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An assessment of gains and losses from international trade in the forest sector

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ABSTRACT

The importance of international trade for the welfare of actors in the forest sector was estimated by comparing the current state of the world with a world in pure autarky with zero imports and exports of roundwood and manufactured wood products. The analysis was done with a comparative statics application of the Global Forest Products Model. The model was first calibrated to replicate observations in the base year 2013, and then solved under autarky conditions. The results showed much variation in the effects of international trade on production, consumption, and prices across countries and sub sectors. Globally international trade did have a positive effect on the economic welfare of the sector. This was due mostly to the positive effect on the surplus of consumers, and to a lesser extent on the increase in value added in forest industries. But value added profited manufacturers in developed countries much more than in developing. Furthermore, while wood producers in developed countries increased their profits with trade, those in developing countries incurred heavy losses that negated any incentive to invest in forest conservation, management and new plantations.

1. Introduction

The international trade in forest products was $US 230 billion in 2015 (FAO, 2016). Some recent initiatives aim at further stimulating this and other trade with international agreements such as the Transatlantic Trade and Investment Partnership or TTIP (USTR, 2016a) and the Trans-Pacific Partnership or TPP (USTR, 2016b). On the other hand, the forest products industry is mired by a collection of bilateral and multilateral trade agreements, many of which employ protectionist policies aimed, not at promoting economic welfare, but at enhancing the interests of specific groups.

Current political movements go further by favoring strong protectionist policies akin to mercantilism, with the potential dismantling of common markets and trade agreements, as reflected by the Brexit referendum of 2016, the contemporary election of Donald Trump in the United States, and the rise of nationalist sentiment in continental Europe. Much of the economic theory argues that the advantages of specialization, and the resulting gains from unrestricted free trade, lead to improved economic welfare (Samuelson, 1962). But, even Samuelson (1964) admits that protectionist measures may be justified in some places and times, and Keynes (1936) recognizes some "element of scientific truth in mercantilist doctrine" to stimulate domestic production. Within the current social climate this controversy of free trade vs protectionism is magnified. And, in the special case of the global forest products industry, it leads to question whether international trade always improves the welfare of participants, or if there are benefits and costs, how are they distributed?

One can refer back to 1776 and 1817, which respectively mark the publications of Adam Smith's (1986 [1776]) *Wealth of Nations* and David Ricardo's (1951) *Principles of Economics*, to find the original theory that supports free trade. They argue that countries should specialize in the production of goods with which they had comparative advantages in terms of labor hours used per unit of output, and that this would benefit all trading countries. The Heckscher-Ohlin model (Feenstra, 2004 p. 31–63) furthers this reasoning by including factor endowments (such as forest resources) to determine the optimal trade between regions.

Despite overall gains from trade, Samuelson and Stolper (1941) show the possibility of unequal distributional effects as suppliers of the relatively abundant factors gain, while those of a relatively scarce factor lose. Still, Samuelson (1962) argues that trade leads to higher social economic welfare and the gains to the winners could offset the losses to the losers. But this assumes that such a distribution does indeed occur, else "With employment less than full and Net National Product suboptimal, all the debunked mercantilistic arguments turn out to be valid. Tariffs can then reduce unemployment, can add to the NNP, and increase the total of real wages earned" (Samuelson, 1964). At a more micro level, parallel arguments are being made for "Provision for

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limited, time-bound protection of new industries by countries in the early stages of industrialization" (Zedillo et al., 2001, p. 8) to stimulate the growth of domestic infant industries.

For the forest sector, there is a large literature on trade issues. The most relevant for the present study focuses on multilateral agreements promoting free trade, such as the removal of the Canadian-U.S. Softwood Lumber Agreement (van Kooten and Johnston, 2014; Parajuli and Zhang, 2016), and the introduction of the North American Free Trade Agreement (Prestemon and Buongiomo 1996; Prestemon 1997) and of the Free Trade Area of the Americas (Turner et al., 2005). A common message is that trade liberalization among groups of countries leads to improved economic welfare, although they are associated with varying distributional effects. In the particular case of the TTIP, Buongiorno et al. (2014) find that implementation of the treaty would increase economic welfare (defined as the sum of producers and consumers surplus) in the United States and the European Union, but decrease it in Asia. For the TTP, the main total welfare gains would be in the United States and Vietnam and the greatest losses in China and Korea (Buongiorno and Zhu, 2016). Others find similar mixed effects of the removal of trade restrictions like the log export ban in Russia (van Kooten and Johnston, 2014), or in Pacific-rim countries (Perez-Garcia et al., 1997). While few economists would argue against trade liberalization, the creation of free trade zones may have perverse economic outcomes by hurting countries outside the agreements, as well as encouraging protectionist policies against countries covered in the free trading blocs (Krugman, 1991).

The objective of this study was to estimate the economic impacts of trade in the forest sector, globally and by country and sub-sector. To that end, a global forest products model was used to simulate the sector, with and without trade, by comparing the global pattern of production, consumption and trade observed in 2013 to a counter factual world in autarky. The results suggest that international trade had a positive effect on the global economic welfare of the sector, mostly attributable to the benefits that accrued to consumers through lower prices and increased consumption. To a lesser extent, value added increased in forest industries, but these benefits flowed to manufacturers in developed countries much more than in developing. Furthermore, while wood producers in developed countries increased their profits with trade, those in developing countries were clear losers, discouraging investments in forest conservation, management and new plantations.

2. Materials and methods

2.1. Theory

The theoretical framework underlying the study is shown in Fig. 1. It symbolizes the demand and supply of a single commodity in a world consisting of two countries. The downward sloping demand curve and the upward sloping supply curves are different in the two countries, depending on the utility of the commodity and the cost of production. Without trade (i.e. autarky) country 1 would produce and consume the quantity C_1 at autarky price P_1, and country 2 would consume the quantity C_2 at a higher autarky price, P_2.

The difference in autarky prices, greater than the transportation cost in this example, motivates trade, leading to exports from country 1 with the lower autarky price and imports from country 2. trade results in a new equilibrium, where the price in country 1 rises from P_1 to P_1', and the price in country 2 falls from P_2 to P_2', such that the difference between P_2' and P_1' corresponds to the cost of transportation (and tariff cost if any).

Due to the domestic price increase induced by trade, country 1 increases production to S_1', and reduces consumption to C_1', leading to excess supply equal to S_1'-C_1'. Consistently, due to its lower domestic price, country 2 reduces production to S_2' and raises consumption to C_2', leading to excess demand equal to C_2'-S_2'. An equilibrium is achieved whereby country 1 is a net exporter of S_1'-C_1' units, and country 2 is a net importer of an equal amount, C_2'-S_2' units.

