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Modeling Forest Trade in Logs and Lumber: Qualitative and Quantitative Analysis

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Modeling Forest Trade in Logs and Lumber: Qualitative and Quantitative Analysis

by

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Abstract:

This paper deals with forest trade modelling from a theoretical, analytic and empirical perspective. An integrated dynamic log-lumber trade model is developed and then used to examine two trade issues, namely, a reduction of Russian taxes on log exports and removal of the taxes on Canadian lumber destined for the United States. To demonstrate the dynamic aspect of the model, both sets of taxes are lowered over a period of time. The trade model consists of five Canadian regions, three U.S. regions, New Zealand, Australia, Chile, Rest of Latin America, Russia, Sweden, Finland, Rest of Europe, Japan, China, Rest of Asia, and Rest of the World – a total of 20 regions. It concerns only coniferous logs and softwood lumber, ignoring hardwoods. The model is also calibrated on 2010 observed bi-lateral flows of logs and lumber using positive mathematical programming. The forest trade model is written using an Excel-GAMS interface, with input data retrieved by GAMS from Excel and GAMS output written to Excel, where final calculations are made.

Keywords: log-lumber trade, spatial price equilibrium model, mathematical programming

JEL categories: Q23, Q27, Q28, F17, Q21

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1. INTRODUCTION

In 2011, global exports of forest products were valued at $245.9 billion, with trade in industrial coniferous roundwood (softwood logs) and coniferous sawnwood (softwood lumber) valued at $79.0 billion and $23.2 billion, respectively.[1] Global production of softwood logs amounted to about 920 million m^3, while that of softwood lumber reached 280 million m^3. Canada is a major producer and exporter of forest products, especially softwood lumber, accounting for an average of 12% of global production of logs and 15% of total lumber output over the period 2006 and 2010. In 2010, Canada accounted for 5% of global softwood log exports and 4% of log imports, but it accounted for more than 23% of softwood lumber exports and less than 1% of imports. Within Canada, British Columbia accounts for 54% of Canada's log production and 45% of softwood lumber production, but nearly all of the country's log exports and then from the BC Coast because of ready access to cheap water transport (often as backhaul in what would otherwise be empty containers). As indicated in Figure 1, lumber exports from BC to the United States and Japan – two of its major markets – have been in decline since about 2006, primarily due to the collapse of the U.S. housing market and financial crisis, while the softwood lumber dispute has also affected export flows from BC and other parts of Canada to the U.S. At the same time both log and lumber exports from BC to China have risen dramatically since 2006 (see Fig 1).

There is also lively trade in roundwood coniferous logs, with the largest trade flows between countries bordering the Pacific. Because lumber trade is also significant, the processing and re-exporting of wood products leads to a complex relationship between logs and wood product flows (Perez-Garcia et al. 1997; Berck 2005). This means that the flows of softwood timber products among the countries of Asia, North America, South America, Europe and Australasia are intertwined in such a way that forest policies in any one country potentially affect

[1] Information available from http://faostat.fao.org (viewed April 18, 2013).

all countries. The most significant shifts in those markets have been the emergence of China as the dominant buyer of logs (where seven years ago they were mainly absent from these markets), and Russia as the largest supplier of logs to the world market and China. Prior to 2009, China had imported logs almost exclusively from Russia, but now imports increasing log volume from New Zealand, the United States and Canada (Fig 2).

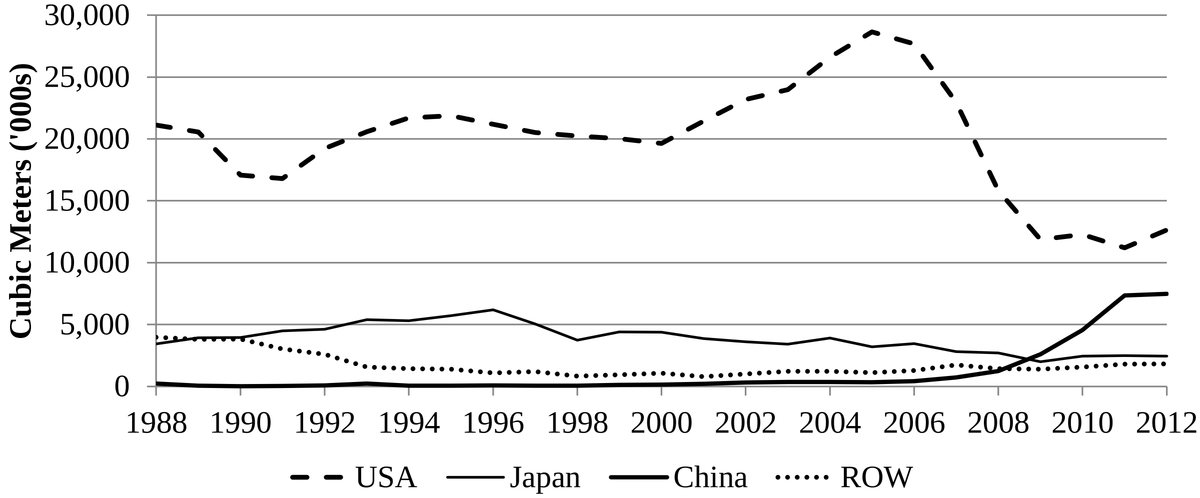

Figure 1: British Columbia softwood lumber exports to major markets, annual, 1988-2012
(Source: BC Stats 2013)

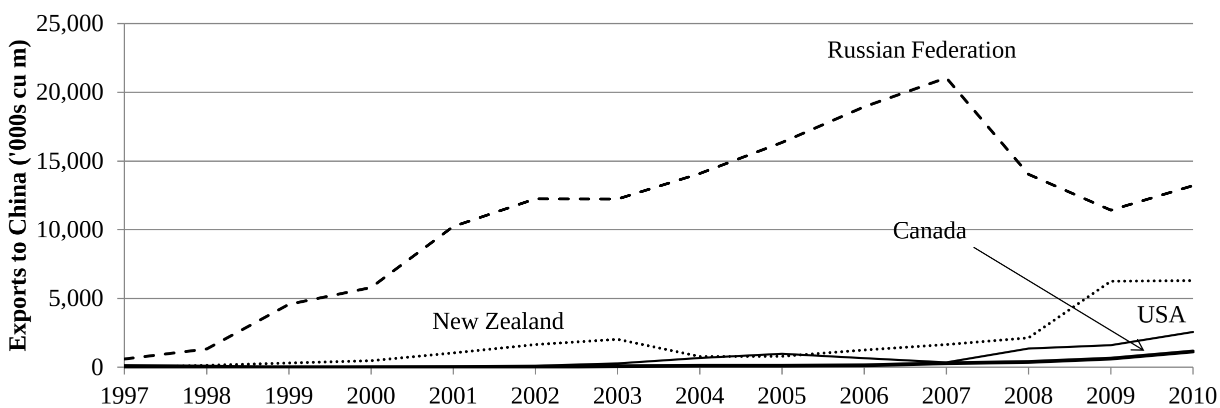

Figure 2: Exports of industrial roundwood logs to China by major supplier, 1997-2010
(Source: FAO 2012b)

