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Domestic and foreign consequences of China's land tenure reform on collective forests

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SUMMARY

Some of the long-term consequences of China's collective forests tenure reform were projected with the Global Forest Products Model (GFPM). The reform had a positive effect on the wood supply and demand balance. By 2020 the reform led to a 14 to 36 percent decrease of China's imports of industrial roundwood. Concurrently, the rest of the world produced less, but several other countries especially in Europe, imported more. Despite the positive short-term effect of the reform on supply, China's industrial roundwood deficit was still increasing, but at a slower rate, after the reform was complete, due to the high demand induced by China's fast growing economy. Furthermore, while the tenure reform on collective forests mitigated China's timber shortage, it also decreased China's forest stock, with adverse effects for biodiversity and carbon sequestration. Nevertheless, globally, this negative effect was compensated by a more than equal increase of forest stock in the rest of the world.

Keywords: China, land reform, economics, supply, demand, trade, GFPM

Conséquences intérieures et internationales de la réforme sur les forêts collectives en Chine

H. ZHANG, J. BUONGIORNO et S. ZHU

Certaines conséquences à long terme de la réforme de la propriété des forêts collectives en Chine ont été projetées avec le Global Forest Products Model (GFPM). La réforme a un effet positif sur l'équilibre entre l'offre et la demande en Chine. En 2020, la réforme conduit à une diminution de 14 à 36 pourcent des importations de bois rond industriel en Chine. Simultanément, le reste du monde produit moins, mais plusieurs pays, en Europe en particulier, importent davantage. Malgré l'effet positif à court terme de la réforme sur la production, le déficit en bois de la Chine continue à augmenter, mais moins vite, après l'accomplissement de la réforme, du à la forte demande induite par la rapide croissance économique de la Chine. En outre, alors que la réforme de la propriété des forêts collectives diminue le déficit en bois de la Chine, elle diminue aussi son stock d'arbres sur pied, avec des effets négatifs pour la biodiversité et la séquestration de carbone. Néanmoins, globalement, cet effet négatif est plus que compensé par une augmentation du stock d'arbres sur pied dans le reste du monde.

Consecuencias domésticas y exteriores de la reforma en China del sistema de tenencia de la tierra para bosques colectivos

H. ZHANG, J. BUONGIORNO y S. ZHU

Mediante el uso del Modelo Global de Productos Forestales (GFPM en inglés) se estimaron algunas de las consecuencias a largo plazo de la reforma de la tenencia de tierras forestales colectivas. Se estimó que la reforma tendría un efecto positivo a la hora de compensar la oferta y la demanda de madera. Para 2020, la reforma reduciría las importaciones de madera en rollo de uso industrial entre el 14 y el 16 por ciento. Al mismo tiempo, en el resto del mundo se produciría menos madera mientras que en varios países, especialmente en Europa, se importaría más volumen. A pesar del efecto positivo a corto plazo sobre la oferta causado por la reforma, el déficit de madera de China estaría todavía en aumento –aunque en menor medida– al término de la reforma, debido a la elevada demanda causada por el rápido crecimiento económico de China. Por otro lado, y aunque la reforma de la tenencia de bosques colectivos mitigaría la escasez de madera en China, ésta reduciría al mismo tiempo las existencias de madera en pie de China, con consecuencias negativas para la biodiversidad y el secuestro de carbono. Globalmente, no obstante, este efecto negativo quedaría compensado por un aumento en mayor medida de la superficie forestal en el resto del mundo.

INTRODUCTION

China is a forest scarce country with 0.2 ha of forest area per capita, compared to a world average of 0.6 ha per capita (FAO 2010). In addition, China's existing forests tend to be poorly stocked or young, with an average density of 71 m^3/ha, approximately half of the world average, and mature or near-mature forests on only 27% of the total forest area (State Forestry Administration of China (SFA) 2010a). Thus China's domestic timber supply is severely limited and will remain so for many years.

Meanwhile, China's wood demand has increased rapidly, driven by its rapid economic growth and exports of forest products. From 2005 to 2009, China's real gross domestic product grew at an average annual rate of 11% (IMF 2010), and China's share of world exports reached 13% for wood-based panels in 2009 (FAO 2012), and 16% for wooden furniture (UN 2011).

The limited domestic supply and large demand make China depend heavily on wood imports. As the second largest importer after the United States, China imported 103 million m^3 of roundwood equivalent in 2008 (Global Witness 2009). China's log imports have been singled out as a reason of ecological degradation in wood exporting countries of the Asia-Pacific region (Zhu et al. 2004), and criticized by environmental advocates such as Greenpeace (ENN 2007).

To increase domestic supply, in 2003 the Chinese government launched a nationwide tenure reform on collective forests, 60% of all China's forests (SFA 2010a), and the source of 46% of its wood supply (Miao and West 2004). This was the latest of many earlier changes in forest tenure (Liu 2001). Before the formation of the People's Republic of China, forests belonged mostly to big landowners. From 1949 to 1952, the communist party confiscated 47 million ha of forestlands and distributed them to 300 million poor farmers (Liu et al. 2006). The subsequent Socialist Transformation led to the merger of private forests into cooperatives, so that 96% of private forests were managed collectively by 1956 (Shen et al. 2009, Miao and West 2004). In 1958 this collectivization was extended by combing cooperatives into communes which owned all means of production and disallowed any private activity.

Decollectivization began in 1981, with the "Three Fixes" policy to grant use and management rights to households. By 1986, nearly 70% of the collectively-owned forestlands had been assigned to individual farmers (Xu and Jiang 2009), at least *de jure*. However, the *de facto* rights of use and benefit from collective forestlands were limited and unclear (Liu 2001), so that neither village collectives nor households had incentives to care for them (Su et al. 2008). In contrast, the reform begun in 2003 which is studied here was meant to give farmers firm rights to use, lease or mortgage forests for 70 years, protected by legal contracts and forest tenure certificates. The government expected that this new round of reform would increase timber supply through improved private forest management (SFA 2010b).