As consumers in net exporting country 1 face a higher price and lower consumption due to trade, they experience a decrease in welfare equal to the change in the value of their consumption, symbolized by the change in the area under the demand curve of country 1 due to trade, given by area P_1,P_1',A_1,D_1. Meanwhile, producers in country 1 experience a welfare increase equal to the profits due to higher price and increased production induced by trade. In Fig. 1 this welfare increase of producers in country 1 is represented by area P_1, P_1', B_1, D_1. For country 1 then, the net welfare change or "net social pay-off" (Samuelson, 1952) due to trade is the sum of the welfare change of consumers (negative) and of the welfare change of producers (positive), equal to the area A_1,B_1,D_1. In the net importing country 2 trade also leads to an increase in net social welfare, but for symmetric reasons, an increase in the welfare of consumers concurrent with lower domestic price and equal to the area P_2, D_2, A_2, P_2', and a decrease in the welfare of producers equal to the area P_2, D_2, B_2, P_2', still giving a net gain in social welfare equal to the area A_2, B_2, D_2.

In sum, market equilibrium theory suggests that international trade does lead to a global increase in social welfare measured by the sum of consumer and producer surplus. But there are winners and losers; consumers are likely to benefit from trade (and producers to lose) in countries and sectors with high relative autarky prices, while consumers are likely to lose (and producers to benefit) in countries and sectors with low relative autarky prices.

Fig. 1 also implies a negative correlation between relative autarky price differences and net trade (export-import). Countries where autarky prices are low relative to others, such as country 1 in Fig. 1, have an incentive to seek foreign markets to benefit from their competitive advantage and thus increase their exports. Symmetrically, countries with high relative autarky prices, such as country 2 in Fig. 1, have an incentive to substitute lower cost imports for expensive domestic products.

The total impact of trade on the global forest sector was estimated by calculating the changes in production, consumption, and prices, and the attendant changes in consumer and producer surplus in each country and sub sector (logging, sawmilling, pulping, etc.…), with and without trade (Varian, 1992, p. 222–224). Although Fig. 1 presents the essence of the theory, its implementation required a more detailed and realistic model of the world forest economy based on actual data.

2.2. The global forest products model

To estimate quantitatively the effects sketched in Fig. 1 we used the Global Forest Products Model (GFPM), described originally in Buongiorno et al. (2003).[1] The GFPM represents the demand, supply, and trade of fourteen commodity groups in 180 countries. The model computes the market equilibrium for all products in any given year and simulates the evolution of this equilibrium from one year to the next to project the future state of the sector. However, in this application we used only the static part of the model, to represent the equilibrium in 2013 with and without international trade. Following Samuelson (1952), the equilibrium was computed by maximizing the sum of the consumers and producers surplus for all products and countries:

$$\max\left(\sum_{i,k}\int_0^{D_{i,k}} P_{ik}(D_{ik})dD_{ik} - \sum_{i,k}\int_0^{D_{i,k}} P_{ik}(S_{ik})dS_{ik} - \sum_{i,k}\int_0^{D_{i,k}} m_{ik}(Y_{ik})dD_{ik} - \sum_{i,j,k} c_{ijk}T_{ijk}\right) \quad (1)$$

[1] The 2016 version of the GFPM, including the software, documentation, and data base are available freely for research purpose at: http://labs.russell.wisc.edu/buongiorno/welcome/gfpm/.

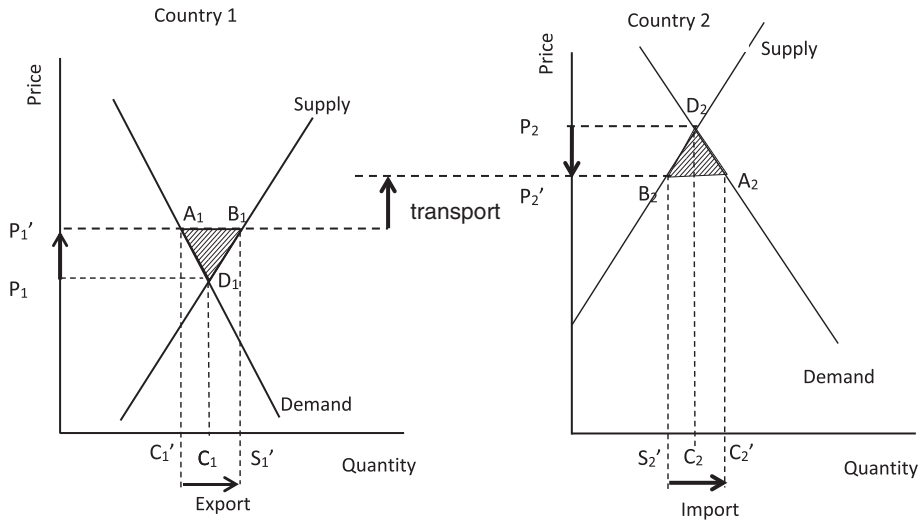

Fig. 1. Effect of trade on the production, consumption, and price of one commodity in two countries. The dashed areas show the net gain in social welfare, sum of change of consumers' and producers' surplus, due to the trade.

where i and j refer to countries, k to products, P is the price, D is the end-product demand, S the raw material supply, Y the manufactured quantity at marginal cost m, and T is the quantity transported at cost c, including tariff and taxes. Thus, the first integral measures the value of the end products to consumers, the second and the third the cost of production, and the last part is the transport cost. The optimization was done subject to the following demand-supply equilibrium constraint for each country and product:

$$\sum_j T_{jik} + S_{ik} + Y_{ik} = D_{ik} + \sum_n a_{ikn} Y_{in} + \sum_j T_{ijk} \qquad \forall\ i,\ k \tag{2}$$

where a_{ikn} was the input of product k per unit of product n. The left part of the equation was the sum of the imports, domestic supply, and manufactured quantity of a product in a country, while the right part was the sum of the domestic demand for the end products, the demand for input in manufacturing other products, and the exports to other countries. The primal solution of this constrained optimization gave the quantities consumed, produced, and traded, while the dual solution gave the equilibrium price for each product and country.

For this study the model was re-calibrated for the base year 2013 following the procedure described in Buongiorno et al. (2003) to obtain input-output coefficients, and manufacturing and transport costs. The data on production, imports, exports, and prices were from the FAOSTAT database (FAO 2016). The elasticities of wood supply were obtained from Turner et al. (2006), and the demand elasticities of the end products are in Buongiorno (2015). According to the calibration procedure, the GFPM solution for 2013 closely replicated the observations for the same year on production, consumption, price, and net trade.

