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An empirical analysis of China's state-owned forests

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Abstract

Using data from 28 provinces and five distinct census periods, we identify what factors have led to declines in forest growth, or equivalently, factors important in moving Chinese forests away from sustainable management since the 1970 reforms. These reforms gave increased autonomy to local forest managers. The central government sets harvest limits (quotas) so that growth rates are maintained or increased, and reforestation is required to compensate for area harvested in state forests. However, monitoring and enforcing local manager decisions is difficult, and this combined with centrally-promulgated policies creates disincentives for state forest managers to harvest and reforest according to the quotas. Our most important finding is that higher quotas lead to declines in forest growth over time. The area of state natural forests and plantations also prove to be significant and negative predictors of growth rates. This in part is due to greater opportunities in larger forests for undetected over-harvesting or under-reforesting by state forest managers, and it supports a large body of anecdotal, but untested, evidence regarding the size of China's state forest enterprises and deforestation within the country.

Keywords: China forest sector; Deforestation; Forest growth declines

1. Introduction

China's state-owned forests account for 42% of the country's total forest area, 68% of total timber volume, and almost all of the nation's natural forest resources. Located in the upper reaches of large river basins and mountainous regions, they provide important ecological services in addition to forest products for domestic consumption. Managing state-owned natural forests in a sustainable manner has become a critical challenge to leaders of the central government.

Historically, China's centrally-planned system left little room for state forest manager autonomy (Lin, 1992; Lin et al., 1999). In 1957, this changed with development of state operated forest enterprises (SOE) (Ross, 1988; Sun, 1992; Yin, 1998).[1] SOEs are local administrative groups who plan and implement harvesting and reforestation on state-owned forests, in theory following specific guidelines set by the central government. The central government sets annual harvesting limits, called quotas, that SOE managers are expected to follow. The central gov-

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[1] State forest enterprises have the highest concentration in China's Northeast provinces of Heilongjiang, Jilin, and Inner Mongolia.

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ernment also specifies minimum reforestation levels for every forest in each year. Harvest quotas are set to guarantee that forest growth rates either increase or remain stable over time for state forests (Xu et al., 2002).

The current system of centrally-promulgated harvest levels and local implementation of harvesting and reforestation by forest managers creates a problem of incentives. It is often argued in the literature that forest managers do not comply with the harvesting and reforestation limits set by the central government (Economy, 1997; Alford and Shen, 1998; Brandt and Zhu, 2000). Two reasons discussed are that the central government has difficulty monitoring SOE manager decisions given the large size of most forest areas (Rozelle et al., 2000; Xu et al., 2002), and managers are promoted based on profits generated from harvesting net of reforestation costs (Xu et al., 2002). The central government is interested in maintaining increasing forest growth over time for each forest, but forest managers are interested in short-term profit generation. Clearly, the incentives of forest managers and the government are not compatible.[2]

Our purpose in this paper is to determine significant predictors of forest growth rates over time for China's state forests, keeping in mind the incentive problems that might exist and the potential for over-harvesting and under-reforesting. We use census data for SOE forests covering 28 provinces and six time periods during the post 1970 reform period. The data are known to be reliable and have not been previously analyzed for our purpose. Several variables affecting growth are considered, including those related to information asymmetries between managers and authorities, monitoring costs, central government harvest quotas, and the usual forest stock and market variables that should drive harvesting in post-reform China. Although measurement of information asymmetries between the government and SOE managers is difficult, if not impossible, we construct suitable proxies, used in other economics work, that find support in the anecdotal literature on Chinese forestry. An example is using the area of state forest plantations and natural forests as proxies for information differences between state forest managers and the government.

Our results establish a connection between area of SOEs and declines in forest growth rates over time. Reductions in forest growth grate are correlated with either short-term unsustainable (excessive) logging or under-reforestation. Given that much of the logging undertaken in our sample area is known to be illegal (see Rozelle et al., 1998), any variable we find that is negatively related to forest growth rate should at least be partially related to non-compliance of enterprise managers with central government regulations.

2. The case for non-compliance

The most significant part of the post-1970 reforms for Chinese forest management was the larger decision-making power given to local forest enterprise managers. A profit-sharing system was established, and in 1988 China adopted an 'SOE manager contractual responsibility system' for all state-owned forest enterprises (SFA, 2001). This contract system specified annual logging limits (termed quotas) for each state forest. State forest managers could sell wood to government buying agents at fixed prices, and all profits net of tax payments could be retained. A punishment mechanism was established by the central authorities to prevent non-compliance with set harvest limits and reforestation levels (China Forestry Yearbook, 1988; SFA, 2001).

The profit motive of forest enterprise managers has likely been quite influential to their decisions. Evaluation and promotion of an enterprise manager hinge on the size of their profit distribution to powerful local forest industry groups. Enterprise managers often enter into short-term profit-based contracts with these groups, and thus building a long-term capacity for forest harvesting is not encouraged. Indeed, to maximize financial performance under this system at current prices and costs, it has been argued that an average state forest manager would need to harvest beyond government quotas by at least 50 000 m^3 per year (Xu et al., 2002).

