Environment for Development

Discussion Paper Series April 2008 ■ EfD DP 08-11

Economic Growth and the Natural Environment

The Example of China and Its Forests since 1978

William F. Hyde, Jiegen Wei, and Jintao Xu

Environment for Development

RESOURCES FOR THE FUTURE

Environment for Development

The **Environment for Development** (EfD) initiative is an environmental economics program focused on international research collaboration, policy advice, and academic training. It supports centers in Central America, China, Ethiopia, Kenya, South Africa, and Tanzania, in partnership with the Environmental Economics Unit at the University of Gothenburg in Sweden and Resources for the Future in Washington, DC. Financial support for the program is provided by the Swedish International Development Cooperation Agency (Sida). Read more about the program at www.efdinitiative.org or contact info@efdinitiative.org.

Central America
Environment for Development Program for Central America
Centro Agronómico Tropical de Investigacíon y Ensenanza (CATIE)
Email: centralamerica@efdinitiative.org

China
Environmental Economics Program in China (EEPC)
Peking University
Email: EEPC@pku.edu.cn

Ethiopia
Environmental Economics Policy Forum for Ethiopia (EEPFE)
Ethiopian Development Research Institute (EDRI/AAU)
Email: ethiopia@efdinitiative.org

Kenya
Environment for Development Kenya
Kenya Institute for Public Policy Research and Analysis (KIPPRA)
Nairobi University
Email: kenya@efdinitiative.org

South Africa
Environmental Policy Research Unit (EPRU)
University of Cape Town
Email: southafrica@efdinitiative.org

Tanzania
Environment for Development Tanzania
University of Dar es Salaam
Email: tanzania@efdinitiative.org

Economic Growth and the Natual Environment: The Example of China and Its Forests since 1978

William F. Hyde, Jiegen Wei, and Jintao Xu

Abstract

China's rapid growth over almost 30 years and its consistent forest data across 28 provinces provide an unusual opportunity to examine frequently discussed questions about macroeconomic and population impacts on the forest. The data support a theoretical argument for separating forests into four components, managed and natural forests administered by either state or private agents. Our regressions suggest 1) cautious optimism for a restrictive dual to Malthusian arguments about population—that is, declining rural populations may go hand-in-hand with forest recovery; and 2) more confident support for a variation of the environmental Kuznets curve for forests; that is, as incomes rise, the natural forest is first drawn down, then, when incomes rise above some level, the natural forest begins to recover. As incomes continue to rise, the managed forest eventually grows even more rapidly and offsets any continuing draw on the natural forest, with an aggregate impact of net expansion for all forests, managed and natural combined. The question that must arise is whether these environmentally satisfying results for China would be prove to be global—if comparable forest data were available elsewhere.

Key Words: Forests, China, Malthus, Kuznets, population, income growth

JEL Classification Numbers: Q23, Q28, P28

Contents

Economic Growth and the Natural Environment: The Example of China and Its Forests since 1978

William F. Hyde, Jiegen Wei, and Jintao Xu*

1. Introduction

The discussion of the effects of aggregate growth on the natural environment has a long history and it continues to receive attention among economists. Two arguments deserve special note. The first maintains that early economic growth in the overall economy is tied to a decline in the natural environment but further growth beyond some level is correlated with environmental recovery. The second argues that population growth leads to environmental decline. The discussion has spawned numerous assessments. (See Dasgupta et al. [2002] and Copeland and Taylor [2004] for reviews of the first argument, and Malthus [1798] and many successors [e.g., Meadows et al. 1972] for examples of the second.) Nevertheless, few have drawn convincing conclusions regarding the effects of either economic growth or population growth on the forest environment—although forests account for an immense 29.6 percent of all global land area (FAO 2001). Good measures of the effects of aggregate growth on the forest are crucial to the global policy dialogue because two other critical issues, biodiversity and climate change, are central to all discussion of global policy and because forests are key resources in any attempt to address either. Forests contain most of the remaining unidentified global biodiversity and forest growth is a fundamental component in any attempt to affect the global carbon balance and mitigate climate change.

The objective of this paper is to revisit the questions of macroeconomic and population effects on the forest. We will use data from China and we will separate forests into their managed and natural, and state-owned and non-state, components in an attempt to find convincing economic and statistical results. Most assessments of forests and those other assessments that make use of forest data overlook these distinctions. Indeed, the official forest

---

* William F. Hyde, University of Gothenburg, (address) 1930 South Broadway, Grand Junction, CO, USA 81503, (tel) 1-970-245-5901, (email) wfhyde@aol.com; Jiegen Wei, Environmental Economics Unit, Department of Economics, University of Gothenburg, Sweden; and Jintao Xu, Natural Resource Economics, Department of Environmental Sciences, Peking University, Beijing 100871, P.R. China. Author order is unassigned. Thomas Sterner and seminar participants at the University of Gothenburg and China’s Center for Agricultural Policy Research, Chinese Academy of Sciences, provided helpful critique.

data for most countries do not make these distinctions. Our discussion and our analytical results will demonstrate their importance.

Official measures of what constitutes a forest vary from country to country by as much as four orders of magnitude.[1] Therefore, consistently measured data from one large and diverse country such as China are an advantage for our assessment. China's rapid economic growth since the introduction of its economic reforms in 1978 adds to this advantage, creating an unusually broad range of both forest and economic data for one nation or even one region of the world. Moreover, China is an interesting example because its economic growth and its forests are especially important in the policy dialogue about climate change. For example, the United States has given China's exemption (as a less-developed country) from the forest cover requirements of the Kyoto Protocol as one reason it chooses to remain the lone significant non-signatory to that international agreement.

The distinctions between managed and natural, and state-owned and non-state, forests are important to any economic characterization of those resources. Managed forests are responsive to market conditions while many natural forests are remote and removed from the market effects. Private forests, similarly, are generally responsive to economic conditions while state-owned forests are often managed according to other, administrative and non-market, criteria. We will argue that these distinctions, supported by the remarkable array of China's data, encourage three convincing observations with respect to growth and the environment.

- First, beyond some level of economic development, income growth is, indeed, associated with growth in managed forests, but natural forest cover may decline.
- Second, beyond some greater level of economic development, income growth may also be associated with recovery of the natural forest environment. However, the institutions of public management instruct caution with these generalizations. The effect of these institutions on the natural forest can be as important as the effect of economic growth, yet their effect is not always positive.
- Third, regarding the Malthusian hypothesis, it is important to distinguish the rural population from the aggregate population. As rural population density generally declines

[1] The minimum area for forest classification in Papua New Guinea, is 10,000 times that for the Czech Republic (Lund 2000, as reorganized and cited in Hyde [2005, 193-210]).

with economic growth, this decline has a beneficial effect on both the managed and the natural components of the forest.

We posit that these three observations for China are general for many other countries as well. We suspect that they are global for forestry, and we suspect that they may have counterparts for other renewable natural environments—if those, too, are examined within the context of similar distinctions in resources and in the institutions that manage them.

The first section of our paper summarizes China's experience with market reform and economic growth since 1978. The second section introduces the economic basis for our distinctions between managed and natural forests and between state and non-state ownerships, and then summarizes China's recent history with respect to these characteristic forest categories. The analytical body of the paper follows, first with a discussion of our model, and then with our econometric results. A final section summarizes and suggests policy implications and the potential global generality of our results.

