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China's Forest Sector: Essays on Production Efficiency, Foreign Investment, and Trade and Illegal Logging

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Abstract

This study explores China's forest sector through the lens of three interconnected issues: production efficiency, foreign direct investment, and trade and illegal logging. China's forest sector is now inextricably linked to markets all over the world and this research provides an important contribution to understanding China's participation in the trade and processing of forest-based resources and products.

First, efficiency metrics were calculated to understand how efficiently Chinese wood-processing enterprises operate, given a set of inputs. Using data collected through an enterprise survey, a stochastic frontier production function was estimated and used to measure technical efficiency for Chinese enterprises. The coefficients for the material and labor inputs proved to be significant, and a mean efficiency score of .70 indicated significant room for efficiency improvements among almost all enterprises.

Second, the location choice of foreign investment in Chinese wood-processing enterprises was examined to understand whether or not the same factors that have been shown to motivate foreign investment in manufacturing as a whole within China also apply to the wood-processing subsector, and to assess the effect of roundwood availability on foreign investment in the wood-processing sector. This was done by employing two estimation methods: tobit and negative binomial. Two variables were found to have an impact on investment: the number of specially-designated economic zones and roundwood production.

The last study examined the effects of the removal of illegally logged resources from China's imports originating in five of China's primary source countries for logs on China's domestic production, consumption, and trade flows. This was performed through the use of a spatial equilibrium approach by modifying the CINTRAFOR Global Trade Model (CGTM). This was performed both by applying a graduated tariff and by changing the supply elasticities in China's primary log source countries. China was evaluated using supply elasticities that simulated the current harvest quota system, and a system that becomes more self-sufficient through increased log production. The results demonstrated large losses in producer surplus resulting from the imposition of a tariff as compared to methods that approach adjusting supply by a change in the cost structure.

In an increasingly globalized world, these issues are fundamental to the long-term sustainable management and provision of, as well as trade in natural resources and environmental services. This research provides an important contribution to understanding China's participation in the trade and processing of forest-based resources and products.

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Introduction

China's global ascendancy over the past thirty years has been the outcome of persistent economic growth guided by transition-oriented policies directed from the central government. During this time, the economy has shifted from a wholly planned economy to a mixed economy with both planned and market features, to its current state of quasi liberalization. Integral to the rapid growth and long-term transformation of China's economy is expanding production of value-added products (Brandt and Rawski 2008; Naughton 2007), including their exports. As production in China's burgeoning export-oriented and domestic industries has grown, China has evolved to become a leading consumer of imported primary and industrial materials such as copper ore, oil, and timber (The Economist 2008). The consumption of these materials fuels the production of both China's manufactured exports and goods consumed domestically.

China's manufacturing role as an intermediary between resource-rich developing countries and income-rich consuming countries has enabled China to play a greater geopolitical role, one that has not always conformed to the expectations of its strategic partners (Zweig and Bi 2005). The increased extraction of primary materials from developing and transitioning economies has led to concerns about the long-term sustainability of resources in those countries and over the equity in the gains from trade (Zhu et al. 2004). The timber trade and China's use of wood products are at the center of this dialogue.

China's role in the international wood products market is now inextricably linked to markets all over the world. As both a consumer and a producer, China's role in the timber market presents challenges and opportunities to those concerned with natural resource use and allocation. One of the challenges stems from the environmental implications for China's increasing role as the world's wood workshop. Since much of the timber processed in China is imported from other countries, there has been an emerging interest in understanding the impact of China's growing trade on countries where timber is sourced. Many of these source countries often either have less-than-stringent environmental regulations or else weak governance that hinders their ability to enforce them (Auer 2003; Contreras-Hermosilla 2002). Accusations that China's timber imports have come from illegal sources have led to calls for boycotts and close monitoring of Chinese products (Financial Times 2006; EIA/Telapak 2005).

Understanding how efficiently China uses timber resources, what its future demand will be, and where those resources will come from are important to those concerned with the impact on China's source countries. As China has evolved to become a major manufacturing hub, the question of efficiency among its manufacturers also plays into issues of labor allocation and investment. This is of great interest to Chinese manufacturers, policymakers, and their international counterparts. China has relatively low labor costs, but questions exist about how efficiently it uses timber resources, both domestic and imported. The answer may provide insight into how resource needs and the distribution of resources will affect production in the future.

China's rise as an exporter of value-added wood products has come about as increased numbers of North American, Asian, and European investors have shifted their production and investment abroad. However, as labor costs increase in China, there is now increasing attention being paid by investors to neighboring countries that enjoy even lower costs of labor as well as favorable investment climates. The costs associated with labor, wood, and capital and subsequent investments have the potential to affect the future availability of forest resources within China and abroad as well as significantly impact the determination of the location of future centers of production.

This study explores a cross section of interconnected issues within China's forest sector, with specific attention to three overarching topics: 1) the relationship between region-specific factors and foreign direct investment in China's forest sector; 2) the efficiency of Chinese enterprises in the production of wood products; and 3) the impacts of restrictions on the flow of illegally logged timber on China's wood products trade. In an increasingly globalized world, these issues are fundamental to the long-term sustainable management and provision of, as well as trade in natural resources and environmental services. This research will provide an important contribution to understanding China's participation in the trade and processing of forest-based resources and products.

The remainder of this study is organized into four chapters. Chapter 1 provides a background to China's forest sector. Chapter 2 provides an examination of the production efficiency of Chinese mills, based on a survey carried out across fifteen provinces. Chapter 3 analyzes location choice within foreign investment in Chinese wood-processing enterprises. Chapter 4 projects the effects of policies aimed at curbing the flow of illegal wood product on China's international wood products trade. The study concludes with a final chapter integrating the results of the previous three chapters.

1 China's Forest Sector: the Reform Era

1.1 Introduction

China is often referred to as being "forest poor" (Démurger et al. 2009; Liu and Diamond 2005; Liu et al. 2003; Liu 1998). Per capita forest coverage is one-fifth the global average, and per capita standing forest stock is just one-eighth the global average. China's constrained domestic resource base is, in many ways, not new. Thousands of years of extraction and everyday use of forests left the country with a depleted resource base before the modern era even began (Li 2004; Song et al. 1997; Menzies 1994; Shaw 1914). Yet China is now the world's largest producer and exporter of forest products (SFA 2009). Issues surrounding long-term forest ecological health and sustainability, the welfare of rural residents who depend on forests or trees for their livelihoods, and industry's reliance on timber for the mass production of forest products are now inextricably linked. These questions are relevant domestically within China, for countries on which it now relies to supply its wood resources, and for countries to which it exports wood products. In order to understand China's current role in the global forest products market, it is useful to examine changes over the course of the modern period, particularly during the reform period beginning in 1978.

The aim of this chapter is to provide an overview of China's forest sector within the context of three broad stakeholders: the forests themselves, the people who live in or near forested areas, and the forest products industry. The period from 1949 through 1978 will be presented in brief, with the objective to introduce land ownership types and provide a background to the period beginning in 1978. The main emphasis of this chapter is on the reform period beginning in 1978. The chapter will include a review of reforms aimed at the collective sector, forest development in the relatively recent era of protection and conservation programs, and current forest and forest industry conditions, as well as a discussion of the ongoing challenges faced by China's forest sector.

1.2 Background: 1949-1978

In the early 1950s, land reform was introduced as a fundamental campaign in the creation of the socialist state (table 1). The primary intent of land reallocation was "to further rural revolution and only secondarily to improve land usage" (Ross 1980). During this process, all forestland was removed from private ownership and redistributed as either state-controlled forestland or collective forestland (Richardson 1966). This two-pronged land ownership structure largely continues today, although national-level reforms enacted in 2008 will eventually lead to the large-scale reallocation of collective forestland to households or self-assigned communities. State ownership historically has been characterized by its vertically integrated silvicultural, logging, and processing capacity (Zhang 2000), and tended to cover large tracts of land, located in natural forests in the upper reaches of river basins and mountainous regions (Xu et al. 2004). Collective ownership comprises townships, administrative villages, and village household groups (Liu 2001). Another distinction may be made by identifying the differences in resource ownership and land ownership. Under state ownership, both land and trees are owned by the state; at the collective level, land ownership and tree ownership may be separated, with land ownership retained by the collective, while trees may be owned by individual households (Démurger et al. 2009). State ownership is dominant in the northeast and southwest, while collective ownership is dominant in the central region. Approximately 58% of forests (by area) are under collective ownership, while 42% of forests are under state-owned entities (SFA 2005a).

Table 1 Land Tenure: 1950-1980

Period	Defining Features
1950-1955	• Removal of land from private ownership • Establishment of state-owned and collective-owned forests • Integration of tree ownership and land ownership • Households maintain rights to fruit and non-timber trees
1956-1981	• Collectives become dominant form of ownership • Introduction of communes: up to 4,800 households per commune • Widespread deforestation and land conversion for purposes of agricultural expansion • Policy reversals first devolve ownership and management to households, then reinstate commune-level collectivization • Collective forest removals used primarily for fuelwood and local uses; state removals used for construction, transportation and other major sectors

Adapted from Liu (2001)

By 1956, 96% of rural land had been placed under the jurisdiction of village leaders (Richardson 1991). Collective forestlands were initially controlled by units consisting of 20 to 30 households; by 1956, the management level had grown to 200-600 households. With the advent of communes in 1958, this number grew even larger to 4,800 households (Liu 2001). This meant that while ownership was ostensibly "collective", it was effectively highly centralized with few households making any independent decisions about planting and harvesting. The majority of wood removals on collective forestlands were used for fuelwood and other local uses (Ross 1980).

Within the state sector, forest bureaus and forest farms were vertically integrated, and operated timber management, logging, and wood-processing activities. Enterprises were given fixed production quotas and set prices under which they were expected to operate. The main objective of the state forest sector was to supply inexpensive logs to support industrialization (Démurger et al. 2007). Wood production to supply the construction, mining, and transportation sectors came primarily from the state sector, which was charged with the bulk of timber production (Ross 1980). Investment in regeneration and equipment under both collective and state ownership structures was low.

Extraction during this era came predominantly from virgin or natural forest areas (Yang 2001). During the Great Leap Forward, it is estimated that nearly 10% of forests were cleared for the use of wood as fuel (Shapiro 2001). The widespread destruction of forests that served to fuel "backyard furnaces" aimed at producing steel was of dubious economic benefit. Although no inventory data are available for the 1950s, estimates of forest coverage at the time vary. Ross (1980) estimated that forest coverage was between 5% and 8% of total land area; other estimates show that forest coverage increased from 8.6% in 1949 to 11.8% by 1962 (Zhang and Song 2006). The northeast had the largest area of forests (Ross 1980). Although the southwest appears to have had the highest stocking density, it was also the most remote. While the central and southeast coastal regions had more accessible forests, combined they accounted for less than 1% of total forest area and had the lowest stocking density (Ross 1980).

After this period, and the massive famine from 1959 to 1961, the government responded with a series of reforms that devolved forest tenure from the commune level to lower administrative levels and even returned certain management responsibilities back to individual households (Liu 2001; Wang et al. 2004). How forestland rights were devolved depended greatly on the location and was left to local governments to decide (Shen et al. 2009). However, these reforms were short lived because in the 1960s, a renewed effort at class struggle came in the form of the Cultural Revolution. Management by households was soon regarded as a return to private ownership (Liu 2001). During this period, as huge numbers of urban residents were sent to the countryside for re-education and to expand agricultural production, and forestland was cleared for the creation of new farmland. This period was marked by an abandonment of the reforms implemented post-Great Leap Forward. For the most part, there was no active forest management despite widespread intensive harvesting (Wang et al. 2004). Investment in both silviculture and industry declined from 1965 to 1969, and did not return to pre-1965 levels again until 1972. According to official estimates, timber production grew from 5.7 million cubic meters (CUM) in 1949, increasing gradually before spiking to 45.2 million CUM in 1959 (table 2). During the 1960s, it declined precipitously, bottoming out two years later at 21.9 million CUM in 1961 before gradually increasing again. Lumber production also followed this trajectory, spiking between 1958-1960 before declining rapidly and not recovering to Great Leap Forward production levels again until after 1979.

Table 2 Log and product production, 1949-1979, in million CUM

Year	Logs	Lumber	Panels	Year	Logs	Lumber	Panels
1949	5.67	NA	NA	**1965**	39.78	11.6	0.22
1951	7.64	NA	NA	**1967**	32.49	11.57	0.17
1953	17.53	6.64	0.04	**1969**	32.83	10.05	0.2
1955	20.93	6.78	0.05	**1971**	40.67	11.05	0.28
1957	27.87	11.88	0.07	**1973**	44.67	9.99	0.35
1959	45.18	14.55	0.16	**1975**	47.03	10.69	0.37
1961	21.94	16.23	0.09	**1977**	49.67	11.25	0.46
1963	32.5	8.26	0.14	**1979**	54.39	12.71	0.77

Source: SFA (2010)

The period between 1949 and 1978 was marked by rapid resource exploitation and depletion, with little concern for regeneration or active management. Although 58% of forests were placed under collective ownership, households had little control over resource decisions. Widespread harvests and forest destruction were aimed toward fueling economic growth and freeing up land for agricultural production. Unfortunately, this appropriation of resources did not serve to drive rapid economic growth, and it was not until the Reform Era that policies designed to promote both economic growth and forest regeneration would take place simultaneously.

1.3 The Forest Sector in the Reform Era: 1978 – Present

Not long after Mao's death in 1976, Deng Xiaoping ushered in a new era of economic reform and revitalization. China's forest sector since 1978 is best understood within the context of these massive economic reforms, as it too has undergone its own series of reforms. Although the overall reform period began in 1978, forestry reforms were not initiated until 1981. Forest sector reforms have been defined by the following three objectives: 1) improving rural livelihoods, 2) improving forest ecology and overall environmental protection, and 3) growing the forest industry. The remainder of this chapter will present a review of these three targets and discuss progress to date.

1.3.1 Rural Livelihoods

Land tenure reforms since 1981 have been the most consequential for the long-term economic welfare and stability of rural populations. Agricultural reform is widely recognized as having been a propelling force in expanding economic reforms to other sectors during the early part of the reform process. Less recognized are the concurrent forestland tenure reforms. This section will discuss collective forest reforms since they have had the greatest impact on rural residents. Reforms in the forest sector have not been as consistently successful as those in the agricultural sector, and have thus followed even more of a "trial and error" process (Shen et al. 2009; Yin et al. 2003).

In the early part of the reform era, decentralization of collective property rights and an upward shift in agricultural prices led to dramatic improvements in the incomes of rural people. Reforms in the forest sector were intended to be as pragmatic as those in agriculture. The first collective forest reform was the introduction of the Resolution on Issues Concerning Forest Protection and Development, also known as the "Three Fixes Policy," in 1981. This reform led to three new forms of management. The first was the creation of family plots (ziliushan). These often consisted of denuded and brush lands, turned over to individual households to replant and manage for production purposes (Liu and Edmunds 2003a). The amount of land turned over depended on household size (Shen et al. 2009). The second was responsibility hills (zerenshan), where families shared management responsibilities and split the income from timber sales between the collective and individual households. The third was where collectives maintained all management decisions (tongguanshan), but individual households were granted monetary shares and allowed the opportunity to contribute to management recommendations. Although management and resource ownership shifted, land ownership itself was retained by the collective. Each province differed in terms of what became the primary management type and the extent. For example, by 1986, in Zhejiang, nearly 77% of collective forests were managed at the household level, and in Jiangxi, nearly 92% were at the household level (Shen et al. 2009; Xu 2008); Fujian, however, pursued an independent path, with a shareholding system evolving out of tongguanshan (Song et al. 1997).

Although these reforms were intended to improve tenure security, they have since been described as initially worsening the problem (Démurger et al. 2009). A combination of competing interests for land usage and policy instability led to a lack of confidence in ownership rights (Liu 2001). In some cases, fear of fluctuating land tenure policies may have led some farmers to harvest trees on their property at the outset of the reform era (Prosterman et al. 2000; Harkness 1998). As households gained access to forested resources, they quickly saw the financial gains to be had from immediate harvesting (Shapiro 2001). Initially, households had been permitted to sell timber produced above quota; in 1985 the two-price system was dropped and households were allowed to sell at market prices, although within certain limitations established by the Ministry of Forestry (Zhang 2003). At that time, prices rose precipitously and induced speculation (Yin et al. 2003). Farmers rushed to harvest and engaged in sparse replanting (Yin et al. 2003; Liu 2001).

This initial period of reform witnessed widespread illegal cutting (Song et al. 1997), and a 10% reduction in forest coverage in southern collective forests (Liu 2001). Some analysts have pointed to the high grading and selective harvesting of large-diameter trees as contributing to the overall economic growth during the early 1980s (Albers et al. 1998); this was certainly not limited to the collective sector and took place across the state sector as well. The high rates of harvest during this time also led to changes in stocking, species composition, and fragmentation of forests (Liu and Edmunds 2003b). In response, the government quickly reversed course, suspending household tenure reforms in 1985 (Xu 2008; Song et al. 1997). Timber markets reverted back to state control in 1986, although they were once again liberalized in 1993 (Hyde et al. 2003; Yin et al. 2003; Yin 1998).

No province was required to implement the 1981 Resolution and the implementation of forest reforms has varied by province; thus their impacts have varied regionally. The southern collective region has faced timber quotas, low fixed procurement prices and high taxes, while the north has been subject to no such fixed procurement system, quotas, or higher taxes. Liu and Landell-Mills (2003) described additional charges collected in the southern collective region for forest restoration, insect and disease control, fire protection and administration charges. This regional discrepancy has been blamed for the low investment in afforestation and replanting in the south (Liu 2001). The agricultural tax, which formerly comprised up to a 16% rate of timber-derived income, was eliminated in 2009. However, further reforms in timber-related fiscal policies are still needed. Given that multiple jurisdictions collect fees and levies, many areas have tax rates between 35-62% of the log sale price (Liu et al. 2004; Zhang 2003).

Table 3 Collective land tenure: 1980-2010

Period	Defining Features
1980-2000	• "Three Fixes" policy introduces three forms of household and shared landholding within collective forests • Responsibility largely returned to households • Policies implemented differently across provinces • Two-track price system for timber harvests dropped in 1985, leads to widespread harvesting • Price system reinstated through early 1990s • South characterized by high taxes and fees, restrictions such as quotas and permits and fixed procurement system; north not subject to such policies
2001-2010	• Reinvigorated efforts at improving rural livelihoods • 2003 Collective reforms establish 6-7 forms of household and share landholding within collective forests • 2008 Reforms further establish households as primary landholder and allow for lease or transfer of rights • 2009 Agricultural tax eliminated

Particularly since 2003, with the Resolution on the Development of Forestry (State Council 2003), there has been a renewed effort aimed at individualizing collective forests and securing tenure rights. This has followed the introduction of the Rural Contract Law and the New Countryside Development Initiative in 2002 (Xu 2008). Further reforms were introduced in 2008 with the Comprehensive Collective Forests Reform (Xinhua 2008). Although retaining collective ownership, this policy established individual farmers as the dominant landholders, allowing them to lease or transfer their plots to other farmers. It established the length of the contract period as 70 years, with the right to extend. It also calls for the clear demarcation between commercial and public-benefit forests[1], distinguishing commercial forests as subject to household management decisions.

However, there are still few studies to date that have examined the impacts since either the 2003 or 2008 reforms. Xu (2008) identified the primary intent of the 2003 reforms implemented at provincial levels as the following: increased timber harvests in provinces where de-collectivization is occurring, increased share of forestry household income, and increased afforestation efforts by farmers. Currently, particularly in the southern region, collective forests are largely made up of plantation and production forests, as well as fruit and cash crop orchards (Wang et al. 2004). In fact, more than 80% of plantations are on collective forestlands. Effective implementation of reforms will help enhance the productive use of these lands, particularly in the context of improving rural livelihoods.

Despite the early phenomenal impact of reform on the agricultural sector, rural household business income continues to lag significantly behind urban and off-farm income[2]. Adjusted for inflation, farm-derived incomes approximately doubled between 1985 and 2005, with the national household average rising from 1,559 Renminbi (RMB) (195 USD) to 3,164 RMB (396 USD) (figure 1).

[1] These are also referred to as ecological welfare forests.

[2] The Rural Household Survey (SSB 2006) defines household business incomes as consisting of three sources (primary, secondary and tertiary production). Primary production includes agriculture, forestry, livestock, and fishing. Forestry income is cash income derived from household forestry activities.

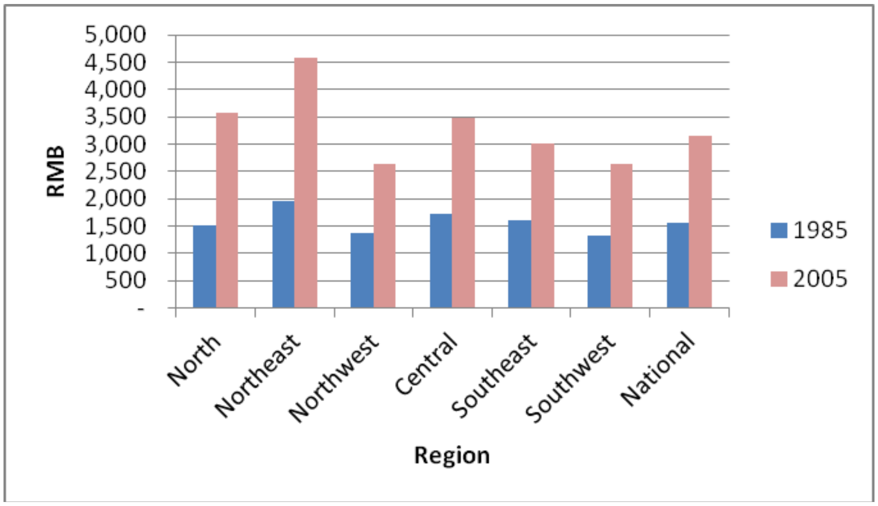

Figure 1 Adjusted farm household income, by region
Source: SSB (2006)

Off-farm incomes are rising. On average, 28% of total rural household income came from off-farm wages in 2005. This percentage was highest among rural areas near urban centers, such as Beijing and Shanghai, and coastal provinces, such as Guangdong and Jiangsu, but it was also high among many non-coastal provinces, such as Jiangxi and Anhui. A notable exception is the island of Hainan, where forestry contributes the highest percentage to farm-derived income, which has one of the lowest shares of non-farm wage income (table 4).[3] This is important as the government is actively seeking to raise the incomes of rural residents by keeping them engaged in agricultural and forestry activities.

Table 4 Relationship between forest coverage and income among five most heavily forested provinces, 2005

Province	coverage as % of total area of province	% of forestry to farm income	% of non-farm wage income to total rural household income
Fujian	62%	3%	33%
Jiangxi	58%	2%	30%
Zhejiang	55%	3%	40%
Hainan	50%	13%	12%
Guangdong	49%	1%	47%

Source: SSB (2007); SFA (2006)

For most rural residents across the country, forestry obviously does not contribute to average farm income. For forest-dependent communities, the story differs. National statistics do not provide data on these farmers' incomes, but according to a survey conducted by Xu (2008), among forest farmers in Fujian, forestry contributes as much as 16% to their overall income; in Jiangxi, it contributes almost 13% of their incomes. Some studies report that up to as much as 70-80% of income in forest-dependent communities can come from forest-related activities (Ruiz Pérez et al. 2004). But even for those whose primary source of income stems from forestry, given the high tax and fee rates described above, there is in fact, little left for the farmer; rural residents in forest-dependent communities continue to be among the country's poorest (Miao and West 2004). These communities are often the poorest because of their

[3] This higher than average ratio is likely due to the island's small population (less than 1% of the total national population in 2005), resulting in a high density of forest to farmer.

geographical remoteness, which affects opportunities for economic development. Liu and Yin (2004) found that increased productivity in rural households and the contribution of forestry to livelihood improvements was offset by increases in production input costs. This has the effect of essentially putting already-impoverished areas at an additional disadvantage in terms of economic development. If the government expects farm-derived incomes to compete with off-farm income sources, the ability to catch up and compete will be critical to improving rural livelihoods.

Viewing rural livelihood improvement solely through the lens of increasing incomes ignores the fact that many rural people rely on a mixture of cash and subsistence farming or agroforestry. This is particularly true in upland forest-dependent communities, where households depend on access to forest resources for fuelwood, building materials, and non-timber forest products (NTFPs). However, peripheral people in China have long been viewed as “uncivilized”, and those practicing shifting cultivation in upland areas as the most primitive (Sturgeon 2005). After 1949, the resources these peripheral people depended on, and had managed through traditional ecological practices, were placed under state or collective management and treated as free goods to be extracted and exploited as the state saw fit (Harkness 1998). Resource policies were further intended to both civilize peripheral people and direct their production efforts toward state goals (Sturgeon 2005).

Studies have shown how the establishment and closing off of nature reserves or conversion of forestland to plantations has led to the reduction or elimination of NTFP collection opportunities, and therefore a reduction of food or income sources (Fu et al. 2009). Additionally, where there is access to modern and more efficient fuel sources, such as electricity, households do not necessarily conform to efforts to “modernize” them, choosing instead to use a mixture of fuelwood and electricity (Trac 2011). In many areas, these communities have been marginalized by policy-making processes and technical assistance programs (Wilkes 2006), while local knowledge and inclusion in policy development are ignored (Urgenson et al. 2011). They have little say in how land is restricted, assigned or, in the cases where conservation policies have prohibited agricultural or grazing practices (see next section), what commercial timber species may be planted. This marginalization does not bode well for the long-term adoption of state priorities, including conservation policies, since the government often provides little incentive to cooperate (Xu and Wilkes 2007).

For rural people, the impacts of the first round of reform have been mixed, and it is too early to assess the impacts of the most recent round of reforms. Regional administrative variation has significantly impacted the type and effectiveness of these reforms. The periodic reversal of tenure rights has left many feeling insecure about their rights. Nationally, forestry does not contribute much to rural incomes. The government faces a difficult task in meeting its objectives to increase forestry incomes as a portion of rural on-farm incomes, to introduce new rural economic opportunities that will stem the rural-urban migration, and to provide greater inclusion of rural people in resource decision-making processes at the local level. Alleviating many of the tax and fee burdens and ensuring property rights are certainly central to doing so, but increased activities are also necessary. This may come in the form of increased production as young plantations mature and are harvested, but there are also many uncertainties associated with the protection and conservation efforts described in the following section.

1.3.2 Forests: Ecology and the Environment

From the 1950s through the 1970s, little effort was made in terms of time or money in investing in silviculture and regeneration. This shifted slightly in the 1970s, with the introduction of the first active conservation efforts. Persistent rains over a three-month period in the summer of 1998 led to a series of devastating floods along the Yangtze River, resulting in the deaths of more than 3,500 people and billions of dollars in damage. These floods were widely blamed on previous excessive logging in steep areas and poor forest management. Conservation and silvicultural improvement efforts increased exponentially after these floods; the narrative that these floods created cannot be underestimated as they became a catalyst for significantly shifting the forest sector from production to conservation. This section will first discuss forest coverage changes and then protection and conservation policies.

Forest Coverage

After the establishment of the People's Republic in 1949, the first forest-specific regulation clearly recognized the degraded state of the forestland base and was aimed at increasing forest coverage. The Directive on Mass Afforestation, Cultivation of Forests and Protection of Forests was promulgated in 1953 and mobilized collectives to begin large-scale afforestation efforts to rehabilitate "wastelands," bare hills, and tree planting in and around villages for shelterbelts and along roads, canals and river banks (FAO 1982). The government called for the afforestation of nearly 100 million hectares (approximately 10% of total land area) during the 1950s, with the focus on creating protected areas and planting fast-growing species of high economic value (FAO 1982). However, these early efforts at afforestation have been largely dismissed as ineffectual, with high rates of mortality, a lack of technical expertise, poor selection of sites and species, and an inadequate definition of responsibility that led to neglect in the maintenance and protection of young forests (FAO 1982).

A forest inventory was launched in 1954, but not completed until the 1960s, leaving experts without a comprehensive picture of the domestic resource base. The first national inventory to rigorously catalogue the country's forest resources took place from 1973-76. Since then, inventories have been conducted in five-year intervals, with the most recent completed in 2008. Since the second national inventory, inventories have been conducted through the use of permanent sample plots, which make use of both remote sensing and ground plots (Lei et al. 2009).

At the time of the 1973-1976 inventory, it was estimated that forest cover stood at 121.9 million hectares, or nearly 13% of the total land area (Démurger et al. 2009). Forest inventories reported a decline in forest cover between 1980 and 1988, a period of ineffectual reforms, very intensive timber harvesting, and land conversion. The mid- to late-1980s witnessed a period of reforestation and the creation of forest plantations, although in some cases those plantations replaced natural forests, a trend that has many concerned about the ecological health of these forests (Stone 2009; Albers et al. 1998).

Afforestation schemes contributed significantly to the increase in forest cover, recovering approximately 5 million hectares per year (WFI 1998). Shelterbelts have received considerable attention; probably the best known is the Great Green Wall, which was first planted in 1978. However, there is some question about the structure, quality and diversity of the trees planted in such programs (Rozelle et al. 2003). There are even questions about whether afforestation efforts are leading to the degradation of soils, thereby potentially worsening the very desertification problems that such a policy was intended to combat (Cao 2008). Particularly since 1998, subsidies from the government and loans from the World Bank have facilitated the establishment of large-scale, fast-growing plantations (Zhang and Chen 2001). It has been pointed out that there are very few close-to-mature forests remaining, and that young- and middle-aged forests have a lower stocking level and lower productivity than older forests (Yin 1998). Additionally, the government's definition of forest area has changed. Fruit trees and cash crops began to be included in the mid-1980s, followed by a reduction in canopy cover requirements, and later by the inclusion of shrubs (Démurger et al. 2009). At present, forestland is defined as land with at least 20% canopy cover.[4]

[4] The canopy coverage requirement for forest area has declined from 40% in the mid-1980s, to 30% in the early 1990s, to 20% by the late 1990s.