Previous studies of the effect of the tenure reform on China's forestry include Yin and Xu (2010) who find, based on household survey data, that timber harvest has increased by 3.7 m^3 per household in the villages where the reform is implemented. Xie et al. (2011) find that the reform has increased reforestation by 7.9%, but Liu and Wang (2010) do not find a significant effect of the reform on forest stock and area. With regard to timber supply itself, Zhang and Buongiorno (2012) conclude that, after accounting for variations in price, growing stock, and other government policies, production increases by 18% (±8%)[1] where and when the tenure reform is implemented.

While land tenure, resource management, and biodiversity are local issues, countries are bound together by international trade. The objective of this paper was to determine further the domestic effects of China's latest tenure reform, by taking into account this trade linkage and the potentially significant effects of policy in a large country like China on the rest of the world. Specifically, how would the reform-induced shift of timber supply estimated by Zhang and Buongiorno (2012), affect the production, consumption, prices of wood products, and the forest stock within China, and what would be the consequences for China's main wood suppliers?

The remainder of the paper is organized as follows. The next section sketches the theoretical influence of China's forest tenure reform in a world of competitive markets. This is followed by an overview of the Global Forest Products Model (GFPM), used to describe in more detail the demand, supply, trade, and prices of forest products within China and in other countries. Two scenarios simulated with the GFPM are then presented to project the effects of China's tenure reform on its own forest sector and on the rest of the world.

METHODS AND DATA

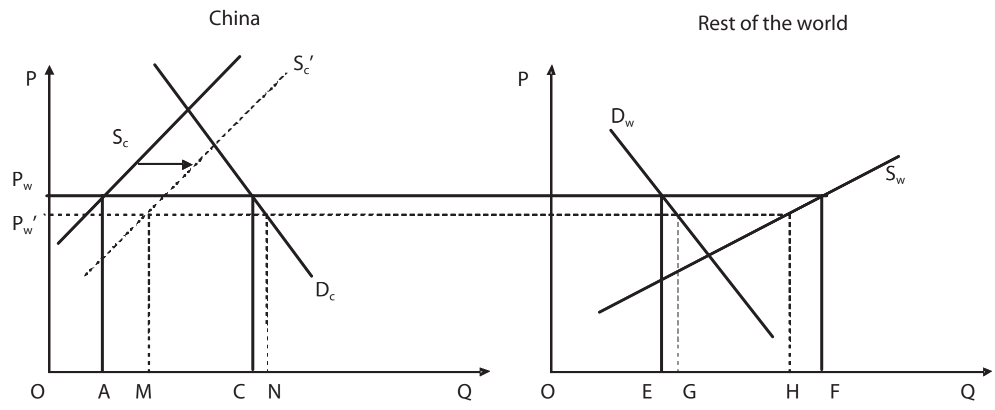
Theoretical framework

The theory underlying the experiments carried out with the GFPM for the present study is depicted in Figure 1. It symbolizes the demand for and supply of industrial roundwood in China and in the rest of the world, in a particular year. The figure assumes no transportation cost between China and the rest of the world. Consideration of the transportation cost, covered in the GFPM, does not change the basic conclusions.

Figure 1 implies that China might influence international markets, as from 2007 to 2010 China's imports of industrial roundwood accounted for 27%-32% of the total world imports (FAO 2012). Two market equilibria are shown: without China's tenure reform on collective forests (in bold lines),

[1] All numbers in parentheses preceded by ± are standard errors.

FIGURE 1 *Theoretical effects of an increase of China's timber supply on the world supply and demand*



and with the reform (in dashed lines). Without China's tenure reform the world equilibrium price of industrial roundwood is P_w. At this price, China's excess demand is AC, equal to the excess supply of the rest of world, EF.

Assuming that the tenure reform on collective forests has a positive effect on China's timber supply, so that China's produces more at any given price, the supply curve S_c shifts outward to S_c'. The new world equilibrium price decreases from P_w to P_w', where the new excess demand MN is equal to the new excess supply GH. Concurrently, China's industrial roundwood production increases from OA to OM, and imports decrease from AC to MN. The increase of China's production is less than the outward shift of its supply curve, due to the decrease of the world price. As per Le Chatelier's principle[2] the market responds to a disturbance in a way that tends to restore the initial equilibrium. In accord with the lower price, China's demand for industrial roundwood increases from OC to ON. Meanwhile in the rest of the world, the demand for industrial roundwood increases from OE to OG, supply decreases from OF to OH, and exports decrease from EF to GH.

In summary, with competitive world markets, China's tenure reform on collective forests is expected to result in: (1) lower wood prices in China and abroad; (2) higher timber production in China, but less than the *ceteris-paribus* shift due to the reform, and lower production abroad; (3) higher wood demand in China and abroad; and (4) lower China imports and foreign exports.

These changes in the wood markets will also have consequences for the world markets for wood products such as sawnwood, panels, and pulp and paper, and they will also affect the forest stock in China and to some extent in other countries. Thus, a more elaborate model than Figure 1, though based on the same principles, was used to describe these effects.

The Global Forest Products Model

The Global Forest Products Model (GFPM) is a dynamic spatial equilibrium model of the global forest products sector (Buongiorno et al. 2003). It was initially developed for the United Nations Food and Agriculture Organizations (FAO) Global Forest Products Outlook studies in early 1990s. The model predicts consumption, production, trade, and prices of 14 product groups in 180 countries, and forest area, forest stock, and value-added in their industries. As a partial equilibrium model, the GFPM focuses on the forest sector, while the evolution of the rest of the economy is represented by changes in GDP and GDP per capita.

Among the variables of the GFPM are supplies of industrial roundwood and fuelwood, which are directly affected by the government policies studied in this paper. Since industrial roundwood is the raw material for all down-stream wood products like sawnwood, wood-based panels, wood pulps, and paper and paperboard, the effect of the policies could be significant across the whole forest sector.