After finding the equilibrium solutions with and without trade, the data were used to compute the consumer surplus for all end products (fuelwood, sawnwood, panels, paper and paperboard) by summing the area under the demand curves up to the consumed quantity and subtracting the cost of the products at the equilibrium price. The producer surplus of the suppliers of raw materials (roundwood, waste paper, other fiber pulp) was computed by subtracting the cost of production, the area under the supply curves up to the quantity produced, from the producer revenues: the equilibrium price times the quantity produced. The producer surplus in manufacturing, the transformation of raw materials and intermediate products (wood pulp) into end products, was computed by first estimating the value added, the value of production minus the cost of raw material and intermediate products, and then subtracting the cost of other inputs (labor, capital, and other materials) from the value added. The minor government revenues arising from import tariffs were calculated from the imports under current conditions, the import costs and the tariff rates. The final social surplus was the total consumer surplus plus government revenues and minus the producer surplus (of raw material suppliers and manufacturers).

2.3. Autarky conditions

Global autarky in the forest sector was simulated by constraining all the trade flows to zero in Eqs. (1) and (2) above. Tables 1 and 2 show, for the main world regions and selected countries, the magnitude of these imports and exports for main product aggregates, and their importance relative to domestic consumption and production. The larger the ratio of import to consumption and/or export to production, the larger was the expected effect of international trade compared to a regime of pure autarky.

For industrial roundwood (logs and pulpwood), Table 1, the global trade in 2013 was approximately 200 million m^3, or 11% of global consumption. Asia was the main importing region, importing 23% of its consumption, and as much as 54% to 55% in Japan and Korea. Europe, and especially the EU-28 countries were the other major importers, with Italy importing 68% of its domestic consumption and Austria 48%. Europe was also by far the main exporter of industrial roundwood, a large part of it coming from Russia which exported 12% of its domestic production, while France and Spain exported approximately 25% of it. The second largest exporter was Oceania where Australia and New Zealand in particular exported 50% to 60% of their production. The United States was also an important exporter, although its exports represented only 6% of production.

The global trade of sawnwood and wood-based panels, was of similar magnitude as the trade of industrial roundwood, near 200 million m^3 in 2013 (Table 1). Asia was the main importing region where China imported nearly 29 million m^3, 11% of its consumption, followed by Japan which imported 46% of it. Europe, and especially the EU was the second largest importing region where the United Kingdom and Italy were the major countries importing respectively 59% and 66% of their domestic consumption. In North America, the United States was the main importer of sawnwood and panels, importing 23% of its needs. Africa as a whole imported 56% of its consumption, and Egypt imported nearly all that it used. Europe was the main exporter of sawnwood and wood-based panels, with Russia the largest individual country, exporting 53% of production, followed by Germany which exported 38%.

Table 1
Solid wood import (I) and export (E), and share of consumption (C), production (Q) in 2013.

	Industrial roundwood				Sawnwood and panels			
	I 1000 m^3	I/C %	E 1000 m^3	E/Q %	I 1000 m^3	I/C %	E 1000 m^3	E/Q %
Africa	**426**	1	**6116**	9	**11,992**	**56**	**2782**	**23**
Egypt	100	28	16	6	5167	99	14	20
Nigeria	1	0	130	1	323	13	7	0
South Africa	21	0	1924	13	508	17	91	4
N/C America	**9688**	2	**28,654**	6	**37,451**	**24**	**43,652**	**27**
Canada	8305	6	8186	6	3859	16	34,392	63
Mexico	30	1	34	1	2936	44	54	1
United States	1153	0	20,041	6	29,332	23	9014	9
S America	**148**	0	**10,766**	5	**1707**	**4**	**8756**	**18**
Argentina	1	0	37	0	85	2	396	8
Brazil	68	0	5085	4	174	1	3125	12
Chile	1	0	3747	9	335	5	3693	36
Asia	**106,254**	23	**30,866**	8	**76,088**	**20**	**36,359**	**11**
China	62,652	27	126	0	28,546	11	14,414	6
India	6856	12	6	0	1130	10	153	2
Indonesia	87	0	2631	4	1048	14	4275	39
Japan	24,180	54	267	1	12,507	46	97	1
Korea, Rep.	5199	55	11	0	4303	44	103	2
Malaysia	30	0	3697	22	1025	19	7194	63
Oceania	**72**	0	**34,365**	58	**1450**	**14**	**3420**	**28**
Australia	6	0	11,414	51	1206	17	439	7
New Zealand	4	0	17,305	58	125	4	2866	50
Europe	**78,374**	15	**88,489**	16	**67,244**	**38**	**109,790**	**50**
EU-28	76,098	21	54,005	16	58,899	43	78,613	50
Austria	10,429	48	1352	11	2749	42	7872	67
Finland	10,251	18	1152	2	722	17	8191	69
France	2437	12	6059	25	4694	33	3823	29
Germany	11,825	25	6026	14	9626	31	12,679	38
Italy	4541	68	213	9	7036	66	1252	26
Russian Fed.	42	0	21,992	12	3091	12	24,571	53
Spain	2585	22	2912	24	1747	38	1996	42
Sweden	9415	13	950	1	1373	21	11,709	69
United Kingdom	601	7	1113	12	8482	59	599	9
Developed	**112,549**	10	**147,627**	13	**123,877**	**33**	**156,791**	**39**
Developing	**82,413**	12	**51,629**	8	**72,055**	**18**	**47,968**	**13**
World[a]	**194,962**	11	**199,256**	11	**195,932**	**25**	**204,759**	**26**

[a] World import and export may differ due to errors, reporting lags or missing data.

Table 2
Pulp and paper import (I) and export (E), and share of consumption (C), production (Q) in 2013.