Table 5 Forest area by region (million ha), and as percentage of total land[5]

	Forest area			As % of total land		
	1999-2003	2004-2008	% increase	Total area	1999-2003	2004-2008
North	26.35	30.67	16%	151.86	17%	20%
Northeast	32.51	36.15	11%	79.18	41%	46%
Northwest	18.12	22.79	26%	304.42	6%	7%
Coastal	28.66	30.53	7%	80.86	35%	38%
Central	36.03	41.66	16%	101.60	35%	41%
Southwest	50.18	57.84	15%	232.77	22%	25%
National	174.91	195.45	12%	950.69	18%	21%

Source: SSB (2009); SFA (2005, 2009)

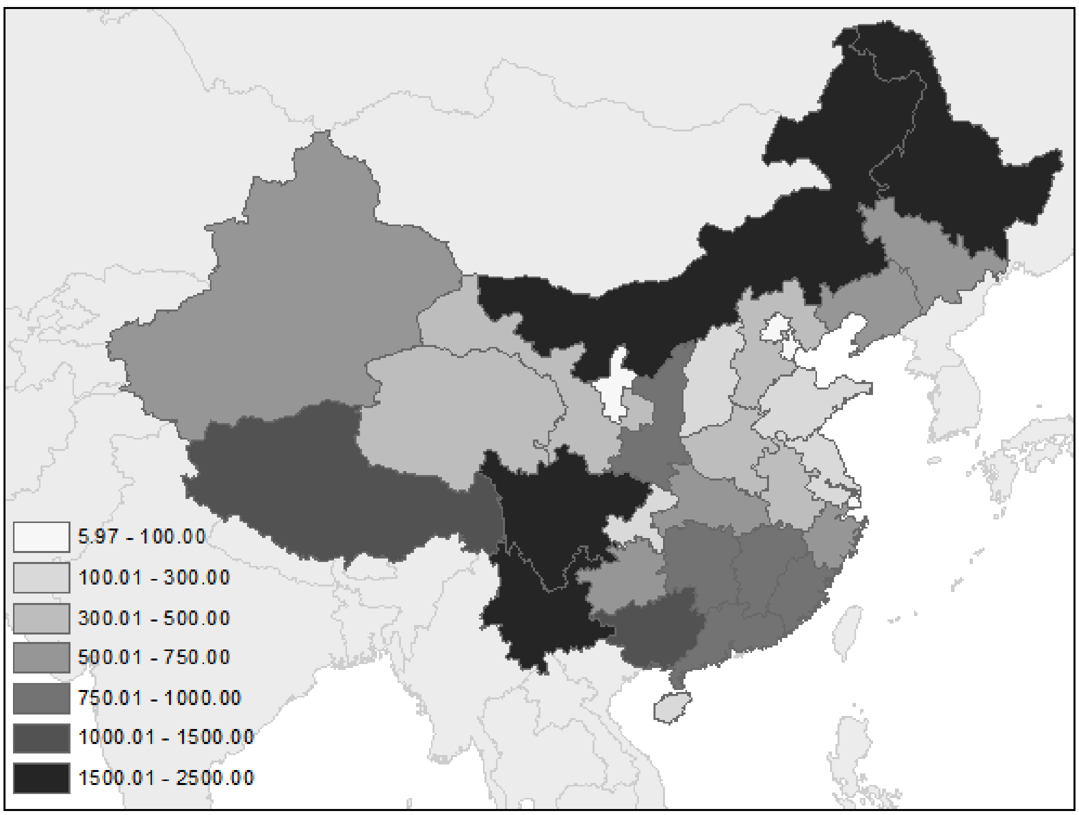

Figure 2 Forest area by province (ha), 2004-2008

Source: SFA (2010)

The Seventh Forest Inventory 2004-2008 (SFA 2009) reported a 12% overall increase in forest coverage (table 5). Total forestland increased by 20 million hectares (ha) to 195 million ha from the previous inventory, and forests now account for 21% of total land area. The government's goal is to increase national forest cover to 26% by 2025 (Wang et al. 2008). Figure 2 shows forest area by province. Inner Mongolia , Yunnan, Heilongjiang, and Sichuan have the largest areas of forest, although there is

[5] See Appendix 2 for a list of geographic regions.

mounting evidence that many of these increases cannot be documented (Trac et al. 2007; Weyerhaeuser et al. 2005). Much of the total increase in inventory occurred in Guangxi, Yunnan, Inner Mongolia, Sichuan, and Gansu. The northwest region, which has the lowest overall forest coverage, experienced the greatest increase, rising 26% above its previous level. The central and southwest regions continue to account for the largest areas of forestland, and together account for half the total forest coverage in the country. The northeast and the north regions combined account for 34% of total forest cover in China.

Protection and Conservation Policies

Soon after the beginning of the reform era, the government introduced a series of new laws aimed at the protection of forests and biodiversity. In 1978, the Three North Forest Protection Project, or Great Green Wall, was launched. This program is the country's oldest ongoing afforestation effort and continues today. In 1979 the government issued the Forest Law, Wildlife Protection Law and Regulations on Wildlife Forest Reserves. These decrees, in conjunction with several others issued in the early 1980s, such as Instruction of Vigorous Development of Afforestation, Regulations for the Implementation of the National Compulsory Tree Planting Campaign, and the Targeted Afforestation Responsibility System, were intended to ensure implementation of afforestation plans.

The late 1980s and early 1990s saw an expansion of the legal framework surrounding forest resources, as well as the adoption of several international agreements. In 1992, after attending the UNCED conferences in Rio de Janeiro, the Chinese government issued the Guidelines for Forest Activities, and an Action Plan on Biodiversity Maintenance (Yang 2001). In 1995, following on the heels of the Rio Summit and the Chinese government's Agenda 21, the Ministry of Forestry put together the Forestry Action Plan for China's Agenda 21. The Action Plan is characterized by three main objectives: a) ensuring sustainable forestry and increasing overall forest coverage and volume, b) modernizing forestry as an industry and raising productivity and efficiency levels, and c) revamping the management system and improving education and public awareness (MOF 1995). Producing an Action Plan according to international standards signified an important step for China's forestry officials in bringing its management and production goals in line with international standards. The development of the forest sector since then has largely conformed to the guidelines outlined in this framework.

All of the above efforts were dwarfed, however, by the policies introduced in the wake of severe flooding along the Yangtze River in 1998. As a consequence of the massive floods, the Central Committee and State Council introduced the National Key Forest Program (NKFP), which is characterized by two monumental conservation efforts: first the Natural Forest Protection Plan (NFPP), followed in 1999 by the Sloping Land Conversion Program (SLCP)[6].

The NFPP called for a reduction in annual timber harvests from natural forests from 32 million cubic meters to 12 million cubic meters, the conservation of nearly 90 million hectares of forest and the afforestation and revegetation of 31 million hectares (Cao et al. 2010). The specific objectives included implementing logging bans in the upper reaches of the Yangtze and Yellow Rivers, reducing logging in state-owned forests, engaging in reforestation and improved silvicultural treatments, and subsequently providing alternative employment opportunities for state workers formerly employed in harvesting activities (Miao and West 2004). The NFPP's reach is extensive, covering 18 provinces and autonomous regions, and focusing mainly on the upper Yangtze and Yellow Rivers, as well as state-owned forests in the northeast and on Hainan Island.

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[6] The SLCP also goes by the names Green for Grain, Grain to Green, and the Conversion of Cropland to Forest program. The latter is the most accurate translation.

The NFPP has been plagued by several problems. First, the central government provided 80% of the funding for implementation, leaving the remainder to come from already hard-pressed local governments (Cao et al. 2010; Xu et al. 2006). Although not targeted directly at collective forests, participation is required, and in regions where collective forests overlap with the ban, landowners are not compensated for economic losses stemming from the reduction in available harvest (Miao and West 2004). As employment among forest-dependent communities has shrunk, it is estimated that rural income will have shrunk by 3-7 billion RMB (469 million USD – 1.09 billion USD), pushing many landowners back into poverty (Xu et al. 2003).

The second policy with important consequences for collective forest owners is the Sloping Land Conversion Program (SLCP). The purpose of this ambitious 337 billion RMB plan is to reduce water and soil erosion and increase forest coverage by converting certain crop growing areas with steep slopes above a 25% grade into grass or forest lands (Xu et al. 2010). The SLCP has been held up as the world's largest payment for ecosystem services program, and claims poverty alleviation as a key component to the program. The primary activity of this program pays for farmers to receive grain and cash subsidies and saplings to plant in lieu of engaging in agricultural activities. A secondary goal of the program is to shift rural farmers into less intensive agricultural activities and off-farm employment (Xu et al. 2004). To date, the SLCP has enrolled more than 21 million hectares (Table 6). By the end of the program, it will have enrolled or affected the landholding size of an estimated 40-60 million households, living in 2,000 counties across 25 provinces (Xu et al. 2010; Bennett 2008).

Table 6 Lands enrolled in Six Key Forest Protection Programs and per hectare cost, 2009

2009	Total hectares enrolled	Average real cost per hectare 1999-2009 (current RMB/USD)
Total NKFP	**83,121,310**	**447 RMB/$66**
NFPP	8,630,590	253RMB/$37
SLCP	21,921,080	572RMB/$84
Beijing-Tianjin Sand Control Program	5,773,690	61RMB/$9
Three Norths and other programs	44,876,280	9 RMB/$1

Source: SFA (2010)

Taken altogether, the six national key forest programs, of which the NFPP and SLCP are two, will comprise the most expensive reforestation and conservation program in the world. From 1999-2009, approximately 269 billion RMB ($42 billion USD) was invested in these programs. These programs vary in terms of their cost (table 6). The average real cost per hectare for the NFPP from 1999-2009 was approximately 237 RMB ($37 USD), while the average per hectare cost for the SLCP during this same period was 538 RMB ($84 USD). The SLCP has been compared to the Conservation Reserve Program (CRP) in the U.S. (Uchida et al. 2005); the per hectare cost of the CRP in 2009 was 838 RMB ($131 USD) (USDA 2009). However, the SLCP is more than twice as expensive as the NFPP and significantly more expensive than some of the government's other conservation efforts, such as the Three Norths Shelterbelt. In total, through the NKFP, more than 83 million hectares have been enrolled, an area equal to slightly less than half of all forestland. Most of the cost of the programs is covered by the central government, with some contributions from multilateral institutions and local governments.

Assessments have found that in some regions the program may be overcompensating landowners for retiring their lands, making the program cost-inefficient (Uchida et al. 2005). In others, there have been large shortfalls in payment delivery and/or landowners have suffered significant income losses amounting to half or more of their income (Bennett 2008). Many rural people have seen their traditional access rights significantly restricted (Xu and Melick 2007), not just in terms of their agricultural practices, but also NTFP and firewood collection, as well as livestock grazing. In place of forest products industries, ecotourism industries have sprung up, creating a limited number of new economic opportunities (Xu et al. 2006). In general though, these programs are not creating short-term economic opportunities and have a fixed period within which they will continue to provide payments. In terms of their ecological mandates, they have ostensibly met their targets for harvest reductions and resource protection (Xu et al. 2006). It is unclear what the effect on the long-term timber supply will be; although up to 75% of the land is slated to be planted as production forests (Bennett 2008), the survival of the trees and shrubs planted has been called into question (Trac et al. 2007; Weyerhaeuser et al. 2005). Not surprisingly, access to better technical support has been suggested as a means of increasing survival rates and reducing program costs (Bennett et al. 2011).

Both programs suffer from a top-down approach that leaves little apparent room for flexibility in local choices (Xu et al. 2010; Bennett 2008; Xu et al. 2006). State directives control even the species permitted to be planted and areas required to enroll, regardless of the ecological suitability (Uchida et al. 2007, 2005). The top-down approach to the NKPP has left many landowners feeling a lack of decision-making autonomy. The longevity of the program's conservation effects has been called into question as landowners may be inclined to reinitiate previous cultivation practices after the subsidies end. Consequently, the poverty alleviation and rural livelihood component may be in conflict with the ecological objectives of the protection programs if greater long-term economic opportunities for rural residents are not created and if local needs and local knowledge are not better incorporated.

1.3.3 Industry Reforms

Since the 1950s, China's forest sector has changed dramatically, both in scale and in structure. To gain a sense of the scale of change, one can begin by examining investment and its changes. In the 1950s, investment was small and dedicated almost exclusively to industry (Figure 3). From the 1960s through the end of the 1990s, investment grew slowly and still largely favored industry over silviculture and afforestation by a ratio of 2:1. However, after 1998, expenditures were dramatically shifted into afforestation and silviculture, with expenditures in this sector coming to dominate industry by a ratio of 9:1. Only since 2008 has industry again increased as a percentage of total investment.
Additionally, while investment in the early years came exclusively from the government, the share of government investment has been consistently decreasing. From 2003 to 2009 alone, the government share of investment dropped from 77% to 53% (table 7). During this same period, investment from foreign sources has fluctuated from a peak of 17% in 2005 to a low of 1% in 2009. Approximately 38% of foreign investment went toward silviculture, 29% toward processing, and the remainder toward other aspects of industry and education. The official data does not present the sources of other investment (labeled undefined in table 7), which comes from private domestic entities and local governments. These are growing sources, since between 2007 and 2009, while foreign investment shrank, other sources of investment in China's forest sector doubled from 65 to 135 billion RMB (10 to 21 billion USD).

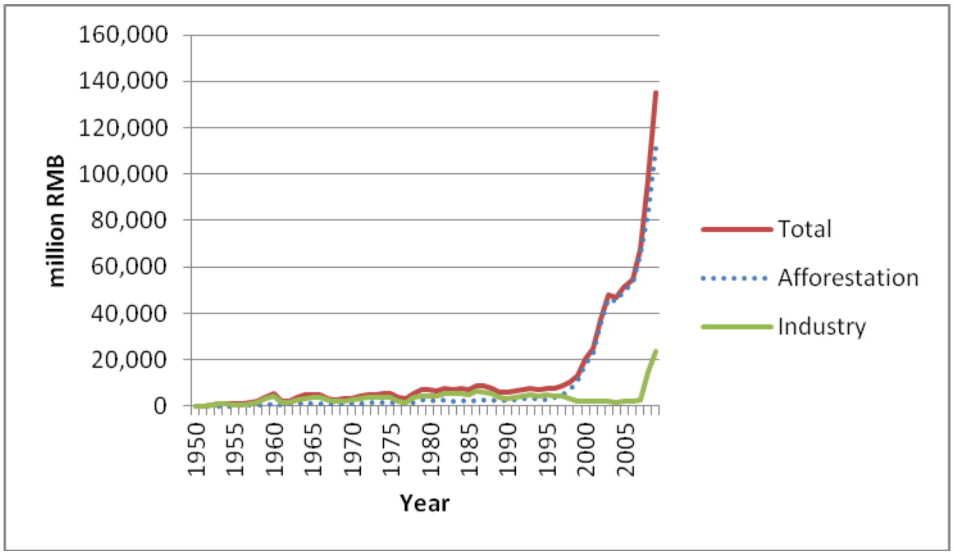

Figure 3 Total real investment in China's forest sector, in million RMB, 1950-2009
Source: SFA (2010)

Table 7 Share of investment in the forest sector, by source, 2003-2009

	2003	2004	2005	2006	2007	2008	2009
Government	77%	78%	77%	75%	69%	51%	53%
Foreign	5%	11%	17%	9%	5%	4%	1%
Undefined	18%	11%	70%	16%	26%	45%	56%

Source: SFA (2004-2010)

State-owned forest bureaus/enterprises once consisted of vertically integrated units that managed forestland, logging operations, and wood processing and were responsible for bringing them to market. These enterprises employed huge numbers of people. For example, the Sanchazi Forestry Bureau in Jilin Province once covered 220,000 ha of forestland and employed 20,000 people (Zhang 2000); while it still manages as much forestland, it now employs fewer than 4,000 people. These large bureaus have dominated the forest ownership and production structure in Heilongjiang, Jilin, and Inner Mongolia[7]. Although the management entities, logging companies, and mills still exist, they are no longer large, vertically integrated bureaus. Investment in these now constitutes about one tenth of overall investment. Reforms in the state-owned forest bureaus began simultaneously with those in other state-owned industries, and to some extent have undergone similar challenges in terms of becoming more market-oriented. It was not until 1989 that this structure was formally decentralized into separate, albeit still connected, units (Zhang 2000). Silvicultural management was further decentralized by splitting up some of the large forest farms and contracting out to collectives, which, as discussed above, further contracted out to household or groups of households (Zhang 2000).

Over the last decade, about three quarters of overall investment in SOEs has come from government sources, with decreasing dependency. Although most of the investment in these state-owned enterprises was directed at silviculture and afforestation in the earlier part of the 2000s, by the end of the decade, industry's share of investment in SOEs had risen from 16% to 55%. However, the number of people

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[7] Other provinces with large areas of state-owned forests include Yunnan, Sichuan, Shaanxi, Gansu, Qinghai, and Xinjiang.

employed by state-owned forests is shrinking rapidly: between 1999 and 2008, the total number of full-time employees declined by 30 %, and the number of full-time employees in state-owned processing enterprises decreased by 85%.

This decline mirrors the overall structural change in employment by ownership type in the processing sector (table 8). As the state sector has declined, private ownership has flourished. The share of privately owned processing enterprises grew from 15% in 1999 to 75% in 2008. From 1999 through 2008, overall employment in this sector increased from 479,898 to 1,312,978. While SOEs, collectives, foreign, cooperative, and shareholding all shrank their share of employment, privately-owned and other ownership types increased their share of employment.

Table 8 Employment in wood-processing enterprises, share by type of ownership, 1999-2008[8]

Owner Type	1999	2008
SOE	26.03%	1.85%
Collective	26.47%	1.61%
Foreign	22.15%	15.11%
Private	10.18%	64.56%
Cooperative	5.37%	0.64%
Shareholding	4.89%	3.17%
Other	4.91%	13.07%
Total Percentage	100.00%	100.00%
Total Number	479,898	1,312,978

Source: SSB (2000b-2009b)

The number of employees per enterprise shifted, but not as greatly as one might expect given the downsizing in SOEs. This would indicate that while the structure of ownership shifted, the enterprises themselves continued to operate and maintained their general size of operations. In 1999, the average number of employees per enterprise was 198, by 2008, this had shrunk to 127. In all, only five provinces experienced a net loss in employment in the timber processing sector.

Overall, those working in the timber processing sector earn less than those in the manufacturing sector (figure 4). For the ten-year period between 1999 and 2008, real manufacturing wages averaged 36% higher than those in the timber processing sector. The average rate of change in timber processing wages follows the same pattern as the rate of change in manufacturing wages across provinces and rose by an average annual rate of 10% between 1999 and 2008.

[8] Note: "Other" is vaguely defined by the State Statistical Bureau and encompasses all other enterprises not included in the preceding list. In effect, any enterprise that is not wholly owned under one of the other classifications (i.e., jointly owned: state-own joint, collective-own, other limited, etc.).

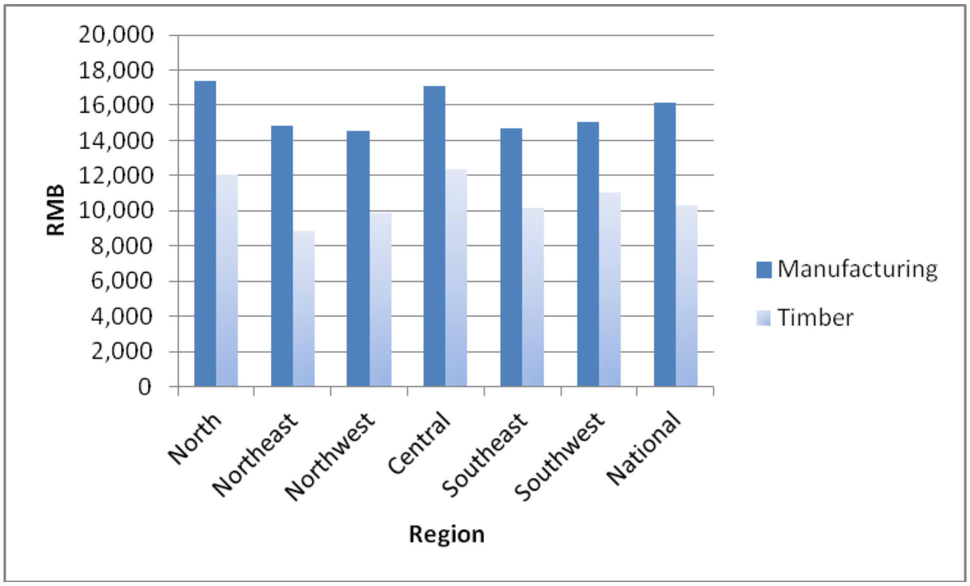

Figure 4 Real ten-year average manufacturing and timber processing wages, 1999-2008

Source: SSB (2000-2009)

Table 9 Number of wood-processing enterprises, by region

	1999	2008	% change
Northeast	185	249	35%
North	361	1,309	263%
Northwest	61	43	-30%
Coastal	1,001	6,007	500%
Central	654	2,315	254%
Southwest	158	390	147%

Source: SSB (2000b-2009b)

The greatest growth in number of wood-processing enterprises has occurred primarily along the coast (table 9). Jiangsu, Shandong, Fujian, Zhejiang, and Guangxi experienced the most significant expansion in number of enterprises. Other provinces, including Guangdong, Henan, and Hunan, also grew during this period, increasing their overall number of enterprises. Although Liaoning, Anhui, Jilin, Heilongjiang, Jiangxi, and Shanghai were all large centers of industry at the start of this period, they experienced slower growth through 2008. The only region to experience a decline was the northwest, which lost 30% of its enterprises. Figure 5 shows the distribution of processing enterprises, with a higher density along the coast.

In terms of volume of secondary materials, the coastal region produces more than the other five regions combined. This is largely because the coastal region is the center of wood panel and flooring production, while also being the primary center of production of lumber, wooden beds and veneer. In 2009, the coastal region produced 61% of the country's wooden flooring, and 48% of its panels. In particular, Zhejiang and Jiangsu provinces are the primary centers of production for flooring, while Jiangsu is the largest producer of panels. This is also demonstrated in the location of processing enterprises (table 9).

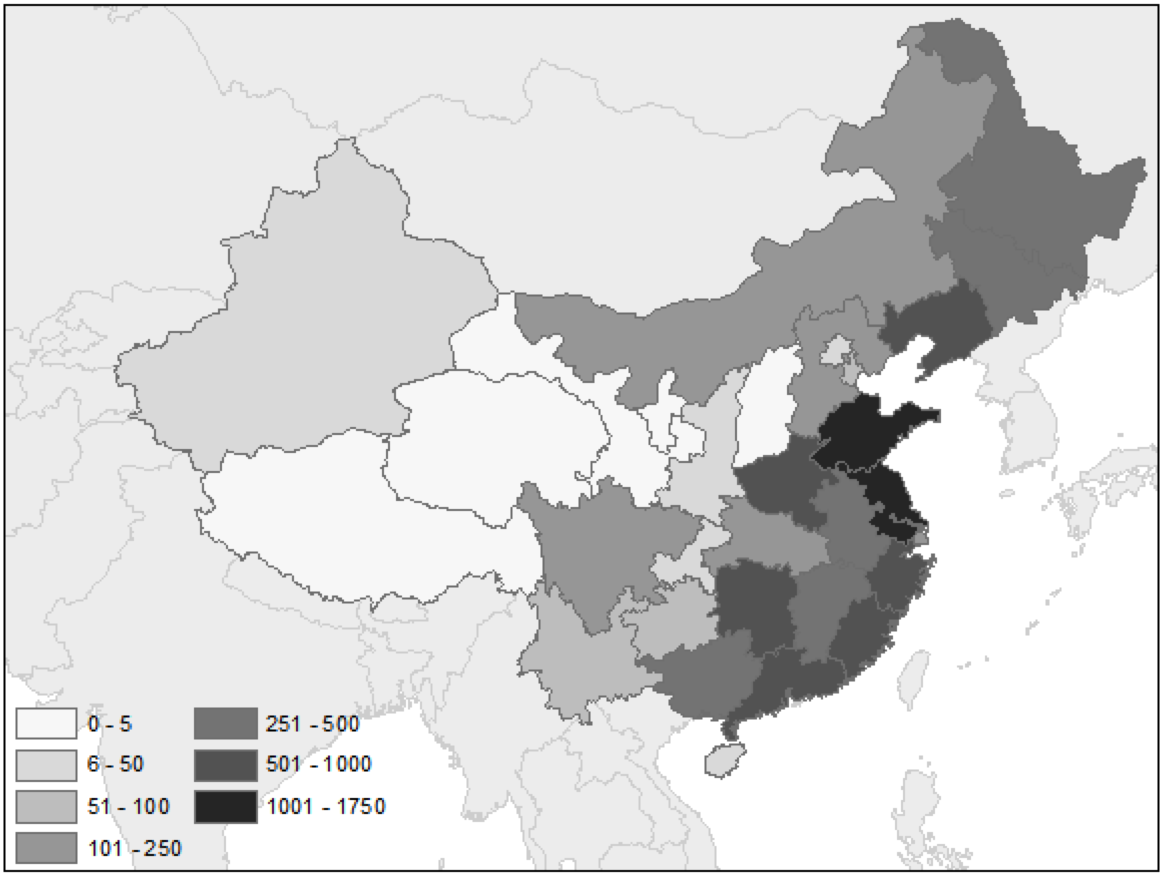

Figure 5 Distribution of forest-processing enterprises by province, 2008
Source: SSB (2009b)

The production of logs is controlled by quotas set by the central government and is intended to limit harvest volumes at or below the annual incremental growth. Domestic logs are consumed or processed domestically, with essentially no log exports. The central region is the highest log producing region (figure 6), with Guangxi, Hunan, and Guangdong in the top five producing provinces (see Appendix 1A). Fujian, in the coastal region, and Yunnan, in the southwest region, are also among the top five producing provinces. From 2003 to 2008, total harvest of logs increased from 43.2 million CUM to 73.6 million CUM, although the harvest volume in 2009 dropped to near-2007 levels, at 70.7 million CUM. These official statistics do ignore above-quota production, which may be close to double the reported production volume. For example, in 2003, the SFA estimated that above-quota log production had averaged 75.5 million cubic meters per year from 1998-2003 (Démurger et al. 2007). Underestimation of domestic production of logs or imported log volumes presents challenges in reconciling production, consumption, and exports of processed wood products. Lumber, panels, and other semi-finished and finished goods are much less likely to be underreported than are timber resources; given the more than 19% annual growth rate in lumber and panel production in China in the last decade, it seems improbable that total log consumption did not also grow apace.

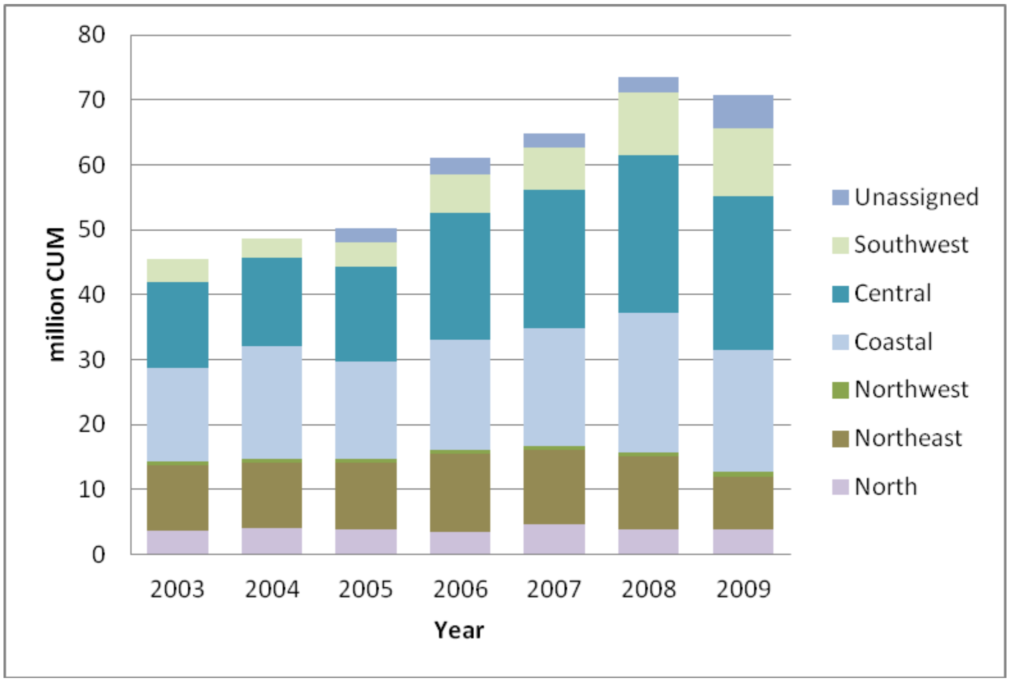

Figure 6 Log production by region 2003-2009
Source: SFA (2004-2010)

Fraud appears to be widespread: between 2003 and 2008, 1.7 million cases of forestry "misconduct" were reported (Xinhua 2011). Misconduct includes activities such as falsified logging permits and ownership certificates. Recent discoveries of falsified documents at companies such as Sino Forest and Cathay Forest point to an expansion of the problem into the private sector. As a result of the revelation of such scandals, these companies have seen their stock prices plummet. This type of fraud poses a threat to continued foreign and private investment in forest management, which may become increasingly important as the government continues to reduce its own investment levels.

Although official production of roundwood has increased, demand continues to outpace the domestic supply (figure 7). As a major producer of semi-finished (e.g., plywood) and finished wood products (e.g., furniture), China is now often referred to as a wood workshop. However, China is increasingly reliant on roundwood imports to fuel its growth. According to official Chinese statistics, total consumption of logs, by volume, grew at an average annual rate of 7.6% between 2000 and 2008, before declining by 4.2% in 2009. The average contribution of imports to this (official) consumption was 33% (table 10). The growth in consumption has led China to become the largest importer of tropical logs, and it also accounts for nearly a third of the global imports of coniferous and non-coniferous logs (table 11).