In the GFPM, demand of end products, including fuelwood, are represented by econometric equations, as is the supply of raw materials. The manufacturing of wood and other fibers into intermediate products such as pulp, and end products such as sawnwood, panels, and paper and paperboard is represented by activity analysis, i.e. input-output coefficients and corresponding manufacturing costs. Trade is driven by the economic growth of the countries and by their relative competitive advantage. The demand-supply equilibrium and the corresponding trade and prices in every projected period are calculated by maximizing the welfare of the world forest sector: the value of the products to consumers, minus the cost of production and transportation. Equilibrium prices are the shadow prices of the material balance constraints which state that, for each product and country, demand (consumption) equals domestic supply (production) plus imports minus exports.

[2] A general statement of the Le Chatelier principle is that "if the conditions of a system, initially at equilibrium, are changed, the equilibrium will shift in such a direction as to tend to restore the original conditions" (Pauling 1964). Some of the first applications of the principle in economics are in Samuelson (1947).

The GFPM has been applied in several previous studies, for example to predict the effects of accelerated tariff liberalization (Zhu et al. 2001), of the Free Trade Area of the Americas on forest resources (Turner et al. 2005), of forest bio-security policies (Prestemon et al. 2008), and of increasing demand of bio-energy on wood and forests (Raunikar, et al. 2010). A mathematical formulation of the model is in Appendix A, and more details are available in Buongiorno and Zhu (2012a). Buongiorno and Zhu (2012b) describe how to update, calibrate, and validate the model with different data. Past validations of the model, comparing projections to actual observations suggest that the model does capture general trends but not annual details, especially in small countries (Buongiorno et al. 2003).

Data updates

Except for China, the assumptions for the future development of the world economy and its links to the forest sector were the same as in the scenario "A1B low fuelwood" of the "Outlook to 2060 for World Forests and Forest Industries" (Buongiorno et al. 2012). This scenario was based initially on scenario A1B of the Intergovernmental Panel on Climate Change (IPCC), modified for the 2010 RPA Forest Assessment (USFS 2012). It assumed strong economic growth and low population growth, and continuing trends in the use of fuelwood, in contrast to the other scenarios that explored the effects of fast increasing demand for energy wood.

Using panel data from 25 provinces from 1999 and 2009, Zhang and Buongiorno (2012) estimate the price elasticity of China's industrial roundwood supply at 0.31 (± 0.12), and the elasticity with respect to the growing stock at 0.31 (±0.17). In addition, they estimate that the land tenure reform increased the supply of industrial roundwood by 18% (±8%) where and when it occurred.

In the GFPM forest area changes endogenously, as a function of GDP per capita, along an environmental Kuznet's curve, and the forest stock also changes endogenously, as a function of forest density (Turner et al. 2006). The initial conditions in China for the rate of forest area change and forest growth on non harvested areas were revised with the latest data of the Forest Resources Assessment of 2010, FRA 2010 in short (FAO 2010) and of the Yearbook of Forest Products 2009 (FAO 2011). The data on forest area implied that China's annual rate of forest area change in the base year of this study, 2006, was 1.39% per year. The estimation of the initial rate of forest growth on non harvested areas was based on the growth-drain equation of the GFPM (Buongiorno and Zhu, 2012a):

$$I_t = I_{t-1} + G_{t-1} - S_{t-1} \quad [1]$$

where I_t was the forest stock at the beginning of year t, over bark. $G_{t-1} = (g_a + g_u)I_{t-1}$ was the growth of the forest stock without harvest during the year t–1, where g_a was the annual rate of forest area change, and g_u the annual rate of forest growth on a given area, without harvest. $S_{t-1} = (S_{r,t-1} + S_{n,t-1} + \theta S_{f,t-1})\mu$ was the harvest from the forest during year t–1, where S_r was the harvest of industrial roundwood (logs and pulpwood), S_n the harvest of "other industrial rounwood" (poles, piling, posts, etc…), and S_f was the total fuelwood production. θ was the fraction of fuelwood production that came from the forest, and μ was the ratio of forest drain to harvest.

According to FRA 2010 China's forest removals of industrial roundwood amounted to 63.9 million m^3 over bark in 2005, while in the FAO Yearbook of Forest Products China's production of logs and pulpwood was 58.9 million m^3 under bark in 2005 (FAO 2011). Therefore, μ was estimated at 63.9/58.9=1.08 for China.

The 2010 Forest Resources Assessment also sets China's production of fuelwood at 64 million m^3 over bark in 2005, of which 100% came from the forest. Meanwhile, the FAO Yearbook of Forest Products shows a total production of fuelwood in 2005 of 207 million m^3 under bark or 207×1.08 million m^3 over bark, which implies that the fraction of fuelwood that comes from the forest is θ=64/(207×1.08), or about 29%.

Solving Eq. (1) for g_u with data on forest stock for 2005 and 2010 from FRA 2010 (FAO 2010) and data on industrial roundwood and fuelwood production during that interval from the Yearbook of Forest Products 2009 (FAO 2011) gave an estimate of g_u=1.90%, for the annual growth of the forest stock without harvest in China. With these parameters and starting in the base year 2006, the GFPM projected China's forest stock at 14.3 billion m^3 in 2010, close to the FRA 2010 estimate of 14.7 billion m^3 in 2010 (FAO 2010).

Wood supply shifts

To implement the forest land tenure reform, the collective forests were divided and distributed to individuals, accompanied with legal contracts and forest tenure certificates, which were used to protect individuals' ownership. According to the State Forestry Administration of China, 77% of this transfer had been accomplished by July, 2011, and it was expected that 85% would be done by the end of 2011 (SFA 2011a). In the GFPM simulations it was assumed that the reform started substantially in 2006 and that it would be completed by 2012.