China must be taken into account in any analysis of trade flows because it is now a dominant player in the world's forest sector. It experienced rapid growth in forest products output (~22% in 2011), and doubled its wood panel production in four years. It doubled pulp, paper and paperboard production in the past decade and now accounts for 25% of global production. China has also become the largest producer of wood furniture in the world (accounting for 20% of global capacity), the second largest producer of wood plastic composites, and the second largest importer and exporter of wood products in the world after the United States (UN ECE 2011, pp.141-146).

Although trade flows have increased in recent years, there are a number of significant distortions in both the log and lumber markets: one example is the Canada-U.S. Softwood Lumber Agreement (SLA) that penalizes lumber exports from Canada but allows logs to enter tariff free; another is Russian restrictions on log exports (Simeone and Eastin 2012). Forest management policies adopted by countries can also influence domestic supply, such as Vietnam's curtailment of production from native forests that influences domestic supply and hence external demand (Vietnam has the world's 4th largest furniture industry) and Japan's subsides to promote domestic supplies for its sawmilling industry.

Canadian export markets for logs and lumber are sensitive to trade policies in other jurisdictions. This was apparent in the case of Russian policy in 2007 to restrict log exports, primarily to China, which then increased log imports from New Zealand, the United States, British Columbia and elsewhere (Fig 2). Along with the poor demand for lumber in its largest market (the U.S.), BC manufacturers of wood products could not 'compete' to use available logs, so that these then went into the export market.

Forest companies wishing to export logs from federal or private lands in British Columbia can do so only if the logs are 'surplus' to domestic requirements. Logs are surplus if no domestic buyer is forthcoming or if an offer to purchase 'surplus' logs is deemed inadequate by the Federal Timber Export Advisory Committee (FTEAC), which adjudicates disparities between offers and bids in the case of log exports.[2] Historically, log exports rose when lumber

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[2] See Foreign Affairs and International Trade Canada's website at http://www.international.gc.ca/controls-controles/systems-systemes/excol-ceed/notices-avis/102.aspx?lang=eng&view=d (viewed 17 January 2013). For logs from provincial crown lands, the procedure is somewhat different – while approval is still given by the TEAC, exporters are also charged a fee-in-lieu that varies according to species (although this was recently revised). In addition, there are blanket exemptions for portions of the harvest from certain regions of the BC Coast. The point, however, is that forest companies cannot choose to export raw logs without permission. Although these procedures are designed to protect processing jobs in BC, economists have generally opposed log export restrictions on grounds that these reduce the value of standing timber (e.g., Uhler 1991).

markets were weak, but fell as demand picked up. More recently, log exports from British Columbia have become an important part of BC's external trade. In 1987, log exports were somewhat less than 4 million m^3, but a decade later they had fallen to under ½ million m^3. As indicated in Figure 3, log exports have risen dramatically since 1997; by 2005, they reached nearly 5 million m^3, falling to about 3 million m^3 by 2009 as a result of the global financial crisis, and then rising rapidly to well over 5 million m^3 in 2011. In 2011, BC's log exports were valued at $588.5 million compared to $3,833.4 million for softwood lumber exports, or some 15% of lumber export value.

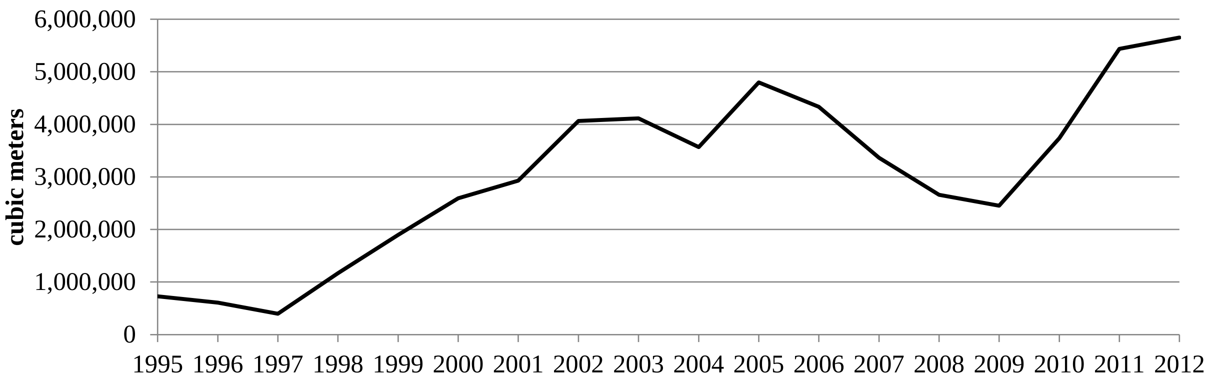

Figure 3: British Columbia log exports, 1995-2012 (Source: BC Stats 2013)

It seems obvious from the forgoing discussion that one cannot examine trade in logs without also considering trade in lumber. Indeed, it may even be necessary to consider other wood products as well, although it is very likely that harvest residues, chips and sawmill waste are insignificant components of trade since they are used locally for pulp production and heat and power.[3] Therefore, even though economists had previously used separate log and lumber models (e.g., Uhler 1991; Margolick and Uhler 1992; Mogus et al. 2006), it is important to any investigation of log markets to include both logs and lumber in the same model (e.g., see Berck

[3] Historically, there had been some forest products trade in residual wood chips that are considered 'surplus' to BC needs. More recently, trade in pellet production and exports from North America (and BC) have increased. To date, these markets have had some impact on sawmilling costs as the bulk of these residuals co-produced with lumber, but revenues are not sufficiently significant to change the relative competiveness of regions. Residuals and other wood fiber may become increasingly important, however, as policies to promote renewables could influence supply, especially since Japan and Ontario, for example, have introduced feed-in tariffs for biomass electricity (as have some Scandinavian countries, which has driven pellet exports from BC).

