# Potential economic impact of limiting the international trade of timber as a phytosanitary measure

RUHONG LI[1], J. BUONGIORNO[1], S. ZHU[1], J.A. TURNER[2], and J. PRESTEMON[3]

[1] *Department of Forest Ecology and Management, University of Wisconsin, Madison WI, USA*
[2] *Scion (New Zealand Forest Research Institute Ltd.), Rotorua, New Zealand*
[3] *Forestry Sciences Laboratory, USDA Forest Service, Research Triangle Park NC, USA*

E-mail: jbuongio@wisc.edu

SUMMARY

We assessed the impact on the world forest sector of reducing the risk of exotic pest spread by curtailing the roundwood trade. The analysis compared predictions from 2006 to 2015, with and without a gradual ban of roundwood exports between 2006 and 2010. With a ban on roundwood trade, world consumer expenditures for wood products and producer revenues would rise by 2.2 percent and 1.9 percent respectively. World value added would remain unchanged. However, producer revenues would decrease for the main log exporters (16 percent for the Russian Federation, and 10 percent for New Zealand). Value added would decrease most for the main log importers (13 percent in Japan, 7 percent in Korea, and 4 percent in China). Although the global cost of banning roundwood trade seems modest compared to the cost of catastrophic pest invasions, its varying effects on countries must be taken into account in forging equitable policies.

Keywords: exotic pests, international trade, policy, wood products, modeling

## Impact économique potentiel de la limitation du commerce international du bois comme mesure phytosanitaire

RUHONG LI, J. BUONGIORNO, S.ZHU, J. TURNER et J. PRESTEMON

Nous avons évalué l'impact de la réduction du risque de propagation des parasites exotiques par le contrôle du commerce de bois rond sur le secteur de la foresterie mondiale. L'analyse a comparé des prévisions de 2006 à 2015, avec et sans une interdiction progressive de l'exportation de bois rond entre 2005 et 2010. Avec une interdiction de commercialiser le bois rond, la dépense du consommateur mondial pour les produits du bois, et le chiffre d'affaires du producteur augmenteraient de 2.2% et 1.9% respectivement. La valeur ajoutée mondiale demeurerait inchangée. Les revenus des producteurs décroiraient cependant pour les principaux exportateurs de bois ( 16% pour la fédération Russe, et 10% pour la Nouvelle-Zélande). La valeur ajoutée diminuerait le plus pour les principaux importeurs de bois ( 13% au Japon, 7% en Corée et 4% en Chine). Bien que le coût global d'une interdiction du commerce du bois rond semble modeste comparé à celui des invasions catastrophiques de parasites, ses effets divers sur les pays doivent être pris en compte pour forger des plans d'action équitables.

## Impacto económico potencial de restricciones al comercio internacional de madera como medida fitosanitaria

RUHONG LI, J. BUONGIORNO, S. ZHU, J. TURNER, y J. PRESTEMON

En este artículo se evaluó el impacto sobre el sector forestal mundial de la reducción del riesgo de propagación de plagas exóticas a través de restricciones sobre el comercio de madera redonda (en forma de troncos). El análisis comparó las predicciones desde 2006 hasta 2015, con y sin una prohibición gradual de exportaciones de madera redonda entre 2006 y 2010. Con la imposición de una prohibición sobre el comercio de madera redonda, el gasto en productos de madera a nivel mundial y los ingresos de los productores aumentarían en un 2.2% y un 1.9% respectivamente. El valor añadido global no experimentaría cambios significativos. Sin embargo, los ingresos de los productores bajarían para los grandes exportadores de madera redonda (p.ej. 16% en el caso de la Federación Rusa y 10% en el de Nueva Zelanda), y el descenso del valor añadido se notaría más para los grandes importadores de madera redonda (13% en el caso de Japón, 7% en Corea del Sur y 4% en China). Aunque el coste global de una prohibición mundial del comercio de madera redonda no parezca importante en comparación con el costo de invasiones catastóficas de plagas, la creación de políticas equitativas requiere la consideración de los efectos de una prohibición en diferentes países.

## INTRODUCTION

Globalization and the liberalization of trade offer new opportunities for countries hoping to strengthen their economy. The international trade in forest products enables growing economies to adjust their consumption and production of a wide variety of wood and paper products in an economically efficient manner. Over the past 40 years, the value of the wood products trade has increased from US$31.6 billion to US$128.5 billion (Turner *et al*. 2006b).

Although the trade of raw wood, mostly industrial roundwood, is less than 7% of the total forest products trade value, it is a major pathway for the introduction of exotic insects and pathogens. For example, the Asian long horned beetle (*Anoplophora glabripennis*), pine shoot beetle (*Tomicus piniperda*), chestnut blight fungus (*Cryphonectria parasitica*) and Dutch elm pathogens (*Ophiostoma ulmi* and *Ophiostoma novo-ulmi*) were imported on raw wood or nursery stock and went on to destroy significant United States tree species (Haysom and Murphy 2003), and to cause pandemics in Europe (Brasier 1991).

Thus, although trade may have marked benefits, particularly in the short-run, the international movement of raw logs creates significant forest health risks in recipient countries with grave long-run implications (Morell 1995, Liebhold *et al*. 1995, Pimentel *et al*. 2000). Hence, the development of effective policies and procedures to prevent pest entry is critical to maintaining the long-run health of forest ecosystems. What losses and gains will result in different countries should be determined to help draft good policies.

Most logs allowed into the United States must be debarked, because logs with bark have higher probability of insect and fungi infestation, and the bark itself hinders inspection and chemical treatment (Aho and Cahill 1984, Childs and Clark 1953, Furniss and Carolin1977, and Lowell *et al*. 1992). But, even debarked logs carry risks, beetles and other insects may lay their eggs within the sapwood or tunnel into wood (Furniss and Carolin1997, Post and Wermer 1988, Richmond and Nijholt 1972), and nutrient-rich sapwood is ideal for fungal colonization (Humphrey 1920, Prybylowicz *et al* 1987, and Zahra and Dickinson 1989). Consequently, the United States maintains a ban on log imports from the Russian Far East (Prestemon *et al*. 2006), and in 1997 the U.S. District Court for the Northern District of California temporarily enjoined the issuing of import licenses by the USDA Animal and Plant Health Inspection Service (APHIS) for logs from New Zealand and Chile, in response to environmental organizations suing APHIS for allowing the importation of unprocessed wood products (Collins 1999).

Other countries that import logs require treatment with methyl bromide (MeBr), an ozone depleting substance (New Zealand Forest Research Institute 1999). The Montreal Protocol requires the phasing out of MeBr in most agricultural uses. Although MeBr fumigation for phytosanitary requirements is exempt (UNEP 2000), mounting awareness of its effects on the ozone layer has caused parties to the Montreal Protocol to call for a total ban.