Based on the econometric results of Zhang and Buongiorno (2012), the tenure reform on collective forestland would increase China's industrial roundwood supply by an expected value of 18% when complete, other things being equal. Acknowledging the standard error of 8%, it was assumed in the GFPM simulations that the cumulative shift of timber supply (industrial roundwood and fuelwood) would be between 10% and 26%, the 70% confidence interval. This translated to an annual rate of supply shift of between 1.6% and 3.9% from 2006 to 2012, apart from the endogenous shifts due to harvest and stock growth. These high and low scenarios with reform were compared with a scenario without reform for up to 2020, to allow for a full adjustment of China's forest sector and of the rest of the world to the new supply conditions.

In contrast to the land tenure reform, another government policy, the Natural Forest Protection Program (NFPP) has reduced timber supply. The NFPP started in 1998, and it was practically completed by 2006. Recently, the Chinese government announced a second stage of the NFPP from 2011 to 2020 (SFA 2011b). But this second stage involves only eleven additional counties, seven of which are in Hubei province, and four in Henan. In recent years all of Hubei produced only 1% to 3% of the National production, while Henan produced 1% to 4% (SFA 2009). Consequently, the effects of the NFPP on timber supply beyond 2006 should be small and they were ignored in the simulations.

RESULTS

Domestic effects of China's land tenure reform

The main domestic impact of China's collective forests tenure reform was on industrial roundwood and fuelwood (Table 1). The GFPM projections suggested that the price of industrial roundwood in China in 2020 was 3 to 8 percent less with the reform depending on the scenario, and the price of fuelwood was 0 to 2 percent less. Concurrently, the reform increased annual industrial roundwood production in 2020 by 8 to 20 percent, and the production of fuelwood by 10 to 24 percent, somewhat less than the reform-induced supply shift, due to the attendant price decrease. Meanwhile China's annual consumption of industrial roundwood was only 1.2 to 2.4 percent higher by 2020 with the reform than without it, while the consumption of fuelwood was practically unchanged.

Consequent to the large increase in production and small increase in consumption, the striking change concerns China's imports of industrial roundwood which decreased by 14 to 36 percent by 2020, and the large increase in fuelwood exports. Nevertheless, China's annual deficit of industrial roundwood was still 33 million m^3 with the high-impact scenario and 45 million m^3 with the low impact. This was substantially lower than the 52 million m^3 deficit projected without reform, but still a challenge for China's forestry.

The effects of China's tenure reform on collective forests were much smaller for wood-derived products (Table 1). The GFPM projected slight price decreases of wood-derived products in accord with the lower price of industrial roundwood, but of much lower magnitude than the decrease of industrial roundwood price. In accord with this small price reduction, the consumption of most wood-derived products hardly changed with the reform. The only significant changes were lower production of sawnwood and attendant higher imports (2 to 21 percent), and higher imports of particleboard (2 to 6 percent), and newsprint (2 to 5 percent), suggesting that the products were cheaper to produce in other countries at the lower world price of wood induced by the increase in industrial roundwood supply due to China's reform.

External effects of China's land tenure reform

Effects on industrial roundwood production and trade

As the main changes occurred for industrial roundwood, Table 2 shows the effects of China's land tenure reform by continent, and for the main exporters of industrial roundwood to China. In response to the positive domestic wood supply shift due to the land tenure reform in China, the rest of the world reacted in opposite direction, in accord with le Chatelier's principle (Table 2). By 2020 the production of industrial roundwood was 2.7 to 6.1 million m^3 less in Europe, depending on the scenario. It was 1.2 to 3.1 million m^3 less in North/Central America, and 0.7 to 1.6 million m^3 less in South America where most of the change was in Brazil. Despite the lower production in the rest of the world, the net result of China's reform and higher production (8.9 to 22.7 million m^3), was an increase of the world industrial roundwood production by 3.6 million m^3 to 10.3 million m^3.

According to the GFPM market equilibrium structure, the price of a product in a given year is the same in all exporting countries, defining the world price, while the price in importing countries is equal to the world price plus the transportation cost to each country. In this instance, and in accord with Figure 1, the world price of industrial roundwood was 0.5% to 1.3% lower in 2020, depending on the scenario, due to the supply shift brought about by China's land tenure reform. In concert with this price decrease, the world consumption of industrial roundwood increased by an amount equal to the increase in production. Meanwhile, annual world imports and exports in 2020 decreased by 3.8 million m^3 to 13.0 million m^3, somewhat more than the change in world production and consumption (Table 2).

Most countries other than China imported more or the same amount of industrial roundwood, and exported less or the same amount as a result of China's land reform. In Europe in particular, imports of the EU-27 countries were 2.3 to 5.1 million m^3 more and exports were 1.1 to 2.7 million m^3 less with the reform. But this pattern was not general, as for example Japan's imports of industrial roundwood were 0.2 to 1 million m^3 lower with the reform than without it. This, added to Japan's lower production, suggested that Japan's industries were less competitive at lower prices of industrial roundwood, thus lowering the derived demand for industrial roundwood.

Effects on forest growing stock

A direct consequence of the increase of wood harvest in China due to the land reform, was a decrease of its own forest stock. The effect was noticeable as early as 2010, and increased steadily throughout the projection period (Table 3). By 2020, China's stock of forest trees was 116 to 301 million m^3 (0.8% to 2.2%) lower in 2020 than without the reform (Table 3). This negative long-term effect contrasts with the results of Liu and Wang (2010) who find no significant effect of the reform on stock, admittedly over a short observation period. The present results also indicate that by 2020, the decline in China's stock was more than compensated by the higher growing stock in the rest of the world due to the lower harvest induced by lower world prices and lower imports in China. The largest increase of growing stock was in Europe, followed by South America, Africa, and North/Central America. As a net result, by 2020 the total world forest stock was 5 to 68 million m^3 higher with the China's tenure reform than without it.