2005). This is done in this study. Nonetheless, the conclusions reached by some of the earlier studies – that log exports could enhance overall wellbeing – remain valid, at least to some extent.

The main purpose of the current study is not to focus on the economic viability of log exports. Rather, the purpose is to describe an integrated log-lumber trade model. First and foremost, the objective is to provide a theoretical grounding for such a model. This is done in the next two sections. I begin Section 2 by examining forest-sector trade issues from an analytical perspective using tools of trade theory and welfare economics (see Just et al. 2004). In particular, I consider issues relating to export taxes, import duties and quotas. Then, in Section 3, I describe a log-lumber trade model consisting of twenty regions, including five Canadian and three U.S. regions. The underlying theory, data and model calibration using positive mathematical programming are discussed. Then, in Section 4, the trade model is used to examine the impact of removing the Russian trade restrictions on log exports and removal of the export taxes applied to lumber from various Canadian regions destined to the United States as prescribed under the Canada-U.S. Softwood Lumber Agreement (SLA). Some conclusions follow in Section 5.

2. THEORETICAL FRAMEWORK FOR MODELLING FOREST TRADE

Economic theory can fruitfully be applied to the problems of forestry trade. In this section, therefore, I provide a qualitative assessment of the impact of government policies regarding trade in logs and lumber. Applied welfare analysis is used to identify and measure of the economic costs and benefits of projects and/or public policies, as well as the income changes that government projects or policies bring about – the income (re)distributional effects (Just et al. 2004). Current qualitative assessments of forest policies in various countries lack the depth of analysis and insights available in the agricultural economics literature, for example (see Schmitz et al. 2010).[4] This section seeks to rectify this shortcoming.

Quantitative assessments of various policies depend on the development of an

[4] This is evident upon examining the qualitative models provided by commentators such as Uhler (1991), Zhang (1996), and Puzon et al. (2011), to name only a few. Because of the richness of the various agricultural policies that have been implemented by the United States, the European Union and other countries over nearly a half-century of intervention (single-desk selling, non-recourse loans, target prices, quotas, payments-in-kind, etc.), the agricultural literature offers an excellent place to look for insights into forest trade policy.

appropriate theoretical framework for conducting the analysis. In this section, I develop such a framework and then provide some examples of how this approach can be used to analyse trade policies related to logs and lumber. However, to make quantitative assessments of the potential economic implications of various forest trade policies requires an appropriate trade model, one that is rooted in the theoretical foundations discussed in this section. Such a model is developed in Section 3.

2.1 Partial Equilibrium Trade Modelling

Trade in any product can be analysed using a spatial price equilibrium (SPE) model of international trade. The SPE approach assumes that, while changes in countries' forest policies will affect prices of forest products, they have very little impact on relative prices elsewhere in the global economy. Spatial price equilibrium models are partial equilibrium trade models that assume any differences in prices between regions are the result of transaction costs, which include costs associated with transporting goods (e.g., freight, insurance, exchange rate conversion fees), plus tariffs and other non-tariff barriers. Thus, in the absence of trade barriers and transaction costs, prices would be the same in every region as a result of spatial arbitrage.

I illustrate the development of the forest trade model with the aid of Figures 4 and 5. In the figures, I consider lumber trade between Canada and the rest of the world, although Canada's primary trading partner in this case of lumber is the United States. I begin in Figure 4 by demonstrating how to derive the excess demand (ED) and excess supply (ES) functions for any given region. In the absence of trade (also referred to as autarky), domestic consumption, production and price of lumber are determined by the intersection of the domestic demand (D) and supply (S) schedules. In the figure, the autarkic equilibrium quantity and price are Q^* and P^*, respectively. A country will generally engage in trade if the world price for the good in question is greater or less than the domestic price (ignoring the transportation cost). If the world price is higher than the domestic price, the country will export the commodity; if the world price is lower, it will import the good. How much will it supply, or how much it will demand?

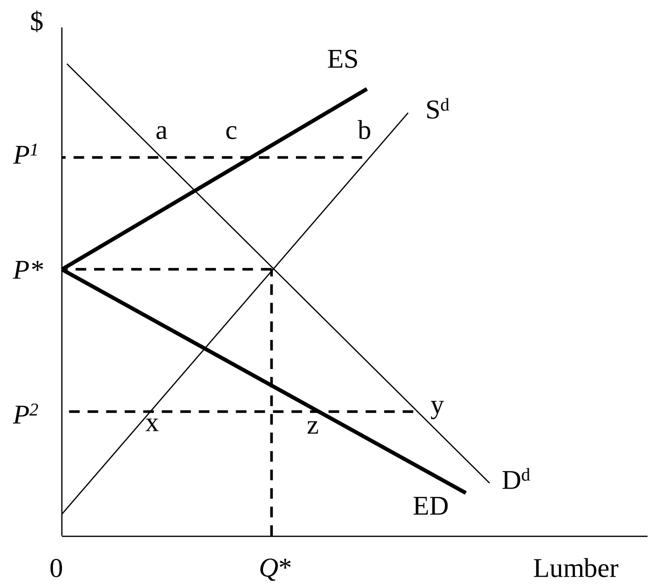

Figure 4: Concepts of excess supply and excess demand

Suppose that the world price, or what firms in the country can get by selling abroad (after transportation and other transaction costs), is P^1 (Fig 4). The amount the country will supply to the world market is equal to the difference between what domestic producers are willing to supply at P^1 (given by point b on the domestic supply curve S^d) and what domestic consumers will buy at that price (point a on D^d). The difference between what producers are willing to supply and what domestic consumers are willing to buy at each price above P^* constitutes excess supply, with the ES function tracing out this excess supply at various prices. Thus, ES at P^1 (= distance P^1c) equals distance ab. Likewise, if world price is below P^*, it is the difference between what consumers are willing to buy and what producers are willing to sell that constitutes excess demand; it is these differences at various prices that trace out the ED schedule. At P^2, ED = xy = P^2z. Both ES and ED are shown in Figure 4.