[2] This is known as a principle-agent problem in economics (e.g. Hey and Lambert, 1987).

Another problem is that the central government cannot effectively monitor its harvest quota or reforestation policies, mainly due to the vast size of many state natural forests and plantations. Conducting thorough inventories of any enterprise is essentially insurmountable, and daily monitoring is impossible. Enterprises have also constructed well-managed forest stand and reforestation demonstration sites in plantation areas. These are often used to create a false sense of compliance when government officials make site visits. Not surprisingly, there has not been a single enterprise manager seriously punished since enactment of the Natural Forest Protection Program in 1999.

Recent research supports non-compliance with central government regulations in the form of illegal logging. Using an analysis of two comparable national forest censuses in 1981 and 1988, Rozelle et al. (1998) concluded that, while post 1970s reform policies have evidently increased forest cover, they had not halted unsustainable harvesting of mature forests.[3] A government survey in 1995 also revealed that illegal logging amounted to 34 million m^3, or roughly 14% over the logging quota for the country as a whole (Chen and Lu, 1999). In Heilongjiang and Yunnan provinces, two of the main state forest areas, logging beyond the quota limits has been most severe, reaching 843 000 m^3 and 768 000 m^3, respectively, or 31% and 21% above their limit quotas (MOF, 1997).[4]

3. Econometric model

We now turn to formally examining the determinants of forest growth rates in China's state-owned forests. We are specifically interested in understanding what factors have caused declines in forest volume growth over time on land managed by local state forestry enterprises and state forestry farms. Changes in forest volume growth rates are at least correlated with illegal over-harvesting or under-reforestation, and inclusion of all important variables, such as quotas and variables related to information differences between managers and the central government, will allow us to assess the marginal effect of each variable on growth holding others constant.

Following our discussion, the estimated equation is assumed to have the following form

$$H_{it} = \Gamma(I_{it}, S_{it}, P_{it}, G_{it}, \phi_{it}) \quad (1)$$

H_{it}, is the forest volume growth rate of SOE forests in province i at time t.[5] I_{it} represents a vector of factors correlated with differences in information between SOE managers and the central government regarding harvesting and reforestation activities (these would also affect the costs of monitoring by the government). S_{it} is a vector of state forest stock characteristics and includes information about natural forest and plantation forest components, P_{it} is a vector of market variables such as demand indicators, reforestation cost indices, and population and regional demographics, and G_{it} is the government policy parameter (harvest quotas) set for state forest i in time t. Finally, the term ϕ_{it} is a random error that is assumed to vary over both provinces and time periods. We should note that tax rates for harvesting are essentially zero for SOE forests and are equivalent across provinces, thus these are not included in Eq. (1). In addition, the only available wood prices are regional averages that have little variation in our sample; therefore these are also not included in Eq. (1).

Our data correspond to a time series cross section panel, and so the error can be decomposed specifically into a component that varies over time

[3] There is also evidence that forest enterprises have taken advantage of liberalization to market products for their own revenue generation and not necessarily for government revenue generation. In 1988, the planned government procurement accounted for 49% of total timber sales in the Northeast state-owned forest regions (MOF, 1989; China Forestry Yearbook, 1988). By 1996, this share declined to 17% (MOF, 1997, China Forestry Yearbook, 1996).

[4] This report also predicted that, by the year 2000, 90 out of the 135 (66.7%) state-owned forest enterprises would exhaust their harvestable forests. It also predicted that most of the 85 state forest enterprises in Northeast China would cease to produce timber due to resource depletion.

[5] It is worth noting that state-owned forests include plantation and natural forest components. While the latter are represented by native species growing very slowly, the presence of the former means that growth rates of all state forests should vary and be positive in many cases (see Table A5 in Appendix A).

and space, and one that is space (province) specific: $\phi_{it}=v_i+\varepsilon_{it}$. Under this assumption, Eq. (1) can be estimated using fixed effects. This corrects for any climatic and geographic factors across provinces that are unobserved but may affect the dependent variable. In our data, this is expected considering that growth of timber volume is affected by many factors such as the climate and other natural conditions, the type of trees, and the age structure of forests that are hard to quantify at the provincial level.

An equivalent form of the fixed effect estimator follows from using cross sectional (provincial) dummy variables in estimating Eq. (1). Here, the cross section dummy variables provide correction for the fixed effect (e.g. see Greene, 1997).[6] We will follow this procedure. Since the provincial dummies serve mainly a corrective role, we will not discuss them in the results.[7]

Some of the right hand side variables might be endogenous if they are correlated with the error in forest volume growth. For these variables, our time series data component allows us to use a lagged value of each variable as a suitable instrument. As discussed in Kennedy (1993) and Greene (1997), lagged variables can be used as exogenous instruments for current values of endogenous variables.[8] Finally, the estimates will be corrected ex post for heteroskedasticity using White's method, and given that our time component involves relatively few observations (see below), we do not expect autocorrelation to be a problem.