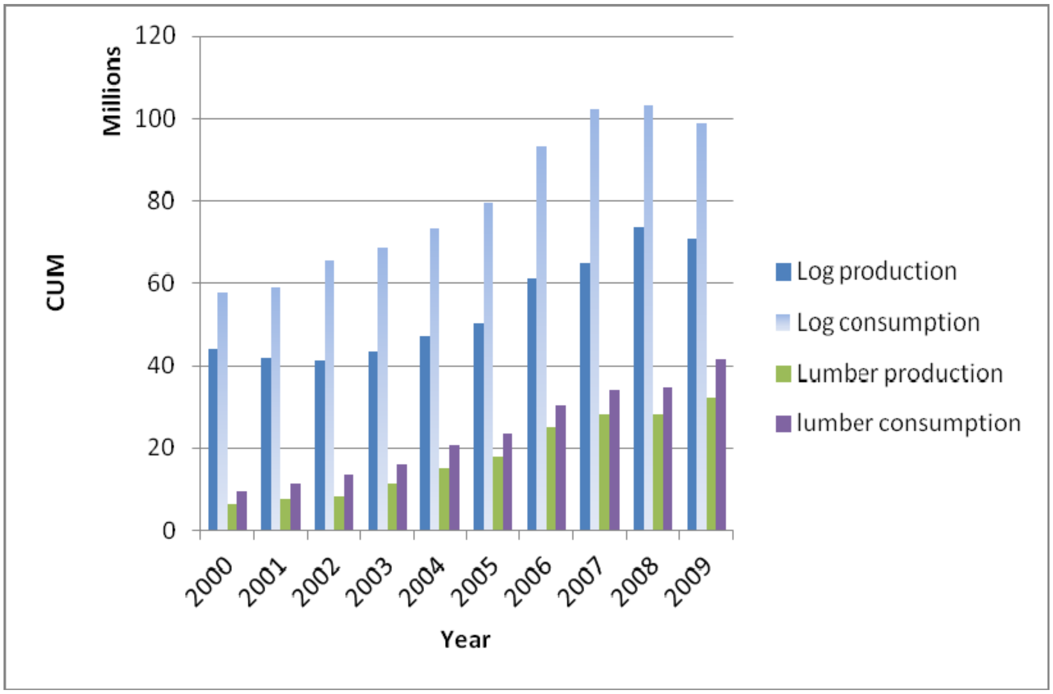

Figure 7 Officially reported log and lumber production and consumption, 2000-2009

Source: SFA (2000-2020)

Table 10 Total official log production and contribution of imports, 2005-2009 (million CUM)

	Domestic production	SFA Reported Imports	Imports as % of total consumption	FAO Reported Imports	Imports as % of total consumption
2005	50.23	29.37	31%	30.73	38%
2006	61.12	32.15	33%	33.08	35%
2007	64.92	37.13	38%	37.92	37%
2008	73.57	29.57	30%	30.30	29%
2009	70.68	28.06	29%	28.65	28%

Source: SFA (2006-2010); FAO (2011)

Table 11 China's share of global imports of logs, 2003-2009

	2003	2004	2005	2006	2007	2008	2009
C Quantity	20.3%	20.9%	22.3%	23.9%	27.4%	26.8%	31.5%
NC Quantity	10.2%	9.4%	14.5%	14.1%	17.5%	13.7%	8.7%
T Quantity	56.9%	57.3%	54.6%	55.7%	57.3%	55.8%	77.9%
C Value	18.8%	19.3%	21.7%	24.1%	27.5%	37.8%	37.7%
NC Value	16.3%	11.0%	22.1%	25.2%	28.4%	27.1%	13.5%
T Value	53.1%	53.8%	47.2%	49.8%	51.3%	80.0%	88.0%

C = Coniferous, NC = Non-coniferous, non-tropical T = Tropical

Source: FAO (2011)

The total value of wood product exports grew from 27 billion RMB ($3.34 billion USD) in 2000 to more than 102 billion RMB ($15 billion USD) in 2009, while imports grew from 28 billion RMB ($3.4 billion USD) to 51 billion RMB ($7.5 billion USD), meaning that nearly half of the value of its exports came from the cost of imports (figure 8). The relative value declined during this time, having peaked in 2000, when the value of imports exceeded the value of exports. This reflects the growth of the processing industry within China.

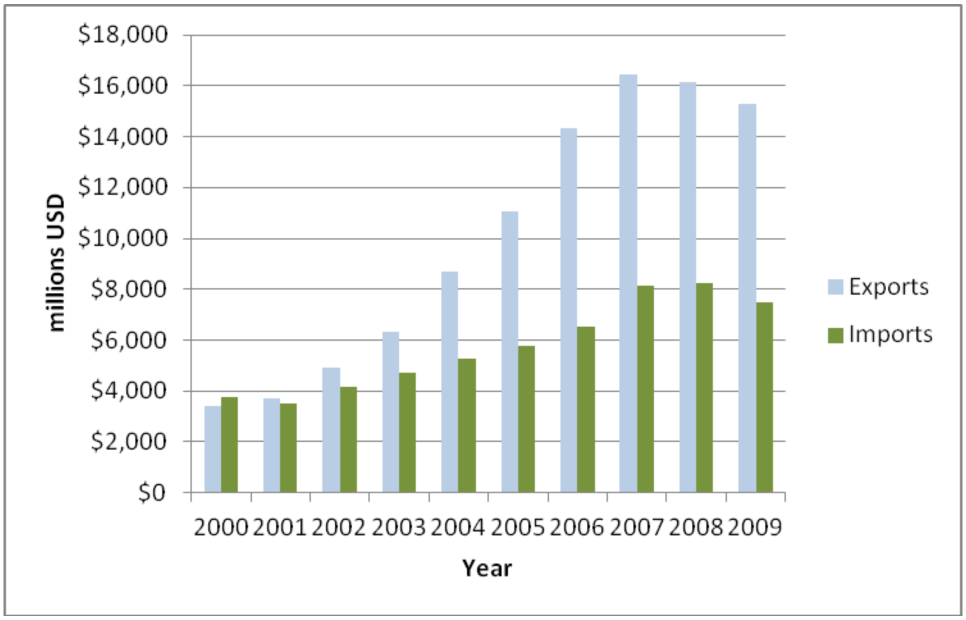

Figure 8 Total value of wood imports as compared to exports
Source: Global Trade Atlas (2011)

China's exports largely go to the EU, Japan, and the U.S. Having risen to become one of the largest producers of wood products, it is still perceived as a producer of low- to mid-quality products and to have a low-production-cost advantage. However, the precise sources of its cost advantages are still unclear. Although it is certainly true that China has enjoyed a low-labor-cost advantage, lower environmental regulations, and worker health and safety regulations, other lower labor-cost countries such as Vietnam, are beginning to make inroads into the market. Many outside of China view the low value of the RMB as another advantage. It is argued that an undervalued RMB makes Chinese exports less expensive in importing countries and as a result, Chinese manufacturers are able to out compete their foreign counterparts. This debate is now at the center of proposed U.S. legislation aimed at pressuring the Chinese government to raise the value of the RMB.

China relies heavily on the developing world for its tropical log imports. The largest source of tropical logs in 2008 was Malaysia, supplying 48% of its tropical logs. There is wide concern that Malaysia serves not only as a source of logs, but also as an intermediary for logs exported illegally from Indonesia, which ranked very low in terms of its own exports to China. According to the FAO, other primary sources included Papua New Guinea, Gabon, and to a lesser extent, Congo, Myanmar, Cameroon, and Equatorial Guinea.[9] The largest single source for both coniferous and non-coniferous logs is Russia (figure 9). In

[9] Estimates for China's imports of tropical roundwood from the International Tropical Trade Organization (ITTO) vary from those of the FAO. The ITTO reports Guyana, Togo, and the Central African Republic as exporting larger quantities than Equatorial Guinea and Myanmar.

2008, Russia supplied 75% of the coniferous logs and 44% of the non-coniferous logs imported by China. Other primary sources of coniferous logs include New Zealand, the U.S., and Canada.

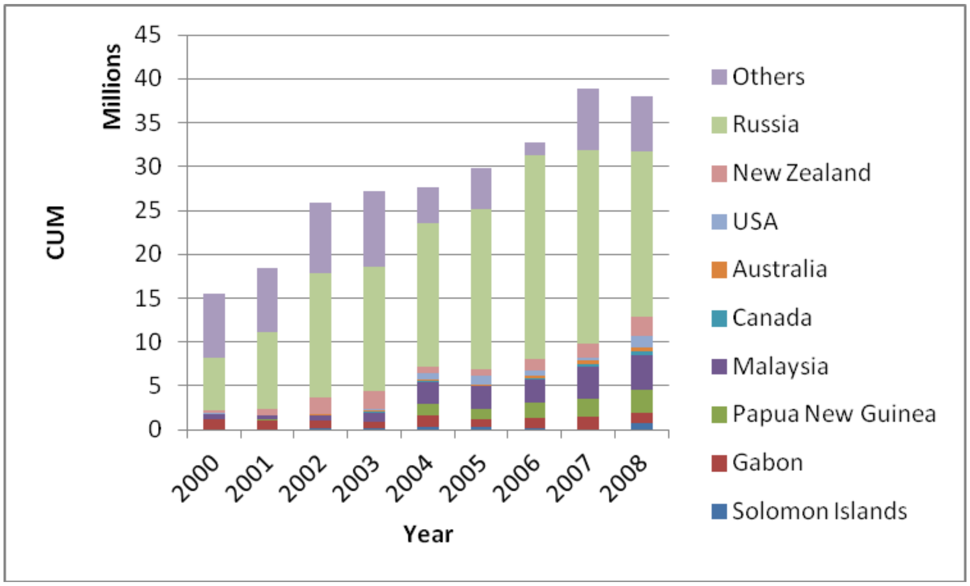

Figure 9 Log imports by source, 2000-2008
Source: FAO (2011)

Domestic constraints to international trade are almost non-existent. Import tariffs on logs were eliminated in 1999 and anyone holding an import license is eligible to import forest products into China. Concerns about the legality of the world's wood products trade, including those that flow through China, have led to the emergence of non-tariff barriers from many of China's most important export destinations. The EU's Forest Law Enforcement, Governance and Trade (FLEGT) program and Voluntary Partnership Agreements serve as de-facto trade agreements, providing licensing rights to "ensure only legally harvested timber is imported into the EU from countries agreeing to take part in this scheme" (EC 2008). The U.S.' Lacey Act Amendment requires importers to supply adequate documentation proving the legality of wood brought into the U.S.

Non-policy mechanisms are also being implemented to control the supply chain of illegal and unsustainable wood products. Many international NGOs and multilateral institutions have collaborated with the Chinese government to encourage the development and expansion of forest management and chain-of-custody certification schemes within China. Three current schemes exist: the Programme for the Endorsement of Forest Certification (PEFC), the Forest Stewardship Council (FSC), and the emerging national China Forest Certification Council (CFCC). The FSC certification system has particularly benefited from the efforts to build certification capacity. As of early 2011, FSC had issued 1,610 certificates within China, while PEFC has a much smaller presence, with only 108 chain of custody certificates issued (PEFC 2011). The CFCC has only recently been launched, although it is expected that 2.66 million ha will be certified in Heilongjiang Province under the scheme (CFCN 2011).

The CFCC program is administered by the State Forestry Administration and is expected to receive mutual recognition under PEFC. All three schemes contain elements that are intended to address the three legs of the sustainability stool: environment, economics, and society. In 2010, 98% of FSC's certifications were for chain-of-custody certificates (FSC 2011). Only 51 certificates had been issued for combined forest management and chain of custody. This reflects a much greater effort on the part of

NGOs to create demand in end markets for FSC products, and on the part of environmental NGOs to drive certification expansion of FSC certified forest management units.

1.4 Conclusion

The biggest challenges to collective forestry reforms can be summarized in a few sentences. Rural people continue to lack awareness and confidence in their rights. Complaints plague the reform efforts; corruption at local levels is systemic and a top-down approach to conservation conflicts with the tenure reform efforts. Household plots are too small to be significant at the individual level; while aggregation may improve the situation, it will require linking objectives between households. Better options to consolidate and rent land are necessary to improve the contribution of forestry to farm incomes. The 2008 reforms were designed to rectify many of these problems, but they have yet to be fully implemented. More attention should be paid to communities that depend on agroforestry or agropastoral practices either for subsistence products or to supplement their incomes. Households in these communities may respond differently to efforts to reform their fuel use (electricity instead of fuelwood) and conservation policies that limit their ability to collect NTFPs or adjust their willingness to continue to implement conservation efforts according to state directives after the programs and outreach conclude. The rise in programs that provide payments for environmental services, through programs such as the SLCP, have been widely touted as successful in promoting forest conservation and improving rural livelihoods; however, many of these programs are subsidized by the central government, and cannot continue indefinitely. Without improved access to economic opportunities and tenure security, the conservation programs could impede, not improve, rural livelihoods in forest-dependent communities. Problems have also continued to plague the state-owned sector, including a concern that the central government has limited capacity to monitor harvest quotas and logging restrictions (Xu et al. 2004; Zhang 2000). The above-quota harvesting estimates mentioned earlier point to this very problem. If this problem is not adequately addressed, it will contribute to a potential overestimation of inventory and forest coverage. China may soon find itself at a crossroads between having to decide whether its investments in forest conservation in rural areas represent investments solely in forest protection or whether they will result in an expanded resource base from which rural people can draw upon to contribute to their livelihoods.

The government has been acutely aware of the resource shortages since before massive flooding prompted conservation-oriented logging restrictions in 1998. In 1985, the government implemented an annual allowable cut, now administered by the SFA. More recently, quotas, permits, high taxes, and other restrictions have been used to constrain supply. It is widely recognized that the domestic resource base is extremely constrained and will be for the foreseeable future, particularly since per-capita forest coverage is low and demand for fiber is high in both industrial and non-industrial uses. The concern over illegal logging has largely been referred to in the context of imports. However, it continues to be a problem domestically, as evidenced in the harvest estimates and fraudulent logging permits and ownership certificates. Although the government has constrained domestic supply by restricting harvests, it has done little to curb demand, in part because domestic demand is still closely linked to its export industry. Consumption has only partly been addressed with product substitution policies by encouraging the use of non-wood building materials such as concrete and brick in construction, which, of course, are not without their own adverse environmental effects. This has pushed the country to become increasingly reliant on imports to fuel its export-oriented wood products industry. One result is that many of these timber products come from countries with lower costs and poorly enforced environmental standards. How efficiently the processing industry operates has not been widely examined and should be of interest both within China and externally, especially for those concerned with global natural resource flows and China’s competitiveness in the global forest products markets.

The most important changes in the forest industry have come about as a result of market reforms: the transformation of state-owned entities and township and rural enterprises into private enterprises. During the period 1999-2008, there was a near tripling of jobs and a quadrupling in the gross output value in the wood-processing sector. Trade liberalization by the Chinese has opened up markets for foreign imports, exports, and sources of capital. Wages in the timber processing sector are on average lower than those in the overall manufacturing sector, indicating that the timber processing sector in China represents lower skilled jobs than other sub-sectors. However, in the last few years, the government has begun to direct increased attention to developing its wood-processing industry, as evidenced by the Forestry Development Plan (SFA 2009), and increased investments, which rose from 3% to 17% of total forestry investments between 2007 and 2009. These moves indicate a strong commitment by the government to affirm China's role as an exporter and a more efficient producer of higher-quality goods. For these improvements to be effective, these investments need to be efficiently used, which remains to be seen.

There is no doubt that China has made enormous strides in its efforts to improve rural livelihoods, improve its forest ecology, and grow its forest-based industries. Yet the results are, in many ways, mixed. Forest-dependent communities continue to be among the poorest and their economic development continues to lag far behind the coastal and urban regions; these same communities are often left out of the decision-making process, thereby further marginalizing them. The push to reform land tenure has proven to be complex. This is particularly true given the long-term nature of investments in forest management, which differ from those of agricultural investments that can be more immediately reaped. Complicating the process of devolution of property rights are conservation-oriented directives that often conflict with the promises of land reform. Forest coverage has increased, but gains may be overstated until the ongoing problems of illegal logging and forest quality within China are acknowledged and controlled. Lastly, the forest industry has expanded rapidly in the last fifteen years or so, particularly along the coast, but it has become reliant on imports to fuel this growth and China will be expected to play an increasing role in ensuring the use of well-managed and legally harvested timber materials, not just at home but abroad as well. It is clear that questions of economic, social and ecological sustainability, both domestically and globally, will not disappear any time soon.

2 The Efficiency of Chinese Wood-Processing Enterprises

2.1 Introduction

Although China's domestic supply of wood is significantly constrained both by a limited natural supply and by conservation-oriented policies, the country is increasingly regarded as the world's "wood workshop" (White et al. 2006). Between 2001 and 2009, the net value of exports grew from $234 million to $7.825 billion U.S. dollars (USD) in value (table 2.1).[10] During this period, the value of imports was equal to nearly half of the total value of wood exports. The increase in net value of exports can be attributed to the processing and furniture manufacturing industries, which expanded rapidly over the last decade. China's total exports of wood furniture grew from a value of $1.4 billion USD to nearly $7.6 billion USD. Wood furniture and plywood combined account for about two-thirds of wood product exports. Similarly, total plywood exports grew in value from $242 million to nearly $3.2 billion in value. China's largest export markets for wood products include the United States, Japan, and the European Union (Global Trade Atlas 2011). These exports were significantly negatively affected by the global economic downturn, beginning in 2007.

Table 12 Net value of total wood exports, 2001-2009

Year	Net value (in millions USD)	% growth over previous year
2001	$234	168.43%
2002	$746	218.24%
2003	$1,612	116.16%
2004	$3,440	113.41%
2005	$5,295	53.93%
2006	$7,781	46.94%
2007	$8,302	6.71%
2008	$7,904	-4.80%
2009	$7,825	-0.99%

Source: Global Trade Atlas (2011)

At the same time, manufacturers in North America and elsewhere have become increasingly concerned about their ability to compete with their Chinese counterparts. The same concerns that permeate discussions about competitiveness within the U.S. manufacturing sector are easily extended to the wood-processing subsector. In addition to complaints about China's currency valuation, U.S. manufacturers are concerned about Chinese imports of potentially illegally harvested wood materials and lower costs from environmental regulations and health and safety standards, and claim that their Chinese counterparts benefit from government subsidies. For example, the concern over subsidization manifested itself in the form of dumping charges brought to the World Trade Organization by the United States. Although subsidies were once present, they were phased out several years ago (Cao and Eastin 2007; American Forest and Paper Association 2004). It is more likely that the industry's growth stems from continued – although declining – relatively inexpensive labor, increased investment, and capacity utilization.

The purpose of this study is to calculate efficiency metrics and understand how efficiently Chinese wood-processing (i.e., sawmills and manufacturers of semi-finished products) enterprises operate, given a set of inputs. Understanding efficiency can provide insight into how enterprise inputs to production affect

[10] Net exports are calculated as the value of exports minus the value of imports.

China's competitiveness in the wood products trade. To do this, a stochastic frontier production function is estimated and used to measure technical efficiency for Chinese enterprises. Previous studies have examined the level of efficiency in pulp and paper mills (Hua et al. 2007) and forest management units (Zhang 2002), but there are no known studies examining the wood-processing sector. Timber processing is a subsector of industry and therefore has much in common with the manufacturing sector in terms of its reliance on capital and labor, as well as on material and energy inputs. It is therefore more comparable to studies on pulp and paper mills and other industrial enterprises than to forest management units.

2.2 Background

In economic theory, it is generally assumed that firms operate at the most productive level possible; the reasoning holds that if there are potential profits to be made, a firm will find a way to realize them. In reality, however, firms vary greatly in their productivity levels. Efficient uses of resources can be affected by events or factors uncontrollable by the firm itself, such as changes in prices and resource availability. The concept behind measuring efficiency is the idea that a production unit transforms a set of inputs into a set of outputs, subject to constraints imposed by fixed technologies. A "production function" expresses the maximum amount of output obtainable from a given bundle of inputs using a given technology. As a result, we may seek to understand the sources of inefficiency, and to compare efficiency levels among a particular set of producers. The underlying concept behind measuring efficiency is the idea that a production unit transforms a vector of inputs into a vector of outputs, subject to constraints imposed by fixed technologies.

There are several aspects to efficiency. Koopmans (1951) defined technical efficiency as occurring when a producer cannot increase output without either reducing the output of at least one other product or increasing input. This is largely an extension of the concept of Pareto efficiency, which describes a situation whereby goods are allocated such that no individual can be made better off without making some other individual worse off. Debreu (1951) and Farrell (1957) were the first to introduce a measurement of technical efficiency that could be incorporated into the production function. Efficiency is not defined in absolute terms, but is a relative measure among a particular set of producers (Farrell 1957).

Each firm's level of technical efficiency is based on the distance of the firm's operations from the (ideal) production frontier. Technical efficiency is a relative measure of a firm's output as a proportion of the corresponding frontier output. The score is bounded by zero to one because it represents a ratio of a) the distance from zero outputs to the actual production and use of inputs, to b) the distance from zero outputs to a perfectly efficient use of inputs. With a score of one, the firm is operating at an efficient level and on the production possibilities frontier (PPF) curve; with a score of less than one, the firm is operating inside the PPF. From an estimated production frontier it is possible to measure the relative efficiency of certain groups or a set of practices using the relationship between observed production and some ideal or potential production.

Figure 10 is a simple demonstration of the relationship between input use and technical efficiency. A firm uses some input set L(y) and produces some output with inputs X1 and X2 at point X^A . However, if the firm were to use inputs more efficiently, input use would contract to point $\lambda^A X^A$. Technical efficiency can then be represented by the ratio $\lambda^A X^A/X^A$. As X^A moves toward $\lambda^A X^A$, the firm becomes more efficient.

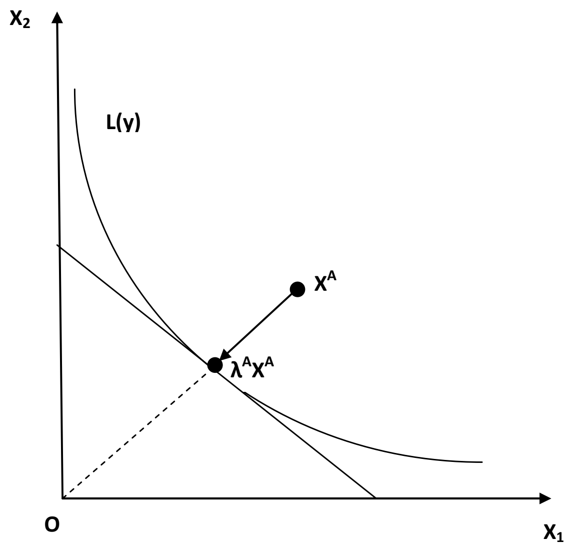

Figure 10 Input-oriented measure of technical efficiency

Production efficiency can be examined using two primary methods. The first is by using stochastic frontier analysis (SFA), an econometric approach that allows the representation of possible deviation of actual production from the idealized frontier. Standard econometric methods such as Ordinary Least Squares (OLS) provide only an "average" of production practices, rather than an estimate of the best practice itself, thus any deviation from the frontier in OLS is considered "noise". However, SFA allows for the distinction of "noise" from (in)efficiency. SFA estimates an industry's technical frontier based on the performance of the most technically efficient firms. The second method involves data envelopment analysis (DEA). DEA is a non-parametric programming method of evaluating the relative efficiency of comparable units by transforming multiple inputs into multiple outputs. One perceived advantage of using DEA is that it does not require any prior assumptions about the underlying functional or distributional relationships between inputs and outputs (Zhou et al. 2007; Seiford and Thrall 1990). However, similar to OLS, DEA does not allow for the distinction of statistical noise (Coelli et al. 1998).

Both the econometric approach and the programming approach can be categorized according to the type of data available and the types of variables available (quantities only, or both quantities and prices). With quantities only, technical efficiency can be estimated, but with quantities and prices, economic efficiency can be estimated and decomposed into its technical and allocative components. Fried et al. (2008) noted that the "majority of DEA studies use quantity data only and estimate technical efficiency only, despite the fact that the procedures are easily adapted to the estimation of economic efficiency in a setting in which prices are available and reliable."

2.3 Literature Review

The literature on production efficiency is large and growing, having expanded greatly in the past two decades. Frontier analysis has been used to study inefficiency in many sectors, including those with environmental implications such as fisheries (Grafton et al. 2000), agriculture (Reinhard et al. 1999), forestry (Carter and Cubbage 1995), health care (Stanford 2004), manufacturing (Tybout and Resende 1995), transportation (Sarkis and Talluri 2004), education (Smith and Mayston 1987) and much more.

SFA has also been used to directly analyze pollution and environmental efficiency, as well as technical and allocative efficiency in renewable resources (Reinhard et al. 1999). In these studies, the argument is that while actual environmental effects can be difficult to measure, the input that causes the environmental effect can be easily quantified and an analysis of the economic and environmental performance of the inputs can then be conducted (Shadbegian and Gray 2005; Reinhard et al. 2002; Reinhard et al. 1999; Xu et al. 1999). Although there have been many studies looking at industries that use natural resources as inputs, there has been relatively little application of SFA to the environmental performance of inputs. Only one study using a DEA approach has been found to examine the environmental components of pulp and paper mills (Hua et al. 2007). The information generated in studying environmental components within efficiency analysis can be used for policy purposes, particularly for those inputs or products subject to government policy and regulation. In fisheries, Kirkley et al. (1995) examined vessel efficiency using a stochastic production frontier based on a sample of sea scallop vessels operating in the Mid-Atlantic. Estimates of technical efficiency were then assessed relative to biological conditions, input levels, and economic performance.

In forestry, studies on mill efficiency using SFA have emerged only in the last decade. Helvoigt and Grosskopf (2005) estimated the rate of change in technical efficiency and impacts to productivity growth in Washington State sawmills between 1968 and 2000. They found increases to productivity, but an inability to keep up in technical efficiency, which they attributed to the declining size and quality of logs during the study period. Similarly, Nyrud and Baardsen (2003) studied efficiency among Norwegian sawmills for the period 1974 to 1991; their results indicated a fairly high level of efficiency. Diaz-Balteiro et al. (2006) analyzed the relationship between productive efficiency and innovation among several types of processing subsectors within Spain’s wood-based industry. They revealed a high level of inefficiency with no clear link between efficiency and innovation, which they attributed to a low level of research and development capacity among the enterprises.

Other studies in forestry have reviewed forest management and the pulp and paper sector. Carter and Cubbage (1995) developed technical efficiency estimates for the southern U.S. pulpwood harvesting industry for two years, 1979 and 1987, and found that efficiency was correlated to firm size. Yin (2000) assessed pulp manufacturers globally and determined that efficiency scores varied somewhat by region but estimated that they are quite high globally.

In the case of China, the DEA literature has outpaced the SFA literature. Zheng et al. (2003) used DEA to investigate the efficiency of state-owned enterprises and found that while productivity increased from 1980 to 1994, these changes occurred not as a result of improvements to efficiency but as a result of technical change. These results are similar to those found in Movshuk (2004) and Ma et al. (2002). Both of these latter studies analyzed the impact of reform on steel and iron manufacturing enterprises. Hua et al. (2007) used DEA to explore the efficiency among paper and pulp mills in Anhui Province, using capital and labor as discretionary inputs and pollutant emissions as a non-discretionary input to calculate the eco-efficiency. Their results indicated that the most significant impediments to efficiency were in discretionary inputs. Zhang (2002) examined the impacts of economic reforms on silviculture and found significant resulting improvements in efficiency, which is attributed to reductions in administrative costs and reductions in labor redundancies. Many of these studies employed data obtained from statistical yearbooks published by the National Bureau of Statistics, which collects and publishes data on state-owned enterprises. No published studies have been found examining wood-processing enterprises in China using either DEA or SFA.

2.4 Description of Variables and Data

The analysis assumes that the production function of an enterprise is dependent on a set of three variables. Each firm produces an aggregated quantity index, containing categorized products, using three inputs. Variables included in this study are labor, capital, and wood materials. Labor and capital are variables used in almost all SFA studies, and are often the only inputs included due to data constraints. Raw wood materials (in the form of roundwood or fiber equivalent) have been used in studies on wood-processing or pulp manufacturing facilities. It was anticipated that an energy attribute would also be included, but the data on this input was inconsistently collected, and was thus omitted from the final analysis. Each variable is described below. Difficulties in the data are explained in section 2.5.2.

2.4.1 Variables

Dependent Variable

The dependent variable is represented by an unweighted, aggregated output of total production measured in tons, by enterprise.

Independent Variables

Labor is calculated as the total number of employees per enterprise. By far the most common measure of labor used in efficiency studies is total number of employees (Kim et al. 2006; Movshuk 2004; Pascoe and Coglan 2002; Siry 2000). Another unit often used is the total number of hours worked (Nyrud and Baardsen 2003; Kirkley et al. 1995; Johnson et al. 1994).

Capital is measured as the level of fixed capital for each enterprise, using the value quantified in RMB. Ma et al. (2002) and Movshuk (2000) employed the value of fixed capital to examine efficiency in the steel sector, measured in Chinese Renminbi (RMB). Nyrud and Baardsen (2003) used only an aggregated value of capital.

Wood inputs are calculated as the total volume of wood materials consumed, in tons. Because there are few studies of the forest sector, there is no definitive measure to employ. Carter and Cubbage (1995) created a dummy variable based on hardwood or mixed species used (1995). Other measures employed have included total volume of materials (Yin 2000), number of sawlogs (Nyrud and Baardsen 2003), and both total forestland and growing stock use (Siry 2001).

2.4.2 Data

An enterprise survey was designed and piloted in 2008 and was expected to be carried out in 2009; however, that specific survey has been indefinitely postponed due to funding constraints. The data used for the analysis in this study were obtained by the Environmental Economics Program of China at Peking University in Beijing. The data come from an enterprise survey implemented in 2007 by the Chinese Academy of Social Sciences' Rural Development Institute across 15 provinces. A total of 545 enterprises participated in the survey. Although the survey was not designed for the purposes of an efficiency study, the questionnaire asked for information on ownership structure, assets, employment, taxes and fees, inputs to production, and sales. The data required to conduct efficiency analysis are often closely guarded by enterprises and, in China, are extremely difficult to obtain. As a result, the survey provides a very rare opportunity to explore enterprise efficiency in China. However, there are a number of limitations to the dataset. For instance, many enterprises provided no response to certain questions. Of the 545 enterprises surveyed, 222 enterprises provided no information on ownership type, assets, or production. For the purposes of summarizing the survey, these enterprises are omitted from any further discussion.

Summary information on sales, assets and employment among the remaining 323 enterprises is provided in table 13. Sales income was far more widely reported than production and is reported here for the 323 enterprises. Materials were not widely reported for this group and thus are not included in the summary information. The most common ownership type was private, followed by private small-medium enterprise (SME). Employment among collective, private, joint ventures, and state-owned enterprises (SOEs) averaged approximately 250 persons, which was higher than the 2006 national average of 144. For the SMEs, employment averaged only 25 persons. Average sales among the former four were 34 million RMB in 2006, while only 5.3 million RMB for the SMEs. Average fixed assets held by the former in 2006, were 38.9 million RMB and 750,000 RMB for SMEs. Production within these enterprises included a variety of products, including lumber, plywood and other panels, fiberboard, packaging materials, and some custom products.

Table 13 Summary statistics for key variables from enterprise survey (n = 323)

Ownership Type	Total	Median Age	Average Number of employees	Average Fixed Assets in 10k RMB	Average Sales Revenue in 10k RMB
Mean	323	4	255	3,896	3,402
Collective	27	4	209	3,508	4,514
SOE	29	9	253	1,439	2,559
Joint	26	3	269	7,798	6,253
Private	149	3	287	861	2,258
Other private (SME)	92	4	25	75	533

Table 14 presents summary statistics on per unit of sales employment, and fixed assets for these same enterprises. Jointly-owned and collective enterprises had the lowest employee-to-sales ratio, while private enterprises and SOEs had the highest. The Jointly-owned also had the highest fixed asset to sales ratio, while SMEs and private-owned enterprises had the lowest.