TABLE 1 *Projected changes in China's production, trade, and prices of forest products in 2020 due to the land tenure reform on collective forests*

Product	Projected in 2020 without reform				Change in 2020 due to tenure reform				
	Price	Production	Import	Export	Scenario	Price	Production	Import	Export
	(US$/m³)	(10³m³)	(10³m³)	(10³m³)		(US$/m³)	(10³m³)	(10³m³)	(10³m³)
Fuelwood	52	224674	0	5613	Low	0	21637	0	21698
					High	–2	53994	0	53610
Industrial roundwood	88	111066	51686	0	Low	–3	8939	–7021	0
					High	–7	22687	–18719	0
Sawnwood	250	28818	3963	416	Low	0	–54	59	0
					High	–1	–833	847	0
Veneer and plywood	402	30450	763	2984	Low	–1	13	0	0
					High	–1	29	0	0
Particleboard	278	11978	411	66	Low	0	–4	9	0
					High	–1	–13	25	0
Fiberboard	358	29825	836	746	Low	0	15	0	0
					High	–1	35	0	0
	(US$/t)	(10³ t)	(10³t)	(10³t)		(US$/t)	(10³ t)	(10³t)	(10³t)
Mechanical pulp	374	2552	199	0	Low	–1	–1	0	0
					High	–1	–2	0	0
Chemical pulp	518	1322	10790	36	Low	–1	2	–1	0
					High	–2	–6	9	0
Other fiber pulp	1063	2929	267	0	Low	0	0	1	0
					High	0	0	3	0
Waste paper	166	41700	14650	0	Low	0	–31	23	0
					High	0	–75	56	0
Newsprint	526	6182	601	102	Low	0	–12	13	0
					High	0	–31	32	0
Printing and writing paper	846	25565	2094	832	Low	0	5	0	0
					High	–1	11	0	0
Other paper and paperboard	808	57533	12514	1808	Low	0	3	0	0
					High	0	7	0	0

Note: The Low scenario assumes a 10% increase in China's timber supply due to the collective forests tenure reform, and the High scenario assumes a 26% increase.

SUMMARY AND CONCLUSION

This paper presented projections of some of the long-term consequences of China's collective forests tenure reform that started in 2003 and expected to end in 2012. Previous econometric estimates suggested that China's domestic wood supply would increase by 10% to 26% between 2006 and 2012 due to the tenure reform. These low and high estimates were applied in the Global Forest Products Model (GFPM) to project the reform-induced changes in the forest sectors of China and of the rest of the world from 2006 to 2020.

The results showed that by 2020 the reform led to a 14 to 36 percent decrease of China's imports of industrial roundwood. Concurrently, the rest of the world produced less, thus diminishing the impact of China's demand on forests in the rest of the world, especially Russia and Asia-Pacific. But several other countries, especially in Europe, imported more, which shows the complexity of the full impact of a policy change with highly interconnected countries, in accord with Zhang and Gan (2007) argument of a displacement effect in world timber markets, as lower wood imports in a country may lead to more in others due to lower wood prices.

Although China would import considerably less industrial roundwood due to the reform, this would only temporarily reduce China's deficit. Figure 2 shows that, according to the scenario with the greatest impact on domestic supply, beyond

TABLE 2 *Projected changes of industrial roundwood production and trade in 2020 due to China's tenure reform on collective forests, by main source of China's imports*

	Base scenario in 2020 (10^3 m^3)			Change due to tenure reform (10^3 m^3)			
	Production	Import	Export	Scenario	Production	Import	Export
AFRICA	**59641**	**11593**	**3202**	**Low**	**–74**	**187**	**–61**
				High	**–153**	**108**	**–138**
Congo, Dem Republic of	4498	0	208	Low	–1	0	–2
				High	–2	0	–3
Gabon	2847	0	1389	Low	–19	0	–19
				High	–44	0	–44
NORTH/CENTRAL AMERICA	**618845**	**7368**	**14715**	**Low**	**–1217**	**669**	**–57**
				High	**–3099**	**1301**	**–443**
Canada	176541	0	0	Low	–545	0	0
				High	–1348	0	0
United States of America	432831	1414	14656	Low	–644	0	–54
				High	–1695	0	–437
SOUTH AMERICA	**173555**	**253**	**9186**	**Low**	**–689**	**0**	**–804**
				High	**–1577**	**55**	**–1924**
Brazil	113880	0	0	Low	–454	0	0
				High	–1058	0	0
Peru	1658	95	0	Low	–8	9	0
				High	–18	19	0
ASIA	**259496**	**97633**	**13316**	**Low**	**8420**	**–7208**	**–203**
				High	**21590**	**–19796**	**–460**
China	111066	51686	0	Low	8939	–7021	0
				High	22687	–18719	0
India	15445	15877	0	Low	–25	26	0
				High	16	–16	0
Indonesia	26431	0	0	Low	–30	0	0
				High	–81	0	0
Japan	35128	5759	0	Low	–182	–233	0
				High	–431	–987	0
Malaysia	26010	0	12041	Low	–159	0	–184
				High	–368	0	–423
Myanmar	4415	0	1037	Low	–15	0	–16
				High	–29	0	–32
OCEANIA	**43081**	**261**	**6733**	**Low**	**–136**	**0**	**–74**
				High	**–323**	**0**	**–157**
Australia	22241	0	0	Low	–54	0	0
				High	–138	0	0
New Zealand	17876	0	4223	Low	–67	0	–58
				High	–150	0	–124
Papua New Guinea	1846	0	1770	Low	–11	0	–11
				High	–24	0	–24

TABLE 2 *Continued*

	Base scenario in 2020 (10^3 m^3)			Change due to tenure reform (10^3 m^3)			
	Production	Import	Export	Scenario	Production	Import	Export
EUROPE	**563976**	**30840**	**99012**	**Low**	**–2661**	**2489**	**–2780**
				High	**–6093**	**5349**	**–9860**
EU-27	393430	30543	36056	Low	–1714	2352	–1095
				High	–3931	5133	–2690
Finland	50902	0	0	Low	–162	691	0
				High	–449	1764	0
Poland	34098	339	0	Low	–149	284	0
				High	–324	703	0
Russian Federation	131362	0	53616	Low	–747	0	–1595
				High	–1719	0	–6685
Sweden	72225	18936	0	Low	–306	752	0
				High	–701	1712	0
WORLD	**1718593**	**147948**	**146163**	**Low**	**3643**	**–3799**	**–3799**
				High	**10344**	**–12982**	**–12982**

Note: The Low scenario assumes a 10% increase in China's timber supply due to the collective forests tenure reform, and the High scenario assumes a 26% increase.