2. China's Market Reforms and Economic Growth

China entered its period of market reforms in 1978 with reforms in agricultural property rights in Fengyang County in Anhui Province. The decentralization of property rights and an adjustment in government procurement prices were the fundamental elements of the early reforms. Property rights for land and agricultural capital were transferred from collectives to individual households and unified government procurement prices for crops were first adjusted upward and eventually, in 1985, eliminated in favor of market transactions. These reforms took different forms in different counties and provinces, but by 1984 the majority of agricultural households across the country had long-term "household responsibility" contracts for both land and the capital implements of agricultural production. Land productivity increased 225 percent and the productivity of agricultural labor increased 172 percent in a period of only six years.[2]

Two additional rounds of market reforms followed. New rural wealth became a source of funding for the development of rural township and village enterprises (TVEs). Initially, the TVEs were responsible to local authorities under contracts similar to those in agriculture. The TVEs grew rapidly, absorbing underemployed labor from agriculture at an annual rate of 15

[2] See Hyde et al. (2003, 1–21) for a chronology of China's market reforms with emphasis on the agriculture and forest sectors.

percent. Their share of rural production increased from 26 percent in 1984 to 45 percent in 1992—by which time the TVEs had become almost completely market-oriented. They accounted for one-half of the increase in China's per capita income during the 1980s. The first signs of change in China's previously egalitarian distribution of income also appeared during this period. Nearly all households benefited, but they did not all benefit uniformly. Households in urban and eastern coastal regions tended to benefit more.

Industrial and financial reforms got their start in the late 1980s, and they too emphasized the contracted transfer of responsibilities that had been so successful in agriculture. The central authorities maintained control over most of the capital investments of the largely urban state-owned enterprises (SOEs), but they transferred discretion for variable inputs and for output levels to the enterprise managers. The productivity of the full manufacturing sector increased as a result, at an annual rate of more than 15 percent between 1980 and 1990.

A third round of reforms began in 1991 when the central government allowed the sale of some SOEs. Seventy percent of small SOEs were privatized by 1997. Beginning in 1995, the central authorities allowed managers of the remaining SOEs to release redundant employees and, by 1998, one-fifth of all employees of SOEs (seven million workers) had been released. Many found employment in the rapidly expanding private sector. Meanwhile, the government simplified the tax system, decreased the number of civil servants, and liberalized international trade. Household incomes continued to grow and savings, the fuel for further investment, grew to a phenomenal 62 percent of gross domestic product (GDP) in 1998.

In sum, China's market reforms have been a source of remarkable growth over the last quarter century. Nevertheless, despite the reforms, the central authority retains a major role in China's economy today and, of special interest to us in this paper, in its forest sector in particular.

Table 1 summarizes the growth in per capita income and also in agricultural production, a crucial measure for a population that was approximately 80 percent rural in 1978 and which remains about 60 percent rural today. The value of agricultural production increased 13 times over (from 112 billion to 1,487 billion yuan in 2003 values), while the land area under cultivation increased less than 2 percent (from 150.1 to 152.4 million hectare). (The land area under cultivation has actually declined 2–3 percent since 2000, while agricultural production has continued to increase.) Per capita annual rural income grew almost 600 percent (from 442 to 2,622 yuan) from 1978 to 2003, but it did not keep up with urban income, which grew an even greater 745 percent (from 1,137 to 8,472 yuan).

Table 1 Summary Statistics: Income and Agricultural Production

	National averages/totals	Highest province	Lowest province
Per capita income 1978[1]			
Rural (yuan)	442	774 (Beijing)	331 (Shanxi)
Urban (yuan)	1,137	1,853 (Shanghai)	637 (Anhui)
Per capita income 2003			
Rural (yuan)	2,622	6,653 (Shanghai)	1,564 (Guizhou)
Urban (yuan)	8,472	14,867 (Shanghai)	6,530 (Ningxia)
Agriculture 1978[1]			
Production (billion yuan)	112.00	28.191 (Jiangsu)	0.513 (Tibet)
Cropland (million hectare)	150.10	11.844 (Sichuan)	unknown (Tibet)
Production/hectare (yuan/hectare)	744.15		
Agriculture 2003			
Production (billion yuan)	1,487.0	59.900 (Shandong)	2.53 (Tibet)
Cropland (million hectare)	152.4	13.684 (Henan)	0.14 (Beijing)
Production/hectare (yuan/hectare)	9,756.0		

[1] Converted to year 2003 values using China's CPI
Sources: China Statistics Bureau 2000 (2004a)

These are national averages, however, and they mask important regional differences. Table 1 also shows the regional extremes. The difference in per capita rural incomes between the highest and lowest income provinces (Beijing and Shanxi, respectively) was 225 percent in 1978.[3] By year 2003, this difference had risen to 425 percent. (Shanghai had the highest per capita income and Ningxia had the lowest by this time.) Perhaps these differences are not surprising for a country that is the world's largest in terms of population and the third largest in land area, a country that ranges from densely populated coastal cities with the best modern infrastructure in the east to sparsely populated continental plateaus 5,200 km to the west, a country that ranges from both the tropics of Hainan and the high himal of Tibet in the south

[3] China is administered as 32 provinces and autonomous regions. The autonomous regions are Beijing, Shanghai, Tibet, and Inner Mongolia. The first two contain the large urban areas of the same names and also the surrounding agricultural lands and forests.

5,500 km north and northeast to the grasslands and deserts of Inner Mongolia and the near boreal forests of Heilongjiang.

Regional income disparities have become a major policy concern in modern China. Per capita gross domestic product in the southwest, for example, is only 44 percent of that in the eastern coastal areas. Income disparities are one important justification for the 12-year, 96.5 billion-yuan (US$ 12 billion) Western Regional Development Program begun in 1998. For us in this paper, however, China's income growth is a source of intertemporal variation and its regional disparities are a source of cross-sectional variation. Variation among observations is a desirable quality in any statistical analysis.

3. Forestry: General Distinctions and China's Recent Experience

China's forests display comparable, if less extreme, variation since 1978. We will review this variation, but first consider two important distinctions in forest classification—the distinction between managed and natural forests and the distinction between forests managed by private households and institutions and those managed by state agencies.

3.1 General Distinctions

Managed forests respond to market forces—otherwise managers would not expend financial resources to manage them. Natural forests, by definition, have been left to grow according to the forces of nature and without substantial human input. Natural forests may have been harvested in the past and they may be harvested again, but their reestablishment subsequent to harvesting is left to natural regeneration, and the subsequent second growth forest remains unmanaged. Natural forests must be of generally lower commercial value than the more market-responsive managed forests. Indeed, some remote natural forests have no commercial value and demonstrate no response whatsoever to the usual market forces.

This distinction anticipates a geographic continuum defined by access to active markets, a continuum from agricultural activities to managed forests to natural forests. Some lower-valued agricultural activities compete with managed forests for land at their mutual margin. Beyond this margin, the intensity of forest management declines gradually until even limited management is no longer economically rewarding. Beyond this latter point, many forests are open access resources and their growth is entirely a function of natural processes.

For the second distinction (between administrative agents), we can anticipate that private landholders are market responsive, particularly on their managed forests. Their (generally smaller) holdings of natural forests are extensions of their managed forests, extensions that may respond to moderate increases in local market prices. For some landholders, these private natural forests are seen as emergency reserves, untouched under normal market and household conditions but crucial resources in times of unusual household need.