The ES and ED schedules can be derived mathematically. Suppose the (inverse) demand and supply curves in Figure 4 are linear:

[1] $P^D = \alpha - \beta q, \quad \alpha, \beta \geq 0$, and

[2] $P^S = a + bq, \quad a, b \geq 0.$

The excess demand and supply curves in the figure are then given by:

[3] $\quad ED = \gamma - \delta q, \quad \text{with } \gamma = \dfrac{a\beta + b\alpha}{\beta + b} \geq 0 \text{ and } \delta = \dfrac{b\beta}{\beta + b} \geq 0.$

[4] $\quad ES = \gamma + mq, \quad \text{with } \gamma = \dfrac{a\beta + b\alpha}{\beta + b} \geq 0 \text{ and } m = \dfrac{b\beta}{\beta + b} \geq 0.$

Notice that γ is the equilibrium domestic price, so that, in the absence of transaction (principally transportation) costs, the excess supply and demand curves start at the same point on the vertical (price) axis. Further, the absolute slopes of the ED and ES curves are identical (although ED slopes down and ES slopes up).

Now consider lumber trade between Canada and the Rest of the World (ROW). The problem with this simplification is that Canada's lumber trade with the rest of the world (mainly the U.S.) is really characterized by bilateral trade among a number of distinct Canadian regions and other regions in the world. There is market fragmentation so that some regions in Canada may export wood to ROW, while others import wood. Thus, a Canada-ROW diagram is inadequate for modelling trade and a numerical mathematical programming model is required instead; this model is developed in Section 3. Nonetheless, the Canada-ROW example offers an excellent way to illustrate how spatial, partial equilibrium trade models can be used to analyse policy.

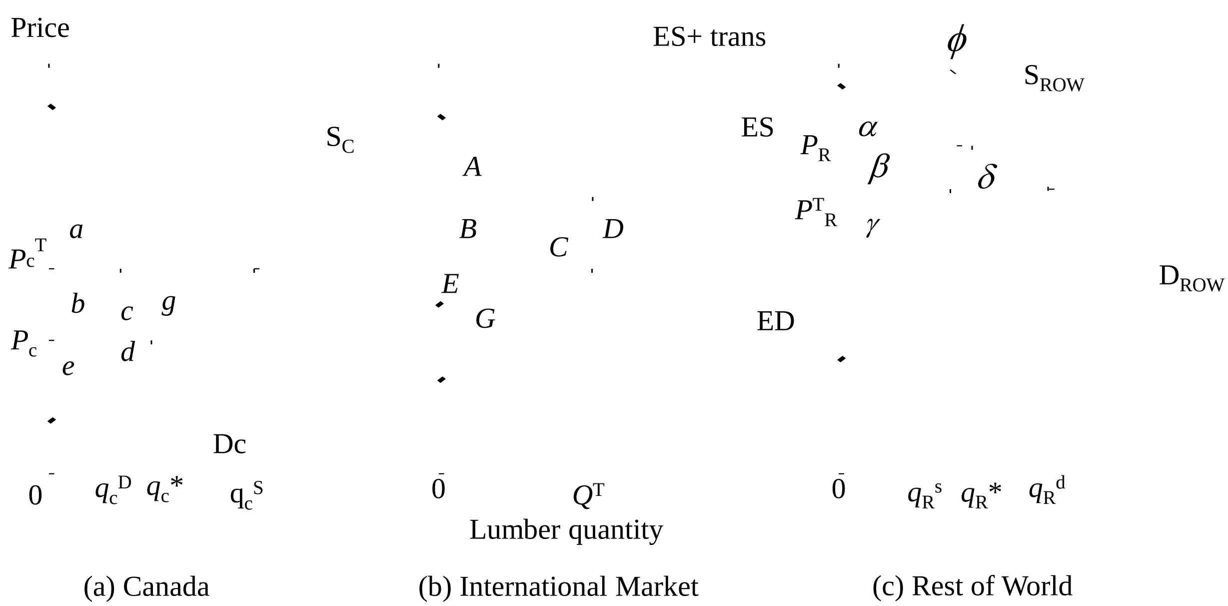

Figure 5: Model of international trade in lumber

The spatial price equilibrium lumber trade model for Canada and the rest of the world is illustrated in Figure 5. In the figure, the domestic demand functions for lumber in Canada and the ROW are given by D_C and D_{ROW}, respectively, while respective supply functions are given by S_C and S_{ROW}. Under autarky (i.e., no trade), an amount q_c* of lumber will be consumed in Canada at a domestic price of P_C (see panel (a)); in the ROW, autarkic consumption will be q_R* at a price P_R (panel (c)). Note that, for trade to take place, the difference between the autarkic prices must exceed the cost of transporting the good from one market to another (i.e., $P_R > P_C + t$, where t is the transportation cost), as demonstrated below. The wellbeing of citizens in each country is determined by the sum of the benefits they receive as consumers (consumer surplus) and as producers (producer surplus). As demonstrated by Just et al. (2004), economic wellbeing or welfare is always determined as the sum of surpluses (e.g., net revenues rather than gross sales). In the absence of trade, the consumer surplus associated with lumber production is given by area $a+b+c$ in Figure 5(a) for Canada and area α in Figure 5(c) for the ROW. The producer surplus (or quasi-rent) is measured, in the absence of trade, by area $e+d$ for Canada and by area $\beta+\gamma$ for the ROW. Total economic wellbeing is the sum of producer and consumer surpluses, and is simply given by the area between the demand and supply curves. For Canada, total surplus in the absence of trade is given by area $a+b+c+d+e$, while it is area $\alpha+\beta+\gamma$ for the rest of the world.

2.2 Unrestricted Free Trade

To demonstrate that trade improves the wellbeing of citizens in each country, it is necessary to show that total surplus in each country increases. This is done using Figure 5. Since in the absence of trade the price in the ROW is greater than that in Canada, lumber will flow from Canada to the ROW as long as the difference in price between the two regions exceeds the transportation/transaction costs.

With trade, the price in Canada rises from P_C to P_C^T, while ROW price falls from P_R to P^T_R. Canadian consumers lose as a result of the price increase, consuming less; consumption in Canada falls from q_c* to q_c^D and consumer surplus falls from area $a+b+c$ to only area a. However, Canadian producers face a higher price ($P_c^T > P_c$ in panel (a)), causing them to increase production from q* to q_c^S. An amount $q_c^S - q_c^D$ ($=Q^T$) is sold to the ROW, while producer surplus increases from $d+e$ to $b+c+d+e+g$. The wellbeing of Canadians as a whole increases by area g, with producers (and those earning a living in the lumber sector) being the main beneficiaries from trade.

The situation in the ROW mirrors that of Canada. The fall in ROW prices causes consumers to purchase more lumber (from q_R* to q_R^D) and increase their overall consumer surplus by an amount given by $\beta+\phi+\delta$. Producers in the ROW now face a lower price and curtail output to q_R^S, giving up a producer surplus or quasi-rent of β in the process. However, the gain to consumers is greater than β, with the net gain to citizens in other countries given by $\phi+\delta$.