Table 14 Inputs per unit of sales income (n=323)

Ownership Type	Average employees per 10k RMB in sales	Average Fixed Assets per RMB in sales
Mean	0.07	1.15
Collective	0.05	0.78
SOE	0.10	0.56
Joint	0.04	1.25
Private	0.13	0.38
Other private (SME)	0.05	0.14

Although the data provide certain general statistics, for the purposes of the efficiency analysis, of the remaining 322 enterprises the number of observations containing full information on all the variables to be included in the efficiency analysis was much smaller. One of the most significant problems was with the energy input. A large number of enterprises reported irreconcilable units. For example, many different enterprises reported multiple energy inputs, with some component in kilowatt hours, some in coal, some in oil, etc. Some reported just a monetary value, leaving it unclear as to whether this was a value or unit price. In the end, energy had to be omitted from the analysis due to the limited number of usable observations.

Many enterprises used units that could not be converted to create an aggregated production index. For example, if a company reported production of a particular number of sheets, panels, beds, or in square meters, they were omitted from the analysis since converting these into cubic meters would not be possible without exact specifications from the mill. The most common unit of measurement for production and material inputs was tons, followed by cubic meters. In Chinese surveys, the 10,000 unit is commonly requested as a unit of reporting. For example, the survey form asked for fixed assets in 10,000 RMB, which would mean that if a company has fixed assets valued at 1,000,000 RMB, they should report it as 100. However, it was found that sometimes the 10,000 unit would be double reported, for example

"100 万 "[11] would be reported. In these instances, if the resulting proportions became distorted and confirmation of the actual amount was not possible, the observation was removed for the purposes of the analysis.

It was originally anticipated that the analysis could be conducted using a panel data setup. However, enterprises were asked to provide information on assets only for the year of establishment and for the year 2006. Because there were no questions regarding capital improvements or depreciation in the intervening years, it is not possible to estimate any transformation of the assets. Only the value of assets in the year 2006 would thus be accurately represented for the purposes of using capital as an input to production. For this reason, although the survey form requested information on materials and energy inputs on multiple years (2000-2006), only the year 2006 is included in this analysis due to the difficulty of measuring capital inputs and in obtaining a large enough sample across years.

As a result, the number of establishments included in the analysis was 79. Summary statistics for the variables included in the analysis are provided in table 15. As is evident from the high standard deviation relative to the mean, there is a large spread in the data. This is due to the fact that enterprises varied greatly in their size. For example, the largest enterprise by production quantity reported 9,500 tons while the smallest reported 30 tons.

Table 15 Summary statistics for variables included in analysis (n=79)

	Production (in tons)	**Material inputs (in tons)**	**Labor (total number of employees)**	**Fixed Assets (in 10k RMB)**
Mean	1,756	2,435	59	340
standard deviation	2,363	4,054	112	883
by ownership				
Joint	*5,300*	*8,259*	*243*	*1,317*
SOE	*4,285*	*9,643*	*171*	*587*
Private	*1,656*	*2,138*	*84*	*702*
Unknown	*1,675*	*875*	*26*	*3*
Collective	*1,505*	*3,229*	*291*	*74*
Private SME	*1,278*	*1,331*	*17*	*149*

Table 16 reports input use per ton of production. Material use relative to output is highest among state and collective enterprises, while private SMEs and those of unknown ownership used the least amount. Collectives also had the highest ratio of employees to production, while private SMEs had the lowest. The average level of fixed assets per ton of production is 1,900 RMB, with the highest levels held by private and joint enterprises, while collectives and unknown ownerships hold the lowest.

[11] One 万 (*wan*) equals 10,000.

Table 16 Inputs per unit of production (n=79)

	Material inputs per ton of production	Number of employees per ton of production	Fixed Assets per ton of production
Mean	1.39	0.03	1,900
standard deviation	1.72	0.05	3,700
by ownership			
Collective	2.15	0.19	500
SOE	2.25	0.04	1,400
Private	1.29	0.05	4,200
Private SME	1.04	0.01	1,200
Joint	1.56	0.05	2,500
Unknown	0.52	0.02	19

Although the survey sampled across provinces, the smaller sample from which the data for the analysis was drawn is far less representative. The north and the northwest regions are highly represented in the data, but none of the enterprises from the central region are included. Provinces included in the analysis come from the northeast (Inner Mongolia, Liaoning), southwest (Sichuan, Yunnan, Chongqing), north (Shanxi), northwest (Shaanxi, Xingjiang), and coastal (Jiangsu, Shandong) regions. Table 17 shows the regional distribution of enterprises included in the efficiency analysis.

Table 17 Number of enterprises by region, 2006

	Total
Northeast	7
Northwest	30
North	29
Coastal	7
Southeast	0
Southwest	6

2.5 Results

The results are reported in table 18. FRONTIER 4.1 (Coelli 1999) was used for the model estimation. FRONTIER 4.1 performs a likelihood ratio test to determine if the model estimation is preferable to an estimation using OLS. This test indicated that the null hypothesis of inefficiency not existing could be rejected and that model estimation is warranted.

Table 18 Maximum likelihood model estimation for production functions

	Model coefficients
Materials	***1.354
Labor	***0.791
Capital	-0.026
Materials^2	-0.025
Labor^2	-0.055
Capital^2	-0.003
Materials * Labor	-0.056
Materials * Capital	-0.004
Labor * Capital	-0.008
Constant	-1.128
σ^2	***1.630
γ	***0.922
Log Likelihood	-61.472

*** indicates significance at .01 level (t=2.68)

The coefficients represent the elasticity parameters for the production function. In the results above, both materials and labor are significant at the .01 level, and both are positive. The coefficient for materials is almost twice as large as that of labor. It is not surprising that materials should be significant as they represent both an input and a major component of the output; many of these enterprises are transforming their wood inputs into a slightly more value-added wood output. Given the magnitude of the coefficient, holding all other factors constant, and given a unit increase of material inputs, one could expect output to increase by 1.35 units. The coefficient for labor is not as large as the material input, but it also appears to contribute significantly to the efficiency of the enterprises. The coefficient for the labor variable can be interpreted similarly to that of material inputs. Given a unit increase in labor use, holding all other factors constant, output could be expected to increase by .79 units. The coefficient for the fixed asset variable is not significantly different from zero. The lack of significance in the fixed asset attribute could indicate one of several issues. It could be that Chinese enterprises do not benefit from increasing investment in fixed assets or that these firms may not be fully utilizing their assets effectively. It may also be possible that there is a high level of variation of asset cost among different types of manufacturers, depending on product type. The negative sign implies that greater output could be achieved with less capital. If the capital variable is removed from the estimation, the results remain largely the same, with the coefficients for material and labor still strongly significant and of the same magnitude. The coefficient for the variance parameter, γ , also has a large t-value, indicating that inefficiency exists.

In examining the efficiency scores by ownership type, we find that there is not a large variability in the distribution of scores (table 19). As indicated above, the regional distribution of the enterprises is heavily skewed toward the north and northwest; it is also skewed toward private enterprises, including large and small-medium enterprises (SMEs). State-owned and large private enterprises tend to have a lower average efficiency. Because there are so few collective, joint-owned, and "unknown" ownerships included, one should remain skeptical of generalizations about these ownership forms.

Table 19 Efficiency scores by ownership type

Ownership	Total	Technical Efficiency
Private	17	0.61
Private SME	49	0.74
Collective	2	0.73
Joint	3	0.76
Unknown	2	0.82
SOE	6	0.64

Table 20 provides efficiency scores based on regional distribution. Enterprises in the southwest had the highest efficiency scores, while the other four regions had fairly similar averages ranging between .68 and .72. However, these low averages for the central and northeast regions and the high average for the southwest region are significantly skewed by the fact that there are only six to seven enterprises included in each region.

Table 20 Technical efficiency scores by region

Region	Total	Technical Efficiency
Coastal	7	0.68
Southwest	6	0.80
Northwest	30	0.67
Northeast	7	0.71
North	29	0.72

The relationship between the efficiency scores and several firm-specific characteristics can also be assessed. For example, efficiency scores have a positive relationship with production size (table 21), when quantity is taken into account. Enterprises producing between 0 and 5,000 tons had efficiency scores of .69, while the largest enterprises producing between 5,000 and 10,000 tons had the highest scores of .81. To test this relationship, as well as the impact of location and ownership, the efficiency scores were regressed on production quantities, and two dummy variables: one representing whether the province was coastal, and the second whether the enterprise was privately owned (private large and SME) (table 22).

Table 21 Efficiency scores by production size

	Production (in tons)	Number	Average efficiency scores
Small/Medium	0 - 5,000	71	0.69
Large	5,000 - 10,000	8	0.81

Table 22 Results from regression of efficiency scores on firm attributes

Variable	Coefficient
Production	***.00002
Private	.05488
Coastal	-.04520
Constant	***.62612
P > F 0.0206	
R^2 0.1214	
N=79	

*** indicates significance at .01 level

The results indicate that there is a strong, albeit very small, relationship between production quantity and efficiency scores. Location and ownership appear to have no effect on efficiency scores. This indicates that enterprises with higher production levels may have efficiencies of scale that other enterprises could replicate. These efficiencies could be related to the costs involved in establishing an enterprise with high levels of sunk costs, such as those necessary for machinery and equipment. This would imply that the larger the production size, the more the enterprise is making use of its machinery and equipment. Given the lack of importance of private ownership type and location, it becomes evident that higher efficiency levels are not necessarily found among privately owned rather than among state or collectives, nor are they necessarily confined to the coastal provinces, but that inland and western provinces are making advances in their efficiency levels.

2.6 Discussion

This study explored the efficiency of domestic enterprises within China using a survey collected by the Chinese Academy of Social Sciences to study wood-processing enterprises in several regions across China. Because of the proprietary nature of the information required to conduct accurate efficiency estimates, such analyses are rarely conducted. This process was particularly illustrative of the difficulties in conducting economic analysis from survey data collected in China. Several suggestions relevant to this particular study can be made. First, survey administrators should regularly check to ensure they are collecting data in a manner consistent with how information is requested on the survey form. Second, questions that were phrased as input per unit of production might be better phrased simply as total amount used, rather than requiring the responding enterprise to calculate their per unit of production use. Additional time during the interview process might be spent to ensure accurate collection of data, which could help avoid problems of trying to determine values post-data collection. Often, redundant questions can be built into surveys in order to elicit information in multiple ways. Such methods might help ensure the most accurate collection of quantitative information when there might be sensitivities involved.

Previous studies have examined other industrial subsectors that were once under heavy state supervision in China, such as iron and steel, and pulp and paper mills, as well as other aspects of forestry, such as forest management. These studies were able to make use of panel datasets and thereby examine changes in efficiency. Ma et al. (2002) examined the iron and steel industry in China and found that production size had an impact on efficiency, but that the differences in products manufactured provided the greatest source of difference. Both Ma et al. (2002) and Movshuk (2004) found that technological change (shifts in the production frontier by year) in the steel industry declined in the mid-1990s. Movshuk (2004) found that the four largest enterprises failed to demonstrate any scale efficiency and therefore recommended a revision of policies aimed at retaining state control any of the larger enterprises. Zhang (2002) found that the economic reforms resulted in significant improvements in efficiency in state-owned forest bureaus, but did not assess the sources of inefficiency.

Unlike the iron and steel industry, and unlike forest management, wood processing in China is no longer subject to high levels of state ownership since it is not strategically important to the State. The positive relationship between material use and labor to wood-processing efficiency found in this study indicate that enterprises are largely reliant on wood and labor inputs, rather than capital inputs. This is of particular relevance given concerns about foreign competitiveness. The results here suggest that the efficiency, and thus the competitiveness of these wood-processing enterprises, stems from the very sources that foreign enterprises are concerned about: relatively inexpensive materials and labor. However, as both of these inputs become more expensive, Chinese enterprises may find it difficult to continue to maintain their competitive edge.

In this study, none of the mills were found to be fully efficient. The average and maximum technical efficiency scores were .70 and .91 respectively. While 82% operated at .6 or higher, only 19% of the sample had an efficiency score above .8 (figure 11). This implies that under available resources and technology, the enterprises could either significantly increase their production using the same total level of inputs or maintain their current output with fewer total inputs. Given the positive and significant coefficients for labor and materials, but the insignificant coefficient for capital, sources for improvement might be found in better utilizing existing capital resources.

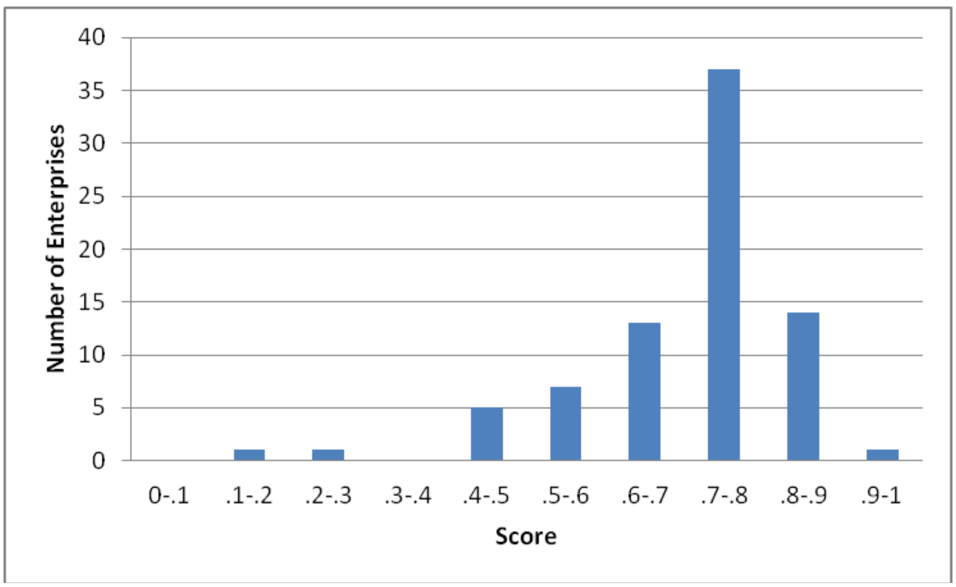

Figure 11 Distribution of efficiency scores

From the results of the regression analysis we can conclude that there is no discernible difference in the effect of coastal location on efficiency scores; nor does there appear to be any effect of private ownership on efficiency scores. This is surprising given the widespread belief that coastal proximity and private ownership greatly affect production efficiency. In contrast, there is a relationship between production size and efficiency scores. Thus, the size of enterprise, as measured by production quantities, appears to be strongly linked to efficiency rates: the larger the production volume, the greater the efficiency. It is possible that this is not an outcome of an economies-of-scale effect, but simply of better management among larger firms.

Two of the stated goals of the government's 2009 Forestry Development Plan (SFA 2009) are to improve the quality and the efficiency of China's forest industries. The results here suggest that by consolidating the operations of small and mid-size firms, efficiency might increase among firms. It also suggests that efficiency currently depends on technology that uses labor and material inputs, but not necessarily on capital improvements. It may be possible to better utilize existing capital instead of investing in new assets. However, there is undoubtedly a certain level of prestige associated with a firm's ability to secure high levels of capital and the ability to demonstrate modern and high-tech facilities. It has been pointed out that this may be just as important to a manager or owner as the production level or profit.

The average efficiency score of .70 provides significant room for improvement among most enterprises in terms of increasing their efficiencies. If consolidation of smaller enterprises into larger ones resulted in increased efficiency, then there might not be such a high reliance on wood materials. Given that nearly half the total value of wood exports comes from the value of imports, this will be of increasing relevance to enterprise managers, particularly if they face higher resource prices.

2.7 Conclusion

This study estimated efficiency metrics for Chinese wood-processing enterprises and examined the efficiency of these enterprises relative to each other, by estimating a stochastic production function. Problems with the survey were found and noted. Useable data for a small number of enterprises were extracted and extrapolated to create a production function, and its associated efficiency frontier. The coefficients for the material and labor inputs proved to be significant, and efficiency scores for the enterprises were calculated and analyzed. A mean efficiency score of .70 indicates significant room for efficiency improvements among almost all enterprises. It is often assumed that coastally located and private enterprises outperform other ownership types and firms in other regions; such a relationship could not be revealed in this analysis. On the other hand, production size appears to be positively related to higher efficiency scores. This is the first study to examine Chinese wood-processing mills from an efficiency standpoint and is useful in terms of providing an initial window into the efficiency of Chinese wood-processing enterprises.

There are a number of limitations to the results of this study. First, the sample used in the efficiency analysis was skewed toward particular regions, and toward particular provinces within regions, and thus not representative of the country as a whole. This is particularly important given the relative differences in regional manufacturing and production. For example, there were no enterprises included from the southeast, which is the second-largest center of production after the central region. The north and northwest were proportionally overrepresented. Additionally, a more even distribution of ownership types might give better insight into the differences in efficiencies between ownership forms. Only a cross-sectional analysis was performed; a time component would allow better insight into efficiency changes. This subject should be of great interest to those concerned with China's processing sector and certainly warrants continued investigation.

3 Foreign Investment Location Choice in Chinese Wood-Processing Enterprises

3.1 Introduction

For the thirty year-period between 1980 and 2010, China's economy experienced an average annual growth rate of 10%. Even in the face of the global financial crises and economic recession, China is expected to continue to grow at 8.5% or more in 2011 (World Bank 2010a). Per capita income, in 2005 U.S. dollars (USD) purchasing power parity (PPP) terms, rose twelvefold from $524 in 1980 to $6,200 in 2009 (World Bank 2011). This rapid growth is the outcome of carefully controlled central planning, with policies directed downward from the national government in Beijing. Underlying this growth has been the massive structural transformation of the economy from a predominately agrarian base to a predominately export-oriented manufacturing base. China is now considered to be the world's manufacturing workshop, having grown its manufacturing sector by 18% per year between 2000 and 2009 (World Bank 2011). Although the U.S. manufacturing sector is still larger, producing an average of $1.62 trillion (in current USD) (compared to China's $838 billion), its small 2% per annum growth rate is dwarfed by that of China. Significantly, China could overtake the U.S. as the largest manufacturer within the next two years, given current growth rates.

Policies and other location-specific factors can have a significant impact in attracting investment in manufacturing and other sectors. Understanding the regional factors that attract investment can help determine the efficacy of both national and regional policies intended to promote economic development. Which policies and factors have the greatest impact on foreign investment are thus of great interest to policymakers, entrepreneurs, investors and managers. Interest in understanding the factors that motivate foreign investment into particular countries, and into particular regions within individual countries, has led to an expanding body of empirical research on investment location choice. Previous literature on investment in China has examined the manufacturing sector as a whole, and found that certain factors influence the location of investment (Du et al. 2008; Cheng 2007; Cheng and Stough 2006; Cheng and Kwan 2002; Fung et al. 2002; Zhou et al. 2002; Broadman and Sun 1997). Many of these studies focus primarily on one source of investment and few have sought to disaggregate the manufacturing sector to examine subsectors within manufacturing.

There are two objectives to this study. The first is to understand whether or not the same factors that have been shown to motivate foreign investment in manufacturing as a whole within China also apply to the wood-processing subsector. The second is to assess the effect of roundwood availability on foreign investment in the wood-processing sector. This study focuses on foreign-invested wood-processing enterprises during the period 2003-2008. It is hypothesized that in addition to roundwood, five other factors affect foreign investment location choice; these include wages, infrastructure, agglomeration, policy incentives, and education.

3.2 Background

3.2.1 Foreign Direct Investment in China

Much of the country's enormous growth over the last thirty years has been attributed to the growth of foreign direct investment (FDI), and indeed, attracting FDI was of primary interest when the government initiated its first reforms (Sit and Lu 2001). Early in the reform period, the central government moved quickly to secure foreign investment, and by 1980 had established its first four special economic zones (SEZs). These zones immediately attracted investment from countries with which China had historic and diasporic ties, such as Hong Kong, Taiwan, and Singapore. After the early success of the SEZs, the government began adding different categories of special zones: export-processing zones, economic and technological development zones, high-tech industrial development zones, and free-trade zones. By 2009, there were an estimated 100 special zones across China (CADZ 2010).

Table 23 Foreign direct investment, net inflows, in billions, 2009

Rank	Current USD	Country
1	194.84	Luxembourg[12]
2	134.71	United States
3	78.19	China
4	72.92	United Kingdom
5	59.99	France
6	52.4	Hong Kong, SAR
7	39.15	Germany
8	36.75	Russian Federation
9	34.58	India
10	33.29	Netherlands

Source: World Bank (2011)

China is the world's third-largest recipient of foreign direct investment (table 23), receiving an average of $75 billion USD per year between 2000 and 2009 (World Bank 2011). Most of this foreign investment has been directed to the provinces along the eastern coast. For instance, the twelve coastal provinces accounted for an average of 81% of foreign investment in fixed assets in China between 2005 and 2008. This is no accident: Beijing-led policy reforms initially focused on these eastern provinces and introduced preferential policies aimed at attracting foreign investment in manufacturing. In the last decade or so, greater attention has been paid to increasing economic development in the western provinces, but these provinces continue to lag behind. In 2008, per-capita income in rural households bordering eastern cities such as Beijing and Shanghai averaged about $1,618 USD, while in some of the most remote western provinces such as Gansu and Qinghai, per-capita income in rural households averaged about $426 USD. If one were to examine the rural-urban divide, the difference would be even more glaring: urban per-capita income in cities such as Beijing and Shanghai is nearly nine times greater than rural incomes in Gansu and Qinghai.

3.2.2 Investment in China's Wood-Processing Enterprises

It is difficult to paint a comprehensive picture of foreign investment in China's wood-processing sector due to a lack of complete information. The data provides only a disjointed view of investment and the published literature is almost non-existent, in English or in Chinese. Data collection differs depending on the source of investment. Industrial surveys collect data on all sources of investment and focus on a particular set of questions, while surveys conducted by the State Forestry Administration collect foreign investment data that excludes Taiwan, Hong Kong, and Macao (this group will henceforth be referred to as *Huaqiao* or "overseas Chinese") and focuses on a different and narrower set of questions. As a result, not all of the data are comparable. Some analyses have sought to separate out investment from *Huaqiao* investors because they are not considered to be truly foreign since they may represent round-tripping, in which Chinese money is moved offshore and then brought back to China disguised as foreign investment (World Bank 2002). Investment by this group may also be driven by a separate set of motivating factors, such as personal relationships and family ties (Broadman and Sun 1997).

Foreign investment in China's timber processing sector has been clustered along the coastal region. During the 2003-2008 period, the coastal regions accounted for an average of 87% of all foreign-invested enterprises (see Appendix 3), and 91% of non-*Huaqiao* foreign investment. Provinces in the northwest,

12 NB: Luxembourg's foreign direct investment appears high due to its role as home to financial intermediary and holding companies.

which are less accessible than the coast, have the lowest number of enterprises with foreign investment (table 24). In fact, although there were a handful of enterprises in this region in 2003, by 2008, there were no longer any foreign-invested wood-processing enterprises. This is likely due to the fact that most of this foreign investment is export platform, which refers to investments in products that are exported back to the parent or to a third country. Foreign investment in China's wood-processing sector generally fits within the export platform FDI profile since a large portion of the wood products manufactured in China are exported and sold elsewhere (Sun et al. 2005). This follows the overall pattern of FDI in China. Several coastal provinces stand out as having the largest number of foreign-invested enterprises (FIEs). These include Guangdong, Zhejiang, Jiangsu, Fujian, Shandong, and Liaoning. In 2008, these six provinces alone accounted for 73% of FIEs.

Table 24 Regional distribution of foreign-invested wood-processing enterprises, in number of firms

Year	2003	2004	2005	2006	2007	2008
Northeast	123	148	143	157	175	161
North	42	39	38	43	50	48
Northwest	6	4	4	2	0	0
Southwest	15	18	20	16	17	19
Central	163	214	218	208	228	239
Coastal	339	507	495	519	552	602
Total	*688*	*930*	*918*	*945*	*1022*	*1069*

Source: SSB (2003b-2009b)

Since 1978, as Beijing has introduced market reforms, the ownership structure of the wood-processing industry has changed dramatically. The number of timber processing enterprises (a category that includes wood and bamboo) has grown from 2,420 firms in 1999 to 10,314 firms in 2008. Just as general economic reforms have fundamentally changed the ownership structure of manufacturing industries throughout China, so too has ownership of timber processing enterprises changed (figure 12). Since 1999, the types of ownership have expanded greatly, with state-owned (SOEs), collective, and cooperative enterprises declining in number. According to the China State Statistical Bureau, ownership categories are defined as follows:

- *State-owned enterprises* are enterprises whose assets all belong to the central government
- *Collective enterprises* are those whose assets all belong to local enterprises, including city, counties, township and village governments
- *Private enterprises* refer to any enterprises whose assets belong to private individuals
- *Share cooperatives* are funded by shareholders and invested, and include limited-liability companies and corporations issuing shares
- *Foreign-funded enterprises* include Sino-foreign joint-venture, cooperative, and solely foreign-funded enterprises
- *Other* includes all other enterprises

SOEs declined from 644 enterprises in 1999 to just 87 enterprises in 2008. Collectives declined during this period from 632 to 119. The number of FIEs has more than doubled, from 498 in 1999 to 1,075 in 2008. The greatest shift has come about in private ownership, which grew from 365 in 1999 to 7,798 in 2008, many of which are small- and medium-sized firms. Other changes included a small increase of share cooperatives from 156 to 193, and other ownerships grew from 125 to 1,071. In terms of overall output value, FIEs accounted for approximately 15% of gross industrial output value within the wood-processing sector in 2008. This marks a decline from 1999, when these enterprises accounted for 32% of gross industrial output value. This reflects the trend of growth in private enterprises, which in 1999 accounted for 13% of output value, but by 2008 had grown to 65%.

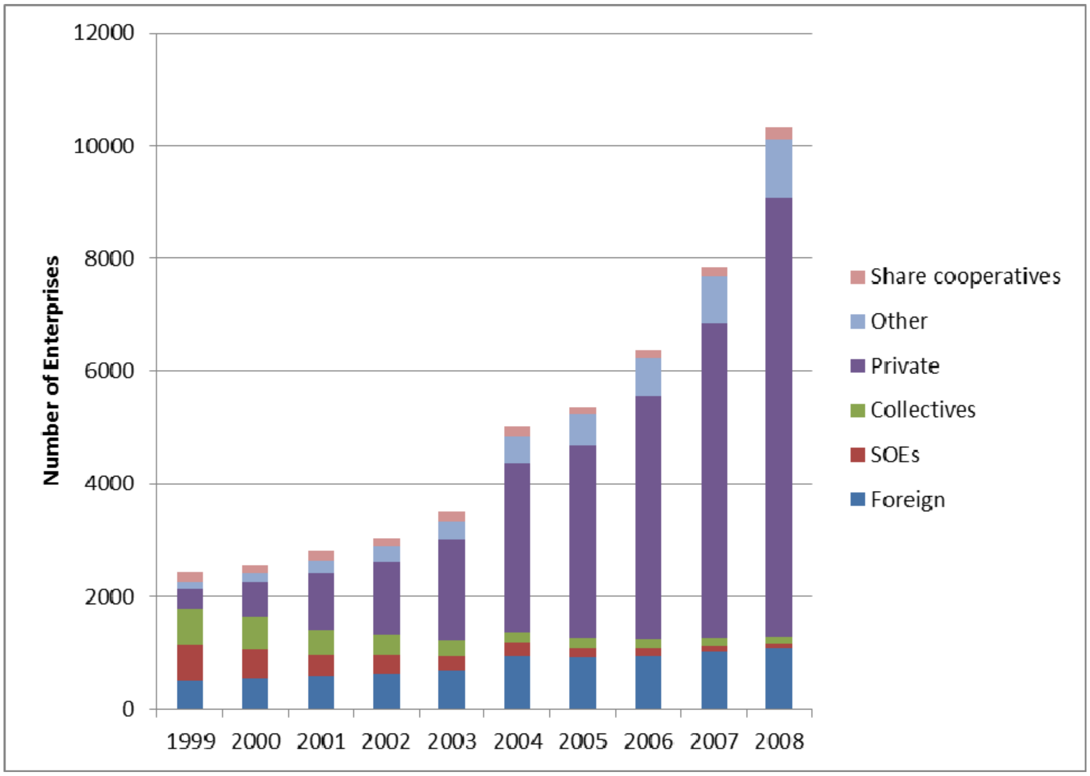

Figure 12 Number of wood-processing enterprises, by ownership type, 1999-2008
Source: SSB (1999b-2008b)

Overall foreign investment in both wood processing and silviculture/afforestation has tended to vary by year (table 25). Investment in afforestation comprises mostly loans, which come from sources such as the World Bank and other multilateral institutions. In contrast, investment in processing relies on almost no loans and comes primarily from private companies. Total investment declined between 2008 and 2009 by nearly half, with the most significant decline occurring in foreign investment in conservation programs, which fell by 80%. However, this may be a result of the project-based nature of such investments. Investment in processing fell by 31%. However, these declines were largely a result of the global economic downturn and will likely rise in the next few years.

Table 25 Total foreign investment in forestry in China by sector, 2003-2009, in millions USD

	2003	2004	2005	2006	2007	2008	2009
Afforestation and silviculture	$151	$301	$766	$183	$226	$362	$152
in the 6 key forest protection programs	*$47*	*$63*	*$81*	$56	*$78*	*$238*	*$47*
Processing	$94	$226	$207	$385	$252	$192	$135
Other	$127	$600	$182	$175	$301	$452	$265
Total	$373	$633	$1,156	$781	$786	$1,008	$554

Source: SFA (2003-2009)

3.3 Literature Review

There are numerous studies examining industrial location choice around the world and the field dates to the early 1980s. The location-choice literature began by examining the motivations for foreign direct investment. Export-platform and vertical FDI[13] may be explained by the imperative to minimize production costs or maximize profits, thereby motivating multinational firms to set up production in countries with lower factor prices; this can be viewed as a desire to make use of a country's comparative advantage. Factor-price differences create an incentive for firms to move their production activities to a country where input prices are less expensive (Helpman and Krugman 1984). Motivations for vertical- or export-platform FDI have been shown to differ significantly from motivations for horizontal FDI. Horizontal FDI refers to investment in firms or factories that produce products for a host market; for example, a Japanese multinational invests in a firm in the U.S. that produces goods for the U.S. market. Horizontal FDI may be explained by a desire by multinational firms to expand their market into foreign countries, and are therefore driven by "market-seeking" motivations. Markusen and Venables (2000) studied how trade costs create incentives for multinationals to establish plants overseas. The goods produced through such arrangements are sold in the host market.