	Wood pulp				Paper and paperboard			
	I 1000 t	I/C %	E 1000 t	E/Q %	I 1000 t	I/C %	E 1000 t	E/Q %
Africa	**421**	**20**	**150**	**8**	**4545**	**60**	**635**	**18**
Egypt	24	37	0	0	1250	67	50	8
Nigeria	20	48	1	4	513	96	0	0
South Africa	125	8	125	8	696	27	448	19
N/C America	**6482**	**12**	**16,412**	**25**	**17,386**	**20**	**20,736**	**23**
Canada	251	3	9110	53	2637	47	8233	74
Mexico	837	85	0	0	3178	41	233	5
United States	5342	12	7301	15	9767	14	12,121	16
S America	**1040**	**13**	**15,422**	**69**	**4400**	**26**	**2722**	**18**
Argentina	123	18	197	26	778	41	102	8
Brazil	434	7	9430	63	1151	12	1749	17
Chile	21	3	4556	88	613	45	532	42
Asia	**25,032**	**51**	**4848**	**17**	**25,047**	**13**	**18,666**	**10**
China	15,640	63	45	0	4642	5	6759	6
India	805	28	2	0	2287	19	606	6
Indonesia	1113	28	3744	56	580	8	3940	38
Japan	1631	16	426	5	2133	8	1117	4
Korea, Rep.	2364	81	13	2	927	10	3343	28
Malaysia	138	64	68	47	1577	48	324	16
Oceania	**284**	**12**	**885**	**30**	**1971**	**47**	**1652**	**42**
Australia	271	16	3	0	1483	43	1196	38
New Zealand	10	2	882	59	432	61	451	62
Europe	**19,269**	**41**	**15,887**	**36**	**52,955**	**58**	**66,308**	**63**
EU-28	18,746	46	13,632	38	48,779	61	61,207	66
Austria	642	34	308	20	1436	64	4026	83
Finland	404	5	2932	28	450	38	9865	93
France	2081	63	370	24	5008	57	4240	53
Germany	4518	76	1150	44	10,995	55	13,527	60
Italy	3467	91	35	9	4695	47	3260	38
Russian Fed.	141	3	1948	27	1614	24	2564	33
Spain	1108	60	1165	61	2822	43	2907	43
Sweden	403	5	2945	26	879	57	10,132	94
United Kingdom	1034	83	11	5	5866	63	1187	26
Developed	**27,055**	**23**	**33,736**	**28**	**71,131**	**35**	**90,015**	**40**
Developing	**25,473**	**52**	**19,868**	**46**	**35,173**	**19**	**20,704**	**12**
World[a]	**52,528**	**32**	**53,604**	**32**	**106,304**	**27**	**110,719**	**28**

[a] World import and export may differ due to errors, reporting lags or missing data.

Austria, Finland, and Sweden each exported more than 65% of their domestic output. North America was the second largest exporting region where Canada was the dominant actor, exporting 63% of its domestic production of sawnwood and panels. Asia was the third exporting region, with China exporting 14 million m^3, 6% of production. Although they exported less, Malaysia and Indonesia's export/production ratios stood at 39% and 63% respectively.

For wood pulp (mechanical, chemical, and semi-chemical), the global trade in 2013 was approximately 53 million t (metric tonne), representing 32% of global production and consumption (Table 2). Asia was the main importing region, where China imported 63% of its consumption, and Korea 81%. In Europe, the second importer, the largest share of imports was by EU-28 countries, where Germany imported 76% of its domestic consumption, Italy 91%, and France 63%. In North America the United States was the main importer and imports were 12% of consumption. In terms of pulp exports, North America, South America, and Europe exported nearly the same. Canada and Brazil were the largest single exporting countries. 53% of Canada's production was exported, 63% of Brazil's, and 88% of Chile's. Within Europe, the main exporters were Finland (28% of production), Sweden (26%), and Russia (27%).

The world trade of paper and paperboard (newsprint, printing and writing paper, other paper and paperboard) was approximately double of the wood pulp trade (Table 2), but its share of global production (27 to 28%) was smaller. Europe was by far the largest importer, with more than twice Asia's imports, mostly due to active imports within the EU. Germany alone imported 11 million m^3 of paper and paperboard, 55% of its domestic consumption. The United Kingdom, France and Italy were also large importers, importing respectively 63%, 57% and 47% of their needs. In Asia, the main importers were China (5% of consumption), India (19%), and Japan (8%). The United States which imported 14% of its consumption was the main importer in North America, but in Canada and Mexico imports represented a much larger share of consumption, more than 40%. In terms of exports of paper and paperboard, Europe, and mostly the EU-28, was the main region (Table 2). Within it, Germany, the largest importer was also the largest exporter, exporting 60% of its output. But the export/production ratio was even larger in Sweden (94%), Finland (93%) and Austria (83%). North America was the second largest exporting region, dominated by the United States and Canada, the latter exporting 74% of its production. Asia exported nearly as much paper and paperboard as North America, with China, Indonesia, and Korea the main countries, but China's exports were only 6% of its production.

In summary, on a global scale, imports and exports are a substantial part of the consumption and production of forest products. For some countries or products, most of the quantity consumed is imported. Thus, an autarky world should be quite different from that observed with

Table 3
Effects of international trade on industrial roundwood production, consumption, and price.

	Production		Consumption		Price	
	1000 m^3	%	1000 m^3	%	$/$m^3$	%
Africa	**3401**	**10**	**−2933**	**−8**		
Egypt	−1007	−88	−918	−80	−751	−85
Nigeria	−834	−13	−1017	−15	−12	−10
South Africa	920	7	−1268	−9	5	5
N/C America	**67,848**	**16**	**49,359**	**12**		
Canada	87,097	148	87,448	149	59	84
Mexico	−5654	−53	−5662	−53	−95	−47
United States	−13,236	−4	−31,964	−9	−3	−3
S America	**78,263**	64	**67,711**	56		
Argentina	1186	10	1026	9	8	8
Brazil	47,218	58	42,717	53	31	39
Chile	22,242	121	18,260	100	46	72
Asia	**−85,122**	**−18**	**−8296**	**−2**		
China	−74,623	−28	−12,933	−5	−102	−44
India	−12,504	−29	−5850	−13	−39	−23
Indonesia	28,203	95	25,498	86	41	59
Japan	−35,162	−64	−10,968	−20	−175	−58
Korea, Rep.	−10,155	−76	−5076	−38	−315	−71
Malaysia	9465	141	5812	87	49	81
Oceania	**36,330**	160	**2186**	10		
Australia	8162	54	−3835	−26	29	37
New Zealand	22,205	325	5839	85	64	140
Europe	**175,524**	**51**	**165,224**	**48**		
EU28	76,095	31	96,344	39		
Austria	430	4	8844	74	3	3
Finland	34,789	259	43,294	323	71	122
France	−4063	−14	−7145	−25	−14	−11
Germany	−7298	−15	−2424	−5	−18	−12
Italy	−8807	−84	−4451	−43	−526	−80
Russian Fed.	83,903	108	63,280	82	43	66
Spain	759	7	362	3	5	5
Sweden	43,994	218	53,589	265	67	110
United Kingdom	−5578	−39	−6126	−43	−54	−33
Developed	**243,978**	**29**	**209,579**	**25**		
Developing	**32,266**	**6**	**63,670**	**11**		
World[a]	**276,244**	**19**	**273,249**	**19**		

[a] World production may differ from world consumption due to differences between reported world imports and exports.

trade. However, one should not expect the change in production and consumption due to trade to be equal to the observed quantities exported or imported, due to price changes and attendant effects on demand and supply.