The main results can be summarized in the international market of Figure 5(b). The amount traded between Canada and the ROW is $Q^T = q_c^S - q_c^D = q_R^D - q_R^S$. The net gain to the ROW is area *A*, which is equal to area $\phi+\delta$ in panel (c); this net gain accrues to ROW consumers and therefore is measured under the excess demand curve ED. The gain to Canada equals the area above the excess supply curve ES below the demand price, or area *B*+*C*+*E*+*G*, but transportation costs of *B*+*C* are incurred. Hence, the net gain from trade is *E*+*G*, which is equal to area *g* in panel (a). Note that both Canada and the rest of the world are better off with trade in lumber than without trade.

For the purposes of analysing policy, a back-to-back representation of the trade model in the previous figure (Fig 5) can also be used. This is done in Figure 6, where q_c* and q_R* again refer to the autarkic quantities in Canada and the rest of the world, respectively, while P_c* and P_R* are the associated autarkic prices. Canada's excess supply curve can be represented in the ROW diagram (right-side panel in Fig 6). With trade in this case, the ES adjusted for transportation costs of $*t* per unit of lumber (ES+*t*) is added horizontally to the domestic ROW supply to find the relevant total market supply S^T in the ROW market. The market clearing price in the ROW market is then P_R^T, while the price in Canada is P_c^T ($=P_R^T - t$). Canada exports Q_c^E ($=q_c^S - q_c^D$) amount of lumber to the ROW.

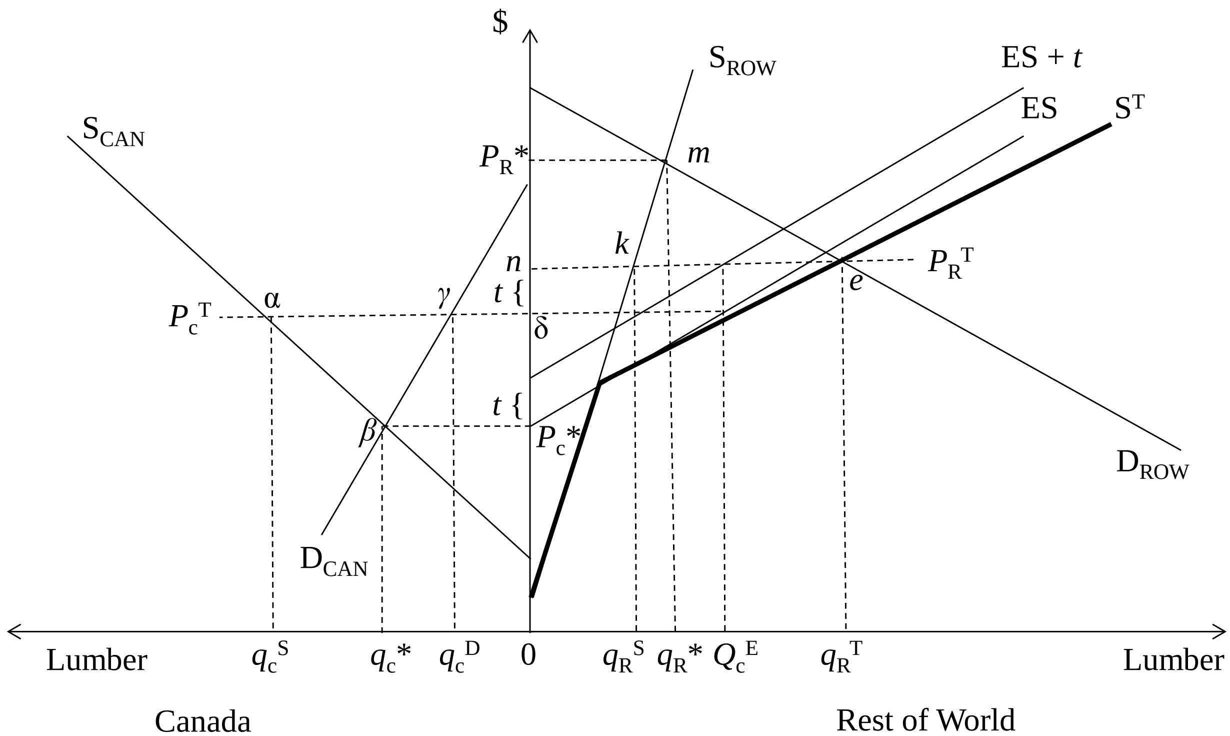

Figure 6: Back-to-back representation of the lumber trade model

The gains from trade and the gainers and losers in each of the two regions can be readily identified. In Canada, consumers lose a surplus equal to the area bounded by $P_c^{*}\delta\gamma\beta$ in the left panel of Figure 6, while producers gain a surplus given by area $P_c^{*}\delta\alpha\beta$; the net welfare gain to Canada thus equals area $\beta\alpha\gamma$. There are gainers and losers in the rest of the world as well. The losers in this case are lumber manufacturers whose producer surplus falls by the area bounded by points $P_R{*}nkm$; lumber consumers gain the surplus area bounded by $P_R{*}nem$. Summing the loss in producer surplus and the gain in consumer surplus leads to an overall gain in welfare in the ROW equal to the area bounded by *mke*. The global increase in welfare from trade in lumber is given by the area bounded by points $\beta\alpha\gamma$ in the left-side panel and the area bounded by points *mke* in the right-hand panel, minus the transportation costs which equal $t \times Q_c^E$. The overall gain must, however, be positive because trade would not otherwise take place.

The approach in Figure 6 is somewhat richer than that in Figure 5, and it is usually used to analyse policies affecting trade, particularly in agriculture and forestry (e.g., Just et al., 2004; Schmitz et al. 2010). We use a similar diagrammatical analysis to investigate the (qualitative) impacts of various restrictions that governments use to favour domestic manufacturers, domestic consumers, et cetera. We first illustrate this with for the case of Russian log export restrictions.