3.1. Choice of variables

Our specific choices of variables were dictated both by available reliable data and by the prior qualitative-based literature. Table 1 provides definitions of all variables used in the estimation. Growth rates H_{it} are taken from State Forest Census data compiled for each forest area at a given point in time. Right hand side variables for Eq. (1) were chosen based on those that should be important to harvesting and reforestation behavior by state forest managers, according to the literature. Since the central government sets quotas in principle to keep growth rates from becoming negative, variables that reduce growth rates are certainly correlated to some extent with illegal harvesting beyond the quota that is known to exist throughout China.

The precise information differences between the government and the SOE manager, I_{it} in Eq. (1), are not known in general. We can use area of state natural forests and plantations as proxies for information differences. Support for these comes from the literature on public harvesting (concessions) contracts. There, it has been argued that monitoring and detection of harvesting laws on public government forests are more difficult as area of the concession increases (Poore, 1993; Gray, 2000; Palmer, 2000; Johnson, 2002). Anecdotal evidence on Chinese forestry also supports use of these proxies. For example, it has been suggested that state forest enterprises with larger landholdings are more effective at hiding their operations from government inspectors and logging beyond the specified quotas. Larger areas also make it more difficult for government personnel to monitor harvest operations.[9] We

[6] Others working with Chinese provincial agricultural crop data have also used dummy variables corresponding to time periods, rather than provinces, to explain the level and changes of total provincial (state and collective) timber volume, but these were insignificant (see Rozelle et al., 1998). Given that Eq. (1) is a regression explaining the growth of state forest volume, adding time-specific dummies to control for changes of growth rates over provinces does not make sense, especially given that the random effect component of the error term ε_{it} already accounts for time-specific variation in the dependent variable.

[7] Results from the full model are available from the authors upon request.

[8] We used one period lags for suspected endogenous variables. Use of more elaborate or higher lags did not make sense given that the relatively small number of time periods in our data would reduce degrees of freedom considerably.

[9] There are many reported instances showing how larger state forest area contributes to illegal logging. In some cases, Ministry of Forestry personnel visited SOEs to carry out on-spot checks for whether logging practices are in compliance with the state-mandated quota. They were given a tour of the forest operations by SOE managers and staff. However, in some of the larger forests, the state forest management staff could always lead the supervision staff to well-preserved and well managed tracts, avoiding the areas where illegal logging or lack of reforestation had been implemented. Often, the Ministry personnel visited different locations of the same logging operation on different days, never knowing they had not left the immediate area or that they were viewing the same operation (Xu et al., 2000).

Table 1
Definitions of variables and units of measurement*

Ttvols_rate (H_{it})	average annual growth rate of timber volume (%)
Tvols_diff (H_{it})	difference in volume across periods (100 m^3)
Urban (P_{it})	urban population as a share of total population (proportion)
Mindex (P_{it})	ratio of total sown area to total arable land area
Nagdp (P_{it})	non-agricultural GDP as a share of total GDP (proportion)
Density (P_{it})	agricultural population density (persons per square kilometer)
Tvols (S_{it})	timber volume of the all state forest enterprises and plantations added together (100 m^3)
Afforestion ratio (S_{it})	newly afforested area as a share of total forest land area in state forests (proportion)
Area1 (I_{it})	weighted average managed area of state forest operations (100 ha)
Area2 (I_{it})	weighted average afforested area of state forest operations (100 ha)
Area3 (I_{it})	simple average managed area of state forest operations (100 ha)
Area4 (I_{it})	simple average afforested area of state forest operations (100 ha)
pvratio (S_{it})	timber volume of plantations as a share of total state forest volume (proportion)
paratio (S_{it})	area of plantations as a share of total state forest area (proportion)

* Symbols in parentheses correspond to Eq. (1) elements.

therefore expect higher natural forest and plantation area to negatively affect forest growth rate in Eq. (1), despite the positive effect that plantations should have on forest growth in regulated forest situations. We also expect that plantations and natural forests entail different information resources, and therefore we treat them as separate variables. As we discuss later, we will use four different area variables in the estimation, none of which is a systematic function of another.

Other variables important in the estimation of Eq. (1) include measures of forest stocking (S_{it}), such as the share of natural forest and plantations relative to all state forests within each province at a given time period. These are taken from the State Forest Census. According to Rozelle et al. (1998); Rozelle et al. (1997a) a province's endowment of land and rural labor should be important in land conversion of forests to competing agricultural uses. Other forest exploitation work has established that economic pressure to harvest forests is described best by urbanization and migration trends in the region (Hyde et al., 1996; Amacher et al., 1998). Following this work, we measure market factors P_{it} using agricultural population densities in each province over time, indicative of the competition for land uses that forest managers face. We also use multi-cropping indices to indicate the intensity and opportunity for agricultural production in each province at a given point in time, and other economic and demographic factors important to wood demand are used. The latter include urbanization indicators and variables measuring the marketability and profitability of harvested logs. Also, included in the P_{it} vector are measures of economic growth such as non-agricultural gross domestic product as a percentage of total gross domestic product.