TABLE 3 *Projected levels of forest stock without China's tenure reform on collective forests, and changes due to the reform, by main source of China's imports*

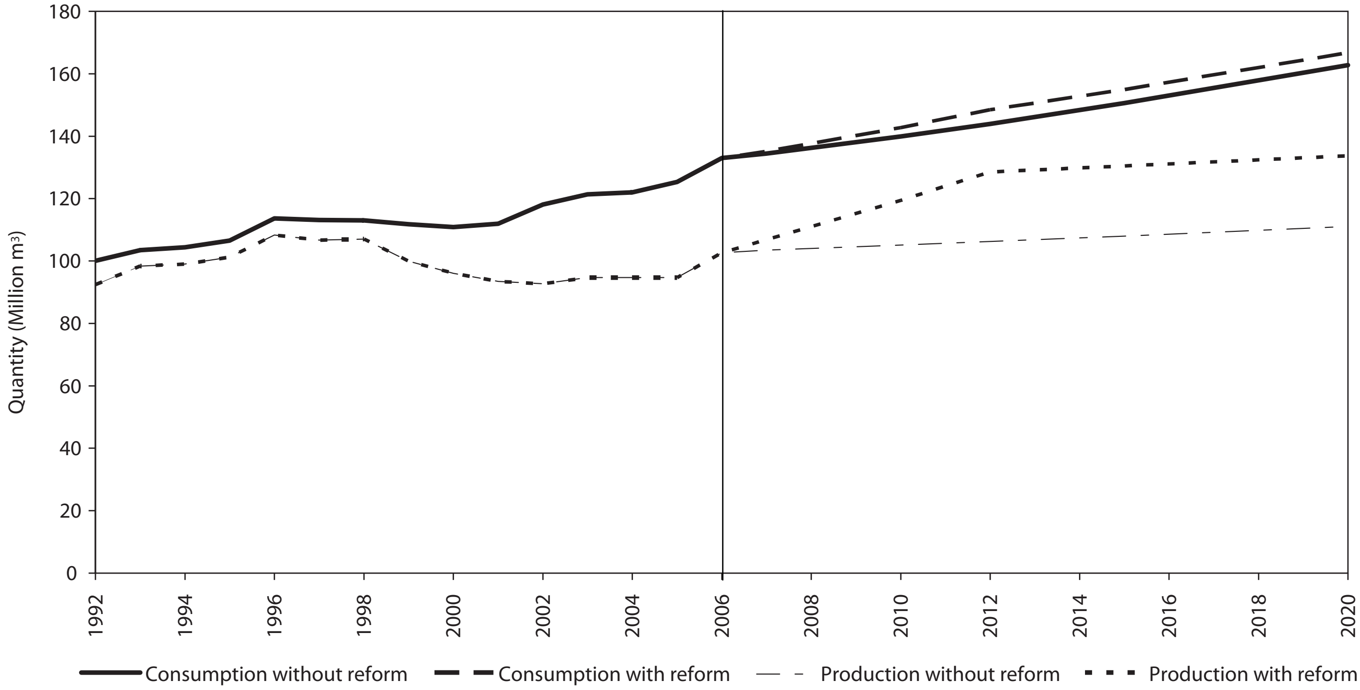
	Base scenario (10^6 m^3)			Stock change with reform (10^6 m^3)			
	2010	2015	2020	Scenario	2010	2015	2020
AFRICA	**63691**	**62923**	**62447**	**Low**	**0**	**7**	**24**
				High	**0**	**34**	**83**
Congo, Dem Republic of	30963	31127	31345	Low	0	2	6
				High	0	10	24
Gabon	4966	5149	5384	Low	0	0	0
				High	0	0	1
NORTH/CENTRAL AMERICA	**74562**	**75128**	**75951**	**Low**	**1**	**9**	**22**
				High	**2**	**29**	**64**
Canada	32884	32784	32726	Low	1	4	8
				High	1	10	21
United States of America	35499	36466	37593	Low	1	4	8
				High	1	9	20
SOUTH AMERICA	**121771**	**122586**	**124474**	**Low**	**0**	**8**	**25**
				High	**1**	**35**	**83**
Brazil	81677	82537	84140	Low	0	5	17
				High	1	24	58
Peru	10148	10050	10032	Low	0	0	1
				High	0	1	3

TABLE 3 *Continued*

	Base scenario (10^6 m^3)			Stock change with reform (10^6 m^3)			
	2010	**2015**	**2020**	**Scenario**	**2010**	**2015**	**2020**
ASIA	**47165**	**47943**	**49448**	**Low**	**–5**	**–52**	**–116**
				High	**–12**	**–132**	**–301**
China	14339	15920	17837	Low	–5	–61	–143
				High	–13	–174	–394
India	4309	3840	3421	Low	0	4	12
				High	0	21	44
Indonesia	4681	4102	3584	Low	0	0	0
				High	0	1	1
Japan	4589	5026	5492	Low	0	1	2
				High	0	2	5
Malaysia	5336	5493	5731	Low	0	1	2
				High	0	2	4
Myanmar	2690	2605	2520	Low	0	1	3
				High	0	5	13
OCEANIA	**12563**	**12593**	**12636**	**Low**	**0**	**1**	**3**
				High	**0**	**4**	**9**
Australia	10296	10409	10521	Low	0	0	1
				High	0	2	4
New Zealand	1141	1098	1060	Low	0	0	1
				High	0	1	3
Papua New Guinea	1004	970	943	Low	0	0	1
				High	0	1	2
EUROPE	**109027**	**109530**	**111345**	**Low**	**1**	**20**	**47**
				High	**3**	**59**	**130**
EU-27	21538	22660	23966	Low	1	12	28
				High	2	34	73
Finland	2210	2273	2352	Low	0	1	3
				High	0	4	7
Poland	1963	2099	2273	Low	0	1	2
				High	0	3	6
Russian Federation	79117	78021	77940	Low	0	6	14
				High	1	18	40
Sweden	3178	3207	3257	Low	0	2	4
				High	0	5	10
WORLD	**428780**	**430703**	**436300**	**Low**	**–2**	**–7**	**5**
				High	**–5**	**28**	**68**

Note: The Low scenario assumes a 10% increase in China's timber supply due to the collective forests tenure reform, and the High scenario assumes a 26% increase.

