural population density	Agricultural population density in the county where an SFE is located (persons per ha)
County non-agricultural GDP share	Non-agricultural GDP as a share of total GDP in the county where an SFE is located
Timber price	Timber price (1000 CNY per m^3)
Manager characteristics:	
Age	Current age of the incumbent manager of an SFE (years)
Education	Education of the SFE manager (1 if college, 0 if lower)
Managerial experience	Number of years being an SFE manager
Promotion at the end of current managerial contract	Manager being promoted to government position (1=yes, 0=no)
Promotion of previous manager	Whether the previous manager was promoted to local government (1=yes, 0=no)

Notes: 1. SFA: State Forestry Administration of P.R. China.
2. SFEs: state forest enterprises.
3. Laid-off refers to the laid-off workers in an SFE who receive a monthly allowance for subsistence paid by the SFE.

Table 2: Summary statistics of SFEs and counties (means)

	Full sample	By year 1980	1985	1990	1995	2000	2004	2008
Measure of deforestation:								
NDVI (EVI from 2003)	0.662	n/a	0.725	0.753	0.773	0.739	0.512	0.516
NDVI in the next year (EVI from 2003)	0.670	0.725	0.732	0.765	0.764	0.761	0.520	0.500
Annual rate of change, vegetation index	0.0183	0.0912	0.0483	-0.0405	0.0251	-0.0448	-0.0509	0.149
Deforestation	0.4740	0.111	0.308	0.667	0.211	0.947	0.809	0
Difficulty in evaluating the SFA's target:								
Total forest land area	256,200	248,853	252,037	242,041	274,746	235,894	259,685	272,471
Total forest stock	20,026	22,669	20,428	18,422	20,203	17,368	19,173	23,365
Area share of natural forest	0.671	0.665	0.642	0.632	0.660	0.671	0.682	0.725
Volume share of natural forest	0.855	0.900	0.897	0.891	0.879	0.830	0.802	0.832
Area share of plantation forest	0.134	0.0684	0.0738	0.103	0.141	0.175	0.175	0.141
Volume share of plantation forest	0.0937	0.0191	0.0457	0.0552	0.0639	0.129	0.150	0.126
Profits transferred to local government	2,190	516.7	925.6	1,686	3,611	2,342	2,965	1,796
Proportion of profits transferred	0.288	0.301	0.295	0.334	0.491	0.228	0.291	0.0807
Control variables:								
Annual growth rate of natural forest volume	0.0276	0.0231	0.0220	0.0267	0.0285	0.0330	0.0316	0.0236
Share of yearly afforestation area	0.0300	0.0515	0.0454	0.0452	0.0440	0.0249	0.0130	0.00593
Yearly afforestation area	5,466	11,658	7,723	8,075	7,812	4,161	2,130	1,359
Population	36,781	35,941	37,569	38,012	40,105	36,580	33,477	36,163
Population density	0.194	0.173	0.203	0.197	0.192	0.194	0.181	0.212
Ratio of employees to the laid-off and retired	0.687	0.101	0.208	0.324	0.393	0.775	1.057	1.411
County population	345,142	233,954	244,995	442,822	522,122	397,232	271,976	235,229
County GDP per capita	7,884	1,074	1,758	1,945	4,581	8,339	15,663	14,591
County urban population share	0.654	0.658	0.677	0.605	0.645	0.671	0.692	0.624
County agricultural population density	0.687	0.501	0.440	1.184	0.913	0.880	0.402	0.436
County non-agricultural GDP share	0.359	0.434	0.393	0.482	0.386	0.292	0.302	0.301
Timber price	0.454	0.0177	0.0369	0.0845	0.190	0.469	0.842	1.092
Manager characteristics:								
Age	48.03	49.22	45.54	47.07	50.05	46.74	47.10	50.33
Education	0.825	0.222	0.692	0.800	0.684	1	1	1
Managerial experience	3.509	1.222	1.769	4.800	3.632	3.053	2.952	5.833
Promotion at the end of current managerial contract	0.412	0.333	0.615	0.667	0.474	0.579	0.286	0.111
Promotion of previous manager	0.5710	n/a	0.231	0.667	0.842	0.579	0.667	0.333
Number of observations:	114	9	13	15	19	19	21	18

Notes: 1. SFA: State Forestry Administration of P.R. China.
2. SFE: state forest enterprise.
3. Laid-off refers to the laid-off workers in an SFE who receive a monthly allowance for subsistence paid by the SFE.
Sources: Author's computation from SFE survey data, and satellite image data (Carroll et al., 2003; Tucker et al., 2010; NASA LP DAAC, 2015).