In fighting the spread of invasive species, national boundaries are an appealing line of defense (Margolis *et al*. 2005). Thus, most past economic and policy studies have a national perspective. For example, USDA Forest Service (1991) assessed the effect of Asian Gypsy moth (*Lymantria dispar*) imported with Siberian coniferous logs into U.S. The result was a policy effectively banning those imports to avoid catastrophic losses to the sector. Prestemon *et al*. (2006) found that 'trade liberalization would have a negligible effect on U.S. imports of Siberian logs and, consequently, on the risk of a pest invasion. But, if it happened, possibly through the trade in other commodities, a successful and widespread pest invasion would have large effects'.

This study took an international perspective, consistent with increasingly global forest product markets. It acknowledged that a main danger of introducing exotic pests was through the trade of raw wood. And, as the trade of raw wood is small in value compared to the trade of manufactured wood products, the presumption was that a progressive ban on the trade of raw wood was worth considering. Accordingly, the study calculated the long-term economic impacts on the forest sector of a gradual, worldwide elimination of trade in industrial roundwood only. This was done for the main forest industries' production, consumption, trade, prices, revenues, expenditures, and value added. To highlight some of the economic equity issues inherent in such a policy, detailed outcomes are summarized below for major producing and trading countries and for world regions, from 2006 to 2015.

## METHODS

The international effects of progressively eliminating the trade of industrial roundwood were simulated with the Global Forest Products Model (GFPM, Buongiorno *et al*. 2003). Initially developed for the Food and Agriculture Organization (FAO) Global Forest Products Outlook studies, the GFPM is a dynamic spatial equilibrium model which predicts production, imports, exports, and prices of 14 forest products in 180 individual countries.

Among the variables of the GFPM are imports and exports of industrial roundwood, including chips and particles, by country. Demand and supply of each product are represented by econometric functions and by activity analysis. Trade is driven by the economic growth of the countries and by their relative competitive advantages, within bounds that simulate trade inertia. The equilibrium in each year is found by maximizing the quasi welfare of the world forest sector: the value of the products to consumers, minus the cost of production and transport. Equilibrium prices are the shadow prices of the material balance constraints in each country, specifying that for each product demand equals domestic production plus imports minus exports in each country.

The mathematical specification of the GFPM model is given in Buongiorno *et al*. (2003). The most recent improvements, including prediction of changes in forest area and forest stock (Turner *et al*. 2006a), are included in the model documentation (Turner *et al*. 2005 a, b).

FIGURE 1 *Competitive equilibrium with two countries and one commodity, with and without trade.*

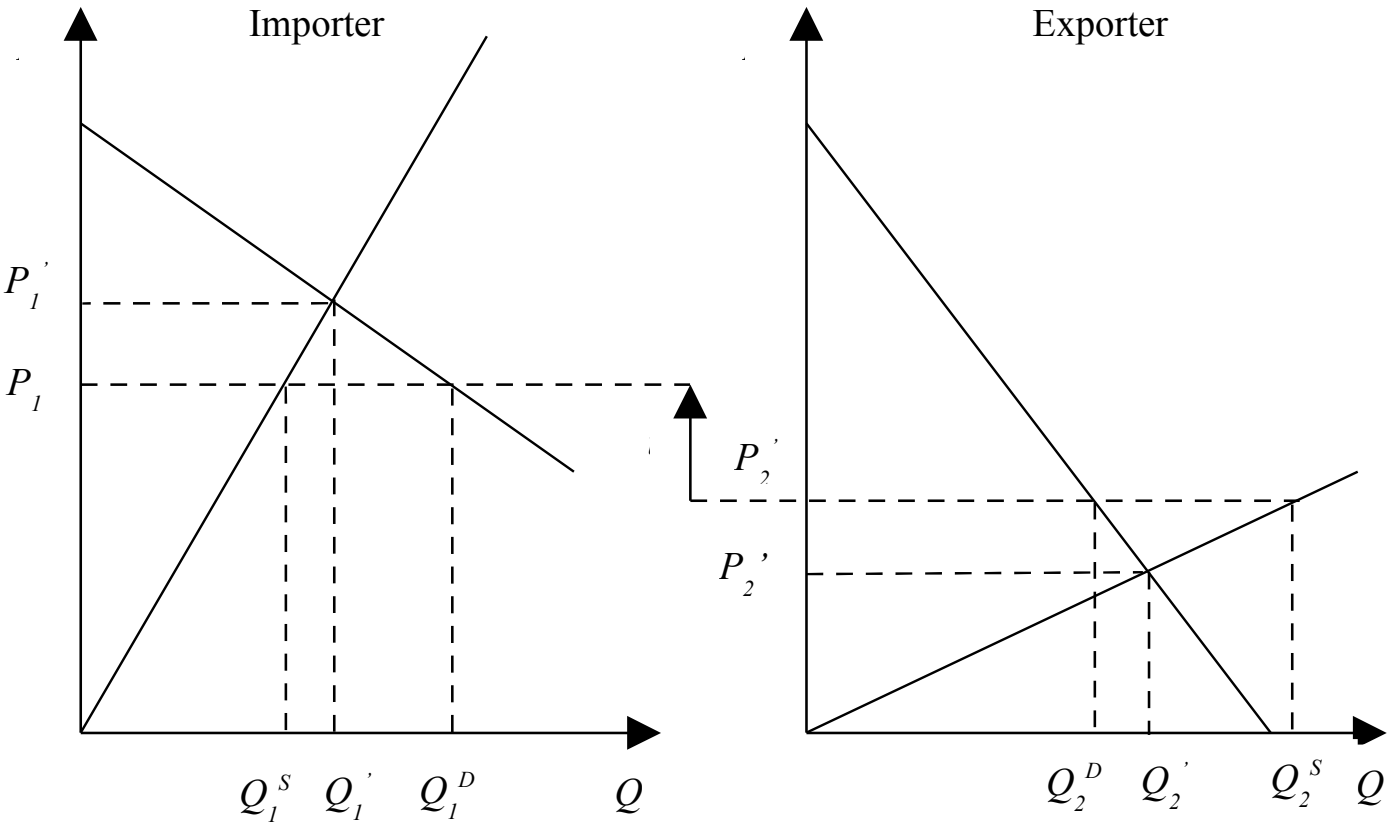


Figure 1 summarizes the main theoretical principles underlying the experiment carried out with the GFPM. The figure symbolizes the demand and supply of industrial roundwood, in a world with only two countries in a particular year. Two equilibrium states are shown: one with trade of industrial roundwood, and the other without trade.

With trade, the price of industrial roundwood in the importer country is $P_1$. At that price, the quantity supplied by the importer country, $Q_1^S$, is less than the quantity demanded, $Q_1^D$. In the exporter country the price is $P_2$, and the quantity supplied $Q_2^S$ is more than the quantity demanded $Q_2^D$. At equilibrium, the importer price is equal to the exporter price plus the unit transport cost: $P_1=P_2+t$, and the net trade of the exporter is the opposite of the net trade of the importer: $Q_1^S - Q_1^D = -(Q_2^S - Q_2^D)$.

