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

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Abstract

Illegal timber harvesting is unsustainable and takes 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. China's wood products industry has become reliant on imports of logs to fuel its growth. Its rise as the predominant wood manufacturing center in the world raises an interesting question regarding the role illegal logging has had in developing the sector in China and how policies that might limit the level of illegal logging activity may affect its future development.

The objective of this study was 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, and the producing countries surplus measures. This was performed by first applying a graduated tariff to coniferous imports from China's largest supplier. Second, changes in the supply curves were applied to production in China's largest sources for non-coniferous logs. Effects depended on how restricted China's own domestic supply might be in the future. Under a tariff scenario, when China's timber equation was set to mimic the current harvest quota, China had little flexibility in terms of shifting from relying on imports to increasing production. Shifting to a more self-sufficient production system resulted in the decline in the volume of imports. When shifting the supply curves in among non-coniferous supply countries, it was demonstrated that given a highly inelastic supply in China, it would continue to import large volumes from these countries, but prices increased significantly. In these case, some countries increased their exports over a no-restriction scenario and China became increasingly reliant on an even fewer number of sources. A more elastic supply in China dramatically increased production there and reduced the need for imports.

The study concludes that China may have the ability to respond positively to policies that are aimed at reducing illegal logging activities by developing internal policies to become more self-sustaining and importing from regions that have greater levels of forest management in place as long as cost increases due to the reduction in illegal activity lead to higher domestic prices and China's policies adapt to these market signals.

Illegal Logging in the Asia-Pacific region

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

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. It may result in 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 domestic 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) defined 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 also 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). The most recent estimates come from Lawson and MacFaul (2010) and Li et al. (2008). Other estimates often employed can be found in Contreras-Hermosilla et al. (2007) and Seneca Creek (2004).

Based on these estimates, it is possible to calculate potential flows of illegally harvested products into China (table 1). Such calculations are based on official trade flows since there are no reliable calculations based on above-official import statistics. The most significant impact was on log imports, while lumber and plywood products were 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.

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 impacts from illegal-logging activity. 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 addressed domestic equity and governance issues, but generally did not concentrate on the explicit linkages with international trade issues, nor measures of any potential gains from trade.

The objective of this study was to examine the effects of the removal of illegally-logged timber from China's imports originating in five of China's primary source countries for logs on China's domestic production, consumption and trade flows, and on the surplus measures in log-producing countries. The study examined the impacts using a spatial equilibrium approach to project changes in forest products prices, production, consumption, and trade flows that would occur if the incidence or severity of illegal practices changed.

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 1), this was partly facilitated by an increase in log imports from the US that ceased after the events of Tiananmen in 1989 and subsequent trade sanctions. Figure 1 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 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.

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 2). In many regions, as demonstrated in the previous section, the coniferous and non-coniferous sectors follow vastly different trends; however, figure 2 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.

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 US, Australia and Canada (figure 3). Russia's exports to China declined from 2007 to 2008 by nearly a third from 21 million cubic meters (CUM) to 14 million CUM. The decline was likely 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. Chinese 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 US have grown in recent years, reaching 1.35 million CUM in 2008; however, this level remains far below US-China export levels reached in the mid-80s, when US coniferous log exports exceeded 5 million CUM.

The largest impediment to increasing US exports to China is cost. If international log prices continue to rise, the US 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 on logs. As a result, if Russian log prices decline, then the US may see its share decrease again.

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 4). 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 US. 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 US, Malaysia, and Thailand.