As studies expanded to examine location-specific factors, an entirely new subset of factors emerged. Studies examining the manufacturing sector are now extensive. For studies that disaggregate from intra-country to intra-regional investment, investment into the U.S., the EU, and China are the most extensive. Coughlin et al. (1991) examined FDI into the manufacturing sector into different states within the U.S., and found that transportation, public infrastructure, density of manufacturing businesses, high per-capita unionization, and unemployment levels all positively contribute to FDI. Some studies have focused primarily on the effects of agglomeration, the clustering of industries or investment within a particular area, and found significant positive effects (Head et al. 1999; Ó hUállachain and Reid 1997; Head et al. 1995; Smith and Florida 1994).

There have been a number of studies investigating location choice of vertical FDI into China. Du et al. (2008) analyzed the role of specific factors such as property rights protection, economic institutions, and contract enforcement on the location choice of FDI in different regions within China and found that investment by U.S. multinationals is positively impacted by regions with protection for intellectual property rights, less government interference in business operations, less corruption and better contract enforcement. Fung et al. (2002) explored FDI into China by several different parent countries, including the U.S., Japan, Hong Kong, and Taiwan. They found different sensitivities to factor prices, with Hong Kong and Taiwan investment more focused in labor-intensive industries. Cheng and Kwan (2002) determined that good infrastructure, access to a large regional market, and preferential investment policies positively affected FDI, while wages negatively impacted the ability to attract investment.

A number of common explanatory variables appear throughout the literature. Labor quality has proven to be an important explanatory variable (Fung et al. 2002; Sun et al. 2002; Hou and Zhang 2001; Coughlin and Segev 2000; Broadman and Sun 1997). Agglomeration has also been a topic of interest in location-choice studies (Cheng and Stough 2006; Cheng 2005; Zhou et al. 2002). Labor cost has been examined frequently, although findings tend to be inconclusive since they differ greatly from study to study, with the variable being insignificant or else contributing either positively or negatively to investment (Cheng and Stough 2006; Cheng 2005; Fung et al. 2002; Sun et al. 2002). Infrastructure has generally been found to positively contribute (Cheng and Kwan 2000; Fu 2000; Wei et al. 1999; Broadman and Sun 1997; Head and Ries 1996).

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[13] Vertical FDI and export-platform FDI are closely related concepts. While export-platform investment can be used for exports to any country, vertical FDI refers to investments in firms that produce goods intended to be exported solely back to the parent country.

Very few studies have explored the location determinants of FDI within the forest products sector globally. The studies that do exist have examined investment only at the inter-country level and not at the intra-country level. In a 2004 paper, Laaksonen-Craig described the relationships between inward FDI in the forest sector by the U.S. and Canada and location-specific factors in Chile and Brazil. In a 2008 paper, Laaksonen-Craig revisited the issue of FDI in the forest sector in Chile and Brazil and found that, in these cases, the primary motivations for FDI were market- and resource-seeking. Nagubadi and Zhang (2008) reviewed investment in foreign forest products industries by Japan and the U.S. and found that exchange rate, per-capita income, capital, labor, as well as market- and resource-seeking factors were significant determinants.

3.4 Description of Variables, Data Sources and Transformation

The analysis assumes that the probability of investing in a particular region is dependent on a set of five variables. Since the timber processing sector is relatively comparable to the manufacturing sector, many of the independent variables included in this study were selected based on inclusion in other industrial location choice studies. Variables included are wages, infrastructure, education, roundwood production volume, agglomeration, and policies. Each variable is described and justified in detail below (table 26).

3.4.1 Variables

Dependent variable

The dependent variable is representative of the number of firms that invest in a given province. Several measures of investment were employed. Since data on the number of new entrants or the extent of the value of new investment is lacking, it is approximated by taking the first difference in values. This is done by taking the difference in the number of firms with foreign investment at the provincial level, by year. This is employed for firms with investment restricted to non-Taiwan, Hong Kong, Macao (e.g., no *Huaqiao*), as well as to firms with investment from all foreign entities.

Independent variables

Wages have been measured using a variety of terms. Broadman and Sun (1997) used average wages. Cheng and Kwan (2000) chose a wage term derived by taking average wage divided by the retail price index and found that this wage cost had a negative effect on FDI. Du et al. (2008) used average manufacturing wages and found that wages negatively impact investment. Fung et al. (2002) selected average wage, lagged one year, and found a strongly negative impact. Here wages are measured in terms of effective timber wages, which is a ratio of wages to productivity. This was done by taking reported average timber wages and dividing them by the ratio of reported gross output value to the reported number of employees.

Table 26 Description of independent variables and their sources

Variable	Description	Expected sign	Source of Data
Wages	Provincial effective timber wages	-	China Labor Statistical Yearbook; China Industrial Survey
Education	Ratio of adults enrolled in college to illiterate adults	-	China Statistical Yearbook
Infrastructure	Provincial density of highways	+	China Statistical Yearbook
Roundwood Production	Provincial roundwood production in million CUM	+	China Statistical Yearbook
Agglomeration	Provincial number of private Chinese wood-processing enterprises	+	China Industrial Survey
Policies	Provincial number of national economic zones established	+	Association of Development Zones www.cadz.org.cn

Infrastructure has typically been represented as the density of highways, railways and navigable waterways. In the studies focused on China, infrastructure, measured in a variety of ways, has typically been found to be significant. Broadman and Sun (1997) used density of roads, waterways, and railways and found a significant positive effect of infrastructure on investment. Zhou et al. (2002) selected the density of a province's road and railway network, and observed a significantly positive effect on investment. Du et al. (2008) used highway density and found a positive effect. Fung et al. (2002) used the density of a province's road and railway network but found no significant impacts. Because roads are increasingly being used to transport processed wood products, often directly in shipping containers to and from ports, the density of highways per square kilometer within a province was employed for this analysis.

The level of education provides a means of describing labor quality. Broadman and Sun (1997) found that adult illiteracy had a small negative effect on the direction of investment. Cheng and Kwan examined levels of education, and found no significant impact on investment. Du et al. (2008) used the number of students enrolled in higher-level educational institutions, and found that it positively affected investment. Fung et al. (2002) employed the ratio of the number of students enrolled in higher education by region and found a positive impact, but also found that the magnitude differed among investors from Japan and the U.S.. In this study, education is included and expressed in terms of the ratio of the percentage of students enrolled in colleges to the percentage of illiterate adults over 15 years of age in a particular province.

The roundwood production variable represents access to natural resource inputs. Resource-seeking has been identified as a potential factor in influencing location choice in foreign investment in natural resource industries. Since China is a wood-scarce country, the interest in this study is in the effect of resource availability on foreign investment in Chinese enterprises. Laaksonen-Craig (2008) chose production volume, and observed that it is positively related to foreign investment. Nagubadi and Zhang (2008) examined roundwood production, and found evidence that U.S. foreign investment is resource-seeking. Here, resource availability is incorporated using total volume of roundwood production, in million cubic meters (CUM).

Many studies have found a positive effect stemming from agglomeration. Zhou et al. (2002) examined the total number of Japanese subsidiaries and found a positive effect on the number of Japanese greenfield establishments. Cheng (2006) employed two measures of agglomeration to examine the effect on Japanese investment in China: Japanese nationality agglomeration and Chinese industrial agglomeration. He found an effect by Japanese agglomeration, but none by Chinese agglomeration. Here the number of privately owned Chinese wood-processing enterprises within a province is included as a measure of agglomeration. Foreign investment follows roughly the same pattern as Chinese enterprises in terms of location selection at the regional level.

Almost all studies examining investment-location choice in China have included a policy variable. Typically this is intended to measure the degree of openness in a particular region. Participation in preferential-treatment arrangements represents the extent of free-trade zones and policies aimed at attracting investment and have been examined in several studies. Cheng and Kwan selected total number of zones by province and found significantly positive effects. Zhou et al. (2002) chose dummy variables to represent the presence of zones, and revealed that these zone and development policies exerted positive periodic, but declining influences on investment. Du et al. (2008) and Fung et al. (2002) employed dummy variables to represent the existence of trade and development zones, and also observed strong positive effects. In this study, the total number of designated free-trade zones, export-processing zones, and Economic and Technological Development Zones is used instead of separate dummy variables because it can account for the difference in extent of zones by year.

3.4.2 Data Sources

Data on the number of non-*Huaqiao* foreign-invested enterprises come from the China Forestry Statistical Yearbook, issued by the State Forestry Administration. Data on all foreign-invested enterprises (i.e., those that include Hong Kong, Macao, Taiwan, Macao, and the rest of the world) come from China Industrial Surveys, published by the National Bureau of Statistics of China. These data appear as total number of entities, by ownership or investment type, by province, at year's end. Wage data come from two sources. First is the China Labor Statistical Yearbook, which contains average wages within the timber processing sector, by province. Second is the China Industrial Survey, which contains data on average gross output value and the number of employees within the timber processing sector. The provincial density of highways was calculated by taking the total length of highways, in kilometers, and dividing it by the total geographic area, in square kilometers. Data for the education and infrastructure variables both come from the China Statistical Yearbooks, published by the National Bureau of Statistics of China. Domestic roundwood production was taken from multiple years of the China Forestry Statistical Yearbook, published by the State Forestry Administration. Data on the number of development zones come from the Association of Development Zones. All data cover the years 2003-2008. Summary statistics for these variables are included in table 27.

Table 27 Summary statistics for variables included in analysis

	Dependent variable	Independent variables					
	New enterprises	**Roundwood production**	**Infra-structure**	**Wages**	**Education**	**Agglomeration**	**Policies**
Mean	3.21	180.86	0.52	0.06	0.02	116.94	3.61
Standard Deviation	8.38	72.08	0.35	0.04	0.02	173.64	3.69
Maximum	65.00	779.65	1.44	0.33	0.13	923.00	18.00
Minimum	0.00	0.00	0.03	0.02	0.00	0.00	1.00

3.4.3 Data Transformation

The model was estimated using both a negative binomial[14] and tobit approach. The data transformation is described in this section. The data were structured as a panel for the years 2003-2008, and divided into two groups. For the dependent variable, when taking the first difference, if the difference yielded a negative number, then that number was converted to a zero, since neither the tobit nor the negative binomial can accommodate negative values. The first group represents all 31 provinces, while the second group represents a subset of 23 provinces. Initially, two different dependent variables were used. The first included enterprises with no *Huaqiao* investment, and the second included investment from all sources. As indicated above, the dependent variable was calculated as the first difference in number of enterprises, beginning in 2004 (taking the first difference from 2003) and ending in 2008 (taking the first difference from 2007).

Preliminary testing indicated that the models that employed the no *Huaqiao* as the dependent variable had unsatisfactory likelihood ratio statistics and were therefore eliminated from further analysis. All further analysis included investment from all sources as the dependent variable. The covariates were all lagged one year, so that the values for infrastructure, education, wages, policies, agglomeration and roundwood represent the years 2003-2007.

[14] Due to the high number of zeros in the dataset, it was expected that the Poisson might not be a good fit. A simple calculation and comparison of the variance against the mean indicated overdispersion. As a result, the negative binomial was selected over the Poisson.

3.5 Results

This section will describe the empirical results of the tobit and negative binomial nested estimations. Estimation was conducted using Stata SE 10. The implications of the results will be detailed in the discussion section that follows.

Table 28 Results from tobit and negative binomial estimations, using all provinces

	Tobit		Negative Binomial	
Variable	**Coefficient**	**Standard Error**	**Coefficient**	**Standard Error**
Policies	***2.334	0.415	***0.177	0.034
Wages	-76.053	56.791	-10.477	6.603
Infrastructure	-3.816	4.517	-0.319	0.484
Roundwood	***0.021	0.006	***0.002	0.001
Education	0.657	57.922	0.067	6.868
Agglomeration	-0.009	0.009	-0.000	0.001
Log Likelihood	-294.89		-258.596	
N	145		145	
χ^2	57.42***		69.94***	
ρ	1.52e-35			

*** indicates significance at .01 level

For the analysis that included all 31 provinces, results are reported in table 3.6. For the tobit, both the policy and roundwood variables demonstrate strong, positive significance at p=0.00. The coefficients for the tobit can be interpreted in a straightforward manner: for every unit increase in the coefficient, the number of new foreign-invested enterprises would increase by the value of the coefficient. Given a one-unit (i.e., one zone) increase in the policy variable, there would be a corresponding increase of 2.334 new enterprises being established in China. For the negative binomial, the coefficients are the difference in the logs of expected counts. Given a one-unit increase in the policy variable, there would be a corresponding 1.19 increase in the number of new enterprises. For the tobit, given a one-unit (i.e., one million CUM) increase in the roundwood variable, there would be a corresponding 0.021 increase in the number of new enterprises. For the negative binomial, given a one-unit increase in the roundwood variable, there would be a corresponding 1.00 increase in the number of new enterprises. No other variables are significant.

Table 29 Results from tobit and negative binomial estimations, limited to 23 provinces

	Tobit		Negative Binomial	
Variable	**Coefficient**	**Standard Error**	**Coefficient**	**Standard Error**
Policies	***2.129	0.415	***0.164	0.036
Wages	-35.175	72.461	-4.567	7.817
Infrastructure	-6.865	4.838	-0.597	0.508
Roundwood	*0.012	0.006	***0.002	0.001
Education	-0.583	57.761	0.622	6.458
Agglomeration	-0.007	0.01	-0.000	0.001
Log Likelihood	-274.389		-249.401	
N	115		115	
χ^2	41.52***		42.96***	
ρ	5.08e-19			

*** indicates significance at .01 level, * at .1 level

For the analysis that omitted several provinces, results are reported in table 29. For the tobit, the policy variable demonstrates strong significance at p=0.00, and the roundwood variable demonstrates somewhat weak significance at p=0.1.

It should be noted that there is a degree of correlation between several variables, including the policy and agglomeration variables; however, several methods to control for potential multicollinearity were employed. First, two subsets of the data were used for the estimation, with little change in the coefficient values or significance. The results of one of these subsets are described in table 29; another subset with random provinces dropped was also run, again with essentially no change in the coefficient values. Second, the models were run with various variables omitted, with little effect on coefficient values and significance.

3.6 Discussion

The empirical analysis of foreign investment location choice using two different estimation methods yields results that are useful both for comparative and policy purposes. The coefficients that are significant in the negative binomial coincide with those of the tobit estimation. The results from the analysis that included only the subgroup of 23 provinces are comparable to the results of the analysis that included all provinces. For this study, roundwood production and the presence of favorable investment policies appear to be the most strongly linked to the establishment of foreign-invested enterprises. The results indicate that many of the findings from previous empirical work exploring foreign investment in the manufacturing sector within China do not necessarily apply to the wood-processing sector.

In terms of education, the results contrast with Du et al. (2008) and Fung et al. (2002), who employed similar measures of education and determined that education positively affected foreign investment levels. Du et al. (2008) were particularly focused on U.S. FDI and attributed the positive effect to the predominance of U.S. investment in highly technological fields. Fung et al. (2002) focused on U.S. and Japanese investors and found that education played a greater role among Japanese investors than among their U.S. counterparts. Their assessment was that Japanese investors place a greater priority on workers' ability to adapt and perform more versatile roles within the workforce. However, in wood processing, although machinery is becoming more technologically advanced, it is far from a high-tech sector and adaptability is not an essential skill. Instead, the lack of significance of the education variable here could indicate that investors in wood processing do not differentiate between levels of labor quality and that skills can be acquired on the job.

There is no consensus on the effects of wages on investment location choice. Some studies have found that wages exert a negative influence on location choice in China (Du et al. 2008; Fung et al. 2002; Cheng and Kwan 2002). These studies all used average manufacturing wages, while this study employs a more specific measure of labor cost. Other studies have demonstrated a positive or negligible influence (Cheng and Stough 2006; Broadman and Sun 1997; Head and Ries 1996). The lack of significance here is consistent with the lack of significance in the education covariate in that investors may not differentiate between labor quality as measured in terms of education or higher wages. It may be that once a firm has chosen to invest in China, it views wages as being fairly similar across provinces, and thus are not a factor in determining the location of investment.

The lack of significance in the infrastructure variable is in contrast with the prevalent finding in the literature that access to roads and railway plays an important role in attracting investment. Density of highways, which was used here, has been commonly used throughout the literature on location choice in manufacturing in China and found to be significant and positive (Du et al. 2008; Cheng 2005; Fung et al. 2002; Zhou et al. 2002). One might have expected the infrastructure variable to play a more important role here given the importance of transporting products. In the case of the wood-processing subsector, it may be that foreign investors are not yet concerned about regional differences in infrastructure and highway accessibility, and have a similar view as that proposed above with respect to the wage attribute. Perhaps other measures of infrastructure, such as access to sea ports and railways may yield different results.

The agglomeration of private Chinese enterprises does not appear to represent an attraction to foreign entities. This echoes the findings of Cheng and Stough (2006) that hypothesized that foreign investors have little information about Chinese-owned enterprises operating within China and therefore do not make decisions based on their operations. This is likely also the case among many foreign investors in wood-processing enterprises in China. Many studies have assessed the impact of same-nationality agglomeration on location choice and frequently found a significant positive effect (Cheng and Stough 2006; Zhou et al. 2002, Wei et al. 1999). Since the data for this study did not allow for the distinction between nationalities of investment origin, a same-nationality agglomeration variable could not be included.

For the roundwood variable, the significance across models would indicate that investment is, at least in some way, resource-seeking. Both models indicate that domestic production is a positive factor for foreign-invested enterprises, and if production were to increase, then there could be a positive effect on investment. The coefficients are extremely small, meaning that any impact from an increase in wood production would be extremely small, although the negative binomial model implies a larger effect than that of the tobit. This could merely reflect a perception on the part of foreign firms, who are not fully aware of resource shortages. It is also possible that should above-quota harvesting be reported in official statistics to reflect actual production volume, which is thought to be higher than reported, there might be an even greater effect on investment. More research should be done in order to understand the impact of wood imports on firm establishment and location choice, as many firms rely heavily on imported materials. This is true of both Chinese wholly-owned and foreign-invested enterprises; nearly 34% of the logs consumed in China from 2003-2008 were imported.

The significance of the policy variable, in this case, the number of free-trade zones, export-processing zones, and economic and technological development zones is consistent with most other studies on China (Du et al. 2008; Fung et al. 2002; Cheng and Kwan 2002; Zhou et al. 2002). The results imply that for every 1-2.5 unit increase in trade zones, the number of enterprises would increase by one. This is not a large increase, but the positive influence of the policy attributes indicates that the number of preferential and development policies is important in attracting investment into these regions. Should the central government, in implementing its next Five Year Plan, begin to refocus its attention away from these zones and away from policies that directly favor foreign investment, it should expect to see a drop in investment. If, instead, it continues to expand these zones and favorable policies in the interior and western region, while holding them constant in regions that have already experienced significant economic development, such as those along the coast, it may see an expansion of investment into the interior and western areas. Given the lack of importance of the education and infrastructure variables, an unskilled workforce in the interior may present significant opportunities particularly for provinces such as Heilongjiang, Jilin, Anhui, Jiangxi, Hunan, and Yunnan. These provinces have relatively high timber production levels compared to the historical number of wood-processing enterprises.

3.7 Conclusion

This study examines the location choice of foreign investment in Chinese wood-processing enterprises by employing several estimation methods, including a tobit and negative binomial. The analysis was performed initially with all 31 provinces, and secondly by omitting the eight provinces in which no new enterprises were established during the study period. Based on previous studies, economic-development policies, infrastructure, wages, education, and agglomeration were employed as measures of location-specific determinants. Additionally, this study introduced roundwood production to determine whether or not investors in the wood-processing sector within China are resource-seeking. Two variables were found to have an impact on investment, with the number of specially designated economic zones and roundwood production having the most consistent, albeit small, impact. These findings indicate that should the government seek to continue to attract investment in the wood-processing sector, it may find expanding the economic and trade zones to be beneficial, particularly in provinces where timber production is relatively high, but the processing industry is currently small.

This is the first study to examine investment-location choice of wood-processing enterprises in China. It also contributes to the literature by focusing on a subsector within an industry (manufacturing), and by examining a specific industry-related factor. The study could be improved by incorporating data on enterprises that demonstrated the year of entry into a particular province, and, more specifically, data that included the year the enterprise initiated or promised investment. Further study of this issue would benefit from the exploration of other explanatory variables, such as the impact of wood imports, as well as other measures of infrastructure, and potentially the use of a survey to examine stated preferences by foreign investors.

4 Impacts of Illegal Logging Restrictions on China's Forest Products Trade

4.1 Introduction

As China's wood products industry has expanded, it has become reliant on imports of logs to fuel its growth. Between 2003 and 2009, according to official statistics, China relied on imports to supply approximately 33% of its total consumption of logs (SFA 2010). Many of these imports came from countries with poor records of environmental regulatory enforcement or high levels of historical forest degradation where illegal logging is a concern. Questions about the sustainability and legality of these imports have led to concerns about the magnitude of China's global forest footprint (Financial Times 2006; Zhu et al. 2004).

Few studies have rigorously examined the interactions between China's increasing demand for domestic and foreign resources, domestic economic development and international trade, and the environmental impacts. Many studies on China's forest sector have addressed issues of forest tenure and user rights (Weyerhaeuser et al. 2006; Xu and Ribot 2004), current resource use and future availability (Bull and Nilsson 2004; Zhang 2003), impacts of domestic reform policies on rural residents (Liu and Edmunds 2003; Yin 2003), and impacts of protection-driven policies on resource improvement (Trac et al. 2007; Ma 2004), all within China. These studies broadly address domestic equity and governance issues, but generally do not concentrate on the explicit linkages with international trade issues.

The objective of this chapter is to examine the effects of the removal of illegally logged resources from China's imports, originating in five of China's primary source countries for logs, on China's domestic production, consumption, and trade flows. This study will examine the impacts through the use of a spatial equilibrium approach by modifying the CINTRAFOR Global Trade Model (CGTM). Using the CGTM enables the projection of changes in forest products prices, production, consumption, and trade flows that would occur if the incidence or severity of illegal practices changed.

4.2 Background

4.2.1 Illegal Logging

Unsustainable and illegal harvest activities take place around the world and in virtually every country that engages in forest harvesting. However, while the extent of these activities may be quite limited or negligible in some countries, in others they can lead to significant forest depletion, and subsequent biological and economic losses. This is particularly true of countries with natural-resource-intensive economies. While most commonly linked to the permanent destruction and degradation of habitat, illegal logging also has significant social and economic consequences, like the displacement of indigenous people (Greenpeace 2006). The World Bank has estimated that between $10 and $15 billion of government revenues are lost every year due to illegal logging carried out on public lands alone (World Bank 2002). It can also impact the competitiveness of forest product industries in countries that import illegally harvested products (Seneca Creek 2004).

Unsustainable logging practices are often identified as a culprit in concerns about forest depletion. However, the definition of "unsustainable" is nebulous and subjective at best. There are many contributing factors to "unsustainable" forest management. Illegal activities constitute one component, and these can be broadly defined to include a wide array of activities and may be motivated by many factors. In a study produced for the World Bank, Contreras-Hermosilla (2002) defines illegal logging as the following activities:

- Logging timber species protected by national and international law such as the Convention on International Trade in Endangered Species of Fauna and Flora (CITES)
- Logging outside concession boundaries
- Logging in protected areas

- Logging in prohibited areas such as steep slopes, riverbanks and water catchments
- Logging in breach of other contractual obligations
- Obtaining timber concessions illegally
- Contracting with local entrepreneurs to buy logs from protected areas outside the concession
- Contracting with local forest owners to harvest on their land but then cutting trees from neighboring public lands instead
- Extracting more timber than authorized

In practice, illegal activities differ greatly across political boundaries since national laws vary greatly. Any proposals aimed at curbing the flow of illegally harvested materials must be based on the laws of the country where harvesting occurs (Auer et al. 2003). Given the difficulty in developing precise measurements of illegal activities and the ethical and feasibility issues involved in subjecting sovereign countries to other nations' regulations, action on illegal harvest activities has been slow going and piecemeal.

China, largely through its heavy reliance on log imports used to fuel the growth of its forest products industry, has been accused of importing illegally harvested goods (Financial Times 2006; EIA/Telepak 2005). Many of China's primary non-coniferous (hardwood) and its primary coniferous (softwood) log sources have been labeled as exporting suspicious logs. These countries include Russia, Malaysia, Papua New Guinea, Gabon, and the Solomon Islands (Lawson and MacFaul 2010; Li et al. 2008; Seneca Creek 2004). Lumber and plywood exports from Russia, Indonesia, and Malaysia have also been categorized as including illegal content (Lawson and MacFaul 2010; Li et al. 2008; Seneca Creek 2004).

Although it may be impossible to fully estimate the precise rate or extent of illegal logging activities, many NGOs and advocacy organizations have developed estimates of illegal activities in terms of total logging activities. These efforts have served to draw public attention to the problem. Illegal harvests are not reported separately in production data, as data provided by national governments represent total official production. Estimates of illegal logging are typically represented as a percentage of total production (Lawson and MacFaul 2010; Li et al. 2008; Seneca Creek 2004). Other estimates often employed can be found in Contreras-Hermosilla et al. (2007) and Seneca Creek (2004).

Table 30 Estimates of illegal rates among China's primary import sources, based on FAO trade volumes, 2008

Source	Range of estimates of illegal logging rates	Source of Estimate	Estimated total volume of illegal logs/ lumber/plywood imported by China in 2008 (in million Cubic meters)
Russia	20-50%	Li et al. (2008)	3.59-7.90
Indonesia	40%	Lawson and MacFaul (2010)	0.18
Malaysia	14-25%	Lawson and MacFaul (2010)	0.66-1.18
Papua New Guinea	20-65%	Li et al. (2008)	0.52-1.69
Gabon	25-28%	Li et al. (2008)	0.30-0.33
Solomon Islands	20%	Li et al. (2008)	0.16
Thailand	30-40%	Li et al. (2008)	0.09-0.12

Based on these estimates, it is possible to calculate potential flows of illegally harvested products into China (table 30). Such calculations are based on official trade flows since there are no reliable calculations based on above-official import statistics. The most significant impact is on log imports, while lumber and plywood products are not as strongly impacted. When compared to China's total volume of official imports of logs, lumber, and plywood in 2008, it would appear that illegal imports by China may have constituted 12-29% of log imports, 6-13% of lumber imports, and 5-6% of plywood imports.

4.2.2 Production, Consumption, and Trade in Forest Products : China and the World

In order to understand the role China plays in the global forest products trade, it is useful to place its production, consumption, and trade in the context of global trends and to examine the sector as it has expanded over time. This section will present an historical view of forest products production, consumption, and trade for logs, sawnwood and plywood from 1961-2009. All data described and used to make the figures in this section come from the Food and Agricultural Organization (FAO) of the United Nations. FAO data are used for this chapter because the FAO is the only source of global production, consumption, and trade flow data that has been collected for fifty years. The data are reported to FAO by each country's respective government and therefore represent official records. Units are reported in cubic meters (CUM), which is the most common international metric for wood product volume. Although consumption figures are not available in the FAO data, production, imports, and exports are. Apparent consumption is calculated here by summing production and imports, minus exports.

The global forest sector is a series of inter-connected subsectors. At the most basic level, timber-producing regions grow and produce timber. The largest timber producing regions include the United States (U.S.), Europe, Canada, Russia and the former Soviet Union (FSU), and Southeast (SE) Asia. Timber is harvested and categorized as coniferous (softwood) or non-coniferous (hardwood) roundwood. Roundwood production includes all logs, including those used for firewood. Roundwood is then processed into logs (sawlogs or veneer logs), chips, pulp, or other industrial roundwood. Logs may either be processed domestically or else exported elsewhere for processing into sawnwood (lumber) and veneers. Veneers can then be further processed into plywood and other products.

In terms of trade, sawlogs and sawnwood can be substitutable. For example, if sawlogs from a particular region become too costly or are restricted by policy, then lumber from another region may serve as a less expensive substitute import. The same may be true for other products such as panels. For example, in SE Asia, plywood and non-coniferous sawnwood exports both grew in the 1990s, while log exports declined following the implementation of log export bans in Indonesia and other efforts in the region to develop local processing capacities.

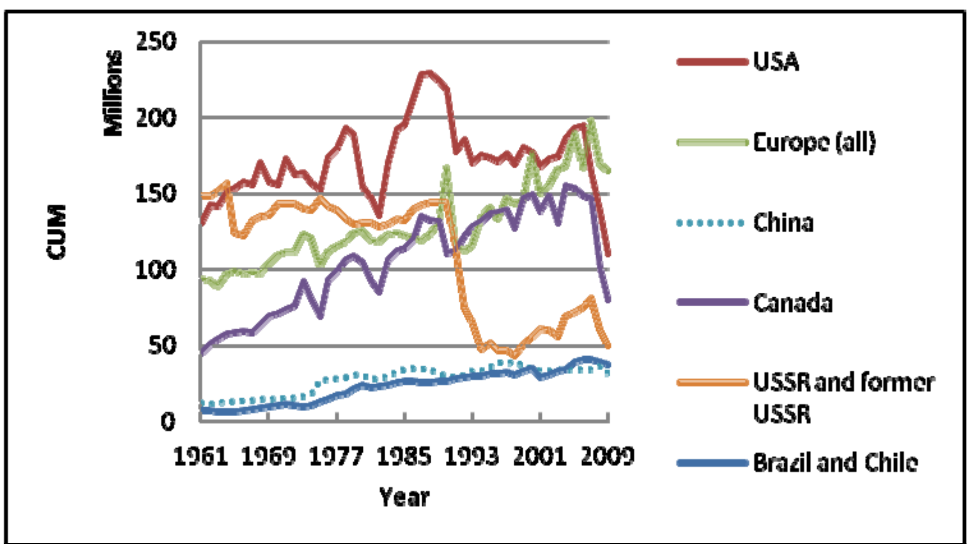

Figure 13 Major producers of coniferous logs, 1961-2009

Global Trends

World production of coniferous logs peaked in 1990 at 743 million cubic meters. The production pattern from the 1960s through 1990 was largely influenced by production in the U.S. (figure 13). Consumption (and production) in the U.S. is driven by economic growth and housing starts; a recession can have a significant impact on forest product consumption and production. The effect of the economic downturn in the early 1980s is clearly evident in the production trends for both the U.S. and Canada. However, several factors outside of North America contributed to a significant decline in global log production at the beginning of the 1990s. Following the fall of the Soviet Union, reported production in the former Soviet states collapsed from approximately 184 million CUM to less than 48 million cubic meters in 1994. It should be noted here that reported production statistics from Russia and the other former Soviet states remain highly suspect. Conversely, certain parts of Europe benefitted from the collapse, which is evident in European production figures. In the U.S., production fell by 20% after the introduction of the Northwest Forest Plan in the early 1990s, which essentially halted all harvest activities in federal forests. The current global recession has had a substantial impact on worldwide production. Figure 13 clearly shows the declines in the late 2000s; world production of coniferous sawlogs has plummeted by 38% since the peak in 2005, and was lower in 2009 than at any other point since 1967.