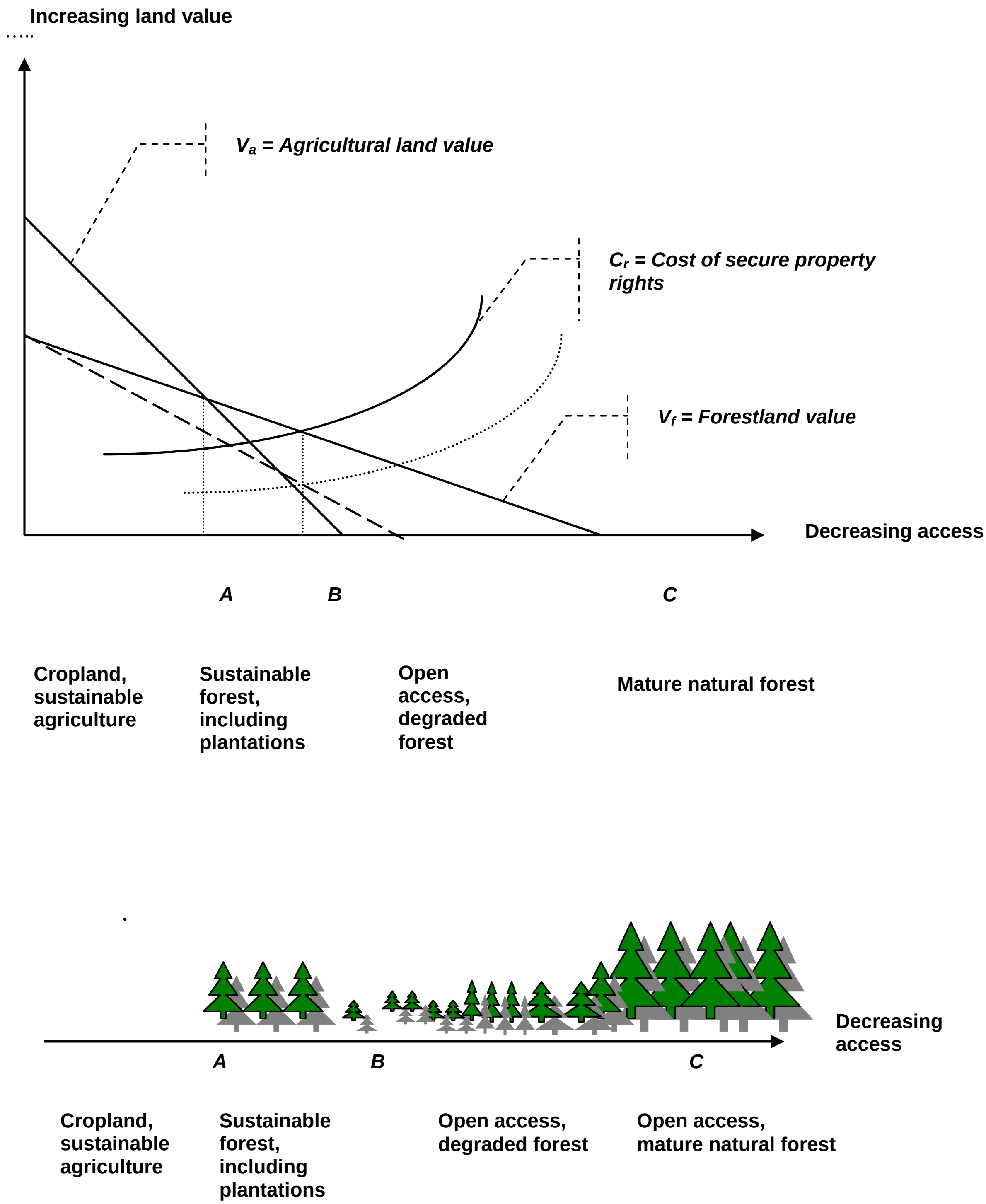
The second set of institutions, state forest agencies, manages many lands that, at the time these agents assumed responsibility, had little commercial value. Some of these lands may have commercial value now. Nevertheless, many state forest agencies manage their commercial forests according to social and political criteria that are at variance with financial criteria. For example, Canada's provinces arguably subsidize their commercial forests and some believe that a full financial accounting would show that the timber operations of the U.S. National Forest System have suffered net losses each year of their existence (Barlow and Helfand 1980; Barlow et al. 1980; Wolfe 1989). In China, the management objective for state-owned forests has been to provide sufficient timber to maintain employment in the mills. Financial criteria have not been important until recently and, as a result, the standing volume of state-owned timber has been drawn down sharply. Many of China's state-owned forests can no longer support either the mills or their own forest workers (Zhang 2001).

Of course, other state forestlands in China and elsewhere, whether of commercial value or not, are managed for non-market values (e.g., parks, watershed management, and natural reserves). Still others are simply remote areas under state stewardship.

These two distinctions (managed or natural forest and state or private administration) anticipate the description of forest lands contained in figure 1 where the vertical axis measures land value net of all costs except the cost of obtaining and maintaining property rights. The horizontal axis reflects ever decreasing access to the geographic center of commercial activity. Agricultural land values are greatest near the commercial center. They decline with decreasing commercial access.[4] Agricultural land value exceeds forest land value near the commercial center but agricultural value declines more rapidly than forest value until managed forestry eventually competes with agriculture at a point like A. Both agricultural and forest product prices affect land management at this point, and forest product prices have both short- and long-term effects inducing both immediate harvesting and also longer-term investment in forest management.

[4] This follows von Thunen's (1826) original description of economic geography. See Samuelson (1983) for a general review and Hyde (2005) for a summary forestry discussion.

Figure 1 The Forest Landscape



The costs of obtaining and enforcing property rights to either agricultural or forest land increase as access decreases—until even the costs of insuring minimal rights to the land eventually exceed the value of land used in either agriculture or forestry at a point like B. Land with positive agricultural or forest value beyond point B becomes an open access resource that is degraded out to a point like C, where forest product prices alone affect land use and the only market response to them is one of short-term resource extraction. Beyond point C the opportunity cost of the extractive activity itself exceeds any value in the extracted natural product. In some poor countries, the degraded open access area between points B and C can be very large. India, for example, has 75.5 million hectares of officially designated wasteland and another 24 million hectares of degraded grazing land, but only 64.1 million hectares of forestland (NRSA 1995; FAO 2001)**.** Finally, the remote lands beyond point C in figure 1 remain in the natural state of a mature forest. Of course, some of these open access forests beyond point B and even beyond point C are sources of important non-market values.

The formulation in figure 1 is clearer for the private sector. The critical points B and C are not as apparent for those state agencies that a) manage some timber according to non-financial criteria, and also b) actively protect the rights to some non-market resources beyond points B and C. Nevertheless, the budgets of all state agencies are limited and, because they are, they limit the extent of those agencies' abilities to vary from the financial criteria that define these two points.

One additional factor, the opportunity cost of labor, has a crucial effect on these two critical points. Since labor opportunities tend to improve as an economy grows, we can anticipate that the impacts of general economic growth and development will proceed through their effect on wages and income to alter the levels of both managed and natural forests. That is, as labor opportunity improves and, therefore, wages and incomes rise, some rural workers will be drawn away from subsistence and even local commercial use of the forest. They have better opportunities elsewhere and can no longer afford to venture as far into the natural forest in pursuit of its resources. Accordingly, the right tail of the forest value function in figure 1 shifts left or inward (dashed line), and points B and particularly C also shift inward. Some natural forest beyond point C becomes recovering secondary natural forest as a result.

We can observe these effects of economic development in any number of countries. The forest inventory in the United States has increased substantially as U.S. income levels have risen over the last 120 years. The state of New Hampshire, for example, was 50 percent forested in the early twentieth century. It is almost 90 percent forested today (USDA Forest Service 2005). Forest cover in France has doubled over the course of the last two centuries (Peyron and Colnard

2002, 169–90). Forest cover increased six-fold in India's Punjab during its period of remarkable economic growth between 1960 and the mid-1990s—as crop area doubled, crop yields tripled and per capita income also doubled (Singh 1994). Surely, we would expect a similar pattern in China as improved property rights have been a feature of China's market reforms and its economic development over the last quarter century, a period during which China has afforested or reforested more than 20 million hectares. China now has more than 47 million hectares of forest plantation, approximately one-quarter of the world's total (FAO 2001).

These distinctions between managed and natural forests and state and private administration, as well as the impact of improved labor opportunity are global. They are also crucial to an understanding of the pattern of forest development in China since its initial market reforms in 1978.