Study Approach

The study examined the interactions between trade and illegal-logging activity using a market model that simulates the trading activity in global forest sector. The model was used to project changes in market conditions based on changes in production, consumption and trading behaviors. The simulation model was selected for a number of reasons. First, it helped understand the effects on producers of changes in assumptions about their businesses, which could be affected in terms of production and prices by economic and environmental policy such as growth, exchange rates, illegal-logging legislation, and others changes (Cardellichio et al. 1989). Second, the model can help inform policymakers how changes in policy might affect trade activity. Third, results from the simulations inform end-users of wood products about the effects on their consumption due to changes in policy or economic conditions. For example, the simulation of market conditions can measure the effect of the imposition of a new product tax on consumption by shifting the demand curve to reflect the amount of the consumption tax, or the introduction of new technologies that lower production costs, or trade policy such as an export tariff that increase the trade cost of getting products out of a specific country.

Several market simulation models exist. Most forest products trade models can be categorized as falling within a spatial equilibrium, static simulation or a dynamic optimization, optimal control framework. Most trade models 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 does not differentiate demand. The frameworks differ in the way they solve for market equilibria and thus differ in the way they model timber harvests, product supply and consumption behavior. 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 over many years (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).

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 breaks out the world markets into 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; 1997).

The study modified the CGTM to simulate several scenarios to help understand illegal log trade and its relationship to China's forest sector. First, the study introduced a timber supply equation to represent China's timber producing behavior and made it responsive to prices. Previously China's timber supply was fixed at a certain variable annual allowable cut regardless of the market price for logs. Since time-series data to establish the price relationship with volume of timber supplied was lacking, the study considered and evaluated timber supply at different supply elasticities. It is expected that an inelastic supply curve would significantly constrain domestic log production, and act similar to an allowable cut policy, while a more elastic supply curve would allow greater production volumes to be drawn from domestic supplies. Inventory data on China's timber resources was used to constrain the availability of timber to meet domestic supply.

Second, the reduction in illegal trade activity from China's log source countries was performed through the introduction of a tariff. An export tariff was used to simulate a policy that increased the cost of trading in the producing countries. Two assumptions regarding demand for logs were assessed. One was where consumption of logs in China was initially held fixed by holding lumber and plywood production and consumption levels fixed. The second scenario increased product supply in China's forest sector so as to consider the effects such increases may have on log consumption, production and trade activities.

Baseline and Scenario Data

Historical data on production, consumption, imports and exports employed in the CGTM were taken primarily from FAO. A consistency of the data was performed to insure production, imports and exports between regions were reasonable, and use of logs to produce lumber and plywood represented reasonable parameters. For example, using officially reported statistics for end products, combined with reasonable input-output coefficients for production, it was estimated that actual timber consumption exceeded officially reported timber 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, consumption was calculated to have been more than 132 million CUM, using reasonable assumptions on the use of logs to produce lumber and plywood. 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 seemed doubtful.

The development of the baseline involved calibrating the model to 2007 conditions, including updating 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 using data points for 2007 and imposing assumptions about the elasticity of supply. 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).

Model Parameters

The interaction of product demand and supply determined the level of output and price in a given year, and the amount of timber required for production was then derived through two separate equations; one that related the input and output of timber and product, and a second that contained wood costs and timber harvesting behavior. Equilibrium required the simultaneous solution of both sectors.

The product demand equation was given by:

$$Q = \alpha P^{\beta} I^{\partial} \qquad \text{(eq. 1)}$$

Where Q is product consumption, P is the product price, I is income measured as GDP, α, β and ∂ are parameters linked to price levels and quantity consumed due to changes in price and income levels. End-use demand was held constant over the projection period so as to analyze the effects of changing levels of timber production, holding sector growth constant.

Product supply was specified exogenously as a certain volume, or through the model using a supply function in the following form:

$$P = C + \alpha K^{\beta} \qquad \text{(eq. 2)}$$

Where P is the product price, C is cost, K is capacity utilization, α and β are parameters linked to cost levels and quantities supplied due to changes in cost. For this study, China's product supply was considered exogenously. There was insufficient data on capacity and its utilization to accurately model production endogenously.

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

$$Q = \gamma S + \theta P \qquad \text{(eq. 3)}$$

Where Q is log output, S is sawnwood production, γ is the technological coefficient for sawnwood, P is plywood production, and θ 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.