Finally, G_{it} is a measure of the harvesting quota set by the Central government, and it should reflect allowable harvest levels by SOE managers in each time period. This policy variable should indirectly affect forest growth given our discussion of the interactions between managers and government authorities. Moreover, including G_{it} in the regression means we can identify the effects of information proxies and other variables on forest growth decline, holding government quota levels constant.

3.2. Data specifics and descriptive statistics

China's national forest resource census data was collected for all 28 provinces in five periods. These data are less vulnerable to problems inherent in forest statistics collected by traditional survey-based collection methods. The census surveys for forest characteristics (volume and growth rates) were carried out by the Ministry of Forestry in the early 1970s (QGSLZYTJ, 1980), late 1970s (QGSLZYTJ, 1983), mid to late 1980s (QGSLZYTJ, 1989), early 1990s (QGSLZYTJ, 1994) and late 1990s (QGSLZYTJ, 1998).[10] These surveys were collected through a comprehensive sampling of permanent plots by trained enumerators. The survey results did not pass through the normal governmental hierarchy, avoiding a well-known source of bias. Rather, the results were collated and published by the Ministry of Forestry in Beijing. Rozelle et al. (1998) have used these data to examine trends in agricultural production; they describe the data collection process in more detail and provide additional arguments for why it was completed in a consistent manner that minimized misreporting bias.[11]

Sampling of forest stocking relied on visiting the same fixed land points in each census. Rozelle et al. (1998) point out that, for the Yunnan Province, census organizers randomly chose 7975 plots of 0.08 ha in size throughout the province to estimate forest yield. Of these plots, only 30% contained forests, while the remainder covered cultivated land, urban districts, lakes, and other non-forested regions. Enumerators visited the precise location of each plot in follow-up sampling. Yunnan forest bureau officials claim that over 95.5% of the plots surveyed in the late 1970s were resampled in 1988. Similar statistics apply to the 27 other provinces included in the sample. Referring to Table A5 in Appendix A, forest volume is highest for state forests in the Southwestern and Northwestern parts of China. Growth rates vary considerably over provinces and differ by as much as 8%; growth rates are most positive in provinces where plantations are prevalent.

Table 2
Descriptive statistics of selected variables*

Variable	Mean	S.D.
Tvols_rat	1.09	10.46
Density	211.61	162.73
Nagdp	0.796	0.102
Mindex	1.59	0.53
Urban	0.26	0.15
Tvols	2108358	3931413
Area1	437.52	722.68
Area2	332.69	603.76
Area3	175.85	226.18
Area4	84.49	110.11
pvratio	0.33	0.31
paratio	0.40	0.30
Afforestation ratio	0.03	0.12

* Based on 112 observations.

Tables 2, A1, A2, A3 and A4 in Appendix A present descriptive statistics for all other variables used to estimate Eq. (1). The variables Area1 and Area3 represent areas of natural managed state forests, while Area2 and Area4 represent areas of state-owned forest farm areas (plantations). All four are measured in 100 ha. The differences between area variables reflect different ways of computing them. Since there is a large difference in the average area between natural forest-based and plantation-based state forest operations, we compute both simple average and weighted average areas. Area3 and Area4 represent simple averages given by total state forest area in either natural forest or plantations divided by the total number of state forest enterprises of each type in each province.

Area1 and Area2 are defined as weighted averages, where we correct for the number of state forest enterprises in each province. Area1 is defined by multiplying the fraction of area of state timber forest enterprises divided by the number of state forest enterprises by the fraction of area of state

[10] We have data of 28 provinces for five census periods. However, in 1976 survey, there was no differentiation between state forest and collective forests in the census. Therefore, only the data from the 1981, 1988, 1993, and 1997 censuses can be used for our analysis.

[11] For example, in one province officials estimated that more than 80% of the survey personnel participated in the 1980 surveys (Rozelle et al., 1998).

forest enterprises divided by total state forest area in each province. Area2 is a similarly constructed weighted average for plantations. Referring to Table 2, the weighted averages are generally two to three times higher than the simple averages, because the weighted averages put more weight on provinces with larger state forests. State-owned natural forests are found mainly in the Northeast, Southwest and Northwest, while plantations are distributed more or less evenly across the country. For example, in the Heilongjiang province, there are 49 large natural state forest enterprises and 368 state plantations.