2.3 Restricted Trade: Russian Log Export Restrictions

To illustrate the analytical methods discussed in the previous section, consider Russian policy regarding log exports. Russia's capacity to process roundwood logs lags behind resource availability; early in the 2000s, only two regions in Russia processed more than 25% of harvested logs while the other five regions utilized less than 10%. Therefore, the government decided to incentivize investment in processing capacity by implementing restrictions on log exports.[5] An ad valorem export tax of 6.5% was imposed beginning January 1, 2007 (see Fig 2); the tax was increased to 20% on July 1, 2007 and then to 25% on April 1, 2008; and it was set to increase to 80% on January 1, 2009, but this was delayed indefinitely as a result of the financial crisis and pressure from the Scandinavian countries. The trade measures had a significant impact, with roundwood log exports falling from 51.1 million m^3 in 2006 to 21.9 million m^3 in 2011, although some of this could be attributed to the global recession. Although the export value of all wood products declined by 16.2% between 2007 and 2011, exports of value-added products (mainly lumber, plywood and veneer panels) increased by 16.8% over the same period.

On August 22, 2012 Russia officially joined the World Trade Organization (WTO) and, as part of accession package, it agreed to reduce tariffs on roundwood exports to 8% by 2015. However, since Russia was permitted to establish a volume tariff rate quota (TRQ), this rate only applied to log exports below the quota. For exports above the quota amount, an 80% export tax could be applied; in essence, then, the quota would be effective. Since much of the quota was allocated to the Scandinavian countries, and because export taxes varied by species, Pacific Rim countries, especially China and Japan, would be most affected by the taxes and quotas (Simeone and Eastin 2012). This, in turn, impacts other Pacific Rim countries that do not trade directly with Russia.

[5] Background information on the Russian forest sector and trade measures is based on Simeone and Eastin (2012).

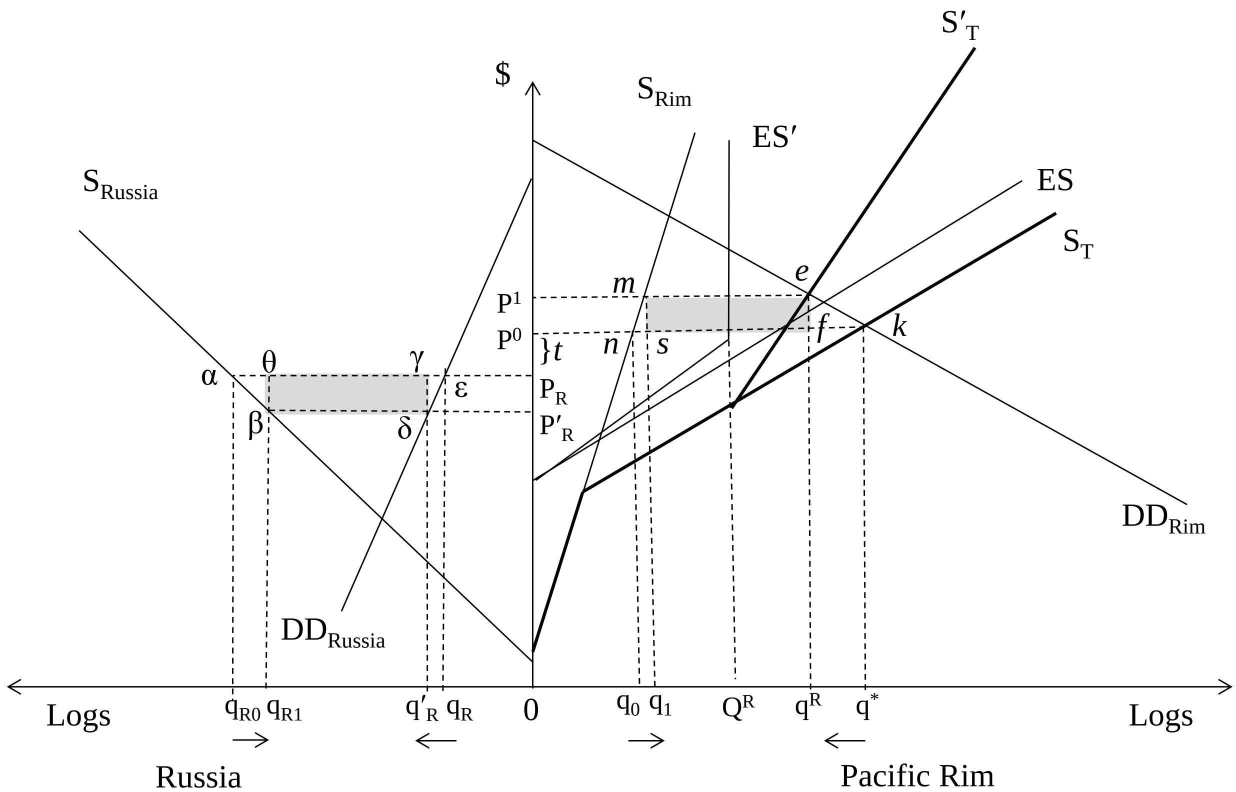

Figure 7: Economics of Russian export TRQ: Nonbinding quota

The economic impacts of the Russian log export measures are examined analytically with the aid of Figure 7. Because logs are a factor of production, an input into the production of lumber and other wood products, the demand functions are derived demands (as denoted by DD). They can be considered the value of the marginal product – the final output price multiplied by the marginal physical product of logs in production of lumber, plywood and other products. For the current purpose, it is assumed that the prices of lumber and other outputs remain unchanged as less or more logs are traded. In practice, it is likely that a restriction on log trade will lead to higher prices of final outputs (lumber, plywood, etc.), because the trade restrictions increase input costs in the most efficient log processing regions (especially China), while shifting some processing to regions with less efficient manufacturers (in Russia). The increase in output price, in turn, increases the value of the marginal product (i.e., demand for logs), thereby offsetting some of the negative impacts of the original trade restriction on logs. However, the net loss in global welfare due to the trade restriction compared to free trade could never be offset entirely because otherwise the original unrestricted allocation of logs across countries would have been inefficient to begin with. Although not captured in the diagram, these indirect (or feedback) effects are taken into account in the log-lumber trade model.

In Figure 7, we further abstract from Russian sales of logs to non-Pacific Rim countries, principally Scandinavia. In the absence of Russian log export restrictions, the excess supply curve facing the Pacific Rim countries (mainly China and Japan) is denoted ES, and when added to the local or domestic supply, the total log supply function in the Pacific Rim countries is S_T. The equilibrium price of logs is then P^0, with the price in Russia slightly lower (at P_R) as a result of transportation costs given by *t*.