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

$$P = \alpha \left(\frac{Q}{I}\right)^{\beta} \qquad \text{(eq. 4)}$$

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 available from the authors. For this study, timber supply equations were developed for China, Russia, Malaysia, Papua New Guinea, West Africa and Oceania. China's supply was considered to be fairly inelastic initially since the central government sets an annual harvest quota and provides assignments to the 31 provinces. Market sensitivity, allowing government planners to respond to price changes, was tested by incrementally changing the elasticity (β) in the timber equation. Adjustments to respective elasticities were also used to simulate the rotation in the supply curve around a fixed cost level based on the elimination of illegal outflows.

The CGTM calculated trade based on the availability of logs, trade cost and prices. Thus the price of a good in an importing country was equal to the price in the exporting country plus the trade cost. Using this relationship, the model directed exports from countries with low prices toward countries with high prices. One result of this was the possibility of triangular flows. Triangular flows occurred when the sum of trade costs across two segments was less than the trade cost directly relating two regions. For example, if the sum of the trade cost for the US Pacific Northwest to export coniferous logs to China plus the trade cost of coniferous logs from New Zealand to China was less than the cost of shipping logs from New Zealand to China, then logs would flow into the US and then be directed to China. While demand for China was being satisfied by New Zealand logs, the peculiarities of the trade cost data and the simplistic relationship between regional prices led to greater trade activity between the US and China. This limitation was resolved by l were flagging all triangular flows and assessing their effect on consumption levels in markets.

On average the trade costs associated with non-coniferous logs was much higher than those of coniferous logs. This was generally because the difference between prices of imports and exports of non-coniferous logs and products are higher than those of coniferous logs and products. As a result, non-coniferous logs were, on average, more expensive than coniferous logs. Similarly, trade costs associated with coniferous sawnwood was higher than those of logs, but less than those of non-coniferous sawnwood. The trade flow costs associated with plywood was higher for coniferous than for non-coniferous. Finally, tariffs were modeled by increasing trade costs.

Results

Results are presented in the sequence that they were investigated in the study. First, the results of timber supply elasticity sensitivity analysis are presented. 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 that is responsive to international price signals. Second, results from the elimination of illegal flows in the non-coniferous sector from Russia, Malaysia, Papua New Guinea, Africa West and Oceania are discussed. Third, once trade constraints were considered, the expansion of China's lumber and plywood production were examined to determine the changes in both the coniferous and non-coniferous log sectors. Emphasis was placed on the effects these simulations had on China's production, consumption, trade flows, and prices, although results for affected trading partners are also discussed.

Restricting illegal log flows in the coniferous sector

A large segment of China's domestic softwood lumber and plywood producers are currently dependent on log imports from Russia. When those imports were restricted by the introduction of a tariff, two effects were felt under normally operating markets. First, as the cost of Russian logs increased for Chinese producers, so too did the domestic price of logs in China. Second, as this occurred, Russian log imports were substituted both by increased Chinese production (if allowed) and by imports from other countries where similar logs were imported at market cost. Using a tariff to study the impacts to trade was useful for several reasons. First, it mimicked the effect of real-world scenarios involving the application of export taxes and demonstrates the effects of small, fixed increases in trade costs on demand from importing countries. Second, it reveals changes to producer surplus in the exporting country. To measure these effects under unencumbered market assumptions and a constant demand, Russia was initially assigned an elastic timber supply curve, making supply there largely responsive to prices. Conversely, China was assigned a highly inelastic supply curve, reflecting its current policy constraints on harvesting. The study first used increases in trade costs of $5 and $25 to represent a range of tariff policy, and then relaxed elasticity assumptions.