3.2 China's Recent Experience

Modern China initially confiscated feudal agricultural and forest land in the late 1940s and early 1950s. This early policy changed, however, as the government began building a planned economic system. The era of cooperatives and people's communes in mountainous and forest areas began in 1958. In effect, two systems of ownership were established, state-owned forestland under the management of the state-owned forest enterprises (SOFEs—integrated forest bureaus and independent forest farms) and collective forests. A quarter century of decline in the forest base followed before the first agricultural reforms in 1978. By this time, the standing forest volume on the collective lands had declined to an average of 50 m^3/hectare—in comparison with a global average of 100 m^3/hectare (FAO 2001).[5]

The reforms that began in agriculture spread rapidly to other sectors. In forestry, households gained land use rights to collective forestlands (a "contract responsibility system" comparable to the "household responsibility system" in agriculture) as the third component of the "three fix" policy: stabilizing the rights and ownerships of forests and mountains, identifying the boundaries of household plots, and establishing a forest production responsibility system. Change was rapid. By 1984, 30 million hectares or 60 percent of the land area in collective forests had been transferred to 57 million individual households and many households began drawing on their own resources to reforest the new lands they managed (Yin and Newman 1997,

[5] See Xu and Hyde (2005, 154–74) for a more extensive review.

Liu and Edmunds 2003). Yin and Newman calculated that household investments were responsible for a 20 percent increase in timber production as early as 1984 in one heavily deforested region.

Four additional factors had important effects on forestry during the subsequent period from 1985 to 2000: auctions of wasteland, the liberalization of the unified procurement pricing system for timber, general economic growth, and trade liberalization. The government began auctioning barren forestlands (the “four wastelands”) for afforestation in 1993, and it allowed private actors to compete in these auctions. By 1996, 3.7 million hectares had passed into private hands under this arrangement. The practice of selling forestland through public auctions has subsequently extended to lands with juvenile and mature stands of timber.

Meanwhile, the unified procurement pricing system was gradually relaxed until planned government procurement was less than 10 percent of all timber sales by the mid-1990s (Zhang et al. 1994; Waggener 1998). Nevertheless, government regulations on timber harvest levels and shipments remain strong and timber markets are still underdeveloped in some regions to this day.

General economic growth, rather than any specialized forest policy, was responsible for some of the growth in forest management in this period. This is not surprising. The forest sector accounts for only 1 percent of China’s GDP. The pattern of growth in the paper industry illustrates this effect. The demand for paper is closely tied to GDP, but it tends to grow faster than per capita income in most economies. Paper production grew at a 13-percent annual rate in China after 1984, a rate in excess of the 8–10 percent rate of annual growth in GDP. As a result, the industry’s demand for wood fiber grew and that created a price incentive to expand forest management (Xu et al. 2003).

Two recent empirical assessments confirm the importance of growth in aggregate demand—after accounting for one semantic modification. That is, China officially labels all managed forests “plantations.” The first step in forest management, in China or anywhere else, is to include a measured area of forest in a central plan. However, some form of managed reforestation, often planting itself, is usually the first physical activity in the forest. Therefore, for our purposes in this paper, and for China, “plantations” and “managed forests” are essentially the same.

Zhang et al. (2000) determined that a 1-percent increase in per capita GDP explained a 0.59 percent increase in plantation area in one province (Hainan), and Rozelle et al. (2003, 109–134) determined that a 1-percent increase in the light industry share of China’s full economy correlated with a 0.13 percent increase in total forest land. This 0.13 percent may actually underestimate the impact on plantations and overestimate of the impact on natural forests because an additional share of plantation forest was necessary to make up for any harvesting that occurred on the natural forests.

On the other hand, trade liberalization absorbed some of the increasing demand for woody raw material, and new restrictions on logging beginning in 1998 assured that log imports would become even more important. Log imports nearly tripled (from 4.8 million m^3 to 13.6 million m^3) between 1999 and 2001 and they have continued to grow since then (China Customs Office 1999–2001; Sun et al. 2003).

Tracing government investment and the performance of the SOFEs is more difficult. The available data are not as complete. Government investment in silviculture did increase, and at an annual rate of 7.9 percent between 1979 and 1997. Much of this investment reflects expenditures on a few very large public investments—in 1979 when the Three North Forest Protection Project (the Green Great Wall) was established, after 1987 when a 1.14 million-hectare fire in northeastern China was followed with great effort and cost to reforest, and between 1996 and 2001 when several large ecological disasters (the floods of the Yangtze and Songhua River basins in 1998 and the dust storms in northern China in 2000–2001) induced the government decisions to restrict timber harvests from natural forests in some regions and to reforest and protect the upper watersheds.

China's industrial and financial reforms have spread only slowly to its forest industry and reforms in the SOFEs are still mostly experimental.[6] The SOFEs are a primary government concern in 2008, however, as 80 percent of them exhausted their mature timber by the mid-1990s and more than half of them are in financial arrears. Meanwhile, the demands on the state-owned forests for wood as a raw material, for fuel, and for environmental and recreational services continue to grow.

Table 2 summarizes the impact of the last quarter century of market reform and aggregate economic growth on China's forests. It maintains our distinctions between managed (or plantation) and natural, private and state forests. Of course, in China the "private" forests are not private in the western European fee-simple sense. Rather, they are collectively-owned forests maintains consistency with China's terminology and identifies these as collective forests.) The

[6] See Zhang (2001) for a discussion of these experiments.

Table 2 Summary Statistics: Forests

	1st Forest inventory (1977–1981)		6th Forest inventory (1999–2003)	
	Collective	*State-owned*	*Collective*	*State-owned*
All China				
Managed (plantation)				
Volume	134.10	119.50	1020.00 (661%)	467.00 (249%)
Area	7.95	4.74	24.27 (205%)	7.68 (62%)
M^3/hectare	16.87	29.80	42.03 (149%)	60.79 (104%)
Natural				
Volume	1665.36	5139.09	2650.00 (59%)	5620.00 (9%)
Area	30.41	47.28	49.51 (63%)	51.98 (10%)
M^3/hectare	29.80	109.00	53.52 (89%)	108.11 (-1%)
Northeast region[1]				
Managed (plantation)				
Volume	13.87	50.14	83.20 (500%)	165.03 (229%)
Area	0.85	1.53	1.94 (128%)	2.68 (75%)
M^3/hectare	15.61	32.77	42.89 (175%)	61.58 (87%)
Natural				
Volume	75.32	2060.00	149.38 (98%)	1970.00 (-4%)
Area	2.48	19.83	2.40 (-3%)	21.25 (7%)
M^3/hectare	52.24	103.88	62.24 (19%)	92.71 (-11%)
South and south-central regions[2]				
Managed (plantation)				
Volume	103.89	24.55	637.01 (513%)	182.17 (642%)
Area	5.41	0.98	14.12 (161%)	2.53 (158%)
M^3/hectare	19.20	25.05	45.11 (135%)	72.00 (188%)
Natural				
Volume	1093.66	195.30	1240.00 (13%)	194.73 (0%)
Area	18.86	2.90	28.38 (44%)	2.16 (-26%)
M^3/hectare	57.99	67.34	43.69 (-25%)	90.15 (34%)

[1] Heilongjiang, Jilin, and Inner Mongolia

[2] Anhui, Fujian, Guangdong, Guangxi, Guizhou, Hainan, Hubei, Hunan, Jiangxi, and Zhejiang

Notes: All areas are in million hectares. All volumes are in million m^3. Percent in parentheses is the percentage change between the first and sixth inventories.

Source: State Forestry Administration (1981, 1988, 1993, 1998, 2003) first row of cells records the forest area and standing forest volume within each of our four categories for the first and the sixth, and most recent, of China's periodic forest inventories (conducted between 1977 and 1981 and between 1999 and 2003, respectively). The second and third rows of cells provide the same information for the two most productive forest regions. The northeast is the traditional industrial forest region. The SOFEs that account for more than 60 percent of its total forest resource dominate this region. The collectives and the farm forests that have performed so very well during this period of rapid economic growth dominate in the south and south-central regions.

The table shows that, in national aggregate, both area and volume measures of the forest grew between the first and sixth national forest inventories for both managed and natural forests and for both collective and state administration. As expected, managed forests grew more rapidly (in both volume and area) than natural forests, and collective forests (both managed and natural) grew much more rapidly than state-owned forests. The managed component of the collective forests increased to more than three times its former area and more than seven times its former volume. Natural forests increased by approximately 60 percent in both volume and area, as there was some decline in uneconomic harvest activities on those forests. Some state-owned forests reverted to the collectives and some were, and still are, inaccessible. Therefore, the opportunity for growth in the state-owned forests was less than for the collective forests. Nevertheless, volume doubled in the managed component of the state-owned forests and the natural forest area and volume of these forests each increased by approximately 10 percent.