3. Results

The effects of international trade on production, consumption, and prices in the world forest sector were obtained by first solving the GFPM for 2013 while allowing for international trade. The GFPM was calibrated for the base year 2013, and consequently the solution replicated closely the observations on prices, consumption and production, and thus also on net trade, the difference between exports and imports in 2013. Then, the GFPM was solved again after constraining the international trade (Tables 1 and 2) to zero, while keeping other things equal. The difference between the solutions with trade and without gave a measure of the effect of international trade on the global forest sector in 2013, compared to a regime of pure autarky. Tables 3 to 7 summarize the effects of trade on production, consumption and prices for the main sub-sectors defined by product groups, by world region and selected countries. Table 8 summarizes the corresponding gain or losses in producer and consumer surplus, and the total contribution of international trade to global welfare within the forest sector.

Table 4
Effects of international trade on **sawnwood** production, consumption, and price.

Country	Production		Consumption		Price	
	1000 m^3	%	1000 m^3	%	$/$m^3$	%
Africa	**−31**	**0**	**7302**	**77**		
Egypt	−550	−98	3968	707	−1596	−84
Nigeria	103	5	37	2	−31	−10
South Africa	−232	−13	−14	−1	15	5
North/Central America	**10,190**	**10**	**−142**	**0**		
Canada	25,207	147	−1153	−7	118	74
Mexico	−1564	−38	272	7	−114	−27
United States	−13,197	−16	383	0	−8	−3
South America	**3664**	13	**−1113**	**−4**		
Argentina	38	1	−41	−1	20	8
Brazil	797	5	−667	−5	78	39
Chile	2150	39	−352	−6	112	67
ASIA	**−24,425**	**−18**	**19,345**	**14**		
China	−19,072	−23	5333	7	−112	−27
India	−29	0	377	5	−94	−23
Indonesia	527	14	−219	−6	103	59
Japan	−4731	−32	2167	15	−233	−43
Korea, Rep.	−1014	−31	756	23	−342	−52
Malaysia	1621	58	−94	−3	57	26
Oceania	**1430**	19	**−170**	−2		
Australia	−462	−9	−90	−2	33	12
New Zealand	1795	82	−120	−5	95	51
Europe	**40,816**	**40**	**2123**	**2**		
EU28	17,926	22	2930	4		
Austria	3176	58	−27	−1	8	3
Finland	6393	161	−340	−9	153	122
France	−1460	−16	110	1	−21	−6
Germany	2747	15	197	1	−17	−6
Italy	−2595	−65	1855	47	−585	−65
Russian Fed.	20,981	166	−798	−6	111	66
Spain	−716	−27	−2	0	2	0
Sweden	11,109	191	−473	−8	146	109
United Kingdom	−5116	−59	421	5	−85	−21
Developed	**48,767**	**21**	**8726**	**4**		
Developing	**−17,123**	**−11**	**18,617**	**11**		
World[a]	**31,644**	**8**	**27,344**	**7**		

[a] World production may differ from world consumption due to differences between reported world imports and exports.

3.1. Effects on industrial roundwood markets

As shown in Table 3, the world production and consumption of industrial roundwood was 19% higher with trade than without it. The main differences were in developed countries where production and consumption were 25% to 30% higher with trade. In Europe, trade increased production and consumption by approximately 50%, in large part due to Russia where production more than doubled with trade and consumption increased by 82%. Major trade- induced increases in Production and consumption took also place in North America where in Canada production and consumption increased by nearly 150%. Production and consumption in South America also benefited from trade, by more than 100% in Chile and more than 50% in Brazil. In Oceania, production increased by 160%. In Asia instead, production was 18% lower with trade and consumption was 2% lower. This was due mostly to lower production and consumption in China, Japan, India, and Korea. However, there was more production and consumption of industrial roundwood in Indonesia (+95% production) and Malaysia (+141% production).

As expected from theory, the changes in production due to trade were always of the same sign as the price changes. For example, the price of industrial roundwood in China was 44% lower with trade than it would have been under autarky, and production was 28% lower, while in Canada the price was 84% higher with trade and production was 148% higher. The relationship between price and consumption is less direct, as the demand for industrial roundwood derives from the demand from intermediate products (pulp) and end product (sawn-

Table 5
Effects of international trade on **wood-based panels** production, consumption, and price.

	Production		Consumption		Price	
	1000 m^3	%	1000 m^3	%	$/$m^3$	%
Africa	**−163**	**−5**	**1561**	**49**		
Egypt	−64	−52	703	574	−1623	−73
Nigeria	−150	−61	118	48	−144	−19
South Africa	−128	−11	−8	−1	5	1
N/C America	**−4366**	**−9**	**276**	**1**		
Canada	2540	28	−949	−10	88	25
Mexico	−633	−34	438	23	−204	−29
United States	−6200	−16	497	1	−10	−2
S America	**2176**	14	**−470**	**−3**		
Argentina	137	13	−20	−2	14	4
Brazil	1163	11	−654	−6	60	17
Chile	803	41	−174	−9	75	21
Asia	**32,753**	**18**	**27,792**	**15**		
China	25,685	17	14,307	10	−100	−17
India	−393	−11	283	8	−115	−17
Indonesia	2414	55	−280	−6	109	26
Japan	−1586	−25	3289	53	−304	−36
Korea, Rep.	663	25	3150	119	−413	−47
Malaysia	4137	163	−144	−6	79	18
Oceania	**197**	6	**−215**	−6		
Australia	−397	−20	−74	−4	29	7
New Zealand	600	48	−151	−12	122	29
Europe	**10,493**	**16**	**7297**	**11**		
EU28	11,313	24	8214	18		
Austria	1876	143	−29	−2	15	4
Finland	572	76	−90	−12	115	31
France	694	14	114	2	−17	−4
Germany	1016	9	509	5	−30	−7
Italy	2411	194	3888	313	−487	−54
Russian Fed.	−600	−4	−1143	−8	76	25
Spain	904	41	−39	−2	13	4
Sweden	−750	−53	73	5	106	37
United Kingdom	−729	−19	1751	47	−9	−2
Developed	**4663**	**4**	**12,207**	**10**		
Developing	**36,429**	**19**	**24,033**	**12**		
World[a]	**41,091**	**13**	**36,241**	**11**		

[a] World production may differ from world consumption due to differences between reported world imports and exports.

Table 6
Effects of international trade on **wood pulp** production, consumption, and price.