An export tariff of $5 per CUM over 2007 price levels reduced Russian log exports to China by nearly 2.6 million CUM in the first year of the tariff (table 2). A tariff of $25 per CUM lowered import volumes by 12.9 million CUM. Further, should Russia implement policies aimed at curbing domestic harvesting, its supply would become more inelastic and production would decrease, largely a result of its reliance on export markets for its domestically harvested timber. Under the scenario of highly price-responsive supplies, it took just a small increment in the tariff for Russia's exports to be reduced to zero. The amount by which log imports into China would be substituted by increased domestic production, holding demand for end products constant, depended on the elasticity of supply in both Russia and China. Under the assumption of a highly inelastic supply curve in China, increased domestic production was more difficult, while a more elastic curve allowed 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 was compared to adjusted levels in order to understand how producers in China might behave. Table 3 illustrates the changes in coniferous log production, imports and prices into China given varying elasticities representing elastic to highly inelastic supply curves, and given a fixed level of consumption of logs.

Shifting from a highly inelastic to a relatively inelastic supply resulted in an increase in production of 29%. As production increased, imports decreased by 19%. An elastic supply curve resulted 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 affected 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, with periodic adjustments as supply shortages occur, while Russia's will remain elastic. Under this scenario, production within China rose 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.

Should the increase in Chinese domestic log production fail to be realized, 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 decreased, production decreased by the same amount, with little substitution occurring, including the possibility of greater domestic lumber production for exports. Effectively, as the tariff increased, exports from Russia continued to decline until they reached zero and total production declined to what is consumed domestically with little substitution of logs by lumber produced by Russian mills for exports to China.

If a relatively elastic curve were imposed on China's timber supply, representing increased domestic production, China was not 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 diminished to zero under this policy. However, when Russia's timber supply became relatively more inelastic, as mentioned above, its exports decreased 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 4). New Zealand and Chile typically had lower log prices and increased their exports to China significantly.

Constraining illegal log flows in the non-coniferous sector

This section describes the results of modeling constraints on timber production in those countries that supply 70% of China's non-coniferous log imports: Russia, Malaysia, Papua New Guinea, Gabon (West Africa region) and the Solomon Islands (Oceania region). The study first imposed an export tariff in the 5 countries listed above on non-coniferous log exports as in the previous section. Then the study defined supply curves for these countries suspected of illegal log exports and varied their elasticity parameter. Making the supply curve more inelastic simulated the implementation of a domestic policy aimed at reducing harvests where illegal log flows exist, assuming the true cost of log production in these countries would increase if illegal activity were to be reduced. As quantity supplied in these regions was lowered, fewer logs were available for export. In these scenarios, domestic demand for logs was held constant. Initially, the supply curve in each country was relatively elastic, reflecting a condition where the costs associated with illegal logging were ignored. The effects of two changes in the supply elasticity were evaluated. These two changes reflected low- and high-reduction scenarios that were intended to mimic a reduction equivalent to the low and high ranges of estimates of illegal logging listed in table 1. The effects on production in these countries and their exports to China are reported below. For China, two supply elasticities were employed: first by setting it to match the current quota system (highly inelastic) and second by setting it to reflect a self-sufficient production condition (elastic).

The study findings suggested that 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 (highly inelastic), a low tariff reduced total imports by 7%, while a high tariff reduced imports by 14% (table 5). With China's timber supply set to produce at a greater level of self-sufficiency (highly elastic), a low tariff had a greater proportional impact, reducing imports by 25%; a high tariff reduced imports by 45%. Additionally, the relative positions of each source shifted as their relative positions on the aggregate supply curve changed. For example, in all cases, Malaysia became more expensive relative to other countries. This would be of particular significance if China's supply curve continued to be highly inelastic as under the current quota system. Both Russia and West Africa increased their exports to China in response. Ironically, a tariff had to be substantially higher to result in a decrease in total production within these regions. As the price increased, almost all of the five countries experienced an increase in production and exports to regions with higher prices. Thus, while exports into China generally decreased, exports to other regions increased and a tariff did not have the intended effect of lowering overall production in the respective countries. This was a result of demand in importing countries being relatively inelastic, with few suppliers from which to source.