The U.S. dominated global softwood log production between 1965 and 2006, when it comprised approximately 27% of total global log production. However, as the global recession has affected log demand in the U.S., it has also affected production there. Consequently, it is no longer the largest producer. Europe’s contribution has grown and represented 31% of total production in 2009. Russia and the FSU is now the fourth largest producing region after the U.S., Europe, and Canada. Other regions with growing production shares include Brazil and Chile, which produced 7%, China (6%), as well as New Zealand (2%).

In terms of volume, global production of non-coniferous sawlogs is about half that of coniferous sawlogs. The U.S. and SE Asia are the largest producers, followed by Europe (figure 14). SE Asian production has generally declined since the 1990s, as countries within the region experienced significant resource depletion and began imposing more stringent environmental regulations. The Asian financial crisis of 1997 severely affected production in this region, from which some countries never fully recovered. The recession beginning in 2007 has also significantly affected production in the region. By 2009, SE Asian production was 64% lower than at its peak production levels in 1988. Conversely, production of U.S. eastern hardwoods has increased by 27% during the same period, although it experienced a peak in 1997 and then a dip during the U.S. recession at the beginning of the 2000s. Over the last two decades, product taste has also changed as many consumers in Europe and North America now prefer lighter hardwoods to tropical hardwoods. Depending on how tastes among middle-class Chinese consumers evolve, there could yet be another reversal in production and consumption trends among different hardwoods. Brazil, West Africa, and China have all increased their production levels steadily, albeit not as rapidly as demand in those regions has increased.

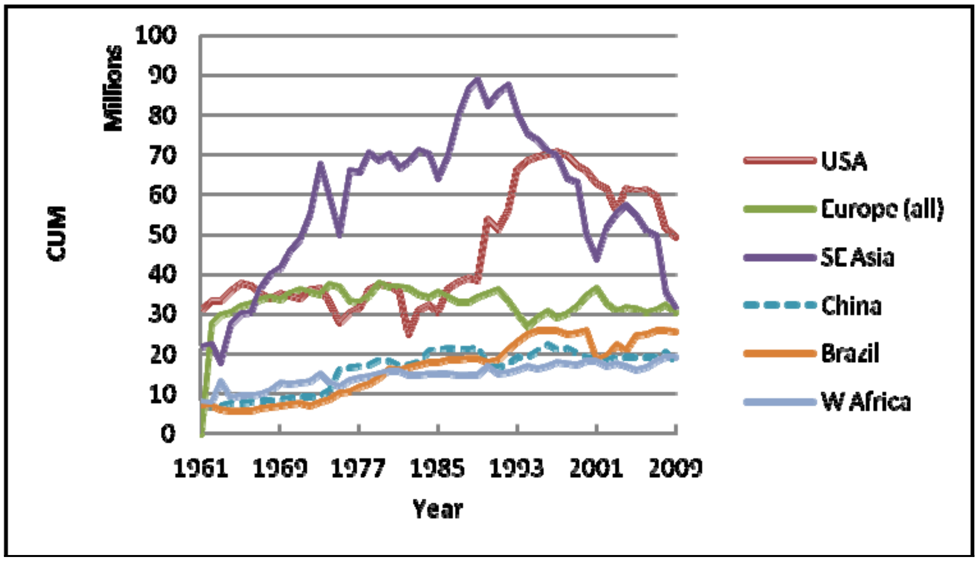

Figure 14 Major producers of non-coniferous logs, 1961-2009

Sawnwood production largely follows the production of sawlogs. The declines experienced in the early 1980s and after the fall of the Soviet Union, as well as in the current global recession, are all clearly evident in production trends (figure 15). In 2009, the U.S., Canada, and Europe together comprised 73% of coniferous sawnwood production. Although these regions have dominated softwood lumber production since the 1960s, just as in the production of softwood logs, other regions, such as China, Southern South America and, to a lesser extent, New Zealand, have increased their production of sawnwood. Japan was historically a major producer; however, production there has steadily declined since the 1990s. Europe has long been the largest producer and, since 2007, is now the largest consumer; in 2009, the region produced approximately 36% of world softwood lumber and consumed 32%. The U.S. is a major producer and consumer of coniferous sawnwood, but demand has been significantly affected by the global recession that began in 2007. In 2009, China produced approximately 5%, while consuming 8% of global sawnwood volume. Brazil and Chile have also gradually increased production over time.

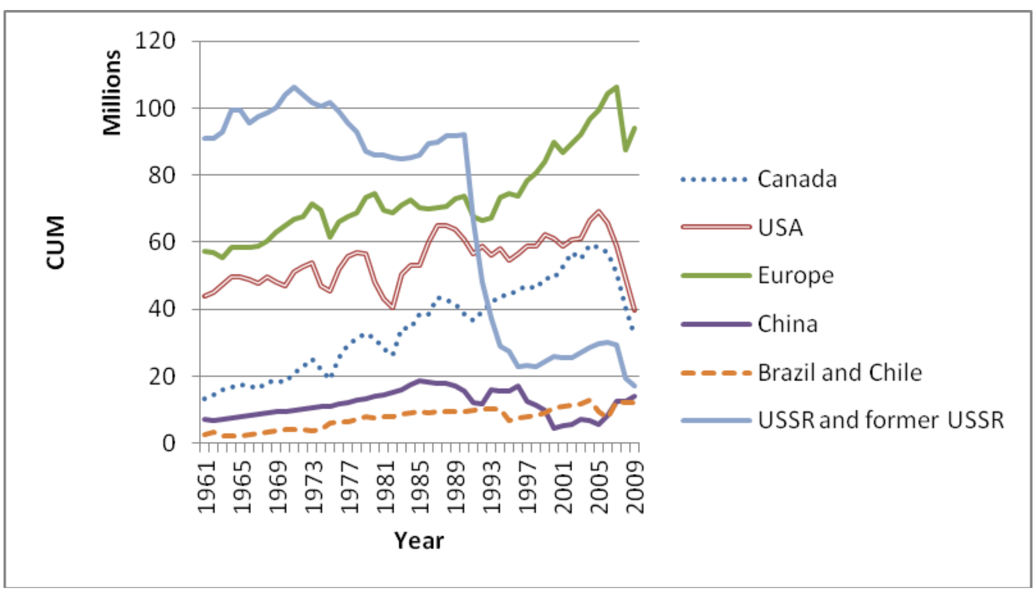

Figure 15 Major producers of coniferous sawnwood, 1961-2009

Production of non-coniferous sawnwood has generally mirrored non-coniferous log production among most of the largest producers: the U.S., SE Asia, Europe, and Brazil (figure 16). China is not a major producer of logs, but it has become a major importer and is increasingly becoming a major center of production of hardwood sawnwood. Although in 2009 it produced only 6.5% of the world's hardwood logs, it produced about 19% of the hardwood lumber. In 2007, China surpassed Europe as the largest consumer and has risen to become the second largest producer after the U.S.

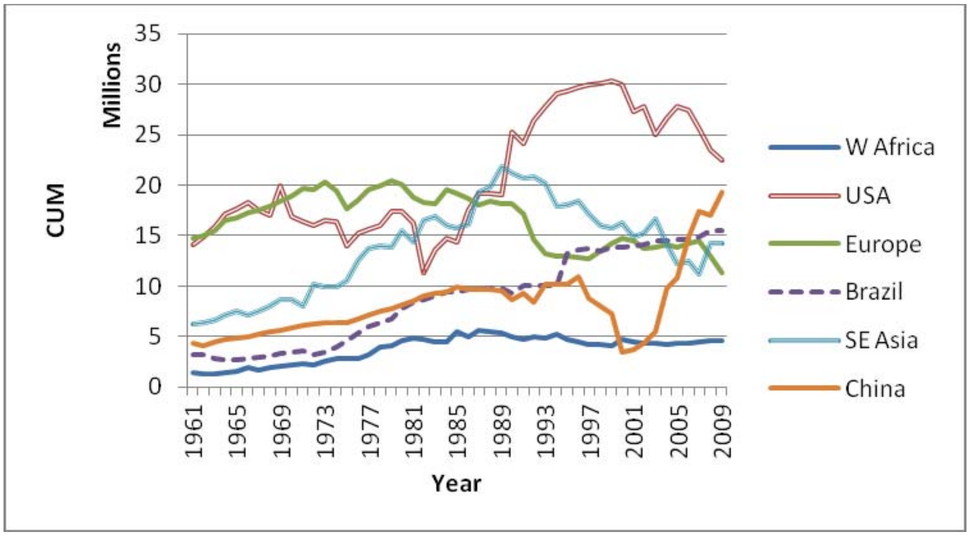

Figure 16 Major producers of non-coniferous sawnwood, 1961-2009

China is the largest producer and consumer of plywood (figure 17). In 2009, it produced 56% of total world output and consumed nearly 52% of total plywood. The U.S., which was surpassed by China as the largest producer of plywood in 2002 and SE Asia in 2008, is now the third-largest producer. The U.S. is the second-largest consumer after China, followed by Europe, and SE Asia. China's dramatic rise in the forest products industry will be discussed in the following section.

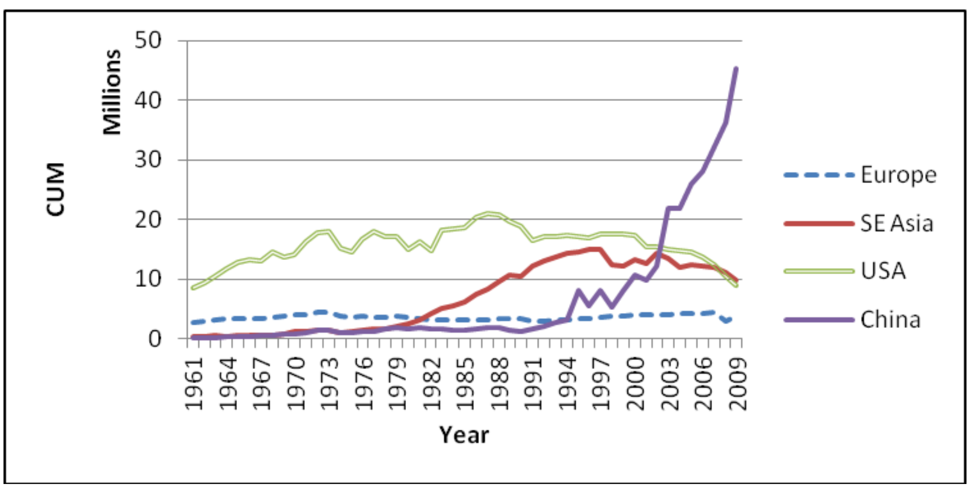

Figure 17 Plywood production, 1961-2009

World trade in logs, lumber and plywood has increased dramatically since the 1960s, reaching a peak in 2005 (figure 18). Lumber trade fairly closely follows log trade. This is not surprising given the fact that lumber production fairly closely resembles log production. Trade in coniferous products has expanded more rapidly than non-coniferous products since the early 1990s, driven by consumption in the U.S., Europe and Japan. Although Europe would appear to be the largest force in the trade of many products, numbers are confounded by the fact that many exports and imports are to and from countries within the continent; as a result, Europe is excluded from this discussion. In 2009, Russia was the largest exporter of coniferous logs, although exports have significantly decreased since the introduction of the log export tariff in April 2008, declining in 2009 by 55% over 2007. The tax, which was intended to spur the development of a domestic processing industry, has not yet resulted in increased lumber exports and has resulted in only negligible plywood exports. China is the largest importer of both coniferous and non-coniferous logs, with imports having more than doubled since 2001, a result of both an expanding domestic processing industry and domestic logging restrictions imposed after 1998. SE Asia continues to be the largest source of non-coniferous logs, although total exports from the region are not much higher than those from West Africa or Russia. Canada has been the largest exporter of coniferous sawnwood, although its position has significantly declined since 2007, while the U.S. remains the largest importer. These imports essentially collapsed in the period 2006-2009, decreasing by 64% during that period.

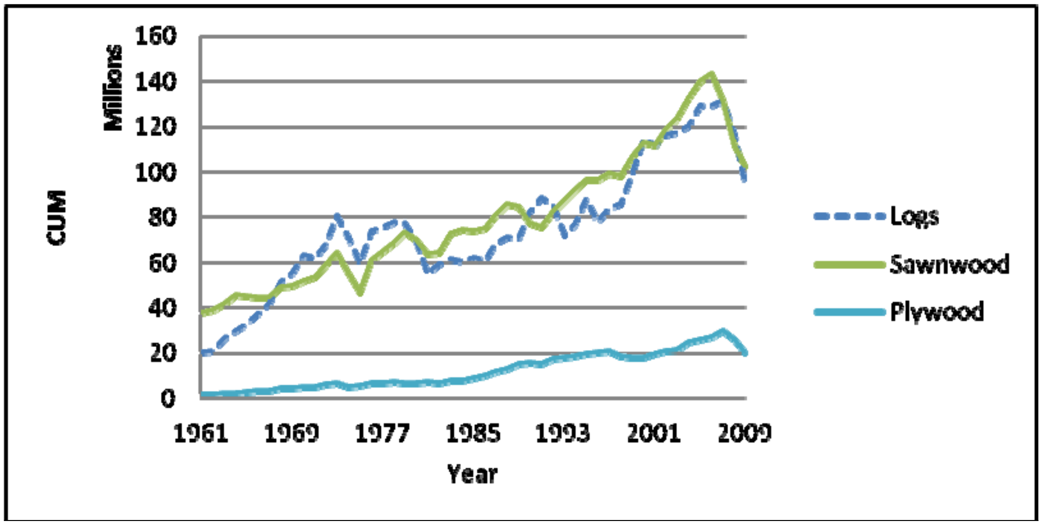

Figure 18 Total world trade in wood products, 1961-2007

China's Forest Sector

China's production, consumption and trade in products, such as lumber and plywood, has grown tremendously since the mid-1980s. Although some growth occurred during the mid-1980s, when there was a period of increased domestic production (figure 19), this was partly facilitated by an increase in log imports from the U.S. that ceased after the events of Tiananmen in 1989 and subsequent trade sanctions. Figure 19 demonstrates a decline in lumber production in the period following Tiananmen, as well as the Asian Financial Crisis after 1997. In the period since 2000, China's rise as a producer and consumer of coniferous and non-coniferous sawnwood and plywood has occurred rapidly. These products are used most widely in the construction industry, infrastructure projects, and in furniture manufacturing. Much of the plywood in China is made of fast-growing poplar, and as China's southern plantations have matured, more material has become available domestically. Additionally, many of China's plywood manufacturers are small- and medium-sized enterprises (SMEs) and rely on inexpensive labor for production. Increasing labor costs may significantly impact this sector in the years to come. China's plywood manufacturers also benefit from the 15% import tariff imposed by the Chinese government, which has encouraged increased domestic production. Despite all the growth in production, China's consumption of these goods exceeds domestic production, and therefore it must still import modest amounts of all three.

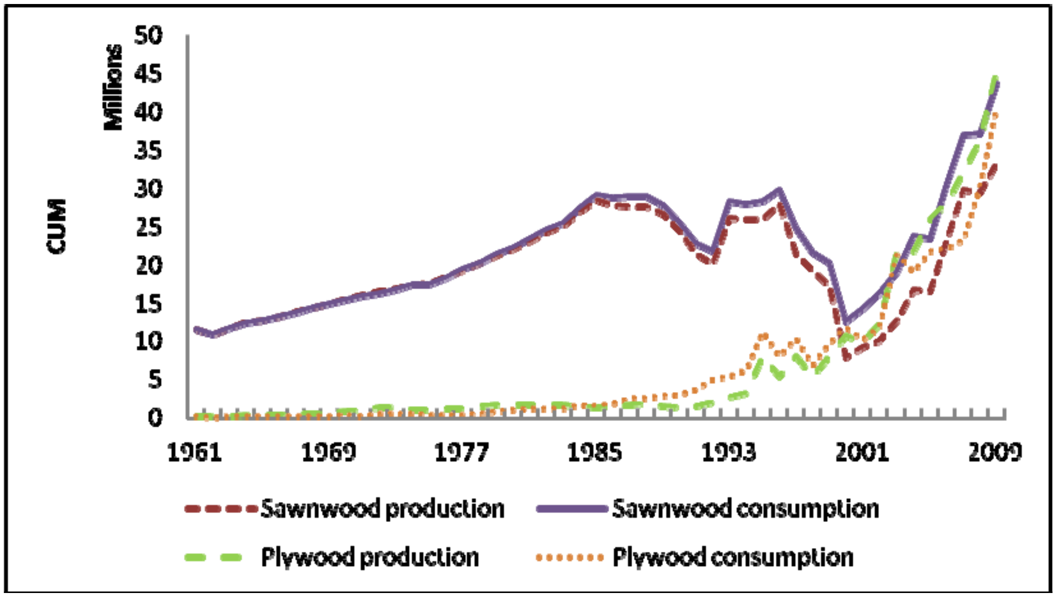

Figure 19 Production and consumption of sawnwood (all) and plywood in China, 1961-2009

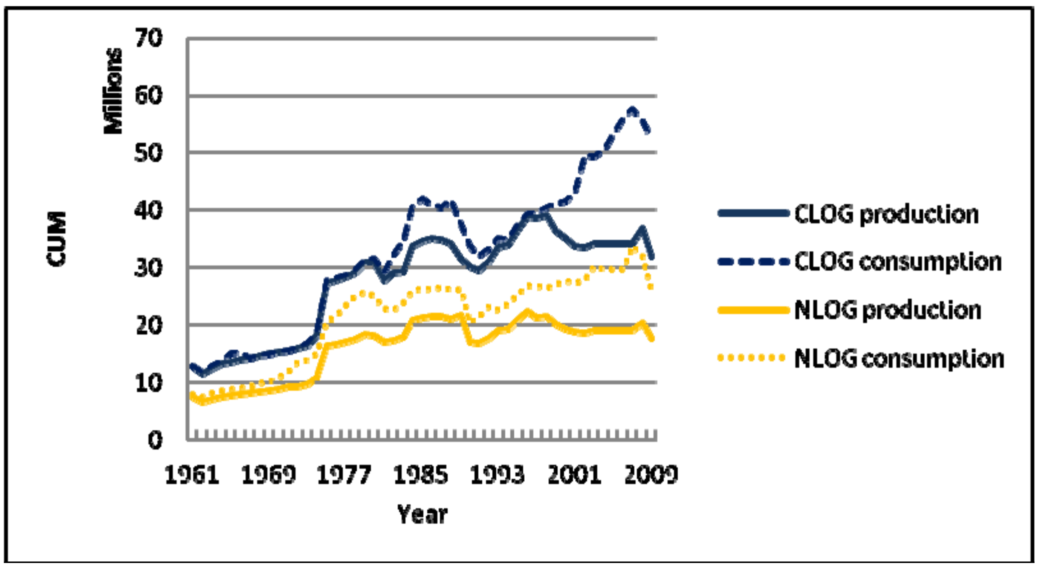

Figure 20 Log production and consumption in China, 1961-2009

The growth in product production has largely been facilitated by the increase in imports of coniferous and non-coniferous logs. Comparing log production against consumption, the magnitude of imports, particularly in the last decade, becomes apparent as the difference between the two (figure 20). In many regions, as demonstrated in the previous section, the coniferous and non-coniferous sectors follow vastly different trends; however, figure 20 demonstrates how the two sectors are more closely linked in China due to policy constraints. Production increased in the mid-1980s as timber markets were briefly liberalized, and then leveled off when they were placed back under state control after a period of intensive harvesting. The 1990s also experienced a steady increase in production as markets were opened yet again, only to be followed by a leveling off and then gradual decrease following the implementation of the logging ban in the period following the 1998 floods. Lastly, since 2007, production has been impacted both by the severe winter storms of 2008 and the global recession.

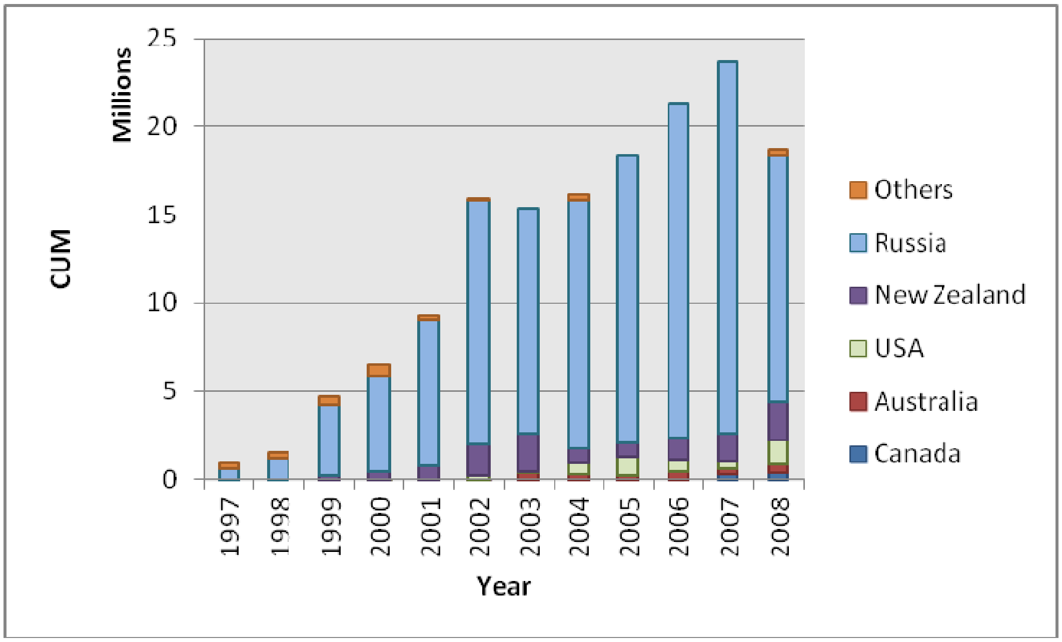

Figure 21 Coniferous log imports into China by source, 1997-2008

China plays a significant role in the international coniferous log sector; although it does not export any logs, it is a major importer. Despite the global recession and decline in production and trade in forest products in general, China's share of global coniferous log imports increased from 27% to nearly 32% from 2008 to 2009. China's main sources of coniferous logs are Russia, New Zealand, the U.S., Australia, and Canada (figure 21). Russia's exports to China declined in 2008 over 2007 by nearly a third from 21 million CUM to 14 million CUM, due to both the Russian log export tariff and the global economic downturn that began in 2007. However, Russian exports to China dwarf all other countries in this sector, accounting for 75% in 2008. Imports from Russia of coniferous log exports remained more than six times the volume of China's second largest source for coniferous logs, New Zealand. Imports from the U.S. have grown in recent years, reaching 1.35 million CUM in 2008; however, this level remains far below U.S.-China export levels reached in the mid-80s, when U.S. coniferous log exports exceeded 5 million CUM. The largest impediment to increasing U.S. exports to China is cost; if log prices continue to rise, the U.S. may again become a competitive supplier to China. However, as Russia prepares to enter the World Trade Organization, it is facing pressure to lower its export tariff. As a result, if Russian log prices decline, then the U.S. may see its share decrease again.

In addition to being the largest importer of coniferous sawlogs, as a country China is also the single largest importer of non-coniferous sawlogs (31% of all imports worldwide). China's largest source of hardwood logs is once again Russia, which in 2008 supplied 25% of China's imports (figure 22).

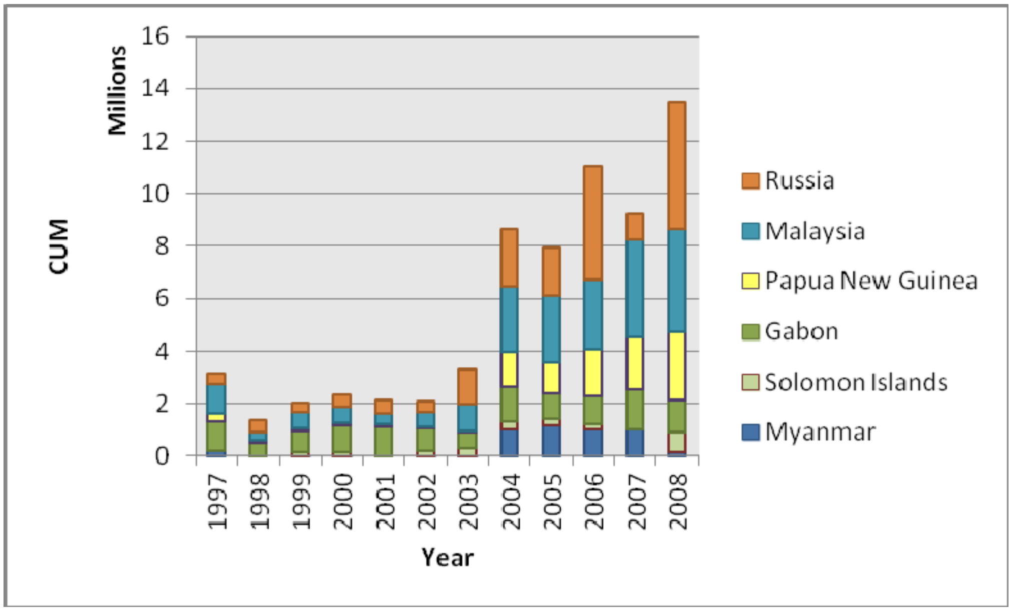

Figure 22 Non-coniferous log imports into China, 1997-2008

Other primary sources include Malaysia, Papua New Guinea, Gabon and the Solomon Islands. Myanmar has also served as a source for logs into China in previous years, but following the introduction of China's own import ban against logs from Myanmar, imports have fallen dramatically and are no longer significant in volume.

Imports of coniferous sawnwood in 2009 came primarily from Russia, and to a lesser extent, Canada, Chile, New Zealand, and the U.S. To fill the gap between demand and domestic production of non-coniferous sawnwood, China imports fairly small volumes from numerous sources. Its largest imports come from the U.S., Malaysia, and Thailand.

4.3 Approaches to Studying Trade and Illegal Logging

In economics, there is a large and growing literature focused on trade and the environment, including illegal-logging issues. This sub-disciplinary focus combines international trade theory with environmental and natural resource economics. It seeks to examine the gains from trade when the environment or natural resources are involved either as inputs to production or as outputs. The two main concerns about the impact of trade on the environment stem from worries that increased trade will lead to a depletion of natural resources (i.e., deforestation) and/or increased pollution in an exporting country (Brander and Taylor 1998). A counter argument is that freer trade and subsequently higher incomes will lead to increased demand by constituents for higher environmental quality (Copeland and Taylor 1995). This literature is largely theoretical, with few empirical applications, and does not estimate specific flows of goods, supply or demand.

Another approach to examining the interactions between trade and the environment is through the use of economic forecasting models. These models can be used to project changes in trends based on changes in contributing factors and can be applied to all sectors of an economy. The projection of these changes can be useful for long-term planning for a number of reasons. First, they can help producers understand potential impacts and change assumptions about their businesses, which could be affected in terms of production and prices by policy (environmental, trade, etc.) or economic (growth, exchange rates, etc.) changes (Cardellichio et al. 1989). Second, they can help inform policymakers how changes in policy might affect trade. Third, they can inform households about the effects on their consumption due to changes in policy or economic conditions. For example, potential assessments include the potential impact of the imposition of a new product tax on consumption, the introduction of new technologies, or policy changes. A few studies have examined the issue of long-term timber supply and demand by developing market equilibrium models. These models predict global flows of wood given particular constraints.

Most forest products trade models can be categorized as falling within a spatial equilibrium/static simulation or a dynamic optimization/optimal control framework. Most global trade models that calibrate supply, demand, and trade fall within the spatial equilibrium category. These include the CINTRAFOR Global Trade Model (CGTM), the Global Forest Products Model (GFPM), the Timber Assessment Market Model (TAMM), and the European Forest Institute Global Trade Model (EFI-GTM), among other models. The most widely referenced dynamic optimization model is the Timber Supply Model (TSM); this dynamic optimization model deals only with the supply of global timber, and not demand. The frameworks differ in the way they solve for consumer and producer surplus and thus differ in the way they model timber harvests and supply. Static simulation models solve for annual harvests and prices by maximizing each period's consumer and producer surplus, while optimal control models solve for the maximum net present value of consumer and producer surplus (Sohngen and Sedjo 1998).

The trade models described above have been used to examine a number of trade and policy issues, including climate change (Perez-Garcia et al. 2002, Sohngen and Mendelsohn 1996) and log export bans or taxes (Turner et al. 2008a, Perez-Garcia et al. 1997). They have also been used to assess the impacts of illegal logging on trade. Turner et al. (2008b) combined the GFPM and the Radiata Pine Market Model to examine the impact of illegal logging on the New Zealand forest sector and concluded that, without illegal logging, prices and demand for New Zealand logs would increase. Li et al. (2008) employed the GFPM to assess the global impacts of the elimination of illegal logging on world trade in forest products. They found that world production would be affected very little, although it would have country-specific impacts: while decreasing in many developing countries, it would rise in others. Moiseyev et al. (2010) used the EFI-GTM to model several policy scenarios aimed at curbing illegal imports into Europe, largely based on voluntary agreements. Countries with high rates of illegal logging that entered into voluntary agreements were expected to experience the highest reductions in trade. Results were comparable to those found in Li et al. (2008) except that prices were expected to increase to a higher level in Moiseyev et al. (2010). No studies specific to modeling the impacts on China's trade in illegal products have been found, although there have been a few studies modeling trade more generally in China's forest products and the effects of domestic restrictions on harvests, such as the National Forest Protection Plan (Zhang and Li 2009, Northway and Bull 2006).

4.4 Method

This study makes use of the CGTM to estimate the impacts of illegal logging on China's forest sector. The CGTM was originally developed as the Global Trade Model (GTM) at the International Institute for Applied Systems Analysis (IIASA) in the 1980s, but was subsequently extended and updated (Cardellichio et al. 1989). It is currently maintained by the University of Washington's Center for International Trade in Forest Products (CINTRAFOR). The model determines equilibrium prices and quantities of forest products—both roundwood and processed products—produced, consumed, exported, and imported by individual countries or groups of countries in the same region (Cardellichio et al. 1989). The model projects a partial equilibrium solution by summing consumer and producer surplus minus transportation costs, subject to material balance and production capacity constraints (Perez-Garcia et al. 1994). The CGTM is considered to be one of the broadest, most global and versatile models (Gilbert 2000). It includes 43 regions and has been applied to a number of global forest sector issues, including the impacts of trade restrictions such as the log export ban and climate change (Perez-Garcia et al. 2002; 1999; 1999).