Assume that, to mitigate the risk of exotic pests, trade of industrial roundwood were not allowed between the two countries. Then, demand would meet supply at the amount $Q_1'$ and price $P_1'$ in the importing country, and at amount $Q_2'$ and price $P_2'$ in the exporting country.

As shown by Figure 1, the effect of a ban on the trade of logs would be to increase price in the importing country, thus increasing production and decreasing total consumption. In the exporting country, the price would be lower, resulting in lower production and higher consumption.

The producer gross revenue or value of shipments in, say, the importer country, changes from $P_1 Q_1^S$ without the ban on trade to $P_1' Q_1'$ with the ban, while consumer expenditures, i.e., how much consumers must pay for the industrial roundwood they use, changes from $P_1 Q_1^D$ to $P_1' Q_1'$.

In equilibrium without trade, producer revenues are equal to consumer expenditures, $P_1'Q_1'$ and $P_2'Q_2'$ for the respective countries. With trade, consumer expenditures are equal to producer revenues plus transport costs. In particular, for the situation depicted by Figure1: $P_1 Q_1^D + P_2 Q_2^D = P_1 Q_1^S + P_2 Q_2^S + t(Q_1^S - Q_1^D)$.

The effect of the elimination of trade on producer revenues and consumer expenditures depends in part on the elasticity of supply and demand with respect to price. For example, in Figure 1, a trade ban would increase producer revenues in both countries, increase consumer expenditures in the importing country, and decrease consumer expenditures in the exporting country.

The GFPM computations follow the general principle of spatial market equilibrium sketched out in Figure 1. However, the magnitude and even the direction of these effects cannot be predicted as simply. The GFPM depicts not only the world market for industrial roundwood, but also the markets of all of the products (sawnwood, panels, and pulp and paper) that use industrial roundwood as an input. Thus, a ban on the trade of industrial roundwood can have extensive repercussions on the production, consumption, trade, and prices of other products in many countries.

Furthermore, adjustments take time. This interdependence and inertia, which are explicit in the GFPM model, are absent

in the simple comparative static model sketched in Figure 1. Another benefit of the GFPM is that its manufacturing activities describe in detail the transformation of raw materials, such as industrial roundwood, into intermediate products such as wood pulp, and end products such as paper and paperboard, thus allowing the computation of value added: the value of the end products minus the cost of the intermediate wood and fiber products.

The effects of a gradual trade ban on roundwood trade were obtained by comparing two sets of projections with the GFPM. One, referred to as the 'base' or 'with trade' scenario, made the same assumptions as those of the World Wood Industries Outlook, which had also been prepared with the GFPM (Turner *et al*. 2006b). According to the Outlook, the world annual exports of industrial roundwood would increase by 38.2 million $m^3$ (23 percent) from 2006 to 2015.

The alternative, or 'without trade', scenario made the same assumptions as the base scenario, except that exports of industrial roundwood were reduced by 20 percent each year for five years, starting in 2006 and ending in a complete ban by 2010. This was implemented with the trade inertia constraints of the GFPM, which allow constraining each year's change in export quantity to be within a specified fraction of its level in the previous year (Buongiorno *et al*. 2003, p. 47).

Both the base and the 'without trade' projections were continued until 2015. The projections were then compared in terms of production, consumption, imports, exports, prices, producer revenues, consumer expenditures, and value added.

## RESULTS

The effects of the progressive ban on trade of industrial roundwood on different industries are summarized in Tables 1 to 8. The policy affected the trade of all forest products around the world, as well as the distribution of production, and the prices of products, with consequences for producer revenues, consumer expenditures, and value added.

### Effects on industrial roundwood

As shown in Table 1, the 'without trade' scenario led to an 81 percent reduction of average annual world imports and exports of industrial roundwood from 2006 to 2015.

TABLE 1 *Industrial roundwood changes of production and trade due to the progressive elimination industrial roundwood exports*[1].

| | Production | | Imports | | Exports | |
|---|---|---|---|---|---|---|
| **Region** | **$10^3m^3$** | **%** | **$10^3m^3$** | **%** | **$10^3m^3$** | **%** |
| AFRICA[2] | -5874 | -7.8 | -431 | -81.6 | -7468 | -79.6 |
| NORTH & CENTRAL AMERICA | 14912 | 2.0 | -13535 | -80.1 | -26788 | -81.7 |
| Canada | 9039 | 3.8 | -10184 | -81.1 | -2843 | -77.7 |
| United States of America | 5552 | 1.1 | -3259 | -77.8 | -23902 | -82.5 |
| SOUTH AMERICA | 1469 | 0.8 | -45 | -79.0 | -7058 | -81.2 |
| Brazil | 3034 | 2.5 | -9 | -78.1 | -2001 | -81.9 |
| ASIA | 23039 | 8.3 | -101152 | -82.0 | -11578 | -80.4 |
| China | 7906 | 6.6 | -53337 | -83.4 | -493 | -71.2 |
| Japan | 11581 | 60.3 | -32927 | -80.5 | -2 | -74.7 |
| Korea, Republic of | 3030 | 234.8 | -5922 | -79.3 | 0 | 0.0 |
| OCEANIA | -19657 | -32.9 | -12 | -79.7 | -22849 | -80.7 |
| New Zealand | -7226 | -25.6 | -4 | -79.7 | -8808 | -80.7 |
| EUROPE | -32529 | -5.2 | -44324 | -79.0 | -78822 | -80.9 |
| EU-25 | 7622 | 2.0 | -39517 | -78.9 | -32266 | -80.7 |
| Germany | -4361 | -10.7 | -879 | -75.4 | -8840 | -82.4 |
| Russian Federation | -37958 | -21.1 | -384 | -77.8 | -39808 | -81.1 |
| DEVELOPED, ALL | -27416 | -1.9 | -90788 | -79.7 | -130249 | -81.0 |
| DEVELOPING, ALL | 8776 | 1.7 | -68712 | -83.0 | -29251 | -80.5 |
| WORLD | -18640 | -1.0 | -159500 | -80.9 | -159500 | -80.9 |

[1] Changes are average changes in annual production, imports, or exports, from 2006 to 2015, when world exports of industrial roundwood are reduced from their current level in 2006 to zero in 2010.

[2] Regions are defined as in FAO (2005).