FIGURE 2 *China's industrial roundwood production and consumption with and without the tenure reform, historical (1992–2005) and projected (2006–2020), assuming a 26 percent supply shift due to the land tenure reform*



2012, when the reform was complete, the gap between domestic production and consumption increased continuously, due to the fast growth of China's economy.

As China's economy must continue to grow to raise the standard of living throughout the country, as much attention should be paid to the wood demand as to the supply. One way to do this could be to improve the domestic utilization of wood. For example, the program "Timber saving and substitution" was launched in 2005, with the aim to help reduce the waste of timber in manufacturing, and to substitute wood with other materials (Central Government 2005). But substitution of wood by steel, glass, plastic, and other materials may have environmental costs that should also be taken into account.

Among environmental issues tied even more directly to forests and forestry, the study suggested that while the tenure reform on collective forests did mitigate China's timber shortage, it also decreased China's forest stock, a basic criterion of healthy forests for biodiversity and carbon sequestration. Although globally this decrease was more than compensated by growth in the rest of the world, China's domestic policy seems in a quandary since measures to augment the country supply tend to exacerbate its environmental problems. At the very minimum it appears that the land tenure reform should be supplemented by additional government actions, such as investment in new plantations to conserve and possibly expand China's forest estate.

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APPENDIX A: MATHEMATICAL FORMULATION OF THE GFPM[3].

Market equilibrium
Obtained by maximizing the social surplus (Samuelson 1952) in any given year:

Objective Function:

$$\max Z = \sum_i \sum_k \int_0^{D_{ik}} P_{ik}(D_{ik})dD_{ik} - \sum_i \sum_k \int_0^{S_{ik}} P_{ik}(S_{ik})dS_{ik} - \sum_i \sum_k \int_0^{Y_{ik}} m_{ik}(Y_{ik})dY_{ik} - \sum_i \sum_j \sum_k c_{ijk}T_{ijk} \quad [1]$$

i,j = country,
k = product,
P = price in US dollars of constant value,

[3] More documentation, software, and data for the GFPM are available at http://forestandwildlifeecology.wisc.edu/facstaff/buongiorno.html

D = final product demand,
S = raw material supply,
Y = quantity manufactured,
m = manufacturing cost,
T = quantity transported,
c = cost of transportation, including tariff.

End product demand:

$$D_{ik} = D^*_{ik}\left(\frac{P_{ik}}{P_{ik,-1}}\right)^{\delta_{ik}} \quad [2]$$

D^* = current demand at last period's price,
P_{-1} = last period's price,
δ = price elasticity of demand.

Primary product supply:

$$S_{ik} = S^*_{ik}\left(\frac{P_{ik}}{P_{ik,-1}}\right)^{\lambda_{ik}} \quad [3]$$

S^* = current supply at last period's price,
λ = price elasticity of supply.

Total wood drain from the forest:

$$S_i = (S_{ir} + S_{in} + \theta_i S_{if})\mu_I \quad [4]$$

r = industrial roundwood,
n = other industrial roundwood,
f = fuelwood,
$0 \le \theta \le 1$ = fraction of fuelwood that comes from the forest,
$\mu \ge 1$ = ratio of drain to harvest.

Material balance:

$$\sum_j T_{jik} + S_{ik} + Y_{ik} - D_{ik} - \sum_n a_{ikn} Y_{in} - \sum_j T_{ijk} = 0 \qquad \forall i,k \quad [5]$$

a_{ikn} = input of product k per unit of product n.

Trade inertia:

$$T^L_{ijk} \le T_{ijk} \le T^U_{ijk} \quad [6]$$

L,U = lower bound, and upper bound, respectively

Manufacturing cost:

$$m = m^*_{ik}\left(\frac{Y_{ik}}{Y_{ik,-1}}\right)^{s_{ik}} \quad [7]$$

m^* = current manufacturing cost, at last period's output,
s = elasticity of manufacturing cost with respect to output.

Transportation cost:

$$c_{ijk} = f_{ijk} + t^X_{jk}\left(P_{ik,-1}\right) + t^I_{jk}\left(f_{ijk} + P_{ik,-1}\right) \quad [8]$$

c = transportation cost, per unit of volume,
f = freight cost, per unit of volume,
t^X = export tax,
t^I = import ad-valorem tariff,
P_{-1} = last year's world export price.
Prices
The shadow prices of the material balance constraints [5] give the market-clearing prices.

Market dynamics
Yearly changes in market equilibrium conditions.

Shifts of Demand:

$$D^* = D_{-1}(1 + \alpha_y g_y + \alpha_0) \quad [9]$$

g_y = GDP annual growth rate, α_y = elasticity with respect to GDP,
α_0 =annual trend.

Shifts of wood supply:

$$S^* = S_{-1}(1 + \beta_I g_I + \beta_a g_a) \quad [10]$$

for k=r, n, f
g_I = annual rate of change of forest stock (endogenous, see below),
g_a = annual rate of change of forest area,
β = elasticity.

Shifts of waste paper and other fiber supply:

$$S^* = S_{-1}(1 + \beta_y g_y) \quad [11]$$

Forest area changes:

$$A = (1 + g_a)A_{-1} \quad [12]$$

$$g_a = \alpha_0 + \alpha_1 y' + \alpha_2 y'^2 \quad [13]$$

A = forest area,
g_a = the annual rate of forest area change
y' = income per capita
α = parameter.