The underlying economic theory behind the CGTM is found in Samuelson's concept of the net social payoff realized through the trade of a single good (Samuelson 1952). For the CGTM, this can be expressed as (Cardellichio et al. 1989):

$$Max\ \sum_{rk}\int_{0}^{q_{rk}} \pi_{rk}(q)dq - \sum_{rm}\int_{0}^{y_m} C_{rm}(Z)dz - \sum_{rsk} D_{rsk}e_{rsk} \quad \text{(eq.4.1)}$$

s.t. $q_r - A_r y_r + \sum_s (e_{rs} - e_{sr}) = 0$ (materials balance constraint)

$q_r \in C_r$ (consumption possibilities)

$Z_r \in Z_r$ (production possibilities)

$(e_{rs}, e_{sr}) \in T_r$ (trade possibilities)

Where $\pi_{rk}(q)$ is the product demand for region r and product k, $C_{rm}(Z)$ is the product supply for region r and product m, $D_{rsk}e_{rsk}$ is the transportation cost for region r, product k and trade flow s.
The CGTM encompasses four major sectors: end product (lumber and plywood) demand, supply, and timber (logs) demand and supply. The interaction between end product demand and supply determines the level of output and price in a given period, and the amount of timber required for production is then derived. Timber demand and supply curves determine the level of timber output and price. Equilibrium requires the simultaneous solution of all sectors.

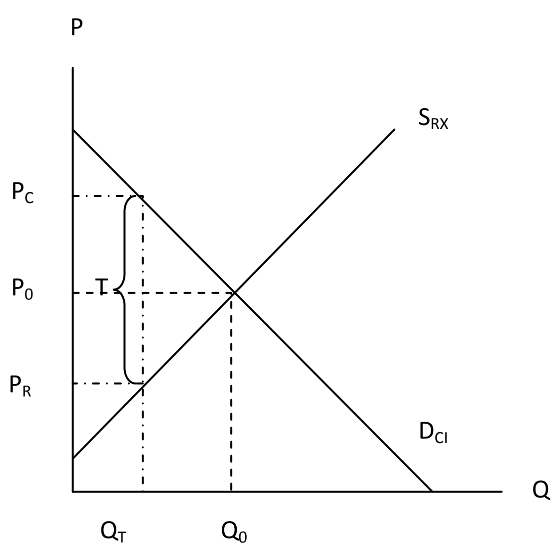

Figure 23 Effect of a tariff on Russian log supply to China

Here, the CGTM was modified to simulate several scenarios. First, the introduction of a timber supply equation in China's forest sector is considered and evaluated at different supply elasticities. It is expected that an inelastic supply curve will significantly constrain domestic log production, while a more elastic supply curve will allow greater production volumes. Second, the elimination of illegal trade flows from China's log source countries is performed through the introduction of a tariff and through the adjustment of timber supply curves. Figure 23 illustrates how a tariff can be used to restrict imports into China. Chinese demand for imports is represented by D_{CI}, and Q_o is the initial quantity supplied by Russia to China at price P_o. With the imposition of a tariff (T), Chinese imports decrease from Q_o to Q_T and a wedge between the export price of logs from Russia and the import price into China is created. The sensitivity of Chinese demand for logs from Russia based on changes in log cost was tested and will be discussed in the results section. Figure 24 illustrates the effects of changing the elasticity of supply of timber production in an exporting region. Illegal logging masks the true costs of timber production.

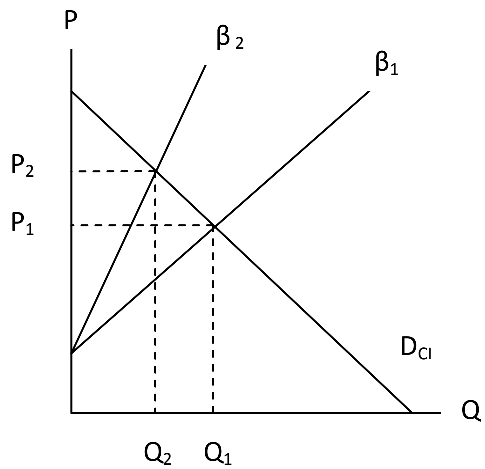

Figure 24 Effect of a change in supply elasticity on foreign non-coniferous log supply to China

The real cost would be more accurately reflected by rotating the supply curve from β_1 to reflect a more inelastic supply at β_2. At the "illegal logging" elasticity a region will export quantity Q_1 at price P_1. With a change in elasticity, the region will decrease its export quantity to Q_2 and price will increase to P_2.

In these two scenarios, consumption of logs is initially held fixed by holding lumber and plywood production and consumption fixed. In a third scenario, increasing product supply in China's forest sector is considered and the impacts such increases may have on log consumption, production, and trade are evaluated.

4.4.1 Baseline and Scenario Data

Historical data on production, consumption, imports, and exports employed in the CGTM are from FAO. The development of the baseline involved calibrating the entire model to 2007, including updating historical data as well as calibrating the model parameters, so that the demand and supply equations were based on the most recent data available. Additionally, timber supply equations specific to China, Russia, Malaysia, Papua New Guinea, West Africa (Gabon), and Oceania (Solomon Islands) were developed. Certain data used to update the China sector were drawn from China's State Forestry Administration and sources and include the China Forestry Statistical Yearbook (2010) and the 7th National Forestry Inventory. Estimates of illegal logging rates come from Lawson and MacFaul (2010) and Li et al. (2008) and are provided in section 4.2.1 in table 13.

4.4.2 Model Parameters

The interaction of product demand and supply determines the level of output and price in a given period, and the amount of timber required for production is then derived through a separate equation using changes in wood cost and timber harvests. Equilibrium requires the simultaneous solution of both sectors. This section provides a description of the underlying equations and parameters that determine model projections.

The product demand equation is given by:

$$Q = \alpha P^{\beta} I^{\varepsilon} \quad \text{(eq.4.2)}$$

Where Q is product production, P is the product price, I is income measured as GDP, α, β and ∂ are estimated parameters. The demand function is updated yearly in the projections using predictions of GDP growth. The elasticities of demand with respect to price for regions with endogenous demand are included in the Appendix 4. In this study, to analyze the effects of changing levels of timber production, demand is held constant over the projection period.

Product supply may be specified exogenously, or it may be specified through the model in the following form:

$$P = C + \alpha K^{\beta} \text{ (eq. 4.3)}$$

Where P is the product price, C is cost, K is capacity utilization, α and β are parameters. The parameters for supply elasticity with respect to price for endogenous regions are included in the Appendix 4. For this study, China's product supply is considered exogenously.

Demand for logs is derived from product supply and is calculated through the use of input/output parameters. Timber demand can be specified in the following form:

$$Q = \gamma S + \theta P \text{ (eq.4.4)}$$

Where Q is log output, S is sawnwood production, γ is the technological coefficient for sawnwood, P is plywood production, and $\theta$is the technological coefficient for plywood. As there is much regional variation in the technological coefficients associated with product production, product production could be the same across regions while requiring varying amounts of logs. The technological coefficients for all regions for log consumption are provided in the Appendix 4.

Endogenous timber supply regions are given a supply equation to determine log production for the following year. The equation is given by:

$$P = \alpha\left(\frac{Q}{I}\right)^{\beta} \text{ (eq. 4.5)}$$

Where P is the log price, α is the harvest and delivery cost, Q is log production, I is timber inventory and β is the slope parameter. Harvest and delivery cost and slope parameters are included in the appendix for regions with endogenous supply functions. For this study, timber supply equations were developed for China, Russia, Malaysia, Papua New Guinea, West Africa, and Oceania. However, China's supply is considered to be fairly inelastic since the central government sets an annual harvest quota and provides assignments to the 31 provinces. The sensitivity of the supply curve was tested by incrementally changing the elasticity (β) in the timber equation. The outcomes of these tests will be described in the results section. Adjustments to respective elasticities were used to simulate shifts in the supply curve based on the elimination of illegal outflows.

The CGTM calculates trade based on available resources and cost. Thus, the price of a good in an importing country is equal to the price in the exporting country plus the trade cost. Given available resources and cost, the model directs exports from countries with low prices toward countries with high prices. Trade costs can be updated in the trade model and are historically calculated as the import price minus the export price. One result of this is that some regions and some products have higher trade flow costs. For example, while the trade costs for the U.S. westside private (see appendix 4 for regional definitions) to export coniferous logs to China could be quite low, they might be many times as large for New Zealand. However, if the trade flow cost between New Zealand and U.S. Westside is much lower, then it is unlikely that New Zealand would export these directly to China. On average the trade costs associated with non-coniferous logs are much higher than those of coniferous logs, which drives up the final importing country's price (table 31). This is generally because the differences between prices of imports and exports of non-coniferous logs and products are higher than those of coniferous logs and products. As a result, in the model, non-coniferous logs are, on average, more expensive than coniferous logs. Similarly, trade costs associated with coniferous sawnwood are higher than those of logs, but less than those of non-coniferous sawnwood. The trade flow costs associated with plywood are higher for coniferous than for non-coniferous. By increasing trade flow costs, they can be used to represent the introduction of a tariff.

Table 31 Average trade flow costs in CGTM

Product	Average Trade Flow Cost	Number of Regions with Trade Flow Cost
Coniferous logs	\$10	41
Non-coniferous logs	\$45	51
Coniferous sawnwood	\$38	93
Non-coniferous sawnwood	\$83	37
Coniferous plywood	\$127	54
Non-coniferous plywood	\$64	44

4.5 Results

This section will describe the results from the scenarios introducing constraints on the flow of illegal logs into China. First, it will present the results from a reduction of illegal outflows of coniferous logs from Russia. Included is a description of the development and testing of the sensitivity of the timber supply equations for both Russia and China. In the case of China, a highly inelastic supply curve represents the current harvest quota system while a more elastic supply curve represents a shift to a more self-sufficient timber supply. Second, results from the elimination of illegal flows in the non-coniferous sector from Russia, Malaysia, Papua New Guinea, Africa West, and Oceania will be discussed. Third, once trade constraints are considered, the expansion of China's lumber and plywood production will be examined to determine the changes in both the coniferous and non-coniferous log sectors. Emphasis is placed on the effects to China's production, consumption, trade flows, and prices, although results for affected trading partners will also be discussed.

4.5.1 Restricting illegal log flows

Constraining illegal log flows in the coniferous sector

China's coniferous sector is currently dependent on log imports from Russia. When those imports are restricted by the introduction of a tariff, two effects are felt. First, as the international cost of Russian logs increases, so too does the price of logs in China. Second, as this occurs, Russian log imports will be substituted both by increased Chinese production (if allowed) and by imports from elsewhere. Russia is initially assigned an elastic timber supply curve, making supply there largely responsive to prices. Conversely, China is assigned a highly inelastic supply curve, reflecting its current policy constraints on harvesting. It is possible to examine the incremental differences as Russian prices increase gradually. For example, a price increase of \$5 per CUM would reduce Russian log exports to China by nearly 2.6 million CUM in the first year of the tariff (table 32). If a large price increase of \$25 per CUM were to occur, then imports could be expected to drop by 12.9 million CUM as compared to no price increase. Should Russia implement policies aimed at curbing domestic harvesting, its supply would become more inelastic and production would decrease. With even just a small adjustment, Russia's exports are reduced to zero and production declines to only what is consumed domestically, even without the imposition of a tariff.

Table 32 Change in Russian and Chinese coniferous log production, with imposition of $5 and $25 tariff, compared to no tariff (million CUM/$)

$5 tariff			$25 tariff		
Change in production in China	Change in price in China	Change in Russian exports to China	Change in production in China	Change in price in China	Change in Russian exports to China
0.40	$1.59	-2.56	1.88	$7.77	-12.88

The amount by which log imports into China will be substituted by increased domestic production depends on the elasticity of supply in both Russia and China. A highly inelastic supply curve in China will make it difficult to increase domestic production while a more elastic curve will allow for greater production volumes. The policy choice on the part of the Chinese government to set a quota for timber harvests can be represented by using a highly inelastic supply function. This highly inelastic supply curve can then be compared to adjusted levels in order to understand how production in China might be affected. Table 33 illustrates the changes in coniferous log production, imports and prices into China given varying elasticities representing elastic to highly inelastic supply curves, and given fixed consumption of logs.

Table 33 Coniferous log production and imports in China given adjustments to supply elasticity (million CUM)

	Elasticity			
	Highly inelastic	Relatively inelastic	Relatively elastic	Elastic
Consumption	77.61	77.61	77.61	77.61
Production	31.29	40.25	60.67	77.55
Imports	46.32	37.35	16.94	0.06

Shifting from a highly inelastic to a relatively inelastic supply would result in an increase in production of 29%. As production increases, imports decrease by 19%. An elastic supply curve would result in China producing nearly all of its logs domestically and reducing imports by 99% as compared to the highly inelastic scenario. Understanding how different elasticities affect domestic production in China can simulate policy decisions on the part of the Chinese government to either allow a higher timber quota or to allow the forest sector to operate more as a market system.

It seems reasonable to assume that China will continue to have a highly inelastic timber supply function for the foreseeable future, while Russia's will remain elastic. In this case, production within China would rise by less than 1 million CUM in the first year under the low-tariff scenario and just over 1 million CUM under the high-tariff scenario. Without increasing domestic production, imports from Russia would be substituted by imports from other regions with competitive prices and lower trade costs. Given Russia's reliance on China as a destination for its log exports, as demand for its exports decreases, production would also be expected to decrease by the same amount. Effectively, as the tariff increases, exports from Russia would continue to decline until they reach zero, and total production there would decline to what is consumed domestically.

If a relatively elastic curve were imposed on China's timber supply, representing increased domestic production, China would not be as reliant on imports in general. This can be described as a move to greater self-sufficiency, which China has been pursuing with planting targets. Within six years of imposing even a $5 per CUM tariff, Russian exports to China would diminish to zero under this policy.

However, if Russia's timber supply were to become relatively more inelastic, as mentioned above, its exports would decrease to zero immediately even without the tariff.

The main beneficiaries of production decreases in Russia would likely be New Zealand and North America, depending on prices and trade costs (table 34). New Zealand and Chile typically have lower log prices and could increase their exports to China significantly.

Table 34 Change in coniferous log exports to China (million CUM), given different elasticities and tariff amounts

China's supply elasticity	Tariff amount	North America	New Zealand
Timber production in China subject to quota system	$5	2.93	0.25
	$25	12.12	2.06
Timber production in China subject to self-sufficiency policy	$5	0.00	0.38

Constraining illegal log flows in the non-coniferous sector

In 2008, 70% of China's non-coniferous log imports came from five sources: Russia, Malaysia, Papua New Guinea, Gabon and the Solomon Islands. In the CGTM, Gabon falls within the West Africa region and the Solomon Islands within Oceania; these latter two regions will be used instead of the country names. This section describes the results of modeling constraints on timber production in these countries first by imposing a tariff and second by making their supply curves more inelastic. Making the supply curve more inelastic simulates the implementation of a domestic policy aimed at reducing harvests, since it would better reflect the true cost of log production in these countries and prices would increase. As quantity supplied in these regions is lowered, fewer resources will be available for export. In these scenarios, domestic demand for logs in these countries is assumed to be fixed; as a result, domestic demand will be met first before making resources available for export. Initially, the supply curve in each country is relatively elastic, reflecting a condition where the costs associated with illegal logging are ignored. The effects of two changes in the supply elasticity are evaluated in this section; these two changes reflect low- and high-reduction scenarios that are intended to mimic a reduction equivalent to the low and high ranges listed in table 13 and the effects on production in these countries and their exports to China are reported. For China, two supply elasticities are employed: first by setting it to match the current quota system and second by setting it to reflect a self-sufficient production condition.

Under a tariff scenario, even a low tariff would induce an effect on both the total volume of non-coniferous logs imported by China and on the amount from each source. With China's timber supply set by quota, a low tariff would reduce total imports by 7%, while a high tariff would reduce imports by 14% (table 35). With China's timber supply set to produce at a greater level of self-sufficiency, a low tariff would have a greater proportional impact, reducing imports by 25%; a high tariff would reduce imports by 45%. Additionally, the relative positions of each source country would shift as their relative cost positions also change. For example, in all cases, Malaysia would become more expensive relative to other countries. This would be of particular significance if China's supply curve continued as under the current quota system. Both Russia and West Africa would increase their exports to China. Ironically, a tariff would have to be substantially higher to result in a decrease in total production within these regions. As the price increases, almost all of the five countries would experience an increase in production and exports to regions with higher prices. Thus, while exports into China would generally decrease, exports to other regions could increase, and a tariff might not have the intended effect of lowering overall production in the respective countries. This is a result of demand in importing countries being relatively inelastic, with few suppliers to source from.

Table 35 Change in non-coniferous log exports to China (million CUM), given different elasticities and tariff amounts

	Timber production in China subject to quota system		Timber production in China subject to self-sufficiency policy	
	Low tariff	High tariff	Low tariff	High tariff
China total imports	-2.33	-4.54	-4.05	-7.39
Malaysia	-4.42	-7.36	-3.67	-3.67
Papua New Guinea	-0.71	0.79	-1.37	-0.54
Russia	2.45	2.03	0.94	-1.43
West Africa	1.05	0.74	-0.04	-1.64
Oceania	-0.79	-0.82	0.07	-0.11

Rotating the supply curves of these five regions has a different effect, particularly depending on whether or not China continues its quota system or relaxes its production policies. The low-reduction scenario reduces supply in Malaysia, Papua New Guinea, Russia, West Africa, and Oceania by an average 15%. In the low-reduction scenario, total global production is affected very little, at less than 1%. As these five countries reduce their total production by 14.7 million CUM, China would respond to a reduction in available imports supply and increased prices by increasing its domestic production by 9 million CUM (table 36). However, while global supply effects are minimal, the effect on trade is large, reducing available exports by nearly 30%. Prices could be expected to more than double for all regions that trade in this sector. As a proportion of production, exports to China from West Africa and Oceania decrease the most significantly, falling to zero. Russian exports to China fall by almost a half. Malaysian exports are the least affected, falling by only 3%. Everything else being constant, Malaysia continues to be the lowest cost producer, while Papua New Guinea, Russia, and Oceania are slightly higher cost producers. West Africa is the highest cost producer. These relative positions do not change throughout the course of adjusting their supply. Thus, in this scenario, as a percentage of its total imports, China would likely become increasingly dependent on Malaysian exports in the face of reduced supply from other regions.

Table 36 Changes in production and exports (million CUM), comparing quota and self-sufficiency systems in China, and low- and high-reduction scenarios in source countries

	Timber production in China subject to quota system				Timber production in China subject to self-sufficiency policy			
	Low reduction in source countries		High reduction in source countries		Low reduction in source countries		High reduction in source countries	
	Total Q	Total X	Total Q	Total X	Total Q	Total X	Total Q	Total X
China	9.11	0.00	15.04	0.00	10.45	0.00	15.30	0.00
Malaysia	-5.27	-5.27	-7.15	-7.15	-8.22	-7.72	-6.51	-6.07
Papua New Guinea	-0.55	-0.55	-1.75	-1.75	0.00	-2.06	0.00	-1.65
Russia	-4.04	-4.04	-7.94	-7.94	-5.43	-3.90	-7.75	-7.77
West Africa	-4.79	-4.79	-4.79	-4.79	-3.10	-4.72	-4.69	-4.72
Oceania	-0.18	-0.18	-0.16	-0.16	-0.25	-0.17	-0.15	-0.16

Note: Q=production; X=exports

The high-reduction scenario reflects an average reduction in production of 27% among these five regions. Total production in these countries would decrease by 21.8 million CUM, while production in China grows by 15 million CUM. Again, this affects the total worldwide supply very little, since 85% of production is consumed within the countries it is produced. Trade effects are large, though, as worldwide available exports decrease by nearly 45%. In a high-reduction scenario, there is no further supply available to decrease in West Africa and Oceania. At a 25% and 20% of production reduction respectively, all exports from these regions cease. This indicates that the estimates of illegal logging in Li (2008) and Lawson and MacPaul (2010) would represent the extent of trade from these regions. Russian exports would decline by 92% over the low-reduction scenario, to almost zero. Again, Malaysia would continue to dominate imports into China.

If China's production were to increase, as under a self-sufficiency system, the effects of rotating the supply curves of its supply countries would have an even greater effect, reducing production in those countries by 22% under a low-reduction scenario and 26% under a high-reduction scenario. Total imports into China would already be much less, and the reductions posed for each country would thus represent a higher percentage of their exports to China.

4.5.2 Increasing product production in China

In the two previous sections, consumption of logs was held fixed by holding production of coniferous lumber and plywood fixed. This enabled the consideration of how the distribution of log suppliers changed in the context of no changes in aggregate demand for logs. This section discusses the results of increasing lumber and plywood production in China by 7% per annum. Consumption in China is also assumed to grow by the same amount, thereby precluding any significant exports of these two products, and simulating current production and consumption conditions. Adjusting these conditions allows for the examination of the impacts of increased demand and supply within China of products on the distribution of log production, consumption, trade flows, and prices. While product production grows in China, it is held fixed for the rest of the world. This allows for the examination of how small changes in one assumption can affect changes to China's forest sector, *ceteris paribus*. All conditions were modeled using both inelastic and relatively elastic supply equations for China. For the coniferous sector, both the no-tariff and high-tariff ($25 per CUM) conditions were applied to Russia. For the non-coniferous sector, scenarios were run under no-reduction, low-reduction and high-reduction conditions were applied for China's main sources of logs.

Coniferous sector

A 7% annual increase in China's product production results in a commensurate 7% annual increase in its log consumption, effectively growing log consumption by nearly 140% by 2020. In turn, by 2020, China could be expected to consume 187 million CUM of coniferous logs. With a highly inelastic supply curve, production of logs would grow minimally in the first few years, and would only provide 36 million CUM, or 19% of the resources needed by 2020. Consequently imports would nearly triple over 2007 levels to 151 million CUM by 2020 (table 37). With no tariff imposed on Russia's log exports, and with the assumption that Russia's elasticity is held constant at an elastic level, Russian logs could be expected to fill about 37 million CUM, or a fifth of China's imports, by 2020. North America, New Zealand, and Chile would have the greatest ability to provide the remaining needed supply. If a tariff of $25 per CUM were imposed in an effort to reduce Russian exports, with an inelastic supply in China, China would greatly reduce, but not completely discontinue importing any logs from Russia, and North America would pick up the difference.

Table 37 Coniferous log production in China and imports, given a 7% annual increase in product production, as compared to no increase in product production (million CUM), 2020

Timber production in China subject to quota system			Timber production in China subject to self-sufficiency policy		
	No tariff	$25 tariff		No tariff	$25 tariff
China production	35.88	36.24	China production	89.41	90.69
China imports	151.14	150.78	China imports	97.62	96.33
North America	85.51	102.60	North America	36.12	52.24
Russia	36.95	19.47	Russia	32.84	15.42
New Zealand/Chile	28.69	28.70	New Zealand/Chile	28.66	28.67

With a relatively more elastic supply curve in China, production there could grow by nearly 50% to 89 million CUM, providing approximately half of the resources needed. Under a no tariff scenario, Russia would continue to provide a significant amount of the import volume needed, with North America and New Zealand/Chile providing the remainder. Clearly, North America would likely not benefit as greatly if China were able to dramatically increase its supply. The introduction of a tariff of $25 per CUM would reduce imports from Russia until the price of logs in China and the cost of logs from Russia reached a point where logs from Russia would resume being competitive even with the tariff. North America and New Zealand are relatively high-cost producers and will continue to be outcompeted by Russia as long as the cost of logs remain lower than the cost of North American logs, even with a tariff.

Non-coniferous sector

A 7% annual increase in production of non-coniferous lumber and plywood would result in an increase in log consumption of 141% by 2020, with consumption in China reaching 133 million CUM. With a highly inelastic supply curve, production could be expected to grow 40% to 27 million CUM. This would provide only 20% of the necessary resources to meet lumber and plywood production levels. Malaysia would provide 60% of the total imports needed, followed by Russia, West Africa, Papua New Guinea, and Oceania (table 38). With a relatively more elastic supply function, China might be able to supply upwards of 43% of total log demand. Total imports would decline, but relative market shares for each region would remain the same as under the highly inelastic scenario. Prices in China would be approximately 18% less if China's supply were allowed to grow to 57.5 million CUM rather than 27.25 million.

Table 38 Non-coniferous log imports to China under a no restriction scenario, by region, given a 7% annual increase in product production (million CUM), 2020

	Timber production in China subject to quota system		Timber production in China subject to self-sufficiency policy	
Imports into China	**Million CUM**	**% of total**	**Million CUM**	**% of total**
Malaysia	62.16	59%	42.06	56%
Papua New Guinea	8.12	8%	5.82	8%
Russia	19.85	19%	15.54	21%
West Africa	12.89	12%	9.67	13%
Oceania	1.99	2%	1.67	2%
Total	105	100%	75	100%

The introduction of supply restrictions in the five regions is complicated by increased demand from China. Under a low-restriction scenario, production is still allowed to increase. As a result, by 2020, given high enough price increases, export flows from these regions could resume their pre-restriction export levels by 2020 (table 39). These price increases occur particularly if China's supply continues to be inelastic. A more elastic supply in China would dramatically increase production in China and reduce the need for imports, under both the low-reduction and high-reduction scenarios. With a greater domestic supply, and with low imports, only Malaysia would continue to be a source of large volumes of logs for China's market as many other sources would diminish their exports to near zero. An important consideration when examining the results here is that the number of trade flows remains fixed to presently existing flows. Europe, Brazil, and North America do not currently export significant volumes of hardwoods to China and are therefore not included in the analysis. Without introducing new potential flows, China is constrained to import from only its current main trading partners.

Table 39 Changes in non-coniferous production and imports in China, given low and high restrictions in source countries (million CUM), 2020

	Timber production in China subject to quota system		Timber production in China subject to self-sufficiency policy	
	Low restriction	High restriction	Low restriction	High restriction
China Production	45.67	56.46	92.50	105.40
China Imports	86.84	76.05	40.01	27.11
Malaysia	53.41	48.03	28.73	21.30
Papua New Guinea	16.19	14.72	1.38	2.43
Russia	14.16	6.29	8.43	2.00
West Africa	1.28	5.22	1.21	0.00
Oceania	1.54	1.53	1.21	1.12

4.6 Discussion

The CGTM was used to model the impacts of restrictions on outflows of logs from countries with suspected illegal flows into China. Under the scenarios in which China's timber equation is set to mimic the current harvest quota, China has little flexibility in terms of shifting from relying on imports to increasing production. Conversely, shifting to a more self-sufficient production system provides insight into how China's forest sector might behave if it were subject to greater market forces, rather than government limits. As a result, the total volume of imports remains largely unchanged when production is subject to an inelastic supply curve, while imports of coniferous logs decline almost completely when China is modeled using an elastic timber equation.

This raises the question of China's ability to dramatically increase domestic supply. While the government has stated its goal of increasing domestic production, and has in fact increased the timber quota over the last two five-year planning cycles, actual annual growth in log production in recent years has been inconsistent, and has averaged only 7% since 2003. More significant increases in log production will likely present a number of challenges. Natural forests have been severely drawn down, and the 12th Five Year Plan calls for reduced harvests from these forests. While plantations will increasingly provide harvestable resources, they are of inconsistent quality and their ability to provide dramatic increases in resources has been called into question (Bull and Nilsson 2004). Despite the stated goal of increasing production, it remains to be seen how extensive this will be and what the impact will be to product quality. It is worth noting that while calculations in the CGTM for China are based on official calculations of inventory and growth, as provided by the 7th National Forest Inventory, it is certainly possible that these statistics are inflated and would therefore affect how much wood fiber is in fact available for production, regardless of quality.

The introduction of a graduated tariff demonstrated the potential impact on both production and exports of Russian coniferous logs. With a highly inelastic supply curve, China is unable to sufficiently increase its domestic production under either a low- or high-tariff scenario. China is reliant on Russia for inexpensive coniferous logs, and Russia is dependent on China as an export destination. Without a market for logs in China, Russian log production will decline dramatically. However, in these projections, it would require a fairly expensive tariff of nearly three-quarters the Russian log price to reduce Russian production by the upper bound of 50% described in table 40. If Russia's log prices reflected the true cost of production, with a more inelastic supply, it would affect production immediately and likely bring about a significant decline in exports.

In the non-coniferous sector, China relies heavily on five sources for its logs: Malaysia, Russia, Papua New Guinea, West Africa, and Oceania. Although the market share among these countries has varied over recent years, they continue to provide the largest volumes of hardwood logs. Whether or not this will continue to be the case will depend on how much China's timber harvests are allowed to grow and how costs will change. In modeling the restrictions on trade, it is clear that even with restrictions, as prices rise, production in these regions will as well. A continual upward adjustment of the supply curves could be made, and prices will follow. Other countries that could potentially gain from restricting trade flows, but from whom China does not currently import large volumes, include Europe and Brazil. North American hardwood logs have not been competitive in this sector due to their relative high cost. Temperate hardwoods from Europe are not a perfect substitute for tropical logs from Malaysia or Papua New Guinea, and might more likely replace Russian logs. Substitution of temperate for tropical hardwoods will depend both on cost and on how wood preferences evolve. With or without the introduction of new trading partners, China will have to balance domestic production with imports from a small number of sources.

Table 40 Percentage changes to producer surplus in China and trading partners due to tariff imposition and supply elasticity changes

Coniferous logs (tariff)			**Non-coniferous logs (supply elasticity change)**		
	$5 tariff	**$25 tariff**		**Low restriction**	**High restriction**
China	2%	12%	China	200%	416%
Russia	-11%	-50%	Malaysia	117%	211%
New Zealand	4%	19%	Papua New Guinea	32%	-11%
North America	15%	78%	Russia	78%	95%
			West Africa	146%	146%
			Oceania	123%	229%

Changes in producer surplus reveal how producers might be affected under different policy scenarios. In the coniferous log sector, with an imposition of a tariff, Russia's producer surplus declines significantly, while Chinese, North American, and New Zealand producers experience increases in their welfare (table 40). In the non-coniferous log sector, while production decreases under both the low-and high-reductions scenarios, prices increase significantly. As a result, producers gain significantly as log prices increase. Under the low-reduction scenario, prices nearly double; under the high-reduction scenario, prices nearly triple. These price increases result in a dramatic increase in producer surplus. Only Papua New Guinea experiences a decline under the high-reduction scenario.

These differences in surplus changes indicate that a tariff, though perhaps effective at reducing outflows from a particular region, also results in a loss of producer welfare as compared to other restriction mechanisms. Although not presented in the table above, a shift in elasticity in Russia, while still reducing exports to China, would in fact result not in a decrease, but in a large increase in producer surplus. Under the tariff scenario for non-coniferous logs, because both production and prices increase, there is an increase in producer surplus; however, it is much smaller than the increase incurred by shifting the supply curve. Thus, if maintaining producer surplus were an important factor in designing trade policies, one that targets shifting the supply curve by better incorporating the true cost of log production would be more effective in the long term than a tariff since it results in an increase in producer surplus.