Population density has been shown to affect forest exploitation (Hyde et al., 1996). In China, the population classified as agricultural rose steadily during the sample period. However, densities vary widely across the sample, from 4.05 people per square kilometer to 728 people per square kilometer, with an average of approximately 212 people per square kilometer (see Density in Table 2). Otsuka (1997) found that land quality had a significant impact on forest area in China, since farmers with better agricultural resources were less likely to exploit forests contained on the farms. Quality of land in our data is measured using a multiple cropping index (Mindex in Tables 1 and A2). This index is calculated as the ratio of total sown area to total arable land area in each province, and it equals 1.59 for the country as a whole (Table 2). It also varies considerably across provinces in our data and is highest in the Southern provinces. Growth in the non-agricultural sector (Nagdp in Tables 2 and A4) is directly related to local domestic demand for timber and other forest products, and to wages and off-farm employment opportunities, the latter of which may reduce pressure on local forest resources. Hence, its expected impact is ambiguous.[12]

[12] Sufficient caution must be exercised in adding these economic factors into the variables that may affect the growth of timber volume in our provincial-based panel data. Given that there is a very strong unbalanced distribution of (state) forests in China, and that the regions demanding most of the timber (usually in the more economic developed coastal areas) are not the regions that supply most of the national timber output, a more or less integrated national timber market means that local economic factors mentioned above might not be important driving forces of local provincial-based forest volume changes. We include the variables because of previous literature, noted above, supporting their impacts on forest exploitation.

The best measure we have for the government harvesting quota is lagged values of timber volume in each province (tvols_lag in Table 1). This variable is an appropriate instrument, because the government sets quotas each period based primarily on forest volume in the previous period, with the overriding goal as one of holding provincial state forest volume and forest growth rates constant at some formula target. Thus, regions with larger timber volumes are given higher logging quotas. We can show that there is considerable variation in this variable over provinces, because the distribution of natural forests and plantations, and hence volumes, differ across provinces (see Table A5).

New plantation establishment in each province is measured using the lagged value of state-owned new plantation area as a percentage of total state forest area (‘Afforestation ratio’ in Table 1). This reflects planting investments made on state-owned forests between two consecutive censuses. It is correlated with the cost of planting during each time period and in each province. It is expected that the estimated coefficient of Afforestation ratio in Eq. (1) should be positive, as new plantations increase forest growth rates. Referring to Table 2, the afforestation ratio is approximately 3% on average in each province.

Finally, as an appropriate measure of state forest age structure we employ two variables. Referring to Table 1, the first is the timber volume of existing state forest plantations as a share of total volume of state forests in each province (pvratio). The second measure is a proportion of the area of plantations relative to total state forest area in each province (paratio). The second measure differs from the ‘Afforestation Ratio’ variable discussed above, because it includes all plantations in a province. Including pvratio and paratio will accommodate possible differences in the impacts of age structure between natural forests and plantation forests on the forest growth rates. We will therefore use these as a form of specification testing.

4. Econometric results

Results from estimating Eq. (1) are presented in Table 3. Several versions of the regression are

Table 3
Fixed effects estimation results for Chinese state-owned forests, for 28 provinces and the periods 1981–1997. Dependent variable is natural log of volume growth rate. Estimated robust *t*-statistics are in parentheses[1,2]

	(1)	(2)	(3)	(4)
Mindex	6.169	15.901	5.282	15.041
	(0.63)	(1.53)	(0.55)	(1.48)
Urban	143.574	119.182	142.374	119.977
	(2.71)***	(2.30)**	(2.68)***	(2.32)**
Nagdp	−20.797	−8.108	−20.662	−13.012
	(0.66)	(0.23)	(0.62)	(0.38)
Tvols_lag	−8.14e-06	−7.42e-06	−8.16e-06	−7.97e-06
	(2.66)***	(2.39)**	(2.38)**	(2.62)**
Density	−0.278	−0.328	−0.259	−0.309
	(1.89)**	(2.12)**	(1.79)*	(2.05)**
Afforestion ratio	81.694	96.726	86.946	97.558
	(1.92)*	(2.48)**	(2.24)**	(2.59)**
ln Area1_lag	−11.787			
	(2.32)**			
ln Area2_lag		−13.963		
		(2.43)**		
ln Area3_lag			−9.547	
			(2.07)**	
ln Area4_lag				−13.315
				(2.42)**
Constant	33.891	35.141	24.384	34.236
	(0.64)	(0.72)	(0.46)	(0.71)
Observations	84	84	84	84
R-squared	0.53	0.56	0.51	0.56

[1] * = significant at 10%; ** = significant at 5%, *** = significant at 1%.
[2] A 'lag' suffix is defined as the one period lag of the variable, while an 'Ln' prefix refers to the natural log of a variable.

presented that differ according to the area measures used (see Table 1). All versions have consistent results. Significant variables at the 0.05 level and higher include the lagged value of SOE forest volume (−), Afforestation (+), population density (−), plantation and natural forest area measures (−), and the urbanization measure in one case (+). These signs are fully expected given our earlier discussion. Increased state forest areas increase the likelihood of illegal logging according to the qualitative-based literature. Our results confirm this; we find that larger areas of plantations and natural forests contribute to lower growth rates for state forests. The fact that the afforestation ratio variable positively affects forest growth suggests that inadequate reforestation can indeed also be an important contributor to unsustainable forest growth trends in China if in fact managers under-reforest. Our findings for agricultural population density are also consistent with other work, suggesting that increasing pressures on harvesting forests for economic growth and rural labor market development reduces forest growth rates of Chinese forests. The lagged value of state forest volume also has an expected negative sign, since higher quotas are known to induce greater harvesting.