In absolute value, this was a reduction of yearly import and exports of nearly 160 million $m^3$. Meanwhile, world annual production of industrial roundwood also decreased, but by much less, about 19 million $m^3$, or 1 percent. Thus, the decrease in industrial roundwood production due to the progressive export ban was largely compensated for by the increased domestic demand for industrial roundwood due to domestic industries stimulated by higher prices. As the

TABLE 2 *Price changes in main forest products due to the progressive elimination of industrial roundwood exports*[1].

| Product | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | ----------%---------- | | | | | | | | | | |
| Industrial roundwood | 2.7 | 4.6 | 5.7 | 6.9 | 7.7 | 6.2 | 5.0 | 4.1 | 3.3 | 2.7 | 4.9 |
| Sawnwood | 1.1 | 2.2 | 3.1 | 3.7 | 4.2 | 4.1 | 3.7 | 3.3 | 3.1 | 3.0 | 3.2 |
| Veneer & Plywood | 2.0 | 4.1 | 5.4 | 6.5 | 7.7 | 5.6 | 4.0 | 3.6 | 3.4 | 3.2 | 4.6 |
| Particleboard | 0.9 | 1.8 | 2.6 | 3.3 | 3.7 | 3.9 | 3.6 | 3.2 | 3.1 | 3.2 | 2.9 |
| Fiberboard | 1.6 | 3.3 | 4.7 | 5.8 | 6.8 | 7.0 | 8.0 | 13.3 | 14.4 | 13.6 | 7.8 |
| Mechanical pulp | 3.7 | 5.3 | 7.0 | 8.8 | 30.3 | 18.5 | 22.2 | 21.2 | 20.3 | 12.9 | 15.0 |
| Chemical pulp | 3.8 | 5.3 | 6.1 | 5.3 | 5.1 | 5.1 | 4.8 | 4.7 | 4.7 | 4.6 | 4.9 |
| Newsprint | 1.6 | 1.8 | 2.4 | 2.7 | 2.8 | 2.8 | 2.7 | 2.8 | 3.1 | 3.2 | 2.6 |
| Printing & Writing paper | 0.8 | 0.9 | 1.2 | 1.5 | 1.6 | 1.5 | 1.4 | 1.2 | 0.8 | 1.1 | 1.2 |
| Other paper & paperboard | 0.4 | 0.9 | 1.1 | 1.1 | 1.2 | 1.3 | 1.2 | 1.3 | 1.3 | 1.3 | 1.1 |

[1] World prices computed as weighted averages of prices in different countries, the amounts of yearly national consumption serving as weights.

TABLE 3 *Sawnwood changes in production and trade due to the progressive elimination of industrial roundwood exports*[1].

| | Production | | Imports | | Exports | |
|---|---|---|---|---|---|---|
| Region | $10^3m^3$ | % | $10^3m^3$ | % | $10^3m^3$ | % |
| AFRICA[2] | 625 | 7.3 | -194 | -3.9 | 452 | 24.5 |
| NORTH & CENTRAL AMERICA | 5914 | 3.4 | -8228 | -18.2 | -1569 | -2.9 |
| Canada | -1696 | -2.3 | 0 | 0.0 | -1578 | -3.1 |
| United States of America | 7563 | 7.9 | -8162 | -19.2 | 0 | 0.0 |
| SOUTH AMERICA | 1960 | 5.4 | 0 | -0.2 | 2023 | 44.8 |
| Brazil | 430 | 1.9 | 0 | 0.0 | 503 | 25.3 |
| ASIA | -9751 | -15.5 | 9319 | 29.5 | 863 | 18.3 |
| China | -3403 | -65.4 | 3162 | 21.0 | 0 | 0.0 |
| Japan | -5408 | -37.8 | 5312 | 77.2 | 0 | 0.7 |
| Korea, Republic of | -699 | -16.7 | 36 | 1.2 | 0 | -1.8 |
| OCEANIA | 1087 | 12.5 | -389 | -33.6 | 578 | 36.2 |
| New Zealand | 610 | 14.5 | 0 | -0.5 | 566 | 40.1 |
| EUROPE | -1651 | -1.1 | -1287 | -2.8 | -3126 | -4.7 |
| EU-25 | -2440 | -2.4 | -1254 | -3.0 | -3492 | -7.9 |
| Germany | 1564 | 11.1 | -1498 | -26.7 | 0 | 0.0 |
| Russia Federation | 384 | 1.4 | 0 | -0.7 | 0 | 0.0 |
| DEVELOPED, ALL | 125 | 0.0 | -4745 | -4.8 | -4128 | -3.4 |
| DEVELOPING, ALL | -1942 | -2.0 | 3966 | 13.4 | 3349 | 30.2 |
| WORLD | -1817 | -0.4 | -779 | -0.5 | -779 | -0.5 |

[1] Changes are average changes in annual production, imports, or exports, from 2006 to 2015, when world exports of industrial roundwood are reduced from their current level in 2006 to zero in 2010.
[2] Regions are defined as in FAO (2005).

world prices[1] of all manufactured wood products increased (Table 2), the derived demand for industrial roundwood increased sufficiently to nearly cancel the loss of export markets.

Nevertheless, the logging industries in some countries that are currently major exporters of industrial roundwood were seriously curtailed. This was the case for New Zealand and the Russian Federation, where industrial roundwood production decreased by 26 percent and 21 percent respectively. On the other hand, logging increased substantially in relative terms in countries that now import logs to make other products, such as China, Japan, Korea, and Finland (Table 1).

**Effects on sawnwood**

At the world level, the progressive ban on the trade of industrial roundwood had little effect on the sawmilling industry and world trade (Table 3). World production, imports and exports were only about 0.5 percent lower with a progressive elimination of industrial roundwood exports. But the world price of sawnwood was, on average, 3.2 percent higher throughout the projected period (Table 2).

As a group, developing countries were affected more than developed countries. Although their production decreased by 2 percent, and correspondingly their imports increased by 13 percent, their exports increased by 30 percent. Meanwhile, in developed countries, exports and imports decreased almost equally, leaving domestic production practically the same.

The countries with sawmill industries that currently rely heavily on imported logs were most affected by a ban on the trade of industrial roundwood. This included China, Japan, the Republic of Korea, and Finland where annual sawnwood production decreased by 65 percent, 38 percent, 17 percent and 9 percent, respectively (Table 3).

In contrast, a ban on the trade of industrial roundwood caused sawnwood production to increase substantially in countries that are currently major exporters of industrial roundwood. This includes the United States, where annual sawnwood production was on average nearly 8 percent higher from 2006 to 2015, Chile (+21.9 percent), New Zealand (+14.5 percent), and Germany (+11.1 percent).