The effect of an 8% ad valorem log export tax is to pivot the ES slightly as indicated. However, the low export tax applies up to the tariff rate quota, which is given by Q^R in the right-hand panel; at that point, the excess supply curve essentially becomes vertical.[6] We denote the effective Russian ES facing the Pacific Rim countries as ES′ The total supply schedule is now the horizontal sum of domestic supply and the new Russian excess supply function, so $S'_T = S_{Rim} + ES'$. (The new total supply S'_T has two kinks rather than the one associated with S_T.) As a result of the Russian TRQ, the price of logs in the Pacific Rim region increases from the unrestricted free trade price P^0 to the restricted price P^1, while the Russian price drops from P_R to P'_R. The arrows in the figure indicate the directional shifts as a result of the Russian log export restrictions.

What happens to social wellbeing? To find out, we apply the same approach as used earlier. First, in the Pacific Rim region (i.e., China/Japan) depicted in the right-hand panel of Figure 7, consumer surplus (i.e., the quasi-rent accruing to lumber and other wood product producers) declines by area P^1P^0ke, but producer surplus accruing to logging companies and forestland owners increases by area P^1P^0nm.[7] The shaded area *msfe* constitutes the part of the tax collected by the Russian government and paid by the wood product manufacturers in foreign countries, while triangles *mns* and *efk* constitute that component of the total deadweight loss caused by the intervention. The deadweight loss results because manufactured wood products

[6] Correctly, the Russian quota does not lead to a vertical ES segment because any exports exceeding Q^R are taxed at an 80% rate. Effectively this implies a vertical ES as no logs beyond Q^R are likely purchased.

[7] Notice two things here. First, quasi-rent is identical to producer surplus. Second, the area under the derived demand curve is not so much a consumer surplus but, rather, a quasi-rent that accrues to the wood products industry that uses logs as an input. Under circumstances discussed below, it is identical to the producer surplus in the wood-products industry.

will have a higher price and, thus, somewhat less products are manufactured since there is less demand – it is the irretrievable loss in quasi-rent that would otherwise accrue to wood product manufacturers.

Next, in the Russian market, domestic wood product manufacturers (consumers of logs) are better off by an amount given by area $P_R P'_R \delta\varepsilon$, but producers of logs lose the larger surplus $P_R P'_R \beta\alpha$. However, part of the loss to log producers (their producer surplus) is collected by the Russian government in the guise of the tax on the export amount$'q_R$-q_{R1}; the amount of the tax paid by Russian log exporters is given by the shaded area $\theta\gamma\delta\beta$ in the left-hand panel. The triangles $\alpha\theta\beta$ and $\gamma\varepsilon\delta$ constitute the other component of the deadweight loss. This component of deadweight loss comes about because it is more efficient for China or Japan to process Russia's logs into manufactured products than have the Russians do so.

Now consider the case where the quota is indeed binding. This is illustrated in Figure 8, where some of the lines and labels appearing in Figure 7 have been removed. The revenue accruing to the Russian government is given by the light-shaded areas A (paid by sellers) plus B (buyers). There is little difference compared to the case where the tariff rate quota is not binding, except that the deadweight loss triangles (dark shading) have increased and log exports have declined. Purchases of logs by Pacific Rim countries have fallen while their price has increased. Logs used by Russian processors have increased and the price has fallen more than in the non-binding case. While the overall wellbeing of log buying regions has declined, it is not clear that Russia is worse off in this case compared to that in the non-binding TRQ case. It depends on whether the sum of the increase in quasi-rent going to Russian wood processors (consumer surplus in the log market), loss in producer surplus accruing to Russian log producers, and government revenue (which could be positive or negative) are positive on net in going from a non-binding to a binding tariff rate quota regime. It depends, in other words, on the elasticities of supply and demand in the various markets.