A closer examination of the area variables reveals some interesting new interpretations. Recall that larger areas of SOEs have been associated with greater difficulties the government has in monitoring forest manager decisions. Larger areas therefore might imply a larger wedge between information possessed by the forest manager and the government. In Table 3, note that the weighted average measures appear to be more significant predictors of growth rate declines than the simple average measures (compare Area2 and Area4 with Area1 and Area3). Note also that natural forests and plantations are not equivalent. Instead, the effect of larger plantation area on growth rate decline is approximately 30% more important than the impact of natural areas.

The findings that weighted averages and larger afforestation areas are better predictors of forest growth decline in China, and hence to information asymmetries, make sense. The former shows that the number of state forests should factor into the government's ease of monitoring and detection of local manager decisions. A manager in a province with many state forests may find the expected benefit of not following the quota to be greater. The latter follows because afforestation areas are often the only place where the government visits, and therefore these serve as the prime means for local managers to mislead government inspectors regarding harvesting and reforestation operations on the state forest. Thus, plantation areas should be more important in explaining forest volume growth rate than the largely remote natural forest areas. Plantations should also be a specific target of government policies seeking to move China's forests to a more sustainable state. Clearly, the importance of plantation area relative to natural forest area implies that plantation area is the best indicator of incentive differences between forest managers and the government.

4.1. Specification tests

We now turn to some important tests of our specification, ex post to estimation. The most important is to investigate whether the results are sensitive to additional measures of forest age struc-

Table 4
Robustness test for information asymmetry (area) variables using fixed effects estimation. Dependent variable is natural log of volume growth rate. Estimated robust *t*-statistics are in parentheses[1]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mindex	6.417	16.193	6.045	15.737	6.988	16.066	6.213	15.340
	(0.63)	(1.56)	(0.59)	(1.53)	(0.71)	(1.55)	(0.64)	(1.51)
Urban	140.312	115.383	132.431	111.271	109.469	98.845	104.813	96.703
	(2.10)**	(1.85)*	(1.96)*	(1.77)*	(1.55)	(1.48)	(1.46)	(1.44)
Nagdp	−20.948	−8.279	−21.342	−13.449	−22.844	−8.823	−23.681	−13.794
	(0.66)	(0.24)	(0.65)	(0.39)	(0.74)	(0.26)	(0.74)	(0.41)
Tvols_lag	−7.55e-06	−7.50e-06	−7.50e-06	−7.58e-06	−7.50e-06	−7.10e-06	−7.50e-06	−7.58e-06
	(2.53)**	(2.31)**	(2.24)**	(2.49)**	(2.43)**	(2.26)**	(2.15)**	(2.46)**
Density	−0.286	−0.337	−0.284	−0.331	−0.346	−0.367	−0.333	−0.355
	(1.63)	(1.96)*	(1.58)	(1.92)*	(1.89)*	(2.01)**	(1.81)*	(1.96)*
Pvratio_lag	1.297	1.507	3.894	3.408				
	(0.09)	(0.11)	(0.30)	(0.26)				
Paratio_lag					17.038	10.729	18.491	12.118
					(1.06)	(0.64)	(1.14)	(0.73)
Afforestation ratio	82.466	97.628	89.073	99.571	79.502	95.936	84.009	96.575
	(1.80)*	(2.42)**	(2.18)**	(2.61)**	(2.11)**	(2.80)***	(2.46)**	(2.96)***
Ln Area1_lag	−11.791				−12.053			
	(2.31)**				(2.46)**			
Ln Area2_lag		−13.968				−13.612		
		(2.41)**				(2.31)**		
Ln Area3_lag			−9.652				−10.120	
			(2.12)**				(2.21)**	
Ln Area4_lag				−13.367				−13.038
				(2.43)**				(2.32)**
Constant	37.351	39.163	35.412	43.560	67.006	53.073	62.362	55.077
	(0.60)	(0.70)	(0.54)	(0.75)	(0.93)	(0.84)	(0.82)	(0.85)
Observations	84	84	84	84	84	84	84	84
R-squared	0.53	0.58	0.51	0.57	0.54	0.58	0.53	0.58

[1] * = significant at 10%; ** = significant at 5%, *** = significant at 1%.

ture. To do this we introduce volume and area of plantations as a share of total state forest volume and area (pvratio and paratio in Table 1) into Eq. (1) and re-estimate it. The null hypothesis implicit in this re-estimation was that the estimated coefficients for the area variables remained the same. Table 4 presents the results. From the table, we see that the new variables are not statistically significant and do not alter the basic findings. This means that our existing set of variables in Table 3 sufficiently correct for forest age structure differences. It also confirms that our estimation results are robust, in the sense that measures of average areas for state forest operations still have significant and negative signs, and the coefficients for the other significant variables are unchanged.