Table 3: SFE fixed-effects (FE) estimates: information asymmetry and deforestation

	1	2	3
Dep. Var.:	Rate of vegetation change, $t+1$		Deforestation
Proportion of profits transferred (γ_t)		-0.023	0.963**
		(0.053)	(0.386)
Log of total forest land area	-0.292*	-0.301*	1.881*
	(0.144)	(0.148)	(1.070)
Log of forest stock volume	-0.106**	-0.104**	0.102
	(0.048)	(0.049)	(0.358)
Area share of natural forest	-0.577***	-0.551***	1.696
	(0.156)	(0.169)	(1.223)
Volume share of natural forest	0.139	0.144	-0.466
	(0.155)	(0.158)	(1.145)
Log of vegetation index value at $t-1$	YES	YES	YES
SFE characteristics	YES	YES	YES
County characteristics	YES	YES	YES
Manager characteristics	YES	YES	YES
Promotion of previous manager	YES	YES	YES
Promotion of previous manager $\times$ He deforested	YES	YES	YES
Upper bureau fixed and year effects	YES	YES	YES
Year trends	YES	YES	YES
Observations	105	105	105
R-squared	0.953	0.953	0.916

Notes: The dependent variable in Models 1 and 2 is the rate of vegetation index change at $t+1$. The dependent variable in Model 3 is binary, with value 1 meaning deforestation given a negative rate of vegetation index change at $t+1$. SFE characteristics include annual growth rate of natural forest volume, log area of newly afforested forest and as a percentage of total forest area, population density at SFE, and ratio of employees to the supported laid-off and retired people. County characteristics include population, GDP per capita, urban population share, agricultural population density, non-agricultural GDP share, and timber price. Manager characteristics include age, education level, and managerial experience. Standard errors are in parentheses. Significance is denoted as: * significant at 10%; ** significant at 5%; *** significant at 1%.
We lose 9 observations (from 114 in total) because we included NDVI values that are lagged by one year and these are not available prior to 1980.

Table 4: Probit estimates: determinants of an SFE manager's political promotion

Dep. Var.: Promotion (1=yes, 0=no)	1	2	3	4
Proportion of profits transferred (γ_t)	2.388**	2.861**	2.904**	0.941**
	(1.084)	(1.245)	(1.324)	(0.423)
Log amount of transferred profits	0.146			
	(0.409)			
Log amount of yearly average transfer		-0.430		
		(0.358)		
Log amount of aggregated tranfer			-0.505*	
			(0.297)	
Log of yearly afforestation area	0.232	0.240	0.245	
	(0.232)	(0.225)	(0.224)	
Share of yearly afforestation area over the total	-10.724*	-15.930**	-17.143**	-4.228*
	(5.920)	(7.089)	(7.167)	(2.366)
Log of total forest land area	8.337*	10.134**	10.378**	3.287*
	(4.652)	(4.487)	(4.713)	(1.809)
Share of natural forest volume over the total	15.431**	11.148*	10.286	6.084**
	(7.195)	(6.529)	(6.726)	(2.746)
Log of population	0.276	0.408	0.386	
	(0.432)	(0.434)	(0.416)	
Population share of the county total	0.098	-0.291	-0.366	
	(1.790)	(1.958)	(1.955)	
Manager education	-0.312	-0.400	-0.434	
	(0.924)	(0.909)	(1.046)	
Managerial experience	0.032	-0.039	0.096	
	(0.112)	(0.100)	(0.166)	
Number of years to retirement (i.e., 65 for males in China)	0.182***	0.203**	0.203**	0.072***
	(0.069)	(0.081)	(0.087)	(0.027)
Promotion of previous manager (1 if yes, 0 otherwise)	-2.174***	-2.072***	-2.124***	-0.857***
	(0.629)	(0.757)	(0.799)	(0.243)
Deforestation by previous manager (1 if yes, 0 otherwise)	-1.942**	-1.555	-1.526	-0.766**
	(0.819)	(0.962)	(0.983)	(0.321)
Promotion of previous manager × He deforested	1.736*	1.538	1.556	0.684*
	(0.993)	(1.072)	(1.148)	(0.388)
Observations	105	105	105	
SFE Fixed-effects	YES	YES	YES	
Pseudo R^2	0.486	0.500	0.508	

Notes: The dependent variable is whether the incumbent manager is promoted to a government position at the end of the current managerial contract.
Robust standard errors in parentheses are clustered at the SFE level. The significance levels of 1%, 5% and 10% are noted by ***, ** and *.
Column 4 reports the marginal effects computed at sample means for Column 1.

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