Similar, comparative experience with forest growth is also broadly true within the two crucial commercial forest regions of northeastern China and south and south-central China, with managed forest volumes on the collective forests in these regions displaying the greatest increases and natural forests under state administration displaying the least.

4. Model and Empirical Assessment

This next section returns to our fundamental question: the effects of economic and population growth on the environment or, specifically in our case, the effects of the aggregate economy and population on the forest and, particularly on China's forests. We will call on the preceding discussion to anticipate the functional relationship, then comment on our data and, finally, review the regression results.

4.1 Regression Model and Data

We will follow a multivariate regression approach. Specifically:

$$F_{it} = \alpha_0 + \alpha_1 Inc_{it} + \alpha_2 Pop_{it} + \alpha_3 Refm_{it} + \alpha_4 Pr_{it} + \varepsilon_{it} \quad (1)$$

where F_{it} is a measure of the forest stock in province i at time t, Pop_{it} is a measure of population, Inc_{it} is a measure of income, $Refm_{it}$ measures the process of land tenure reform, Pr_{it} contains market price information, and the ε_{it} are randomly distributed errors. The α_i are parameters to be estimated.

The coefficients on the first two independent variables address the aggregate economic growth and Malthusian questions that are central to this paper. The third coefficient separates out the tenure effect that is basic to China's rapid growth since 1978. The fourth coefficient is the standard economic price term. Failure to obtain expected results for this final coefficient would raise doubt about all other findings no matter how reasonable they might seem otherwise. Our assessment will follow this general form for two independent sets of regressions, one for the managed component of China's forests and one for the natural component.

4.2 Dependent Variable

China's National Forestry Census summarizes forest stock in terms of both area (hectares of forest cover) and volume (cubic meters). Its collection of these data is based on a sampling and direct estimation procedure similar to that used for forest surveys in most developed countries. The survey results do not pass through the government hierarchy and they are used only for assessing the status of the country's forests—and not for evaluating the performance of local officials. Therefore, data consistency and misreporting—often a concern for those who use China's data—are probably not serious problems.

To date, China has completed six rounds of periodic forest inventories, one every five years since the first inventory conducted between 1978 and 1981 (summarized in table 2). These data are complete for the 28 most forested of China's 32 provinces and autonomous regions (China National Forest Bureau 1976, 1981, 1988, 1993, 1998, 2003). We divided these forest areas and volume data by the total land area of each province in order to normalize for differences in province size.

Data from the first forest inventory did not distinguish between managed and natural forests. As a result, we are left with complete data for five of the six forest inventory periods and 28 provinces or autonomous regions—for a total of 140 pooled observations for managed forests. The Shanghai autonomous region did not record any natural forests for the final three inventories. Therefore, 137 pooled observations are available for the natural forest regressions. The time period of our analysis is consistent with China's rapid development since the beginning of market reforms and, therefore, is appropriate for an assessment of the effects of markets and economic growth on the forest.

Beginning with the fifth forest inventory (1994–98), the National Forestry Census modified the definition of forest used in its survey from 30-percent ground cover to 20-percent cover. This modification should increase the official measures of forest cover and volume, and the increase should be most notable in remote areas where the forest cover is minimal and there are few competing land uses. We will introduce a dummy variable associated with the fifth and sixth inventories to control for the effect of this change in definition of the measures of forest cover and forest volume.

4.3 Independent Variables

Income: Higher levels of per capita income go hand-in-hand with greater demands for consumption goods—such as the commercial products of both the managed forest and the exploitable frontier of the natural forest. Greater demand leads to expansion in the managed forest and more production from it. Greater demand also leads to increased harvests from, and a reduction in, the natural forest. However, as incomes rise, so do wages and higher wages mean better opportunities away from the forest for those who previously depended on the more remote natural forest for a portion of their livelihood. Therefore, the expected sign on the income variable in the managed forest regressions is positive, but the expected sign in the natural forest regressions is uncertain.

Growth in the demand for consumable forest products is generally less rapid at higher income levels. Furthermore, at higher per capita income levels, non-market demands on the resource also tend to increase and they work to protect some of the forest from increasing consumptive demands. Therefore, we introduced a second order income term. The sign on this term should be opposite to the first order sign for all regressions. The coefficient on this second order income term will enable us to identify the turning point associated with an environmental Kuznets curve for forests.

Population: The Malthusian hypothesis encourages the view that larger populations are destructive of the environment. Our intuition is that population density, specifically the density of the rural population and not absolute population level, is what matters for the forest environment. The entire population, urban and rural, consumes a variety of marketed forest products, but this consumption is captured in a measure of aggregate economic performance. It is largely the rural population, with its component of low opportunity cost and often subsistence demands, that degrades the forest. Therefore, the important measure of population for our purposes is the rural population density (the ratio of rural population to total land area) of each province.

Property rights: Improved property rights (or tenure) are an inducement for longer-term forest management. As production on the managed forest increases, the relative level of reliance on the natural forest for extractive products decreases.

We measured property rights in forests as the increasing household-managed share of a province's total forest. Yin and Newman (1997) used the same measure, and Lin (1992) used a similar measure in his classic assessment of the effects of market reforms on China's agricultural sector. This share largely originates with increasing household allocations from the collective forest. Therefore, the expected sign for the tenure coefficient in the collective managed forest regression is positive. Improved tenure may also have a positive impact on the smaller and more marginal category of collective natural forests as improvements in land tenure included some transfer of these latter forests to the households.

A smaller share of state-owned forest was transferred as well to individual household management (as part of the "three fix" program), also resulting in an increase in our measure of property rights. Therefore, the state forests lost area and volume in the process of improving household tenure and the expected sign of the tenure coefficient on the state forest regressions is negative.

Prices: Two sets of prices should be relevant, the prices of the agricultural products that compete for land with managed forestry and the prices of forest products themselves. Grazing by domestic livestock is generally the lowest-valued use of agricultural land. Therefore, grazing is often the agricultural competitor with managed forestry. As livestock prices rise, agriculture may compete more successfully with the intensive margin of forest management. It is unclear whether rising livestock prices also induce China's livestock industry to extend its operations into previously open access natural forests in regions where forest product prices are too low to justify managed forests and where grazing, perhaps, competes with other uses of the natural forest.[7]

An increase in the price of commercial forest products induces an immediate increase in harvests from both managed and natural forests. The volume and area of both managed and natural forests decline as a result. However, more sustained forest product price increases also induce reinvestment in managed forests. We expect that they have no effect on the natural forest. We examined several possible price lags for forest products. The one-year lag performed best. Yin and Newman (1997) also observed that a one-year lag predicted well.

Tables 1 and 2 show the national trends in per capita income and in forest survey data, as well as the extremes for those regions and provinces that are most important for forestry. Table 3 provides summary national data for the remaining independent variables as well as comparable data for two key provinces, Heilongjiang in the northeast where state-owned forestry dominates and Hunan in the predominantly collective south-central part of the country.[8] It is clear that the sample data display wide geographic dispersion, and that all but the population data display substantial intertemporal variation.

These data permit us to estimate the regressions for both forest volume and forest cover for each of four categories of the dependent variable, with managed and natural forests each separated according to collective and state administration—a total of eight regressions. Ours are fixed effect, double log regressions. The former means that our regressions control for exogenous differences between provinces, and the latter means that the estimated coefficients are elasticities.

4.4 Results: Collective Forest Lands

Consider the collective households first. Four regressions predict forest area and forest volume, first for managed forests and then for natural forests. The first column of table 4 identifies the independent variables. Subsequent columns identify the expected signs and record the results for each regression, including the estimated coefficient (elasticity) and the t-value and

[7] We also considered a grain price index for this variable. The livestock price index performed better—probably because grazing tends to be a lower-valued use of agricultural land and, therefore, a closer substitute for managed forest land. Regression results available from the authors.