5. Concluding remarks

Using data from 28 provinces and five census periods, we examined for the first time what variables have been important to declines in forest growth rates for China's state-owned forests since the 1970 reforms, which gave increased autonomy to local forest managers. Variables used in our estimation were chosen according to those that should affect local forest manager exploitation of forests; in addition to growth and market factors, some variables are in part related to either over-harvesting beyond government quotas or under-reforesting. Those variables we identified as significantly reducing growth rates are those that are important for moving Chinese forests to unsustainable states, and therefore they are indicative of appropriate policy targets for the government.

The relationship between local forest managers and the central government is best described by a divergence of incentives to make harvesting and reforestation decisions in a sustainable manner. Managers are promoted based on profit generation from harvesting, while the centrally-located government imposes limits on maximum harvesting in an attempt to keep forest growth either increasing or stable. The government cannot effectively monitor manager decisions given the sheer size of state forests, and penalties for non-compliance are often not assessed.

The key premise we assume, and then find to hold, in our empirical model is that the larger the size of state forests under control of local managers, the greater is the reduction in forest growth rates. Following a large set of qualitative literature, we surmise this is because information differences between managers and supervising authorities become larger as the size of state forests increase. Interestingly, the size of plantations on state forests is more important than the size of remote natural areas, at least with regard to growth rates. Economic factors are also important to forest growth trends given state forest manager profit incentives, and we find that these are significant predictors of forest volume growth on state forests. Higher forest volumes and less stringent central government harvest quotas predictably lead to significant declines in growth, while new afforestation investments appear to be significant and positive factors in increasing growth of China's state forests according to our data.

Our results have implications for the recent ban on logging in state-owned forests. The work here indicates that the logging ban may not be effective either in increasing forest growth over time or moving China's national forests to a more regulated condition. Rather, the results could be used to argue that other means should be explored in the long run to ensure reforestation is adequate and harvesting is reduced. Any policy that can remove the wedge in incentives of local forest managers and the central government would be most effective in this regard. An example might be to decentralize forest management to local communities and allow them to share in the long-term benefits generated from the forests. Or, manager compensation could be more closely linked to the area of afforestation, and advances in GIS might be used as a low-cost monitoring tool. Programs such as these could provide specific incentives for afforestation and also reduce the cost of monitoring efforts by the government.

Appendix A

Tables A1, A2, A3, A4 and A5

Table A1
Density of agricultural population by region[1]

Region*	1981	1988	1993	1997	1981–1997 Percent change
1. Northeast region	26.32	26.52	27.23	28.10	6.76
2. Southwest region	120.03	126.74	131.37	136.45	13.68
3. Northwest region	18.23	19.42	21.13	22.35	22.60
4. Southern region	213.49	226.02	238.06	247.16	15.78
5. Less forested region	263.87	276.03	286.54	293.67	11.29
China	99.33	104.38	109.17	112.91	13.71

[1] The region division is based on convention in forest statistics. Northeast (state forest) region includes Heilongjiang, Jilin and Inner Mongolia. The Southwest (state forest) region includes Sichuan and Yunnan. The Northwest (state forest) region includes Xinjiang, Qinghai, Gansu, and Sha'anxi. The Southern (collective forest) region includes Anhui, Zhejiang, Hubei, Hunan, Jiangxi, Fujian, Guangdong, Guangxi, Guizhou and Hainan. The less forested region includes Liaoning, Beijing, Tianjin, Hebei, Shanxi, Ningxia, Henan, Shandong, Jiangsu and Shanghai.

Table A2
Multi-cropping index by region

	1981	1988	1993	1997	1981–1997 Percent change
1. Northeast region	0.97	0.95	0.97	0.92	−5.15
2. Southwest region	1.71	1.79	1.92	1.98	15.79
3. Northwest region	1.06	1.11	1.12	1.13	6.60
4. Southern region	2.06	2.09	2.17	2.34	13.59
5. Less forested region	1.41	1.49	1.51	1.49	5.67
China	1.47	1.51	1.55	1.55	5.44

Table A3
Urbanization level by region

	1981	1988	1993	1997	1981–1997 Percent change
1. Northeast region	33.72	37.30	40.01	41.00	21.59
2. Southwest region	12.13	14.00	15.64	16.95	39.74
3. Northwest region	18.70	21.22	22.15	23.04	23.20
4. Southern region	14.25	17.48	19.95	21.55	51.23
5. Less forested region	17.67	21.01	24.63	26.48	49.86
China	17.03	20.07	22.81	24.36	43.04

Table A4
Non-agricultural GDP share by region (%)

	1981	1988	1993	1997	1981–1997 Percent change
1. Northeast region	75.43	79.86	81.07	78.39	3.92
2. Southwest region	60.37	71.63	77.75	82.05	35.91
3. Northwest region	69.97	77.43	79.61	82.52	17.94
4. Southern region	64.34	76.27	82.27	86.73	34.80
5. Less forested region	79.25	84.82	88.56	90.71	14.46
China	72.40	80.34	84.70	87.57	20.95