Changes of forest stock:

$$I = I_{-1} + G_{-1} - pS_{-1} \quad [14]$$

$$G_{-1} = (g_a + g_u)I_{-1}$$

$$g_u = \gamma_0\left(\frac{I_{-1}}{A_{-1}}\right)^{\sigma} \quad [15]$$

I = forest stock at the beginning of the current year,
g_u = annual rate of forest growth on a given area, without harvest, and
σ = elasticity.

Changes in manufacturing coefficients:

$$a = a_{-1} + \Delta a \quad [16]$$

Δa = annual change in input-output coefficient.

Changes in manufacturing cost:

$$m^* = m_{-1}(1 + g_m) \quad [17]$$

g_m = the exogenous rate of annual change in manufacturing cost.

Changes in freight cost:

$$f = f_{-1} + \Delta f, \quad t = t_{-1} + \Delta t \quad [18]$$

Δf, Δt = annual changes in freight cost, taxes.

Changes in trade inertia bounds:

$$T^L = T_{-1}(1-\varepsilon)^p \qquad [19]$$
$$T^U = T_{-1}(1+\varepsilon)^p$$

ε = absolute value of maximum annual relative change in trade flow.

APPENDIX B: Countries and products, data and parameters.

The 180 countries represented in the GFPM model are listed in Table B1. For each country the model projects the forest area and forest stock, and the production, consumption, imports, exports, and prices of the forest products listed in Table B2. The growth of demand for end products in each country, including China is determined by GDP growth in each country (equation [9] above). The demand elasticity parameters were based on Simangunsong and Buongiorno (2001), updated with more recent data, and the timber supply parameters were based on Turner et al. (2006). The main database for production, import and export data for the base year of 2006 was the FAOSTAT (FAO 2012). The GDP and population data came from the World Bank Development Indicators Data Base (World Bank 2012), and the assumptions regarding the growth of GDP and GDP per capita from 2006 to 2020 were the same as in USFS (2012). The data on forest area and forest stock were from the Global Forest Resources Assessment 2000 (FAO, 2010), supplemented with data from USFS (2012) for the United States.

TABLE B1 *Countries represented in the GFPM model*

AFRICA	Uganda	Brunei Darussalam	New Zealand
Algeria	Congo, Dem Rep. Zambia	Cambodia	Papua New Guinea
Angola	Zimbabwe	China	Samoa
Benin	**NORTH/CENTRAL AMERICA**	Cyprus	Solomon Islands
Botswana	Bahamas	Georgia	Tonga
Burkina Faso	Barbados	Hong Kong	Vanuatu
Burundi	Belize	India	**EUROPE**
Cameroon	Canada	Indonesia	Albania
Cape Verde	Cayman Islands	Iran, Islamic Rep of	Austria
Central African Rep	Costa Rica	Iraq	Belgium
Chad	Cuba	Israel	Belarus
Congo, Rep	Dominica	Japan	Bosnia and Herzegovina
Côte d'Ivoire	Dominican Rep	Jordan	Bulgaria
Djibouti	El Salvador	Kazakhstan	Croatia
Egypt	Guatemala	Korea, Dem Peop Rep	Czech Republic
Equatorial Guinea	Haiti	Korea, Rep	Denmark
Ethiopia	Honduras	Kuwait	Estonia
Gabon	Jamaica	Kyrgyzstan	Finland
Gambia	Martinique	Laos	France
Ghana	Mexico	Lebanon	Germany
Guinea	Netherlands Antilles	Macau	Greece
Guinea-Bissau	Nicaragua	Malaysia	Hungary
Kenya	Panama	Mongolia	Iceland
Lesotho	Saint Vincent/Grenadines	Myanmar	Ireland
Liberia	Trinidad and Tobago	Nepal	Italy
Libyan Arab Jam.	United States of America	Oman	Latvia
Madagascar	**SOUTH AMERICA**	Pakistan	Lithuania
Malawi	Argentina	Philippines	Macedonia
Mali	Bolivia	Qatar	Malta
Mauritania	Brazil	Saudi Arabia	Moldova, Rep
Mauritius	Chile	Singapore	Netherlands

TABLE B1 *(cont.)*

Morocco	Colombia	Sri Lanka	Norway
Mozambique	Ecuador	Syrian Arab Rep	Poland
Niger	French Guiana	Tajikistan	Portugal
Nigeria	Guyana	Thailand	Romania
Réunion	Paraguay	Turkey	Russian Federation
Rwanda	Peru	Turkmenistan	Slovakia
Sao Tome and Principe	Suriname	United Arab Emirates	Slovenia
Senegal	Uruguay	Uzbekistan	Spain
Sierra Leone	Venezuela, Boliv Rep.	Viet Nam	Sweden
Somalia	**ASIA**	Yemen	Switzerland
South Africa	Afghanistan	**OCEANIA**	Ukraine
Sudan	Armenia	Australia	United Kingdom
Swaziland	Azerbaijan, Rep	Cook Islands	Serbia and Montenegro
Tanzania, United Rep	Bahrain	Fiji Islands	
Togo	Bangladesh	French Polynesia	
Tunisia	Bhutan	New Caledonia	

TABLE B2 *Commodities represented in GFPM model*

Product	Type	Unit
Fuelwood	r,f	10^3 m^3
Industrial roundwood	r	10^3 m^3
Other industrial roundwood	r,f	10^3 m^3
Sawnwood	f	10^3 m^3
Veneer and plywood	f	10^3 m^3
Particleboard	f	10^3 m^3
Fiberboard	f	10^3 m^3
Mechanical wood pulp	i	10^3 t
Chemical and semi-chemical wood pulp	i	10^3 t
Other fiber pulp	r	10^3 t
Waste paper	r	10^3 t
Newsprint	f	10^3 t
Printing and writing paper	f	10^3 t
Other paper and paperboard	f	10^3 t

Note: r=raw material, f=final product, i=intermediate product

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