[8] These three tables substitute for the single table of descriptive statistics included in many empirical analyses.

Table 3 Additional Summary Statistics

	1981	1988	1993	1998	2003
All China					
Rural population density*	98	103	107	108	102
Tenure**	0.425	0.486	0.500	0.541	0.553
Timber price (an index)	126.95	408.56	443.32	543.75	522.0885
Timber price lagged one year	100	298.87	399.02	537.84	528.965
Livestock price (an index)	101.10	224.13	269.48	431.34	361.2655
Northeast region, Heilongjiang					
Rural population density*	44	44	45	44	43
Tenure**	0.001	0.0642	0.0388	0.0673	0.0741
Timber price	126.94	331.15	358.6	431.67	433.2
Timber price lagged one year	100	248.42	344.81	404.56	431.9
Livestock price	101.1	228.49	320	500.15	462.8
South and south-central regions, Hunan					
Rural population density *	222	237	245	245	201
Tenure**	0.881	0.921	0.93	0.937	0.943
Timber price	125.9	596.49	602.13	626.43	581.26
Timber price lagged one year	100	368.66	571.28	638.56	579.52
Livestock price	101.1	231.39	307.59	516.94	525.2

* Rural population density calculated as agricultural population/total land area.

** Tenure calculated as (household contracted forest area/total forest area)

Sources: China Statistics Bureau (1999, 2004); State Forestry Administration (1981, 1988, 1993, 1998, 2003); China National Price Bureau (1998); China Statistics Bureau, Rural Comprehensive Survey Team (1982, 1989, 1994, 1999, 2004).

statistical significance for each variable. The equation F statistics and R^2s for all four regressions are satisfactory.

For the managed forest, the signs on all eight coefficients in the forest area regression (table 4) followed expectations and three coefficients are statistically significant. Seven of eight signs in the forest volume regression followed expectations and four are statistically significant. We expect these to be the most reliably predicted of all regressions because decisions for these managed forestlands most closely follow predictable market incentives.

For the natural forests managed by collective households (also table 4), six of seven signs in the area regression followed expectations (although three expectations are uncertain), but only the sign on tenure is significant. All seven signs in the volume regression followed expectations and the coefficient on tenure continues to be significant.

Table 4 Fixed Effect Regression Results for Collective Forests

Independent variables	Managed (plantation) forest				Natural forest			
		Cover		***Volume***		***Cover***		***Volume***
ln (rural population/area)	-	-0.671 (0.98)	-	-1.738 (1.68)*	-	-1.111 (0.89)	-	-2.346 (1.25)
ln (rural income/cap)	+	3.004 (2.93)***	+	4.862 (3.13)***	?	-1.201 (0.62)	?	0.52 (0.18)
ln (rural income/cap)^2	-	-0.195 (2.80)***	-	-0.327 (3.10)***	?	0.114 (0.88)	?	-0.007 (0.03)
ln (tenure)	+	1.48 (16.25)***	+	1.421 (10.30)***	+	1.008 (6.24)***	+	0.96 (3.95)***
ln (timber price)	-	-0.076 (0.23)	-	-0.036 (0.07)	-	-0.245 (1.06)	-	-0.004 (0.01)
ln (timber price lag)	+	0.098 (0.28)	+	0.169 (0.32)				
ln (price of livestock)	-	-0.054 (0.18)	-	0.378 (0.81)	?	-0.288 (0.48)	?	-0.852 (0.95)
Definition change	+	0.144 (0.93)	+	0.167 (0.71)	+	-0.022 (0.08)	+	0.438 (1.01)
Constant		-17.032 (3.17)***		-27.966 (3.43)***		-2.278 (0.24)		-8.711 (0.60)
Observations		140		140		137		137
Number of provinces		28		28		28		28
R-squared		0.87		0.86		0.37		0.23
F(8,104)		86.12		78.41		–		–
F(7,102)		–		–		8.48		4.42

Absolute values of t-statistics are in parentheses.
* significant at 10%; ** significant at 5%; *** significant at 1%

In sum, decision making for the collective forestlands very largely followed expectations since the introduction of market reforms—and once we made our own important distinction between managed and natural forests. Improved household land tenure had a large and significant effect on both managed and natural forests. This result is consistent with the prior literature for both forestry and agriculture in China. Also, as anticipated, increased rural population density was associated with decline in both managed and natural forests. Greater per capita incomes led to greater demand for the products of the forest, more forest management, and less natural forest as some of the latter was, perhaps, converted to managed or plantation forest. Per capita income had the most elastic of all productive responses for both forest area and forest volume. However, this effect declined as incomes continued to rise. It will be interesting to observe whether the income terms exhibit similar effects on the state-owned natural forests which tend to be less accessible for market exploitation and often are more attractive for environmental preservation. Finally, the timber and livestock price effects also followed expectations, although their coefficients were not statistically significant and the responses to changes in these variables were generally not as elastic as for the other predictive variables.

4.5 Results: State-Owned Forestlands

The regressions for managed forests administered by the state did not perform as well. We know that, in countries around the world, even timber harvest operations in these forests are often determined by administrative rather than market criteria, and we know that, in China, the management decisions for these forests have been guided by the need to support mill employment, rather than by financial criteria. Many state forest bureaus and state forest farms have continued to operate only with the exogenous budgetary support of the central government. Therefore, it is not surprising that state-owned *managed* forests do not predictably respond to the economic variables in our regression.

As an alternative to our economic variables, central government budget allocations for silvicultural management might be a useful predictor of state forest management. Silvicultural budget data are available for a limited period covering the second to the fourth forest inventories for many provinces. Independent regressions incorporating this new variable were more satisfying in all respects.[9] However, the limited number of observations, limited period of time,

[9] Regressions available from the authors.

and the absence of any basis for understanding adjustments in these government budgets all encourage caution in reporting these results. We conclude only that decision making on the state-owned and managed component of all forest lands is more complex and less predictable than decision making for either component of the collective forests.[10]

The regressions for state-owned *natural* forests presented in table 5 are more satisfying. Signs on five of the seven coefficients followed expectations in the area regression and all five are statistically significant. All seven signs in the volume regression followed expectations and three are statistically significant. The equation F statistics and R^2s are also satisfactory.

To summarize, population density had an indeterminate effect on the generally less accessible state-owned natural forests. In any event, these forests are too inaccessible for us to have predicted any substantial population effect. Improved household tenure also had an indeterminate effect. Improved tenure may have drawn land away from some managed state forests, but apparently it had little effect on more remote natural forests. The change in forest definition for the most recent two inventories had a significant effect only on this one category of forest, apparently adding lower grade and less accessible lands and volume to the state-owned natural forest base.

The standard economic variables performed as predicted. Rising timber prices led to significant increases in timber harvests for these natural forests and, as a result, to decreases in the natural forest area. (Logging restrictions on state lands since 1998 may have temporarily limited this effect.) Rising livestock prices may have induced some infringement on the natural forest, particularly in western China where grazing often remains an open access activity. However, rising incomes had the largest effect by far, and this effect was positive. These regressions argue that China has added substantially to its state-owned natural forests at the same time its per capita income has risen dramatically. Perhaps some timber harvest activities have shifted away from natural forests and to more productive managed forests, as Rozelle et al. (2003) suggest. Certainly China has added substantially to its protected natural reserves (86.4 million hectares or 8.6 percent of its land area since 1982) and much of the addition must have been in the form of recovering natural forest (SEPA 1998; FAO 2001). Additional forest area

[10] The focus of this paper on the effects of aggregate economic and broad demographic factors restricts further attempts to assess other determinants of behavior on the state-owned forests at this time.

that was previously either managed or open access and degraded must also be recovering naturally.