Table A5
Volume and growth of state forests

	Volume of state-owned forests					Growth rate of state-owned forest timber volume (%)		
	1981	1988	1993	1997	1981–1997 Percent change	1981–1988	1988–1993	1993–1997
1. Northeast region	31 440 658	31 532 286	33 584 623	34 283 066	9.04	0.04	1.27	0.52
2. Southwest region	15 173 948	17 303 504	17 105 596	17 498 787	15.32	1.94	−0.23	0.57
3. Northwest region	4 312 335	4 546 107	4 511 610	4 673 109	8.36	0.76	−0.15	0.88
4. Southern region	2 338 061	1 859 868	2 343 239	2 546 954	8.93	−3.22	4.73	2.11
5. Less forested region	1 344 982	1 147 616	1 993 696	1 651 041	22.76	−2.24	11.68	−4.61
China	54 561 958	56 389 381	59 538 764	60 652 957	11.16	0.47	1.09	0.46

References

Alford, W.P., Shen, Y., 1998. The limits of the law in addressing China's environmental dilemma. In: McElroy, M.B., Nielsen, C.P., Lydon, P. (Eds.), Energizing China: Reconciling Environmental Protection and Economic Growth. Harvard University Press, Cambridge, pp. 405–429.

Amacher, G., Cruz, W., Grebner, D., Hyde, W., 1998. Environmental motivation for migration: population pressure, poverty, and deforestation in the Philippines. Land Economics 74 (1), 92–101.

Brandt, L., Zhu, X., 2000. Redistribution in a decentralized economy: growth and inflation in China under reform. Journal of Political Economy 108, 422–439.

Chen, X., Lu, X., April 1999. Natural forest resource conservation and sustainable management in key forest areas. Forestry Economics 2, 9–16.

China Forestry Yearbook (1988, 1991, 1996). China Forestry Publishing House, Beijing.

Economy, E. 1997, The Case Study of China: Reforms and Resources: The Implications for State Capacity in the PRC. Occasional Paper, Project on Environmental Scarcities, State Capacity, and Civil Violence. Cambridge: American Academy of Arts and Sciences and the University of Toronto.

Gray, J. 2000. Forest Concession Policies and Revenue Systems: Country Experience and Policy Changes for Sustainable Tropical Forestry. World Bank Technical Paper, Forest Series, Washington DC.

Greene, W.H., 1997. Econometric Analysis. Prentice Hall International, London.

Hey, J.D., Lambert, P.J. (Eds.), 1987. Surveys in the Economics of Uncertainty Blackwell, Oxford.

Hyde, W.F., Amacher, G.S., William, M., 1996. Deforestation and forest land use: theory, evidence, and policy implications. The World Bank Research Observer 11 (2), 223–248.

Johnson, S., 2002. Documenting the undocumented. Tropical Forest Update 12 (1), 6–14.

Lin, Y., March 1992. Rural reforms and agricultural growth in China. American Economic Review 82, 34–51.

Lin, Y., Cai, F., Li, Z., 1999. China's Miracle, Second ed. Shanghia Sanlian Press.

MOF (Ministray of Forestry), 1997, China Forestry Yearbook 1996, China Forestry Publishing House, Beijing.

Otsuka, K. 1997. Property Rigths and Forests in Africa, Working Paper, International Food Policy Research Institute, Washington, DC.

Palmer, C. 2000. The Extent and Causes of Illegal Logging: An Analysis of a Major Cause of Deforestation in Indonesia. CSERGE Working Paper 0967.

Poore, E., 1993. The sustainable management of tropical forests: the issues. In: Rietbergen, E. (Ed.), The Earthscan Reader in Tropical Forestry Earthscan Publications Ltd, London.

QGSLZYTJ, 1980. Quanguo Senlin Ziyuan Tongji [National Forest Resource Statistics]. Ministry of Forestry, 1983–1989. Beijing.

QGSLZYTJ, 1989. Quanguo Senlin Ziyuan Tongji [National Forest Resource Statistics]. Ministry of Forestry, 1983–1989. Beijing.

QGSLZYTJ, 1998. Quanguo Senlin Ziyuan Tongji [National Forest Resource Statistics]. State Forestry Administration: Beijing.

Ross, L., 1988. Environmental Policy in China. Indiana University Press, Bloomington, IN.

Rozelle, S., Albers, H., Guo, L., Benziger, V., 1998. Forest resources under economic reform in China. China Information 13, 106–125.

Rozelle, S., Huang, J., Husain, S.A., Zazueta, A., 2000. China: From Afforestation to Poverty Alleviation and Natural Forest Management. The World Bank, Washington, DC.

SFA (State Forestry Administration), 2001, China Forestry Development Report 2000, Beijing: China Forestry Publishing House.

Sun, C., 1992. Community forestry in Southern China. Journal of Forestry 90, 35–39 [in Chinese].

Xu, M., Qi, Y., Gong, P., 2000. China's new forest policy. Science 289, 2049.

Xu, J., Katsigris, E., White, T.A., 2002. Implementing the Natural Forest Protection Program and the Sloping Land Conversion Program: Lessons and Policy Recommendations. China Forestry Publishing House, Beijing.

Yin, R., 1998. Forestry and the environment in China: the current situation and strategic choices. World Development 26, 2153–2167.