Rotating the supply curves—making it more inelastic—of these five regions had a different effect, particularly depending on whether or not China continued its quota system or relaxed its production policies. The low-reduction scenario reduced supply in Malaysia, Papua New Guinea, Russia, West Africa and Oceania by an average 15%. In the low-reduction scenario, total global production was affected very little, at less than 1%. As these five countries reduced their total production by 14.7 million CUM, China responded to a reduction in available imports supply and increased prices by increasing its domestic production by 9 million CUM (table 6). However, while global supply effects were minimal, the effect on trade was large, reducing available exports by nearly 30%. Prices more than doubled for all regions that traded in this sector. As a proportion of production, exports to China from West Africa and Oceania decreased the most significantly, falling to zero. Russian exports to China fell by almost a half. Malaysian exports were the least affected, falling by only 3%. Everything else being constant, Malaysia continued to be the lowest cost producer, while Papua New Guinea, Russia, and Oceania were slightly higher cost producers. West Africa was the highest cost producer. These relative positions did not change throughout the course of adjusting their supply. Thus, in this scenario, as a percentage of its total imports, China became increasingly dependent on Malaysian exports in the face of reduced supply from other regions.

The high-reduction scenario reflected an average reduction in production of 27% among these five regions. Total production in these countries decreased by 21.8 million CUM, while production in China grew by 15 million CUM. Again, this affected the total worldwide supply very little, since 85% of production was consumed within the countries it was produced. Trade effects were large, though, as worldwide available exports decreased by nearly 45%. In a high-reduction scenario, there was 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 ceased. This indicated that the estimates of illegal logging in Li (2008) and Lawson and MacFaul (2010) would represent the extent of trade from these regions. Russian exports declined by 92% over the low-reduction scenario, to almost zero. Again, Malaysia continued 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 were already much less, and the reductions posed for each country represented a higher percentage of their exports to China.

Increasing product production in China

In the two previous sections, consumption of logs was held fixed by holding production of 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 was 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 allowed 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 grew in China, it was held fixed for the rest of the world. This allowed 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 resulted in a commensurate 7% annual increase in its log consumption, effectively growing log consumption by nearly 140% by 2020. In turn, by 2020, China was expected to consume 187 million CUM of coniferous logs. With a highly inelastic supply curve, production of logs would grew minimally in the first few years, and provided 36 million CUM, or 19% of the resources needed by 2020. Consequently imports nearly tripled over 2007 levels to 151 million CUM by 2020 (table 7). With no tariff imposed on Russia's log exports, and with the assumption that Russia's elasticity was held constant at an elastic level, Russian logs filled about 37 million CUM, or a fifth of China's imports by 2020. North America, New Zealand and Chile provided 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 greatly reduced but not completely discontinued importing any logs from Russia, and North America picked up the difference.

With a relatively more elastic supply curve in China, production grew by nearly 50% to 89 million CUM, and provided approximately half of the resources needed. Under a no tariff scenario, Russia continued to provide a significant amount of the import volume needed, with North America and New Zealand/Chile providing the remainder. North America did not benefit as greatly when China was able to dramatically increase its supply. The introduction of a tariff of $25 per CUM reduced imports from Russia until the price of logs in China and the cost of logs from Russia reached a point where logs from Russia resumed being competitive, even with the tariff. North America and New Zealand were relatively high-cost producers and continued to be outcompeted by Russia as long as the cost of logs remained 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 resulted 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 grew 40% to 27 million CUM. This provided only 20% of the necessary resources to meet lumber and plywood production levels. Malaysia provided 60% of the total imports needed, followed by Russia, West Africa, Papua New Guinea and Oceania (table 8). With a relatively more elastic supply function, China supplied upwards of 43% of total log demand. Total imports declined, but relative market shares for each region remained the same as under the highly inelastic scenario. Prices in China were approximately 18% less when China's supply grew to 57.5 million CUM rather than 27.25 million.