	Production		Consumption		Price	
	1000 m^3	%	1000 m^3	%	$/$m^3$	%
Africa	**−446**	**−20**	**−247**	**−11**		
Egypt	−49	−54	−18	−20	−2067	−77
Nigeria	−210	−90	−186	−80	−278	−29
South Africa	−87	−5	−128	−8	20	3
North/Central America	**13,658**	**26**	**3773**	**7**		
Canada	13,172	332	4291	108	155	47
Mexico	−1104	−89	−258	−21	−571	−47
United States of America	1567	3	−342	−1	−6	−1
South America	**14,810**	190	**317**	4		
Argentina	282	62	241	53	32	6
Brazil	9217	156	125	2	134	29
Chile	4397	585	−101	−13	129	32
Asia	**−16,306**	**−35**	**4399**	**9**		
China	−14,368	−61	1453	6	−213	−25
India	−1262	−29	−411	−9	−149	−20
Indonesia	4364	191	1906	83	160	36
Japan	−675	−7	612	6	−463	−42
Korea, Republic of	−1794	−76	523	22	−955	−60
Malaysia	−198	−53	−102	−27	88	16
Oceania	**−44**	−1	**−616**	−21		
Australia	−1011	−41	−738	−30	71	13
New Zealand	967	177	113	21	179	53
Europe	**16,929**	**58**	**20,171**	**69**		
EU28	13,959	60	18,973	82		
Austria	683	75	1054	116	12	2
Finland	9363	830	7022	622	234	69
France	−2092	−52	−507	−13	−81	−11
Germany	−2214	−46	1014	21	−84	−12
Italy	−2656	−87	693	23	−1651	−72
Russian Federation	2056	38	166	3	179	44
Spain	106	6	24	1	16	3
Sweden	9742	585	7111	427	234	73
United Kingdom	51	29	1084	614	−30	−5
Developed, all	**30,870**	**33**	**24,139**	**26**		
Developing, all	**−2270**	**−5**	**3659**	**8**		
World[a]	**28,600**	**20**	**27,798**	**20**		

[a] World production may differ from world consumption due to differences between reported world imports and exports.

wood, panels, paper) which shift the demand for industrial roundwood. As a result, for the countries in Table 3, with the exception of South Africa and Australia, the consumption of industrial roundwood changes with trade in the same direction as its price.

The results also confirmed the expectation of a negative correlation between the observed net trade and the autarky prices computed with the GFPM. For the countries in Table 3, the Spearman rank correlation (Stata, 2011, p. 2033) between industrial roundwood net trade and autarky prices was −0.46, with the expected sign and statistically significant at the 2% level (Fig. 2a).

3.2. Effects on sawnwood and wood-based panels markets

Table 4 shows the difference in production, consumption, and price of sawnwood due to international trade. With trade, the world production and consumption was 7 to 8% higher than without it. The main effect on production was in Europe where it was 40% higher with trade, with especially large increases in Russia (166%), Sweden (191%) and Finland (161%). On the other hand, consumption in Europe was only 2% higher with trade, the main impact being in Italy (47% increase). With trade, sawnwood production was also higher in North America, 147% in Canada, but consumption was hardly different in the region as consumption in the United States was unchanged by trade. In Asia as a whole, there were almost opposite effects of trade on production and consumption. Production decreased by 18% (23% in China and 32% in Japan), while Asian consumption increased by 14% (7% in China and 15% in Japan). As sawnwood is a final product in the GFPM, there was a direct inverse relation between consumption and price, expected from demand theory and verified in Table 4. For example to the 27% lower price in China induced by trade corresponded a 7% increase in consumption, while the 59% higher price in Indonesia was matched by a 6% lower consumption. Like for industrial roundwood, there was as expected from theory, a significant negative correlation across countries between the observed net trade and the computed autarky prices, with $R_s = -0.88$, statistically significant at least at the 1% level (Fig. 2b).

For wood-based panels (veneer and plywood, particleboard, fiberboard), the world production and consumption of wood-based panels was 11% to 13% higher with international trade than it would have been in autarky (Table 5). As expected, since wood-based panels are end products in the GFPM, the changes in national consumption had the opposite sign of the price changes, with the exception of Sweden due to the aggregation of plywood, particleboard and fiberboard into wood-based panels and their price computed as the consumption-weighted average of the components. International trade raised the consumption of wood-based panels in all world regions, except in South America where it decreased by 3%. The largest increases in national consumption were in China, Italy and Japan. On the production side, there were large increases in wood-based panels in Asia (18%), especially in China and in Indonesia, and in Europe (16%), especially Italy, Austria and Germany. But international trade lowered production in North America by 9% and by 16% in the United States alone. In accord with expectations, the observed net trade of wood-based panels tended to

Table 7
Effects of international trade on **paper and paperboard** production, consumption, and price.

Country	Production		Consumption		Price	
	1000 t	%	1000 t	%	$/t	%
Africa	**−653**	**−15**	**3300**	**77**		
Egypt	−340	−34	802	80	−631	−35
Nigeria	−166	−78	285	135	−985	−47
South Africa	−222	−9	3	0	−2	0
N/C America	**5038**	**6**	**1586**	**2**		
Canada	5192	89	−345	−6	139	17
Mexico	−1923	−28	951	14	−286	−21
United States of America	1607	2	−823	−1	24	3
S America	**823**	6	**2519**	18		
Argentina	456	61	1104	147	29	3
Brazil	202	2	−348	−3	74	8
Chile	10	1	58	5	−25	−3
Asia	**16,827**	**10**	**23,984**	**15**		
China	7254	7	5364	5	−109	−10
India	−653	−6	992	9	−185	−16
Indonesia	5365	110	2000	41	21	2
Japan	847	3	1905	8	−144	−13
Korea, Republic of	3599	45	1256	16	−272	−22
Malaysia	−988	−33	214	7	−145	−13
Oceania	**−315**	−7	**122**	3		
Australia	−455	−13	−55	−2	44	5
New Zealand	130	20	115	18	174	22
Europe	**33,279**	**46**	**20,457**	**29**		
EU28	29,593	47	17,690	28		
Austria	2931	149	245	12	−218	−19
Finland	9261	682	−126	−9	231	31
France	−622	−7	147	2	−27	−3
Germany	2641	13	201	1	−22	−2
Italy	1604	23	3125	44	−686	−41
Russian Federation	680	10	−334	−5	116	14
Spain	68	1	99	2	−30	−3
Sweden	8833	432	−175	−9	235	35
United Kingdom	1111	34	5928	179	−265	−21
Developed, all	**40,880**	**22**	**22,664**	**12**		
Developing, all	**14,119**	**9**	**29,304**	**18**		
World[a]	**54,999**	**16**	**51,968**	**15**		

[a] World production may differ from world consumption due to differences between reported world imports and exports.

Table 8
Effects of international trade on the surplus of end-product consumers and wood and fiber suppliers, and value added in manufacturing.