TABLE 4 *Wood-based panels changes in production and trade due to the progressive elimination of industrial roundwood exports[1].*

| | Production | | Imports | | Exports | |
|---|---|---|---|---|---|---|
| **Region** | **$10^3m^3$** | **%** | **$10^3m^3$** | **%** | **$10^3m^3$** | **%** |
| AFRICA[2] | 303 | 10.3 | -56 | -6.0 | 247 | 30.7 |
| NORTH & CENTRAL AMERICA | 2706 | 3.5 | -5776 | -21.2 | -2362 | -11.1 |
| Canada | -2486 | -9.3 | 0 | 0.0 | -2431 | -12.1 |
| United States of America | 5166 | 10.5 | -5748 | -23.0 | 53 | 5.4 |
| SOUTH AMERICA | 306 | 2.4 | -43 | -11.4 | 273 | 6.7 |
| Brazil | -5 | -0.1 | -2 | -1.5 | 9 | 0.3 |
| ASIA | -13252 | -15.7 | 11374 | 56.0 | 853 | 6.0 |
| China | -12004 | -25.8 | 7098 | 317.7 | -3047 | -74.8 |
| Japan | -3289 | -59.2 | 2948 | 45.1 | 0 | -3.4 |
| Korea, Republic of | -1754 | -50.1 | 1324 | 19.5 | 0 | -0.5 |
| OCEANIA | 786 | 16.0 | -110 | -25.6 | 620 | 31.4 |
| New Zealand | 489 | 22.9 | 0 | -3.9 | 472 | 64.3 |
| EUROPE | 5457 | 6.6 | -1332 | -6.1 | 4425 | 16.1 |
| EU-25 | 4838 | 7.2 | -1334 | -6.9 | 3973 | 17.5 |
| Germany | 2803 | 18.8 | -88 | -3.5 | 2671 | 69.8 |
| Russia Federation | 194 | 2.1 | 0 | -0.1 | 36 | 1.5 |
| DEVELOPED, ALL | 5659 | 3.3 | -4272 | -7.6 | 2663 | 5.3 |
| DEVELOPING, ALL | -9353 | -9.8 | 8328 | 52.0 | 1393 | 7.3 |
| WORLD | -3694 | -1.4 | 4056 | 5.8 | 4056 | 5.8 |

[1]Changes are average changes in annual production, imports, or exports, from 2006 to 2015, when world exports of industrial roundwood are reduced from their current level in 2006 to zero in 2010.
[2]Regions are defined as in FAO (2005).

[1] World prices are weighted averages of prices in different countries, the amounts of yearly national consumption serving as weights.

Nevertheless, sawnwood production increased modestly in the Russian Federation, suggesting a less efficient sawmill industry than in competing countries.

**Effects on wood-based panels**

The progressive exclusion of industrial roundwood exports stimulated the international trade of wood-based panels, increasing annual world exports and imports by nearly 6 percent (Table 4). However, the policy led to a slight (-1.4 percent) decrease in the world production of wood-based panels.

The new demand-supply equilibrium occurred at higher prices for all panel products. In particular, the price of veneer and plywood was nearly 8 percent higher by 2010, compared to the free-trade policy, but the price difference decreased thereafter (Table 2).

The production of wood-based panels was most affected in developing countries, where it declined by nearly 10 percent. In contrast, production rose in developed countries by 3.3 percent. Exports of wood-based panels increased both in developed and developing countries.

The most negatively affected producers were all in Asia, in the countries that currently import logs to make wood-based panels. Average annual production declined by 59 percent in Japan, 50 percent in the Republic of Korea, and 26 percent in China. Concurrently, China's average annual exports of wood based panels were 75 percent lower during the period considered.

Meanwhile, production of wood-based panels was stimulated in countries that currently export industrial roundwood. The United States increased annual production by nearly 11 percent, mostly for domestic consumption. Production was also higher in Germany and New Zealand but the increase went largely to exports. The Russian Federation was unable to increase production significantly. Canada experienced a substantial shrinkage in both production and exports.

**Effects on wood pulp**

The world total production of wood pulp was hardly affected by a policy that would eliminate the trade of industrial roundwood by 2010. However, the annual volume of trade was nearly 14 percent higher (Table 5). While exports of wood pulp were higher both in developing and developed countries, production was substantially lower in developing countries.

The price of chemical pulp, the main wood pulp product, was, on average, 4 percent to 5 percent higher from 2006 to

TABLE 5 *Wood-pulp changes in production and trade due to the progressive elimination of industrial roundwood exports*[1].

| | Production | | Imports | | Exports | |
|---|---|---|---|---|---|---|
| **Region** | **$10^3$t** | **%** | **$10^3$t** | **%** | **$10^3$t** | **%** |
| AFRICA[2] | 2 | 0.1 | 29 | 15.6 | 20 | 2.9 |
| NORTH & CENTRAL AMERICA | 4443 | 4.8 | -2252 | -25.1 | 1992 | 12.5 |
| Canada | 2201 | 7.5 | 0 | -0.2 | 1972 | 16.5 |
| United States of America | 2197 | 3.5 | -2211 | -27.8 | 20 | 0.5 |
| SOUTH AMERICA | 1312 | 9.1 | -81 | -11.5 | 1225 | 20.2 |
| Brazil | 1105 | 13.4 | 0 | 0.0 | 1126 | 48.4 |
| ASIA | -7546 | -22.0 | 6866 | 48.8 | 408 | 25.1 |
| China | -3938 | -74.1 | 3900 | 83.8 | 0 | 0.1 |
| Japan | -4232 | -25.9 | 3184 | 199.4 | 0 | -0.3 |
| Korea, Republic of | -113 | -15.3 | -17 | 0.1 | 0 | 0.0 |
| OCEANIA | 627 | 17.2 | -3 | -1.6 | 360 | 49.7 |
| New Zealand | 432 | 23.8 | 0 | -1.8 | 360 | 49.7 |
| EUROPE | -90 | -0.1 | 603 | 4.3 | 1155 | 9.1 |
| EU-25 | 34 | 0.1 | 772 | 5.8 | 1272 | 14.4 |
| Germany | 174 | 3.9 | -154 | -3.7 | 4 | 1.6 |
| Russia Federation | 39 | 0.4 | 0 | 0.0 | 0 | 0.0 |
| DEVELOPED, ALL | 712 | 0.4 | 1573 | 6.5 | 3508 | 11.8 |
| DEVELOPING, ALL | -1964 | -6.0 | 3588 | 25.7 | 1652 | 20.7 |
| WORLD | -1252 | -0.6 | 5160 | 13.6 | 5160 | 13.6 |

[1] Changes are average changes in annual production, imports, or exports, from 2006 to 2015, when world exports of industrial roundwood are reduced from their current level in 2006 to zero in 2010.

[2] Regions are defined as in FAO (2005).

2015 with the reduction of roundwood trade (Table 2). The price of mechanical pulp was 30 percent higher by 2010, when the ban was completed, but the price differential is less than half that much by 2015.

Consequent to the reduction of exports of industrial roundwood, Canada, Brazil, and New Zealand experience the largest relative increases in production and exports. The United States increased its domestic production of wood pulp while it decreased imports, compared to the base scenario.

Symmetrically, the largest decline in production, and largest increase in imports was in Asia. In particular, average annual wood pulp production was 74 percent lower in China, 26 percent in Japan, and 15 percent in Republic of Korea, from 2006 to 2010. The same countries increased their volume of imports by almost as much as they decreased their domestic production of pulp, to maintain their production of paper and paperboard.

**Effects on paper and paperboard**

The policy that progressively banned exports of industrial roundwood by 2010 led to a less than 1.5 percent increase in the world prices of paper and paperboard from 2006 to 2010 (Table 2). The impact was larger only on the price of newsprint, a minor product. Concurrently, world annual consumption (equal to production) and world trade of paper and paperboard was only 0.2 percent lower (Table 6). Production was higher in developing countries, and lower in developed countries. As a result, the trade balance for paper and paperboard of developing countries improved.