Table 5 Fixed Effect Regression Results for State-Owned Natural Forests

Independent variables	Natural forest			
		Cover		***Volume***
ln (rural population/area)	-	0.290 (0.61)	-	-1.103 (1.08)
ln (rural income/cap)	?	2.33 (0.947)**	?	5.442 (1.69)***
ln (rural income/cap)^2	?	-0.171 (0.06)***	?	-0.372 (0.11)***
ln (tenure)	-	0.023 (0.08)	-	-0.143 (0.14)
ln (timber price)	-	-0.317 (0.11)***	-	-0.235 (0.20)
ln (price of livestock)	-	-0.195 (0.29)*	-	-0.609 (0.52)
Definition change	+	0.489 (0.14)***	+	0.526 (0.25)*
Constant		-8.067 (4.68)*		-19.882 (8.36)**
Observations		137		137
Number of provinces		28		28
R-squared		0.27		0.16
F(7,102)		5.45		2.70

Absolute values of t-statistics are in parentheses.
* significant at 10%; ** significant at 5%; *** significant at 1%

4.6 Net Effects: The Aggregate of Collective and State-Owned Experience

Table 6 reports summary regressions for the aggregate of all collective and state managed forests and for all collective and state natural forests. The explanatory power of these regressions is not as great as those in tables 4 and 5, but it may be more meaningful to obtain aggregate regressions in tables 4 and 5 generally performed slightly better than the volume regressions. All

Table 6 Summary Fixed Effect Regression Results for the Combination of Collective and State-Owned Forests

Independent variables	Managed forest cover		Natural forest cover	
ln (rural population/area)	-	-0.578 (1.11)	-	0.153 (0.40)
ln (rural income/cap)	+	1.449 (1.85)*	?	-0.038 (0.06)
ln (rural income/cap)^2	-	-0.077 (1.44)	+	0.003 (0.08)
ln (tenure)	+?	0.162 (2.32)**	-?	-0.004 (0.08)
ln (timber price)	-	-0.034 (0.14)	-	-0.161 (2.28)**
ln (timber price lagged 1 year)	+	0.009 (0.04)		
ln (price of livestock)	-	-0.111 (0.47)	?	0.193 (1.06)
Definition change	+	0.053 (0.44)	+	0.14 (1.59)
Constant		11.589 (2.82)***		-2.305 (0.78)
Observations		140		137
Number of provinces		28		28
R-squared		0.70		0.38
F(8,104)		30.96		–
F(7,102)		–		9.03

Absolute values of t-statistics are in parentheses.
* significant at 10%; ** significant at 5%; *** significant at 1%

eight signs for the new managed forest regression followed our expectations and two (income and tenure) are significant.[11] All seven signs for the new natural forest regression followed expectations and one (timber price) is significant. Once more, the equation F statistics and R^2s are satisfactory.

The predictable market effects observed in the collective regression (table 4) dominate the summary managed forest regression (table 5). First, the small coefficient on population provides a minimum of cautious support for the Malthusian hypothesis that an increasing population is associated with a declining resource. In fact, the (opposite) declining population perspective may be a better way to consider this effect. That is, as the rural population density begins to decline (as it has in some parts of China), the decline may be accompanied by increases in the managed forest resource. At the least, this is a possibility worthy of consideration. If this is an accurate appraisal of the population effect of China, the question that arises is whether we could predict a similar population-managed forest relationship elsewhere in the world, if and as other rural populations also begin to decline.

Second, our additional coefficients show that improved land tenure was an indisputable incentive for longer-term forest management. The timber price coefficient shows that rising timber prices worked not only to increase timber harvests but also to encourage longer-term forest management, and the livestock price coefficient shows that livestock grazing was a substitute use of some managed forest land.

Third, the significant first order income term displays the most elastic response of any independent variable. It shows that increasing per capita incomes had a positive effect on total land area devoted to managed forests. This positive income effect is triple the magnitude of the negative population effect—although the second order income term shows that this effect did decline for higher income levels. A share of this effect is due, no doubt, to recent investment by the central government in several immense forest recovery programs. However, this recent public investment, at best, can account for only 40 percent of the total area afforested since 1978. The remaining 60 percent is due to non-public participation. Therefore, we can conclude that

[11] These general managed-forest observations are consistent with those of Demurger and Yang (2006) for the recently afforested subset of all managed forest area in China. Demurger and Yang observed that afforested land is a negative function of agricultural prices and rural population density and a positive function of the level of rural assets.

rising per capita incomes have had an undeniable positive effect, increasing the demand for forest products and, thereby, inducing an increase in the land area under forest management.

The summary natural forest regression reflects a mix of the effects observed in the disaggregated collective and state-administered natural forest regressions. Increasing rural population density had a small and insignificantly positive effect on the natural forest. The price terms show the merit of separately describing effects on managed and natural forests. Rising timber prices induced harvesting from the natural forest, but they had no long-term effect on the natural forest in this or any other regression we examined. We did not expect livestock prices to have a substantial effect on natural forests, and they do not. Finally, rising per capita income had a small and decreasingly negative effect on the natural forest.

Aside from the general conclusion of the theoretical and empirical merit of separating the forest into managed and natural components, the income terms may be most interesting. They seem to suggest that rising incomes cause some drawdown of the natural forest, but this decline subsides with further increases in income. Meanwhile, rising incomes have a much stronger positive effect on the land area devoted to managed forests. While this latter effect also declines with rising incomes, the net effect—across the income range observed in China over the last quarter century—has been strongly positive, and total forest area has increased as a result.

These income observations, taken together, seem to support the contention of an environmental Kuznets' curve for forestry. The turning point for natural forest cover occurred at an income level of 563 yuan, although this income level might have been a little higher if China had not changed the level of minimal cover in its official forest definition. This means that the decline in natural forest area probably ended in the mid-1980s. The turning point for expanding managed forest cover occurs at a per capita rural income level of 12,198 yuan. Since average per capita rural income for all China was only 2,622 yuan in 2003 (table 1), we can expect that China's managed forests will continue to expand for many years. Indeed, these two conclusions are consistent with our personal reflections on the data and our impressions from years of travel to the field. Natural forest cover did decline through the early 1980s, but we have not observed additional decline in recent years anywhere in our travels throughout the country, and there is some evidence of recovery in secondary growth natural forests. There is also abundant evidence of increasing managed forest cover in almost all provinces today.

5. Conclusions

We are left with two broad conclusions, one regarding the best way to describe forests for management and policy analysis, and one regarding macroeconomic effects on the forest.

For the first, forests are best described in two parts, managed and natural. We hypothesize that the former respond to both short- and long-term forest product price incentives and, at their intensive margins, to competitive agricultural prices. Natural forests are more remote or less accessible to the market and that is the primary reason they remain in a natural state. Natural forests respond only to short-term price signals and only to those from the market for forest products. The Chinese data support this hypothesis, but we anticipate that it is a valid hypothesis for forest measurement and for forest management and policy in other countries as well.

More generally, we must also wonder whether our resource distinctions between managed and natural, state and non-state management are valid for other biological resources. In particular, would these distinctions improve our understanding of commercial fish stocks, such as salmon or trout or some shellfish (which include both wild and managed components), subject to both state and private administration, or even our understanding of the few large game species whose stocks fall into similar management and ownership categories?

For the second broad conclusion, the more general economic environment has two identifiable effects on these forests, one for which we have only very limited support and one for which China's evidence is most convincing. First, declining rural population density may be associated with an increase in land devoted for forest management. This is the cautious and optimistic dual to Malthusian warnings of the dire consequences of general population growth. Is it possible that the rural-to-urban migration we observe around the world could have a beneficial effect on forest area and, therefore, at least this one beneficial environmental effect?