	Consumer surplus		Supplier surplus		Value added	
	Million $	%	Million $	%	Million $	%
Africa	**14,356**	**8**	**−4792**	**−8**	**−1331**	**−24**
Egypt	5974	109	−2181	−58	−840	−60
Nigeria	567	3	−221	−4	−393	−89
South Africa	−16	0	141	5	−239	−12
N/C America	**1867**	**1**	**18,694**	**26**	**1526**	**2**
Canada	−3496	−12	18,694	441	5181	80
Mexico	2984	14	−4526	−51	−3211	−41
United States	−695	0	4875	9	−450	−1
South America	**323**	**0**	**14,981**	**57**	**4080**	**29**
Argentina	1225	23	596	34	230	29
Brazil	−2473	−4	9589	56	2132	24
Chile	−673	−6	4033	173	1574	98
Asia	**89,469**	**14**	**−113,917**	**−31**	**6910**	**3**
China	35,334	11	−84,387	−34	2602	2
India	3196	3	−7212	−17	−318	−6
Indonesia	898	3	5819	83	4545	103
Japan	10,106	16	−17,376	−67	−1086	−5
Korea, Rep.	5615	33	−7335	−71	1557	22
Malaysia	102	1	898	48	1100	28
Oceania	**−583**	**−3**	**6556**	**260**	**−4**	**0**
Australia	−382	−3	2265	128	−747	−18
New Zealand	−302	−8	3497	1725	734	66
Europe	**35,109**	**12**	**22,607**	**28**	**17,921**	**23**
EU-28	**34,886**	**15**	**3809**	**6**	**15,123**	**22**
Austria	468	5	−571	−17	2685	134
Finland	−970	−12	6802	630	6811	675
France	518	2	−403	−5	−1629	−17
Germany	1206	2	−2619	−18	1542	8
Italy	10,892	73	−8768	−78	−2381	−26
Russian Fed.	−3114	−9	15,364	172	538	8
Spain	162	1	−446	−9	234	5
Sweden	−1278	−9	8799	553	5523	433
United Kingdom	8980	39	−215	−6	−1823	−27
Developed	**48,902**	**8**	**33,838**	**20**	**21,321**	**11**
Developing	**91,639**	**10**	**−89,710**	**−21**	**7782**	**4**
World	**140,541**	**9**	**−55,872**	**−9**	**29,103**	**7**

be lower in countries with higher autarky prices, with a Spearman rank correlation $R_s = -0.50$, significant at the 1% level (Fig. 2c).

3.3. Effects on pulp, and paper and paperboard markets

The world production and consumption of wood pulp (mechanical, chemical and semi-chemical) was 20% higher with international trade that it would have been in an autarky world (Table 6). The trade effect was largest in Europe where Finland and Sweden were especially large beneficiaries. Production also increased with trade in South America, primarily in Brazil and Chile, while in North America Canada was the most positively affected. But in Asia, wood-pulp production was 35% lower with trade than without it in China in particular, production was 61% lower. In contrast, Asian consumption was 9% higher with trade than without it. In Europe, trade raised wood-pulp consumption by 69%, with especially strong positive effects in Finland and Sweden. As wood pulp is an intermediate product, its demand was affected by its own price, but also the price of input (such as industrial roundwood) and the price of the output (paper and paperboard). Consequently, there was no systematic relation between the price change and the consumption of wood pulp. Still, the expected negative correlation between net trade and autarky prices was confirmed with a Spearman rank correlation $R_s = -0.79$, statistically significant at least at the 1% level (Fig. 2d).

The GFPM divides paper and paperboard in three distinct commodities: newsprint, printing and writing paper, and other paper and paperboard. The model results show the production, consumption and price of each of these commodities. As each commodity is an end product, in this application the changes in consumption due to international trade were always inversely related to the price change induced by eliminating trade. This inverse relationship was also observed in general for total paper and paperboard (the sum of the three sub commodities). For example, the ability to import reduced the price of paper and paperboard in China by 10%, and correspondingly increased consumption by 5% (Table 7). The three exceptions in Table 7 were due to the price of paper and paperboard being estimated as the consumption weighed average of the three sub products. There was no such direct relationship between the price of paper and paperboard and its production as the marginal cost of production depended in part on the cost of the input, including that of wood pulp (Table 6). In all, the ability to trade increased the world consumption and production of paper and paperboard by 15 to 16%. Production was higher in all regions with trade, except in Africa. The largest increases of production were in Europe, 682% in Finland and 432% in Sweden, and secondly in Asia, especially in China and Indonesia. In North America, the main trade effect on production was in Canada (+89%). Consumption was higher with trade in all regions, with the largest increase in Asia, followed by Europe, notably in Italy (+44%). Although the trade effect in North America was positive, it was relatively small. The results confirmed the expected negative relation between the net trade of paper and paperboard and autarky prices, with a rank correlation $R_s = -0.67$, statistically significant at least at the 1% level.