Production of paper and paperboard increased the most in China with a roundwood trade ban. The largest decrease of production occurred in Japan, which consequently increased its imports by nearly 70 percent. Other changes in production and trade were small.

**Effects on forest stock**

The global elimination of roundwood trade had a very small impact on the global level of forest stock, the standing volume of trees (Table 7). Nevertheless, the effect increased steadily from 2006 to 2010. The forest stock of developing countries declined, while that of developed countries increased by three times the volume of the decrease in developing countries.

The main increases in forest stock occurred in the Russian Federation, in Europe, and in Oceania, where especially New Zealand experienced a substantial relative change in growing stock due to the curtailment of its log exports.

TABLE 6 *Paper and paperboard changes in production and trade due to the progressive elimination of industrial roundwood exports*[1].

| | Production | | Imports | | Exports | |
|---|---|---|---|---|---|---|
| **Region** | **$10^3$t** | **%** | **$10^3$t** | **%** | **$10^3$t** | **%** |
| AFRICA[2] | 17 | 0.3 | -15 | -0.8 | 2 | 0.2 |
| NORTH & CENTRAL AMERICA | 235 | 0.2 | -40 | -0.2 | 276 | 0.9 |
| Canada | -7 | 1.0 | 0 | 0.0 | 274 | 1.5 |
| United States of America | -46 | 0.0 | -7 | -0.1 | 0 | 0.0 |
| SOUTH AMERICA | 29 | 0.2 | -50 | -1.9 | 13 | 0.9 |
| Brazil | -27 | -0.3 | 0 | 0.0 | 0 | 0.0 |
| ASIA | -991 | -0.8 | 637 | 1.8 | 239 | 2.1 |
| China | 871 | 1.7 | -1107 | -4.9 | 1 | 0.1 |
| Japan | -2047 | -6.1 | 1797 | 69.7 | 0 | -0.1 |
| Korea, Republic of | -246 | -1.6 | 0 | 0.1 | -208 | -4.2 |
| OCEANIA | 395 | 8.6 | -302 | -16.0 | 81 | 5.6 |
| New Zealand | 82 | 6.7 | -1 | -0.3 | 81 | 12.0 |
| EUROPE | -415 | -0.3 | -437 | -0.9 | -817 | -1.3 |
| EU-25 | -339 | -0.3 | -387 | -0.8 | -643 | -1.2 |
| Germany | 39 | 0.2 | -32 | -0.3 | 19 | 0.2 |
| Russia Federation | 47 | 0.5 | 0 | 0.0 | 1 | 0.0 |
| DEVELOPED, ALL | -1836 | -0.6 | 1045 | 1.5 | -460 | -0.5 |
| DEVELOPING, ALL | 1110 | 0.9 | -1252 | -3.1 | 253 | 2.0 |
| WORLD | -726 | -0.2 | -207 | -0.2 | -207 | -0.2 |

[1] Changes are average changes in annual production, imports, or exports, from 2006 to 2015, when world exports of industrial roundwood are reduced from their current level in 2006 to zero in 2010.

[2] Regions are defined as in FAO (2005).

The largest decrease in forest stock was in countries that currently import considerable amounts of logs but which were not able to continue doing so when the ban was in full force. In the Republic of Korea in particular, where industrial roundwood production increased considerably to compensate for lost roundwood imports (Table 1), forest stock was nearly 3 percent lower over the period considered. In Japan, the decrease in forest stock was even larger in absolute terms. Forest stock also declined in Canada, though less in relative terms.

**Effects on revenues, expenditures and value added**

Table 8 summarizes the effects of a policy curtailing the trade of industrial roundwood in terms of producer revenues and consumer expenditures. Producer revenues are the sum of the value of production of all the 14 products considered in the study, at local prices, in all 180 countries. Consumer expenditures are the sum of the value of consumption (production plus imports, minus exports), for the same products and countries. Consumer revenues and producer expenditures were computed in constant US$, with the purchasing power of 2002.

As a result of the progressive exclusion of log trade from 2006 to 2010, the annual consumer expenditures were on average about US$13 billion, or 2.2 percent, higher. The corresponding average producer revenues were about US$11 billion, or 1.9 percent higher. The difference between the change in world consumer expenditures and the change in world producer revenues is the change in transportation cost due to the changes in quantity traded.

The effects could be considerably larger in relative terms at the level of a country or region. With a ban on roundwood trade, producers in most countries obtained higher gross revenues. The exceptions were countries that are today major exporters of industrial roundwood. In particular, average annual producer revenues were US$3.4 billion, or 16 percent lower in the Russian Federation, and US$364 million (10 percent) lower in New Zealand. In these same countries, consumer expenditures were also lower with a ban on log trade, but only by 9 percent in the Russian Federation and by 6 percent in New Zealand.

In countries that are currently heavy importers of industrial roundwood, such as Japan and Republic of Korea, producer revenues increased by about 5 percent due to increased domestic production and prices. However, the relative increase in consumer expenditures in Japan and Korea was about double the increase in producer revenues.

Table 8 also shows the changes in value added in the entire forest sector due to the progressive elimination of exports. Value added is the value of all products, minus the cost of wood or fiber input. Thus, the value added in sawmilling is the value of the sawnwood minus the cost of the logs, and the value added in papermaking is the value of the paper minus the cost of the wood pulp. The value added in Table 8 is the total value added over all products. It shows that the main

TABLE 7 *Forest stock changes due to the progressive elimination of industrial roundwood exports.*

| Region/country | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | ----------$10^6 m^3$---------- | | | | | | | | | | % |
| AFRICA[1] | 0 | 2 | 5 | 9 | 16 | 24 | 31 | 38 | 45 | 52 | 0.0 |
| NORTH & CENTRAL AMERICA | 0 | -2 | -7 | -15 | -26 | -40 | -59 | -79 | -101 | -125 | -0.1 |
| Canada | 0 | -3 | -9 | -17 | -28 | -39 | -51 | -62 | -72 | -82 | -0.1 |
| United States of America | 0 | 1 | 2 | 3 | 2 | 0 | -6 | -15 | -27 | -40 | 0.0 |
| SOUTH AMERICA | 0 | 0 | 0 | 1 | 1 | 1 | 1 | -1 | -4 | -7 | 0.0 |
| Brazil | 0 | -1 | -2 | -3 | -5 | -8 | -11 | -14 | -19 | -24 | 0.0 |
| Asia | 0 | -8 | -24 | -44 | -73 | -109 | -141 | -169 | -195 | -218 | -0.2 |
| China | 0 | -2 | -7 | -12 | -21 | -33 | -44 | -54 | -65 | -76 | -0.2 |
| Japan | 0 | -5 | -15 | -28 | -44 | -65 | -81 | -95 | -106 | -113 | -1.2 |
| Korea, Republic of | 0 | -1 | -3 | -6 | -10 | -14 | -19 | -23 | -26 | -29 | -2.8 |
| OCEANIA | 0 | 5 | 15 | 30 | 51 | 76 | 100 | 125 | 150 | 175 | 0.5 |
| New Zealand | 0 | 2 | 6 | 11 | 18 | 28 | 37 | 46 | 55 | 65 | 2.1 |
| EUROPE | 0 | 7 | 20 | 40 | 68 | 105 | 143 | 185 | 231 | 279 | 0.1 |
| Germany | 0 | 1 | 4 | 7 | 11 | 17 | 22 | 28 | 33 | 39 | 0.5 |
| Russia Federation | 0 | 9 | 27 | 54 | 90 | 135 | 182 | 230 | 280 | 333 | 0.1 |
| DEVELOPED, ALL | 0 | 5 | 15 | 31 | 53 | 82 | 113 | 148 | 188 | 232 | 0.0 |
| DEVELOPING, ALL | 0 | -2 | -5 | -9 | -17 | -27 | -37 | -49 | -62 | -77 | 0.0 |
| WORLD | 0 | 3 | 10 | 22 | 37 | 55 | 76 | 99 | 126 | 155 | 0.0 |