The introduction of supply restrictions in the five regions was complicated by increased demand from China. Under a low-restriction scenario, production was still allowed to increase. As a result, by 2020, given high enough price increases, export flows from these regions resumed their pre-restriction export levels by 2020 (table 9). These price increases occurred particularly when China's supply continued to be inelastic. A more elastic supply in China dramatically increased production in China and reduced the need for imports, under both the low-reduction and high-reduction scenarios. With a greater domestic supply, and with low imports, only Malaysia continued to be a source of large volumes of logs for China's market as many other sources diminished their exports to near zero. An important consideration when examining the results here was that the number of trade flows remained fixed to presently existing flows. Europe, Brazil and North America did not currently export significant volumes of hardwoods to China and were therefore not included in the analysis. Without introducing new potential flows, China was constrained to import from only its current main trading partners.

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 was set to mimic the current harvest quota, China had little flexibility in terms of shifting from relying on imports to increasing production. This suggested that policies aimed at curbing illegal logging through export tariffs led to shifts in domestic policies regarding production quotas in China. Shifting to a more self-sufficient production system provided 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 remained largely unchanged when production was subject to an inelastic supply curve, while imports of coniferous logs declined almost completely when China was modeled using an elastic timber equation. Should China decide to mimic market reactions, it would likely choose to increase its domestic production to offset any negative effect from a tariff imposition.

This raised 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 were 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 was unable to sufficiently increase its domestic production under either a low- or high-tariff scenario. China was reliant on Russia for inexpensive coniferous logs, and Russia was dependent on China as an export destination. Without a market for logs in China, Russian log production declined dramatically. However, in these projections, a fairly expensive tariff of nearly three-quarters the Russian log price was needed to reduce Russian production by the upper bound of 50% described in table 1. 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. Policies aimed at including all production costs in their supply chain may be effective in limiting export quantites.

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 continued 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 were allowed to grow and how costs changed. In modeling the restrictions on trade, it was clear that even with restrictions, as prices rose, production in these regions did 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.

Changes in producer surplus revealed how producers might be affected under different policy scenarios. In the coniferous log sector, with an imposition of a tariff, Russia's producer surplus declined significantly, while Chinese, North American and New Zealand producers experienced increases in their welfare (table 10). In the non-coniferous log sector, while production decreased under both the low- and high-reductions scenarios, prices increased significantly. As a result, producers gained significantly as log prices increased. Under the low-reduction scenario, prices nearly doubled; under the high-reduction scenario, prices nearly tripled. These price increases resulted in a dramatic increase in producer surplus. Only Papua New Guinea experienced a decline under the high-reduction scenario.

These differences in surplus changes indicated that a tariff, though perhaps effective at reducing outflows from a particular region, also resulted 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 increased, there was an increase in producer surplus; however, it was 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.

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, 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 was calculated to have been more than 132 million CUM. While lumber and sawnwood production grew over the past decade by an average 21% and 19% per year, respectively, log consumption reportedly grew only by 6% per year. This seems doubtful. This discrepancy was 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).

Conclusion

This study examined 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.

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Tables

Table 1 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

Table 2 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

Table 3 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

Table 4 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
	$25	0.00	0. 72

Table 5 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

Table 6 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 (elastic supply)				Timber production in China subject to self-sufficiency policy (inelastic supply)			
	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