Finally, economic growth and development, as measured by per capita rural income, has a substantial effect on both managed and natural forests. This observation should not surprise us. Forestry contributes less than 1 percent of China's gross domestic product and more than 5 percent to the GDP of only one country in the world (Finland, at 7.6 percent [FAO 2001]). Surely forestry's small share of the full national economy suggests that the national economy has a greater effect on forestry than forestry has on the full economy. Our regressions tell us that China initially drew down its natural forest cover in the 1970s, but, since the mid-1980s, income growth (and with it, increasing consumer demand for marketed forest products, increasing demand for forest-based environmental services, and decreasing subsistence demands on the forest) has been by far the greatest force behind managed forest growth and the substitution of forest management for the products of the (no-longer-declining) natural forest. Furthermore, we can anticipate that a broad range of additional income growth will continue to have a strong favorable effect on forest management and aggregate forest cover. We suspect that similar research for other countries around the world would yield similar encouraging results.

References

Barlow, T., and G. Helfand. 1980. “Timber Giveaway—A Dialogue,” *The Living Wilderness* 44: 38–9.

Barlow, T., G. Helfand, T. Orr, and T. Stoel. 1980. *Giving Away the National Forests: An Analysis of U.S. Forest Service Timber Sales below Cost*. Washington, DC: Natural Resources Defense Council.

China Customs Office. 1999, 2000, 2001. *China Customs Office Statistical Yearbook*. Beijing: China Customs Office Press.

China National Price Bureau. 1998. *Collection of the Price of Main Commodities and Services in New China*. Beijing: China Pricing Publishing House.

China Statistics Bureau, Rural Comprehensive Survey Team. 1982, 1989, 1994, 1999, 2004. *China Rural Statistical Yearbook*. Beijing: China Statistics Publishing House.

China Statistics Bureau. 1999, 2004. *China Price and Household Survey Yearbook*. Beijing: China Statistics Publishing House.

———. 2000. *Comprehensive Statistical Data and Materials on 50 Years of New China.* Beijing: China Statistics Publishing House.

———.2004a. *China Statistics Yearbook 2004*. Beijing: China Statistics Publishing House.

Copeland, B., and M. Taylor. 2004. “Trade, Growth, and the Environment,” *Journal of Economic Literature* 27(1): 7–71.

Dasgupta, S., B. Laplante, H. Wang, and D. Wheeler. 2002. “Confronting the Environmental Kuznets Curve,” *Journal of Economic Perspectives* 16(1): 147–68.

Demurger, S., and W. Yang. 2006. “Economic Changes and Afforestation Incentives in Rural China,” *Environment and Development Economics* 11: 629–49.

Food and Agriculture Organization of the United Nations (FAO). 2001. *Global Forest Resources Assessment 2000*. FAO Forestry Paper, no. 140. Rome: FAO.

Hyde, W. 2005. “The Limitations to SFM: An Economic Perspective.” In *Institutions, Sustainability, and Natural Resources: Institutions for Sustainable Forest Management*, edited by S. Kant and R. Berry. Dordrecht, The Netherlands: Springer.

Hyde, W., J. Xu, and B. Belcher. 2003. "Introduction." In *China's Forests: Global Lessons from Market Reforms,* edited by W. Hyde, B. Belcher, and J. Xu. Washington, DC: Resources for the Future.

Lin, J. 1992. "Rural Reforms and Agricultural Growth in China," *American Economic Review* 81(1): 34–51.

Liu, D., and D. Edmunds. 2003. "Devolution as a Means of Expanding Local Forest Management in South China: Lessons from the Last 20 Years." In *China's Reforms and Its Forestry Sector: Lessons for Global Forest Policy,* edited by W. Hyde, B. Belcher, and J. Xu, 27–44. Washington, DC: Resources for the Future.

Lund, H.G. 2000. "Definitions of Forest, Deforestation, Afforestation, and Reforestation." Contract study. Forest Information Services, Manassas, VA. http://home.comcast.net/~gyde/. Accessed March 3, 2008.

Malthus, T. 1798. *An Essay on the Principle of Population*. London: St. Paul's Churchyard.

Meadows, D.H, D.L. Meadows, J. Randers, and W. Behrens III. 1972. *Limits to Growth*. New York: Universe Books.

National Remote Sensing Agency (NRSA). 1995. "Report on Area Statistics of Land Use/Land Cover Generated by Using Remote Sensing Techniques." Hyderabad, India: Department of Space, National Remote Sensing Agency.

Peyron, J., and O. Colnard. 2002. "Vers des comptes de la forêt? [Toward forest accounts?]" In *Forêt, Economie et Environnement: rapport de la Commission des Comptes et de l'Economie de l'Environnement sûr la Forêt* [Forest, economy, and environment: Contribution to a report of the Commission of Environmental Economics and Accounts]. Orleans: Institut français de l'Environnement (IFEN).

Rozelle, S., J. Huang, and V. Benzinger. 2003. "Forest Exploitation and Protection in Reform China: Assessing the Impacts of Policy and Economic Growth." In *China's Reforms and Its Forestry Sector: Lessons for Global Forest Policy,* edited by W. Hyde, B. Belcher, and J. Xu. Washington, DC: Resources for the Future.

Samuelson, P. 1983. "Thunen at Two Hundred," *Journal of Economic Literature* 21(4): 1468–88.

Singh, H. 1994. “The Green Revolution in Punjab: The Multiple Dividend, Prosperity, Reforestation, and the Lack of Rural out-Migration.” Unpublished paper. John F. Kennedy School of Public Policy, Harvard University, Cambridge, MA.

State Environmental Protection Agency (SEPA). 1998. *China’s Biodiversity: A Country Study*. Beijing: China Environmental Science Press.

State Forestry Administration. 1981, 1988, 1993, 1998, 2003. *China National Forest Statistics.* Beijing: China Forest Publishing House.

Sun, X., E. Katsigiris, and A. White. 2005. “Meeting China’s Demand for Forest Products: An Overview of Import Trends, Ports of Entry, and Supplying Countries with Emphasis on the Asia-Pacific Region.” Washington, DC: Forest Trends, Chinese Center for Agricultural Policy, and Center for International Forestry Research.

USDA Forest Service. 2005. USDA Forest Service Forest Inventory and Analysis web site. Authors’ data sort. http://fia.fs.fed.us. Accessed March 8, 2008.

von Thunen, J. 1826. *The Isolated State*. Translated by C.M. Wartenberg and edited by Peter Hall. Oxford and New York: Pergamon Press, 1966.

Wolfe, R. 1989. “National Forest Timber Sales and the Legacy of Gifford Pinchot: Managing a Forest and Making It Pay,” *University of Colorado Law Review* 60: 1037–1078.

Waggener, T. 1998. “Status of Forest Products Pricing under Reforms toward Market Economies: China, Mongolia, Myanmar, and Vietnam.” Final report for the FAO “Support to the Reorientation of Forestry Policies and Institutions of Countries of Asia in Reform to Market Economy” project. Bangkok, Thailand: FAO.

Xu, J., G. Amacher, and W. Hyde. 2003. “China’s Paper Industry: Growth and Environmental Policy during Economic Reform,” *Journal of Economic Development* 28(1): 49–79.

Xu, J., and W. Hyde. 2005. “From Centrally Planned Economy to Vigorous Rural Enterprise: China.” In *Plantations, Privatization, Poverty, and Power: Changing Ownership and Management of State Forests*, edited by M. Goforth and J. Mayers. London: Earthscan.

Yin, R., and D. Newman. 1997. “Impacts of Rural Reforms: The Case of the Chinese Forest Sector,” *Environment and Development Economics* 2: 291–305.

Zhang, Y., G. Dai, H. Huang, K. Fanwen, Z. Tian, X. Wang, and L. Zhang. 1999. “The Forest Sector in China.” In *World Forests*. Vol. 1 of *World Forests, Society, and Environment*, edited by M. Palo and J. Uusivuori. Dordrecht, The Netherlands, and Norwell, MA: Kluwer Academic Publishers.

Zhang, Y., J. Uusivuori, and J. Kuuluvainen. 2000. “Econometric Analysis of the Causes of Forestland Use/Cover Change in Hainan, China,” *Canadian Journal of Forest Research* 30: 1913–21.

Zhang, Y. 2001. “Economic Transition and Forestry Development.” PhD dissertation. Department of Forest Economics, University of Helsinki, Finland.