[1] Regions are defined as in FAO (2005).

gains in value added would be in countries that currently export logs and that have efficient manufacturing, such as the United States, Europe, Canada, and New Zealand.

Although it is currently a large exporter of logs, the Russian Federation would not gain much value added, due to its inefficient industries. The countries that would lose the most value added would be those that currently manufacture wood products from imported roundwood, in particular China, Japan, and Republic of Korea. At the world level, the change in value added would be negligible.

This study investigated the impacts of a gradual reduction in world exports of industrial roundwood. We used the Global Forest Products Model to predict changes in the world forest sector from 2006 to 2015, with and without roundwood trade. The specific policy assumed that exports of industrial roundwood would be reduced progressively from their level in 2006 to a total ban in 2010.

With this policy, annual total producer revenues would decrease substantially in countries that are currently major exporters: an average of 16 percent from 2006 to 2015 in the Russian Federation, and 10 percent in New Zealand. But, producer revenues would rise in most countries: by 5 percent in Japan, Canada, and Republic of Korea. Annual total consumer expenditures for forest products would increase the most in relative terms in countries that are currently major importers of logs, such as Japan (11 percent) and Republic of Korea (10 percent).

TABLE 8 *Changes in producer revenues, consumer expenditures, and value added due to the progressive elimination of industrial roundwood exports*[1].

| | **Producer Revenues** | | **Consumer Expenditures** | | **Value added** | |
|---|---|---|---|---|---|---|
| Region | US$ $10^6$ | % | US$ $10^6$ | % | US$ $10^6$ | % |
| AFRICA | -304 | -1.2 | -64 | -0.2 | 126 | 3.3 |
| NORTH &CENTRAL AMERICA | 6797 | 3.7 | 3947 | 2.3 | 2357 | 2.5 |
| Canada | 2567 | 5.3 | 1225 | 4.2 | 294 | 1.5 |
| United States of America | 4100 | 3.3 | 2608 | 2.0 | 2038 | 2.9 |
| SOUTH AMERICA | 995 | 2.9 | 597 | 1.9 | 409 | 3.1 |
| Brazil | 802 | 3.6 | 473 | 2.3 | 201 | 2.8 |
| ASIA | 4661 | 2.8 | 7908 | 4.0 | -3803 | -3.9 |
| China | 61 | 0.1 | 1427 | 1.7 | -1459 | -4.0 |
| Japan | 1752 | 5.3 | 4160 | 10.8 | -2865 | -12.7 |
| Korea, Republic of | 536 | 4.9 | 1229 | 9.6 | -631 | -7.2 |
| OCEANIA | -1068 | -12.1 | -436 | -6.0 | 474 | 10.2 |
| New Zealand | -364 | -10.4 | -136 | -6.0 | 216 | 11.5 |
| EUROPE | 4188 | 3.3 | 2436 | 1.9 | 518 | 0.7 |
| Germany | 354 | 1.8 | 79 | 0.4 | 611 | 3.9 |
| Russian Federation | -3400 | -16.0 | -1352 | -9.3 | 43 | 0.6 |
| WORLD | 10780 | 1.9 | 12678 | 2.2 | 264 | 0.1 |

[1] Changes are average changes in annual revenues, expenditures, or value added, from 2006 to 2015, when world exports of industrial rounwood are reduced from their current level in 2006 to zero in 2010.
[2] Regions are defined as in FAO (2005).

## SUMMARY AND CONCLUSION

Invasive exotic insects and diseases are serious threats to indigenous and plantation forests around the world. Economic globalization and the attendant cargo trade increase the risk of exotic pest invasions across international borders. Wood in raw form, such as logs and pulpwood, is an especially important vector for the introduction of forest pests. Classical phytosanitary measures such as fumigation are, at best, imperfect and costly.

Yet, the raw wood trade is less than 7 percent of the total value of the trade in forest products. Should then one consider an international policy that would progressively ban altogether the trade of raw wood? To answer this question, it is helpful to evaluate the economic implications of such a policy.

However, the overall effect on world annual revenue of producers in all industries would be modest (1.9 percent), slightly lower than the increase of the world annual expenditures of consumers (2.2 percent). The effect on value added would be negligible at world level. However, value added would decrease substantially in countries that are currently major log importers (Japan, Republic of Korea, China, and Finland), while it would increase in countries with efficient industries and well endowed in forest resources (the

United States, Brazil, Germany, New Zealand).

These summary numbers, and the details for individual countries and industries, should be useful in deciding whether a policy that would progressively ban the trade of roundwood should be considered. Some countries would clearly be more affected than others, both economically through effects on producers and consumers, and ecologically, through effects on the forest stock. It is conceivable that an international system of compensation could be created that would alleviate the negative effects of a ban that would be experienced in some locations. Regardless, the monitoring of a ban on roundwood trade should be much easier to monitor and police than the rigorous treatment of logs at the port of departure.

A complete assessment of a roundwood trade ban should also take into account the catastrophic losses that may result from the introduction of exotic pests (USDA Forest Service 1991, Prestemon *et al*. 2006). It is possible that the cost of trade and production disruptions reported in this paper would be dwarfed by the ecological and economic cost of exotic pest invasions.

The full social impacts of the trade restriction measures discussed here would also need to be examined. In particular, China is now the leading importer of raw wood and a major exporter of manufactured wood products. China's trading position in forest products is partly the result of a policy to 'encourage the development of industries and enterprises that can provide large number of jobs' (Liu 2005). Thus, measures to restrict raw wood imports would be strongly resisted in China on social grounds. The situation may be similar in other countries, such as Vietnam and South Korea.