Table 7 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

Table 8 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%

Table 9 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

Table 10 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%

Figures

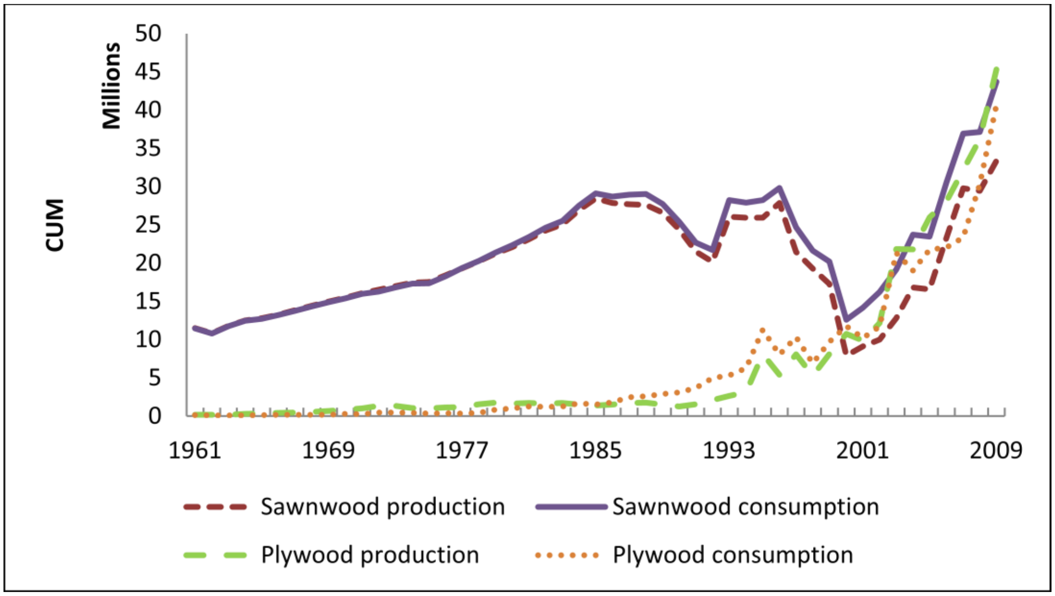

Figure 1 Production and consumption of sawnwood (all) and plywood in China, 1961-2009