Between 2000 and 2009, production of lumber in China grew at an average rate of 18% per year, plywood at 19%. The estimated 7% annual growth in production of sawnwood and plywood through 2020 included here is conservative compared to these growth rates, and conservative when compared to the 12% annual growth presented in the latest Forestry Development Plan (SFA 2009). With an inelastic supply curve, growth in timber consumption would outpace growth in timber supply, and China would need to increase its imports by more than 19% per year to reach the levels needed by 2020 to contribute to the production of lumber and plywood. In the coniferous sector, these logs will come not only from inexpensive suppliers such as Russia and New Zealand, but increasingly from relatively more expensive producers in North America. In the non-coniferous sector, China will continue to rely on its current sources, even if it faces higher costs. Expansion of production of sawnwood and plywood will be dependent on access to logs from outside of China. Even if China is able to expand its domestic production, as demonstrated under a more elastic supply curve, it would still need to increase its imports by 13% per year by 2020.

It should be noted that estimated consumption of logs using the CGTM greatly exceeds officially reported statistics. As described earlier, the CGTM calculates derived demand for timber as a fixed proportion of sawnwood and plywood production. Using officially reported product statistics, combined with reasonable input-output coefficients for production, it is estimated here that actual timber consumption exceeded officially reported consumption by approximately 45% in 2007. Total consumption of coniferous and non-coniferous logs, if calculated using official statistics, was between 91-102 million CUM in 2007. However, using the CGTM, consumption is calculated to have been more than 132 million CUM. While lumber and sawnwood production grew over the past decade grew by an average 21% and 19% per year, respectively, log consumption reportedly grew only by 6% per year. This seems doubtful. This discrepancy is likely a result of underreporting in both domestic log production and import volumes. Above-quota logging is not uncommon in China and has been widely discussed (Démurger et al. 2007).

As described in Chapter 2, Chinese wood-processing enterprises are highly dependent on wood resources and it seems improbable that growth in the product sector could grow at such a rapid rate without a concomitant increase in log consumption. The results of that study indicate that under available resources and technology, Chinese wood-processing enterprises could either significantly increase their production using the same total level of inputs or maintain their current output with fewer total inputs. To do so would require a significant shift in enterprise operation and might be brought about by better utilization of their capital resources. If they fail to improve their operations, there will be a continued heavy reliance on wood resources that are likely to become more expensive and come under greater legal scrutiny, particularly if Europe's Forest Law Enforcement, Governance and Trade (FLEGT) rules and the U.S.' Lacey Act Amendment are rigorously pursued.

4.7 Conclusion

This study examines the impact of restricting the flow of logs to China from countries with suspected illegal-harvest activities. Two approaches were used. First a graduated tariff was applied to Russia's exports of coniferous logs to China. Second, changes in the supply elasticities in Malaysia, Papua New Guinea, Russia, West Africa, and Oceania were applied to production of non-coniferous logs. These changes were initially applied to China's forest sector while holding demand for logs constant. Next they were examined in the context of increasing China's production of lumber and plywood at a conservative growth rate. The magnitude of impact depended in large part in the magnitude of change in the elasticities in both the supply countries and in China. China was evaluated using elasticities that simulated the current harvest quota system, as well as a system that becomes more self-sufficient through increased log production. The results of the producer surplus indicators demonstrated that there is a large loss resulting from the imposition of a tariff as compared to methods that approach adjusting supply by a change in the cost structure. Additionally, predicted consumption levels were compared to reported consumption levels and revealed a large discrepancy.

This is the first study to examine the impacts of illegal-log-flow restrictions on China's forest sector. China is the largest driver of demand for the trade in tropical logs, and is becoming a significant driver of demand for trade in coniferous logs. Without a significant increase in domestic production of both coniferous and non-coniferous logs, it will continue to be reliant on imports to fuel its growth in product production. In the coniferous sector, Russia, North America, and New Zealand will be the greatest beneficiaries of increased imports. In the non-coniferous sector, there is greater concern about where China will draw its imports from. Even if it is able to increase non-coniferous log production, it will be unable to produce large volumes of tropical logs. These may continue to come from countries with suspicious logs, unless steps are taken to curb the flows. How China's demand for increased fiber resources will be met is of wide interest to those in industry, resource management, policy-making, and the environmental fields.

5 Conclusion

China's rise as a geopolitical leader is undisputed. The 21st century is likely to witness the continued rise and expansion of China's economy and global position. As a consumer and producer of wood products, it is currently facing – and will continue to face – challenges in facilitating sustained growth in its forest sector. To date, the growth of its forest products industry has been assumed to be dependent on intensive resource use and relatively inexpensive labor. Such a hypothesis is largely borne out in this paper. As a result, China faces many constraints in continuing to expand its forest sector. Dependency on intensive resource use for a resource-scarce country poses difficulties if it is to continue expanding. The same holds for a reliance on inexpensive labor in a country where wages are rapidly rising and the number of young workers entering the employment age will be dwarfed by those retiring.

This research explores three questions fundamental to the expansion of China's forest sector. It began with an introduction to the history and current conditions underlying China's forest sector. It then investigated three overarching but inter-connected topics within China's forest sector. First, it examined the relationship between regional-specific factors and foreign direct investment in China's forest sector. Second, it estimated efficiency metrics for Chinese wood-processing enterprises. Third, it modeled impacts of restrictions to the flow of illegally-logged timber on China's wood products trade.

China's forest sector entered the reform era with depleted forests and little investment in either forest management or industry. In industry, reforms have led to a transition from state and collective ownership to the privatization of a majority of enterprises. In forest management, while the state has retained control over state forests, collective management has largely given way to household management. Yet, while industry has grown tremendously, forest-dependent communities continue to be among the poorest, and their economic development lags far behind the coastal and urban regions. The push to reform land tenure has proven to be complex. Household plots are small, and quotas, taxes, and permits have stymied the ability to earn significant income from managing forestland. Conservation-oriented directives often conflict with the promises of land reform and have had dubious long-term, sustainable benefits for rural households and questionable ecological benefits. Forest coverage has increased, but gains may be overstated until the ongoing problems of illegal logging and underreported harvests are acknowledged. The forest industry has expanded rapidly in the last fifteen years or so, particularly along the coast, but it has become reliant on imports to fuel this growth.

The study on efficiency revealed that China's wood-processing enterprises, serving as the world's "wood workshops," are reliant on labor and natural resources, while capital appears to be underutilized. It was found that no enterprise achieved total efficiency, and that all enterprises showed significant room for efficiency increases. The technical efficiency scores imply that under available resources and technology, Chinese wood-processing enterprises could either significantly increase their production using the same total level of inputs, or maintain their current output with fewer total inputs. More effective use of current or future capital resources will be fundamental to the expansion of China's forest sector, particularly as labor costs continue to rise and improved use of capital is one way to substitute for higher labor costs. If resources become more expensive and scarcer, China's processing enterprises will find themselves increasingly hard pressed to remain competitive. As it is, many industry representatives in China already complain about high costs and small profit margins. An additional potential means of improving efficiency scores could come from consolidating smaller enterprises into larger ones, which tend to outperform their smaller counterparts. Contrary to widely held assumptions, further privatization may not provide additional marginal improvements in efficiency; ownership structure and location do not necessarily affect efficiency.

Two of the studies included in this paper indicate that coastal location does not play a critical role in either enterprise efficiency or in location choice for foreign investment in processing enterprises. In the study on foreign investment location choice, it was found that a more important factor is the presence of free-trade and pro-investment policies, presenting an opportunity to reconsider where to locate investment, and how to structure incentive policies aimed at attracting foreign investment in industry. It would also appear that foreign investors are attracted to the availability, or perhaps the perception of the availability, of natural resources. If China were to rely on its own resources to a greater extent, it might pursue the expansion of industry in provinces that are further from the coast. Given the apparent lack of importance on the education and infrastructure variables, provinces located further in the interior may present significant opportunities for development. These include Heilongjiang, Jilin, Anhui, Jiangxi, Hunan, and Yunnan, which have relatively high timber production levels compared to the historical number of wood-processing enterprises.

Even if China does expand its use of domestic resources, it will be years before these resources are of high quality. China imports wood of varying quality and for various purposes. Tropical, North American and European hardwoods, which can be costly, largely go into higher end furniture, for both the domestic and export markets. Russian softwoods and hardwoods are largely used for components and lower-quality products. If the supply of any of these resources is restricted, China may find it difficult to produce either a higher percentage of higher-quality goods or a mixture of both. Continuing to produce only low-quality wood resources domestically will have an effect on the ability to produce higher-quality wood products. As a result, although China may expand its plywood production, in order to produce higher-quality goods, it will need higher-quality wood, and this is unlikely to be sourced domestically. There will most certainly be a large domestic market for inexpensive goods, which may stimulate greater domestic demand. In the chapter on trade and illegal logging, it is estimated that officially reported production and import numbers grossly underestimate the amount of timber required even to produce the current level of lumber, plywood, and other products. It was demonstrated that without the ability to provide domestic resources, China will be reliant on a relatively small group of countries to supply its resources. In the coniferous sector, it will likely rely on Russia, New Zealand, Chile, and North America. If trade or production restrictions are imposed on the Russian forest sector, Chinese demand can be relatively easily met by resources from these other regions. In the non-coniferous sector, China is more constrained to Southeast Asia and Africa as resource providers. There may be new opportunities for trade between China and regions from which it does not currently import significant quantities, such as Brazil, but there are a limited number of sources of tropical wood. There is a higher likelihood that if governments in those regions took greater steps to enforce forest governance and efforts against illegal logging, their costs would be borne out or conservation measures would be better implemented.

The Lacey Act Amendment, passed by the U.S. Congress in 2008, makes it unlawful to "import, export, transport, sell, receive, acquire, or purchase in interstate or foreign commerce any plant, taken, possessed, transported, or sold in violation of the laws of the United States or any foreign law that protects plants or that regulates certain plant related offenses." (Federal Register, October 8, 2008). While this policy puts the onus on the U.S. importer to provide proof of legality, it is highly likely that costs associated with implementation will eventually be borne further down the production chain, resulting in higher resource prices. Consequently, one way to interpret adjustments to the supply curves for China's source countries is that they mimic the effects of increasing production costs associated with ensuring legal timber exports. Thus the more inelastic supply curves for China's primary source countries described in Chapter 4 reflect the higher production costs that will result from the implementation of the Lacey Act.

If China's domestic production continues to be assigned by quota, then it will face increasingly high prices for timber resource imports. This would be particularly true for tropical logs, where the number of exporting countries is fairly limited. Should implementation of the Lacey Act prove to be costly for producers, then by 2020 the price of logs imported into China could triple or quadruple those under a business-as-usual scenario. It is unlikely that China would remain competitive in such a case. Higher resource prices on the international market could lead source countries to develop domestic industries to process their resources instead of exporting them. Even if China's domestic resources were opened up to expanded production, it would be unable to supply tropical logs. In such a case, there would need to be a substitution of temperate for tropical hardwoods. Even if this shift in product taste were to occur, China would still face higher prices for all non-coniferous logs on the international market.

Conversely, the effect would likely not be large in the coniferous sector, given China's multiple potential sources for logs. Although there would be a substantial price increase for Russian logs, the price of logs from other regions would not increase greatly, and China would experience only a small increase in log import price. This could allow China to continue to remain competitive in processing coniferous logs.

In short, China's own forest resources are constrained in age and quality. Only the passage of time can rectify the former, and the latter will need to come from improved silvicultural practices. In the meantime, it should take several steps to improve – not simply expand – its domestic industries. These include reducing its reliance on labor and natural resources to fuel the growth of its industry. If the government continues to seek foreign investment in processing and industry, it should increase, not limit, the number of free-trade zones within China. This includes creating new incentives to attract investment into provinces that may not be located on the coast, but have the potential to serve as centers of production. The government might also seek new ways of attracting foreign investment into forest management projects. Not only would this take advantage of potential resource-seeking on the part of foreign investors, but it could enable the development and expansion of improved plantations, which are often regarded as being of poor quality. This would only be successful if prices continue to rise and companies see a clear incentive to invest in plantations or afforestation. In the past, tenure security and long-term guarantees have been mentioned as a source of concern for foreign investors interested in forest management. Current reports of fraud receiving attention in the press are undoubtedly a new source of concern for those interested in investing.

There are a number of limitations to the studies included in this paper. Data in China, as in many other countries, are often fraught with problems. The efficiency chapter demonstrated several challenges associated with using survey data collected in China, and the inconsistencies that are revealed after data collection is completed. Additionally, the sample was skewed toward particular provinces within regions, and thus not representative of the country as a whole. The investment chapter relied on provincial-level data; firm-level data would provide greater insight into firm-level decisions. Further study of this issue would benefit from the exploration of other explanatory variables such as the impact of wood imports on location choice.

China is a clearly a driver in the demand for natural resources, and is a major producer of semi-finished and finished wood products. However, the country may soon find itself at a crossroads in terms of its conservation-production pull. Questions surround its ability to sustain growth in the production of semi-finished and finished wood products in the face of increased conservation. The government has clearly stated its intent to expand, not limit, the forest-processing industry. It seeks to improve the quality of China's products and production standards of its enterprises. But grossly underestimating the volume of wood needed to maintain – let alone increase – production will create incentives for continued misreporting of resource use, and inhibit the ability to improve product quality. As resources abroad become more expensive, there will likely be a push to open up designated conservation areas to greater timber production. The U.S. has a long history of the push and pull between conservation and industry. Although China is unlikely to follow the same path as the U.S., it will undoubtedly face difficult policy decisions in the decades ahead. It will not have the luxury of postponing these decisions. As a geopolitical leader, it will be expected to participate in, and demonstrate leadership in industry development and efficient resource use and trade.

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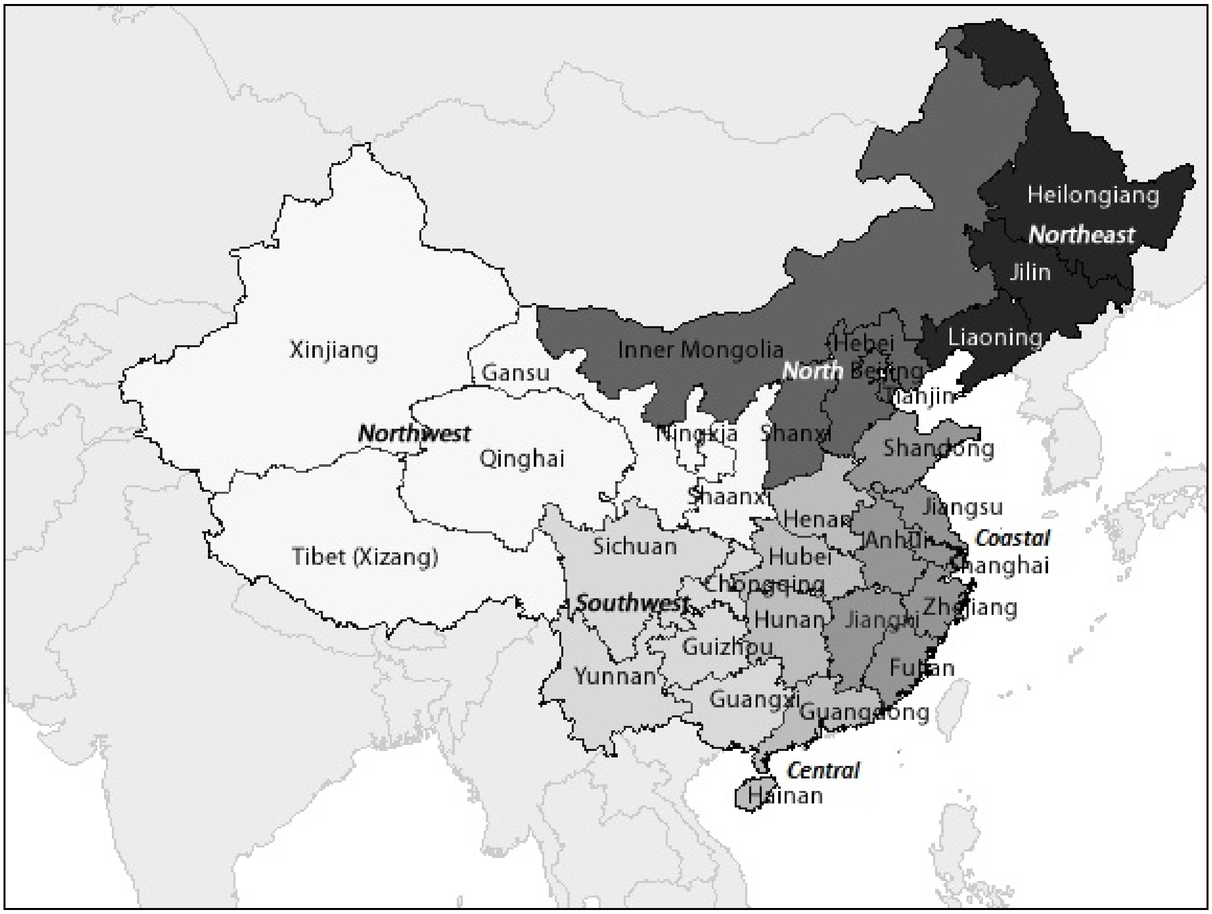
Appendices

Appendix 1: Log production by province, 2003-2009, in million CUM

	2003	2004	2005	2006	2007	2008	2009
National	47.59	47.12	50.23	61.12	64.92	73.57	70.68
Beijing	0.03	0.03	0.03	0.06	0.07	0.07	0.08
Tianjin	0.00	0.00	0.00	0.00	0.05	0.05	0.05
Hebei	0.39	0.38	0.46	0.47	0.51	0.47	0.58
Shanxi	0.05	0.06	0.05	0.09	0.09	0.07	0.06
Inner Mongolia	3.28	3.58	3.28	3.27	4.00	3.31	3.12
Liaoning	1.30	1.30	1.40	2.22	1.86	1.69	2.30
Jilin	3.77	3.95	4.16	4.39	4.16	4.18	1.87
Heilongjiang	4.98	4.74	4.75	5.43	5.32	5.34	3.95
Shanghai	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Jiangsu	0.38	0.61	0.55	0.58	0.73	1.06	0.99
Zhejiang	2.04	1.58	1.67	1.79	1.87	2.95	1.97
Anhui	2.79	2.40	2.66	3.34	3.46	3.40	3.74
Fujian	5.18	5.18	5.61	5.97	6.18	6.56	6.35
Jiangxi	3.54	3.64	3.96	4.25	4.34	5.78	3.40
Shandong	0.43	4.01	0.62	0.98	1.52	1.58	2.21
Henan	0.60	0.65	0.63	2.11	1.42	0.52	1.10
Hubei	1.07	0.77	1.29	1.65	1.70	1.91	2.19
Hunan	4.12	4.36	4.50	5.91	6.34	8.16	5.46
Guangdong	3.08	3.09	3.24	3.62	4.16	4.72	5.25
Guangxi	4.45	4.73	4.86	6.25	7.74	9.09	9.64
Hainan	0.71	0.38	0.54	0.60	0.64	0.88	1.53
Chongqing	0.00	0.01	0.02	0.11	0.17	0.20	0.24
Sichuan	0.51	0.40	0.68	0.94	0.98	2.53	1.92
Guizhou	0.29	0.33	0.54	0.88	1.20	2.07	1.30
Yunnan	1.80	1.75	1.90	3.30	3.57	3.81	4.76
Tibet	0.20	0.12	0.10	0.17	0.06	0.06	0.67
Shaanxi	0.15	0.11	0.10	0.14	0.15	0.20	0.37
Gansu	0.01	0.03	0.04	0.03	0.05	0.08	0.04
Qinghai	0.02	0.02	0.02	0.02	0.02	0.01	0.00
Ningxia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Xinjiang	0.32	0.47	0.34	0.41	0.38	0.32	0.37

Source: SFA (2004-2010)

Appendix 2: Geographic regions



Appendix 3: Number of foreign-invested wood-processing enterprises, by province, 2003-2008

	2003	2004	2005	2006	2007	2008
Beijing	9	5	5	6	5	6
Tianjin	21	23	22	24	28	24
Hebei	9	7	8	8	9	9
Shanxi	0	0	0	0	0	0
Inner Mongolia	3	4	3	5	8	9
Liaoning	82	97	91	100	113	102
Jilin	22	27	26	27	30	30
Heilongjiang	19	24	26	30	32	29
Shanghai	63	78	72	64	64	65
Jiangsu	50	88	71	78	94	129
Zhejiang	66	131	132	138	138	149
Anhui	16	15	16	18	20	21
Fujian	75	88	95	103	116	116
Jiangxi	10	12	12	17	13	12
Shandong	59	95	97	101	107	110
Henan	14	11	14	9	11	5
Hubei	10	10	8	9	7	4
Hunan	7	8	6	6	10	14
Guangdong	109	151	153	146	161	168
Guangxi	18	31	33	34	35	44
Hainan	5	3	4	4	4	4
Chongqing	1	1	1	0	0	0
Sichuan	7	7	9	8	8	11
Guizhou	1	2	0	0	0	0
Yunnan	6	8	10	8	9	8
Tibet	0	0	0	0	0	0
Shaanxi	3	2	2	1	0	0
Gansu	0	0	0	0	0	0
Qinghai	0	0	0	0	0	0
Ningxia	0	0	0	0	0	0
Xinjiang	3	2	2	1	0	0
National	**688**	**930**	**918**	**945**	**1,026**	**1,075**

Appendix 4: Regions, elasticities, coefficients and parameters used in CGTM

Regions used in the CGTM

United States	**Canada**
Western Washington/Oregon Private (WSV) Western Washington/Oregon Public (WSB) Eastern Washington Private (ESV) Eastern Washington Public (ESB) Inland Rockies and California Private (INV) Inland Rockies and California Public (INB) Alaska (ASK) California Redwood (CAL) U.S. South (USS) U.S. North (USN)	British Columbia Coast (CBC) Interior Canada (CIN): Interior BC, Alberta, Saskatchewan, Manitoba Eastern Canada (CEA)
South America	**Africa**
Brazil (BRA) Rest of North (SAN): Bolivia, Colombia, Ecuador, Guinea, Guyana, Peru, Suriname, Venezuela Chile (CHI) Rest of South (SAS): Argentina, Paraguay, Uruguay	Africa East (AFE): Kenya, Madagascar, Malawi, Mauritius, Mozambique, Uganda, Tanzania, Zambia, Zimbabwe Africa West (AFW): Benin, Cameroon, Central African Republic, Congo, Cote d'Ivoire, Democratic Republic of the Congo, Equatorial Guinea, Gabon, Ghana, Guinea-Bissau, Liberia, Mali, Nigeria, Senegal, Sierra Leone, Togo Tunisia (AFN) South Africa (AFS)
Central America (CAM): Bahamas, Barbados, Belize, Costa Rica, Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama	Australia (AUS) New Zealand (NWZ) Oceania (OCN): Fiji, Solomon Islands, Vanuatu
Europe	**Asia**
Finland (FIN) Sweden (SWE) Rest of Western Europe (EUW): Austria, Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Switzerland, United Kingdom Rest of Eastern Europe (EUE): Bosnia, Bulgaria, Croatia, Czech Republic, Hungary, Poland, Romania, Slovakia, Slovenia, Turkey Russia (SUE) Rest of former USSR (SUW): Belarus, Estonia, Georgia, Kazakhstan, Latvia, Lithuania, Moldova, Ukraine, Uzbekistan	Japan (JPN) South Korea (KOR) China (CHN): China, North Korea, Mongolia Singapore (THK) East/ West Malaysia (MAE/MAW): Malaysia, Brunei Darussalam Indonesia (IDN) Philippines (PHL) Papua New Guinea (PNG) Indochina (ICH): Cambodia, Laos, Myanmar, Thailand, Vietnam India (IND): Bangladesh, India, Nepal, Pakistan, Sri Lanka Middle East (MDE): Cyprus, Iran, Israel, Kuwait, Lebanon, Saudi Arabia, Syria, United Arab Emirates

Demand elasticities for regions with endogenous demand

	CSAW	NSAW	CPLY	NPLY
INV	-0.30	-0.50	-0.50	-0.50
USS	-0.30	-0.50	-0.50	-0.50
USN	-0.30	-0.50	-0.50	-0.50
CEA	-0.30	-0.50	-0.50	-0.50
CAM	-0.50	-0.50	-0.50	-0.50
BRA	-0.50	-0.50	-0.50	-0.50
SAN	-0.50	-0.50	-0.50	-0.50
CHI	-0.30	-0.50	-0.50	-0.50
SAS	-0.50	-0.50	-0.50	-0.50
FIN	-0.30	-0.50	-0.50	-0.50
SWE	-0.30	-0.50	-0.50	-0.50
EUW	-0.30	-0.50	-0.50	-0.50
EUE	-0.50	-0.50	-0.50	-0.50
JPN	-0.67	-2.42	-0.50	-0.55
KOR	-1.52	-1.06	-0.50	-0.85
CHN	-0.50	-0.50	-0.50	-0.50
THK	-0.50	-0.89	-0.50	-0.91
MAE	-0.50	-0.99	-0.50	-0.50
MAW	-0.50	-0.55	-0.50	-0.50
IDN	-0.50	-0.91	-0.50	-1.50
PHL	-0.50	-1.56	-0.50	-0.50
PNG	-0.50	-0.50	-0.50	-0.50
ICH	-0.50	-0.50	-0.50	-0.50
IND	-0.50	-0.50	-0.50	-0.50
MDE	-0.50	-0.50	-0.50	-0.50
SUW	-0.50	-0.50	-0.50	-0.50
SUE	-0.50	-0.50	-0.50	-0.50
AFE	-0.50	-0.50	-0.50	-0.50
AFN	-0.50	-0.50	-0.50	-0.50
AFS	-0.50	-0.50	-0.50	-0.50
AFW	-0.50	-0.50	-0.50	-0.50
AUS	-0.50	-0.50	-0.50	-0.50
NWZ	-0.45	-0.50	-0.50	-0.50
OCN	-0.50	-0.50	-0.50	-0.50

Product supply elasticities for endogenous regions, 2007

	CSAW	NSAW	CPLY	NPLY
WSV	1.4241		-0.65017	
ESV	4.1336		-0.74577	
INV	2.5018		2.641235	
USS	-1.9523	-0.40427	-0.487	
USN	1.2554	-0.15534		
CBC	0.4455			
CIN	-1.4634			
CEA	0.851			
CAM		7.677249		-3.06811
BRA		5.551041		-4.18254
SAN		-121.541		23.69835
CHI	-0.676			
FIN	9.0906			
SWE	3.4994			
EUW	-5.1887	0.217768		
JPN	-0.2839	-1.03811		8.514226
KOR	0.8345	-1.14688		
CHN				
THK		-0.08114		-0.1609
MAE		-0.16843		32.7524
MAW		0.327325		30.47658
IDN		-0.0037		-0.2743
PHL		0.283212		1.537408
NWZ	0.9373			

Technological coefficients for 2007

	CSAW	NSAW	CPLY	NPLY
WSV	-1.799	-2.786	-1.800	
ESV	-2.602		-1.800	
INV	-2.371		-1.800	
ASK	-1.908			
CAL	-2.556		-1.800	
USS	-3.136	-2.304	-1.800	-1.800
USN	-1.837	-2.247	-1.800	-1.000
CBC	-1.568		-1.800	
CIN	-3.544	-2.786		
CEA	-2.723	-2.247	-1.800	
CAM	-1.927	-1.313	-1.800	-1.800
BRA	-2.037	-1.682	-1.800	-1.800
SAN	-2.653	-1.433		-1.800
CHI	-2.078	-2.322	-1.800	-1.800
SAS	-1.862	-1.553		-1.800
FIN	-2.307	-2.500	-1.800	-1.800
SWE	-2.135	-2.500	-1.800	-1.800
EUW	-1.781	-2.858	-1.800	-1.800
EUE	-2.064	-1.913	-1.800	-1.800
JPN	-1.658	-2.500	-1.800	-1.800
KOR	-1.179	-2.500		-1.800
CHN	-2.522	-2.500	-1.800	-1.800
THK	-2.500	-2.500		-1.800
MAE		-2.500		-1.800
MAW		-2.500		-1.800
IDN		-3.710		-1.800
PHL		-2.500		-1.800
PNG		-2.500		-1.800
ICH	-2.500	-2.500		-1.800
IND	-2.500	-3.270		-1.800
MDE	-3.219	-4.304		-1.800
SUW	-1.394	-2.500	-1.800	-1.800
SUE	-1.344	-2.500	-1.800	-1.800
AFE	-2.386	-2.235		-1.800
AFN	-2.662	-4.884	-1.800	
AFS	-2.613	-2.500	-1.800	
AFW		-3.037		-1.800
AUS	-2.129	-2.528	-1.800	
NWZ	-2.147	-2.500	-1.800	
OCN	-2.500	-2.396		-1.800

Base parameters for regions with endogenous timber supply functions for 2007

Region	Product	H&D	Slope	Region	Product	H&D	Slope
WSV	CLOG	3340.36	1.49	CHN	CLOG	0.10	1.90
ESV	CLOG	1215.71	0.95		NLOG	0.25	1.90
INV	CLOG	2459.61	1.26	MAE	NLOG	5.00	0.75
USS	CLOG	6308.76	1.48	IDN	CLOG	50.00	0.00
	NLOG	6.16	0.64	PHL	CLOG	50.00	0.00
USN	CLOG	272660.12	2.00		NLOG	0.87	0.00
	NLOG	55571.65	1.35	PNG	CLOG	50.00	0.00
CBC	CLOG	17.40	0.31		NLOG	2.00	0.00
CIN	CLOG	0.28	0.88	ICH	CLOG	50.00	0.00
	NLOG	25.00	0.00		NLOG	60.00	0.00
CEA	CLOG	2.37	0.68	IND	CLOG	50.00	0.00
	CLOG	50.00	0.00		NLOG	60.00	0.00
CAM	CPWD	20.00	0.00	MDE	NLOG	50.00	0.00
BRA	CLOG	50.00	0.00	SUW	NLOG	50.00	0.00
SAN	CLOG	50.00	0.00	SUE	CLOG	1.33	1.00
CHI	CLOG	45.41	0.35		NLOG	2.00	1.25
SAS	CLOG	50.00	0.00	AFE	CLOG	50.00	0.00
FIN	CLOG	78.17	0.35		NLOG	50.00	0.00
	NLOG	34213.81	1.08	AFS	CLOG	28.87	0.00
SWE	CLOG	523421.24	2.47		NLOG	50.00	0.00
EUW	CLOG	1714.23	1.00	AFW	NLOG	5.00	1.10
	NLOG	11013.23	1.00	AUS	CLOG	50.00	0.00
EUE	CLOG	32.22	0.00		NLOG	50.00	0.00
JPN	CLOG	16080.03	1.05	NWZ	CLOG	71.38	1.00
				OCN	NLOG	40.00	1.40