In terms of forest production, it is uncertain whether the wood from domestic plantations would be adequate to take the place of imported roundwood. For example, although growing stock is plentiful in Japan, it is not sure whether the changes in production implied by this analysis would be feasible because of environmental constraints. Nevertheless, once they are known such constraints can be directly taken into account, and their impact predicted with the GFPM model. The present calculations are therefore just one, though important element, in a full benefit-cost analysis of such a policy, which should be the objective of future research.

## ACKNOWLEDGMENTS

The research leading to this paper was supported in parts by the USDA Forest Service, Southern Forest Experiment Station, USDA-CREES NRI grant 2003-35400-13816, the PREISM program of the USDA Economic Research Service, the School of Natural Resources, University of Wisconsin, Madison, and by Scion (New Zealand Forest Research Institute Ltd.). We are grateful to two anonymous reviewers for their helpful suggestions.

## REFERENCES

AHO, P.E. and CAHILL, J.M. 1984. Deterioration rates of blowndown timber and potential problems associated with product recovery. Gen. Tech. Rept. PNW-167. USDA Forest Serv., Pacific Northwest Forest and Range Expt. Sta., Portland, Oregon. 11p.

BRASIER, C.M. 1991. Ophiostoma novo-ulmi sp. nov., causative agent of current Dutch elm disease pandemics. Mycopathologia 115(3):151-161.

Buongiorno, J., Zhu, S., Zhang, D., Turner, J. and Tomberlin, D. 2003. The Global Forest Products Model: Structure, Estimation and Applications. Academic Press, San Diego. 301p.

CHILDS, T.W. and CLARK, J. 1953. Decay of windthrown timber in western Washington and northwestern Oregon. Forest Pathology Special Release No. 40. USDA Div. of Forest Pathology, Beltsville, Md. 20 p.

COLLINS, K. 1999. Market Opportunities for Australia's Plantation Resource. World Forest Institute, Portland, OR. http://www.fwprdc.org.au/Content/PDFS/WFI%20Market%20Opportunities%20for%20Australia's%20Plantation%20Resource.pdf (Accessed 24 October 2006).

FAO 2005. FAO yearbook, forest products 1998-2003. Food and Agriculture Organization of the United Nations, Rome, Italy. 243pp.

FURNISS, R.L. and CAROLIN, V.M. 1977. Western Forest Insects. Misc. Publ. 1339. USDA Forest Service. Washington, D.C. 654 pp.

HAYSOM, K.A. and MURPHY, S.T. 2003. The status of invasiveness of forest tree species outside their natural habitat: a global view and discussion paper. Department of Forestry, Food and Agriculture Organization of the United Nations, Rome, Italy. 80p.

HUMPHREY, C.J. 1920. The decay of ties in storage. Proceedings of the American wood-Preservers Association 16:217-233.

LIEBHOLD, A.M., MACDONALD, W.L., BERGDAHL, D. and MASTRO, V.C. 1995. Invasion by exotic pests: a threat to forest ecosystems. Forest Science Monograph No. 30. 49 p.

LIU, Y. 2005. Employment situation and employment policies in China. Ministry of Labor and Social Security (www.jil.go.jp/foreign/countryreport/pdf/200311/china_report_liu_pdf.pdf)

LOWELL, E.C., WILLITS, S.A. and KRAHMER, R.L. 1992. Deterioration of fire-killed and fire-damaged timber in the western United States. Gen. Tech. Report PNW-GTR-292. USDA Forest Service., Pacific Northwest Research Station, Portland, OR. 27 p.

MARGOLIS, M., SHOGREN, J. F. and FISCHER, C. 2005. How trade politics affect invasive species control. Ecological Economics 52(3):305-313.

MORRELL, J.J. 1995. Importation of unprocessed logs into North America: A review of pest mitigation procedures and their efficacy. Forest Products Journal 45(9):41-50.

NEW ZEALAND FOREST RESEARCH INSTITUTE 1999. Study of Non-Tariff Measures in the Forest Products

Sector. Report prepared for the APEC Secretariat by the New Zealand Forest Research Institute Ltd., Rotorua, New Zealand. 134p.

PIMENTEL, D., LACH, L. ZUNIGA, R. and MORRISON, D. 2000. Environmental and economic costs of nonindigenous species in the United States. Bioscience 50:53-65.

POST, K.E. and WERMER, R.A. 1988. Wood borer distribution and damage in decked white spruce logs. Northern Journal of Applied Forestry 5:49-51.

PRESTEMON, J.P., ZHU, S. TURNER, J.A. BUONGIORNO, J. and LI, R. 2006. The forest product trade impacts of an invasive species: modeling structure and intervention tradeoffs. Agricultural and Resource Economics Review 35(1):128-143.

PRYBYLOWICZ, P.R., KROPP, B.R, CORDEN, M.E. and GRAHAM, R.D. 1987. Colonization of Douglas-fir poles by decay fungi during air-seasoning. Forest Products Journal 37(4):17-23.

RICHMOND, H.A., and NIJHOT, W.W. 1972. Water misting for log protection from ambrosia beetles in B.C. Environment Canada, Forestry Service, Pacific Forest Research Centre Information Publication P-4-72. 34 p.

TURNER, J.A., BUONGIORNO, J., ZHU, S. and LI, R. 2005a. Using the Global Forest Products Model (GFPM version 2005). Staff Paper Series #56. Department of Forestry, School of Natural Resources, College of Agricultural and Life Sciences, University of Wisconsin-Madison. 38p.

TURNER, J.A., BUONGIORNO, J., ZHU, S. and LI, R. 2005b. Calibrating the Global Forest Products Model (GFPM). Staff Paper Series #57. Department of Forestry, School of Natural Resources, College of Agricultural and Life Sciences, University of Wisconsin-Madison. 55p.

TURNER, J.A., BUONGIORNO, J. and ZHU, S. 2006a. An economic model of international wood supply, forest stock, and forest area change. Scandinavian Journal of Forest Research 21:73-86.

TURNER, J.A., BUONGIORNO, J. MAPLESDEN, F., ZHU, S., BATES, S. and LI, R. 2006b. World Wood Industries Outlook: 2005-2030. Forest Research Bulletin 230. Ensis, Rotorua, New Zealand. 84 p.

UNITED NATIONS ENVIRONMENT PROGRAM (UNEP). 2000. Montreal Protocol on Substances that Deplete the Ozone Layer. Secretariat for the Vienna Convention for Protection of the Ozone Layer and the Montreal Protocol on Substances that Deplete the Ozone Layer. United Nations Environment Programme, Nairobi, Kenya. http://ozone.unep.org/pdfs/Montreal-Protocol2000.pdf (Accessed 24 October 2006).

USDA FOREST SERVICE. 1991. Pest Risk Assessment of the Importation of Larch from Siberia and the Soviet Far East. USDA Forest Service Miscellaneous Publication 1495, Washington, DC. 263p.

ZAHRA, A.R. and DICKINSON, D.I. 1989. Pretreatment decay in air-seasoning Scots and Corsican pine poles in England. Doc. No. IRG/WP/1390. International Research Group on Wood Preservation, Stockholm, Sweden. 10 p.