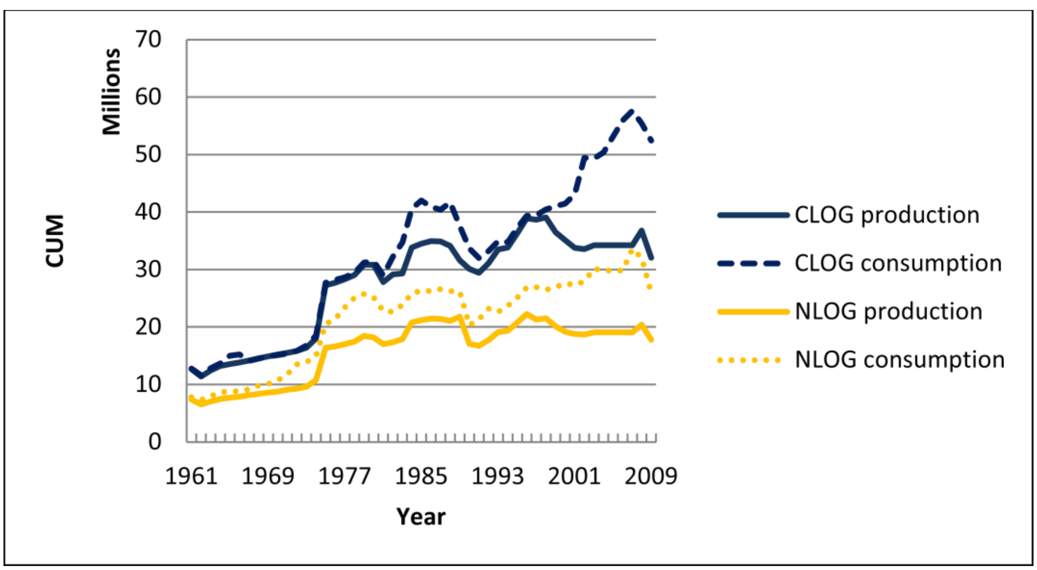

Figure 2 Log production and consumption in China, 1961-2009

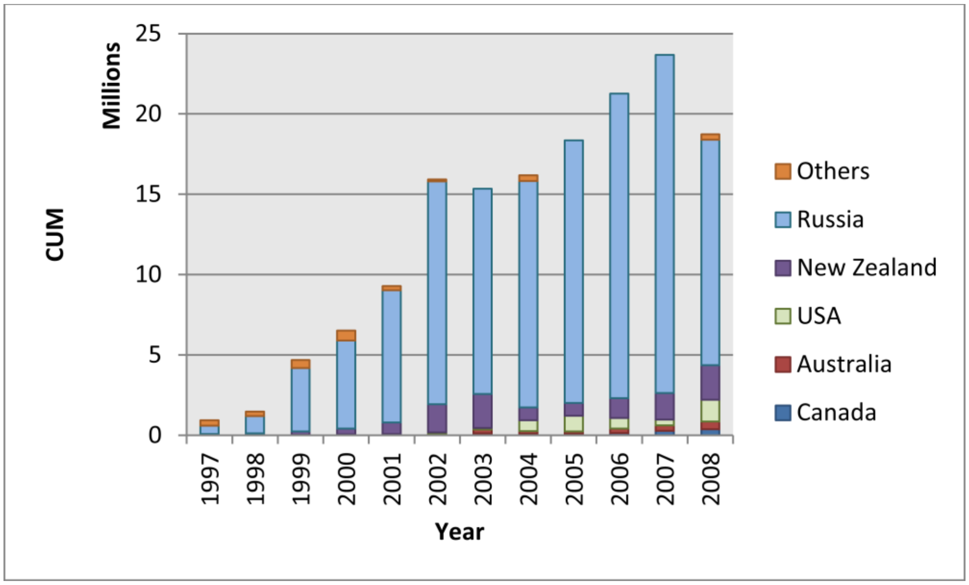

Figure 3 Coniferous log imports into China by source, 1997-2008

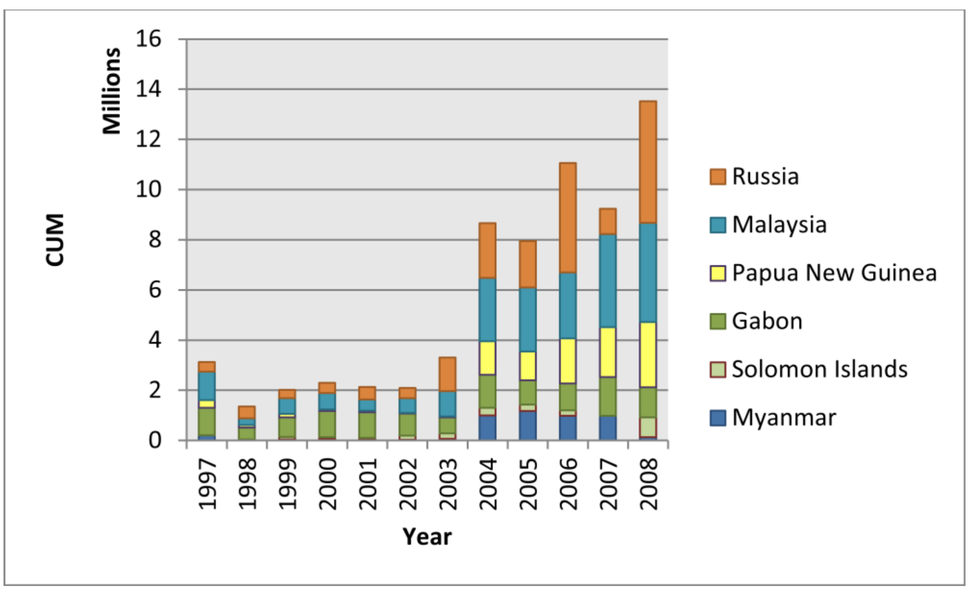

Figure 4 Non-coniferous log imports into China, 1997-2008