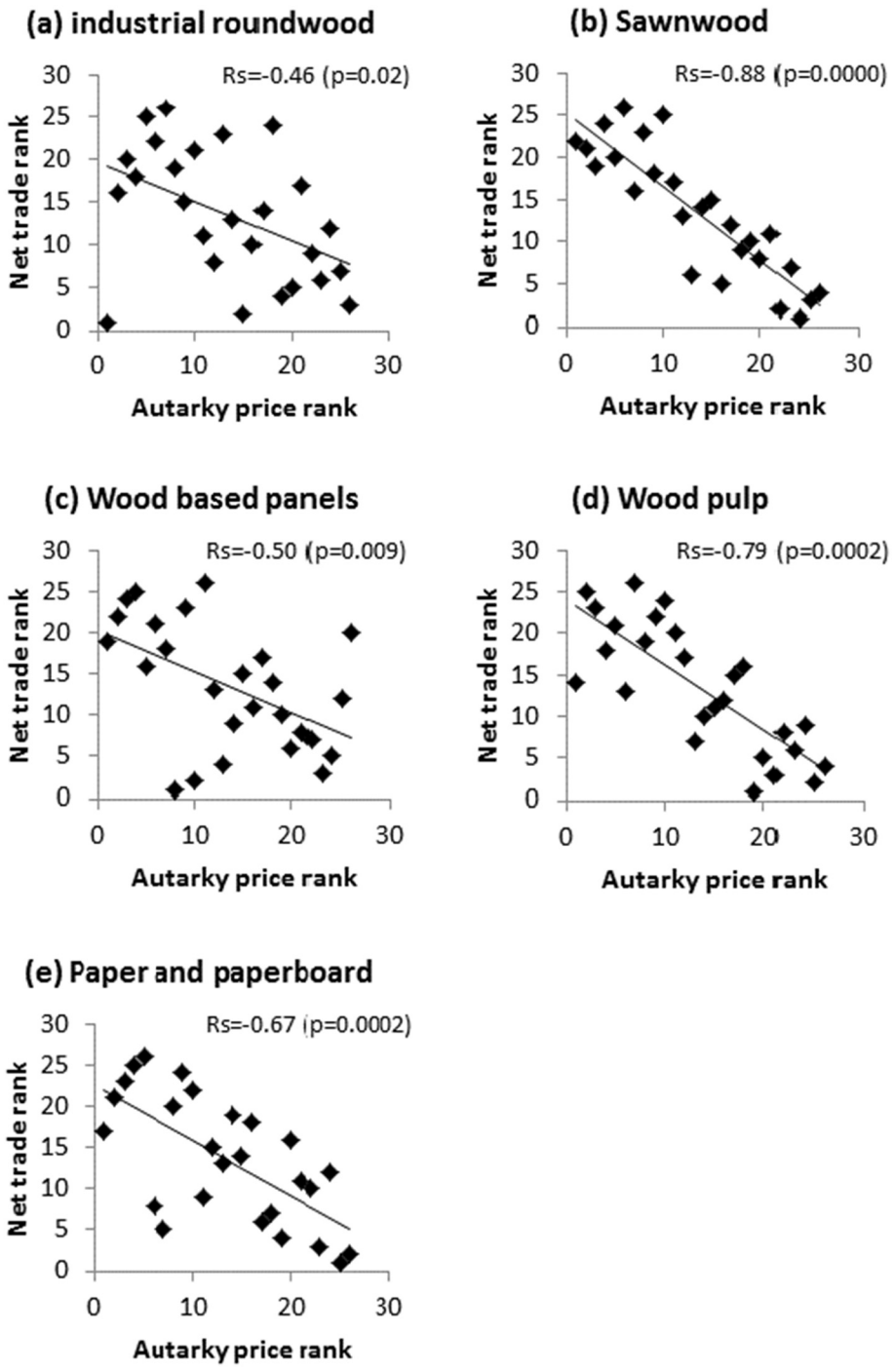

Fig. 2. Rank correlation, R_s, between net trade and autarky price, and significance level, p.

3.4. Effects on consumer and producer surplus and value added

The changes in indicators of economic welfare resulting from international trade are summarized in Table 8. For consumers of end products (fuelwood, sawnwood, panels; paper and paperboard), the global surplus was approximately \$141 × 10^9 or 9% higher with trade than without it. The main gains were in Asia, especially in China (+ 11%) and Japan (+ 16%). In Europe, consumer surplus increased markedly in Italy (+ 73%) and in the United Kingdom (+ 39%).

In contrast, for suppliers of raw materials (wood, waste paper and other fibers) the economic surplus or profit was globally lower with trade by \$56 × 10^9 or 9%. The losses were especially large in Asia, \$114 × 10^9 or 31%, concentrated in China, India, and Japan, reflecting the fact that these countries would produce much more raw materials in autarky (see Table 3). Still, there were net gains due to trade in suppliers' surplus in North America, especially in Canada (419%), South America (56% in Brazil and 173% in Chile) and in Indonesia (+ 83%). In Europe, producer surplus was 28% higher with trade than in autarky mostly due to the 172% increase in Russia, and despite the 78% decrease in Italy. Overall, the brunt of the losses was borne by suppliers in developing countries, while in developed countries producer surplus actually increased by 20%.

This loss of suppliers was in part compensated by the higher value added in industries induced by trade. In this study value added was the difference between the value of the manufactured output (sawnwood, wood panels, pulp; paper and paperboard), and the cost of raw

materials (wood and other fibers). At world level, value added increased with trade by $\$29 \times 10^9$ (7%). However, this gain was nearly three times as large in developed countries as in developing. The highest gains were in Europe, especially in Finland (675%) and Sweden (433%). But there were also notable losses in Italy (− 26%), the United Kingdom (− 27%) and France (− 17%). Other large value added gains from trade occurred in Canada (80%), Brazil (24%), and Indonesia (103%), while Mexico and African countries experienced decreases in value added of 41%, and 24%, respectively.

4. Discussion and conclusion

International trade is an important part of the world forest economy. For sawnwood and panels 25% of the world consumption is imported, and for pulp and paper it is nearly 30%. This study attempted to determine the effects of this active international trade on the forest sector. A global forest products model was used to simulate the sector, with and without trade. The model was calibrated to closely reproduce the global pattern of production, consumption and trade observed in 2013, and then solved again after constraining all trade flows to zero and thus simulating a regime of global autarky. The paper summarized the differences in production, consumption, and prices with and without trade in the main sub sectors of the forest economy. The complexity of the demand, supply and price system within the 180 countries considered and between them led to results very different across countries and sub sectors. Although the detailed results could not be inferred from theory alone, general patterns were in agreement with theoretical expectations, such as the negative correlation between the price change of end products and consumption, and the statistically significant inverse relation between observed net trade and autarky prices.

Overall, the opportunity to trade in all segments of the forest economy raised global production and consumption of industrial roundwood by 19%, sawnwood 7 to 8%, wood-based panels 11 to 13%, wood pulp 20% and paper and paperboard 15 to 16%. These increases and attendant price changes were accompanied by a global increase of the economic welfare of consumers of $\$141 \times 10^9$ (9%). Trade also raised the value added in the world wood manufacturing industries by $\$29 \times 10^9$ (7%), but the surplus of roundwood suppliers was lowered by $\$56 \times 10^9$ (9%).

Much of the neoclassical economic theory argues that unrestricted free trade increases social welfare through specialization associated with comparative advantage in capital, labor and factor endowments. This study shows, at the global level, that the forest sector is no exception, as economic social welfare clearly benefited from unrestricted free trade. So why then, is the forest products industry subject to a series of bilateral and multilateral free trade agreements with some countries, and protectionist policies with others?

The issue resides primarily in the distribution of gains and losses. According to the results, while consumers of wood products benefited from trade in many countries, in China and Japan in particular, others did lose, such as in Russia, Canada and Brazil. And while many suppliers of wood raw material benefitted from trade, including in Canada, Russia, and Brazil, others lost, such as in China, Japan, Italy. For industrialists, international trade boosted value added in countries such as Finland, Sweden and Indonesia, but decreased it in Mexico, Italy, and the United Kingdom. This, and the attendant power of lobbyists for consumers and producers in various countries may help explain why, despite its clear overall benefits, there is no unrestricted broad free trade in the forest products sector but rather narrow protectionist policies for particular countries and industrial sub sectors.

Most troubling from the point of view of global equity was the indication that while trade raised the profits of roundwood producers in developed countries by nearly $\$34 \times 10^9$, it depressed those in developing countries by almost three times as much, thus giving little incentive to those countries to invest in forest protection, management, and new plantations. What policies, including some degree of protectionism, would keep the main benefits of trade while correcting their harmful distributional effects is a difficult but important issue that needs to be examined in future studies.

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