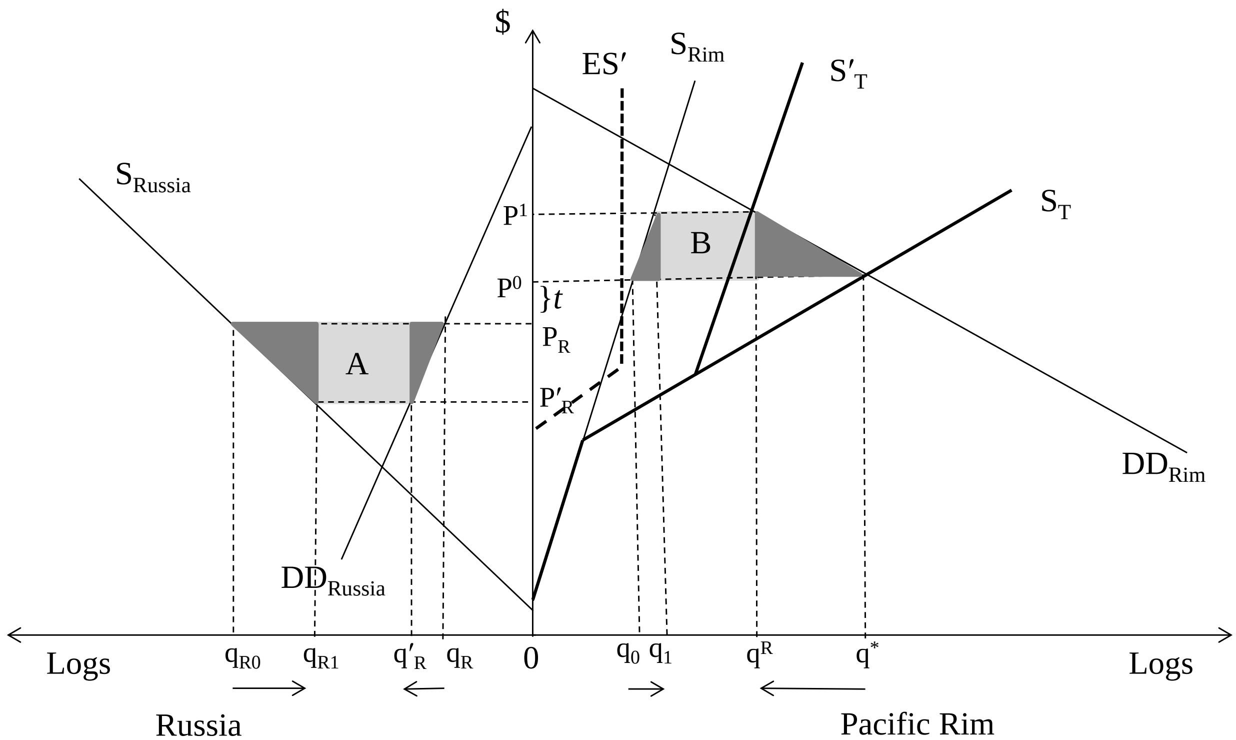

Figure 8: Economics of Russian export TRQ: Binding quota

2.4 Export and Import Taxes

It is clear from the forgoing analysis that an exporter of logs or lumber can gain by imposing a tax or quota on exports. This is true as long as other countries do not retaliate, and the exporter has some degree of market power. Export restrictions create economic rents (represented by the light shaded areas in Figs 7 and 8) that can be captured by the government of the exporting country through an export tax, by the importing country through a countervail duty, or by producers by self-imposing a limit on exports (i.e., behaving like a monopolist).[8] Import taxes levied by the importing country (a countervail duty) or export taxes levied by the exporting country can have the same effect on price as a quota if the duty or tax is set to achieve the same quantity reduction. Taxes are discussed with the aid of Figure 9. Countervail duties and export levies are *ad valorem* taxes that pivot the excess demand (ED) and excess supply (ES) curves, respectively. Both taxes are shown in Figure 9: the import duty shifts excess demand to ED′ while the export tax shifts excess supply to ES′. The taxes result in the same trade quantity as a

[8] There are variants of these scenarios. For example, an importing country could set a quota on imports and allocate the quote to a private importer.

binding quota (Fig 9). Again the tax (whether export or import) creates a wedge between the import and export prices that exceeds the transportation cost. The only difference between the quota and tax cases is the distribution of rents. The rents are equal to shaded areas A plus B in Figure 8 (or the shaded areas in Fig 7), or equivalent areas A and B in Figure 9. In the quota case, exporting firms collect the (quota) rent (A+B). With an export tax, it is the exporting government that collects A+B; with a countervail duty (CVD), it is the importing government that collects this same area.

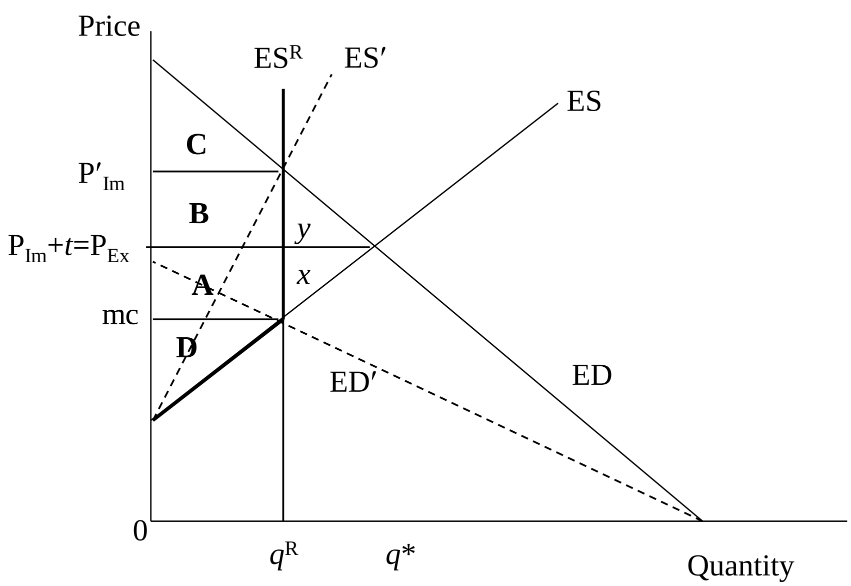

Figure 9: Impacts of quota, countervail duty and export tax: International market

2.5 Free Trade: Canada-U.S. Lumber Trade Dispute Revisited

The 2006 Canada-U.S. Softwood Lumber Agreement was extended to the end of October 2015. Under the SLA, Canada imposes a varying export levy on Canadian lumber exported to the U.S., with lumber from Atlantic Canada entering the U.S. free of the export tax. For other regions in Canada, the ad valorem tax rate declines as the price of lumber rises: If the monthly average price is below \$133.50/m^3, the charge is 15%; 10% if the price is higher but less than \$142/m^3, 5% if the price is below approximately \$150.50/m^3, and zero once the lumber price exceeds \$150.50/m^3. The lumber price is a simple weighted average of 15 price series taken from Random Lengths (2007, 2012), as indicated in Figure 10. What happens when the tax is removed entirely?

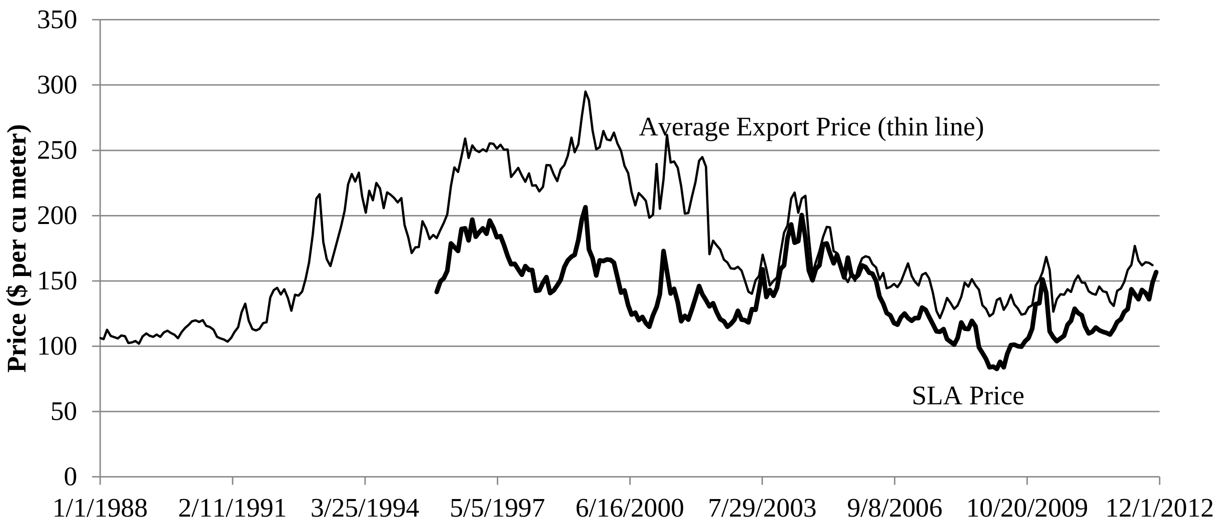

Figure 10: Nominal prices for lumber, BC export price based on value of exports and SLA framing lumber composite price based on 15 price series from Random Lengths

Researchers have previously examined various economic aspects of the Canada-U.S. softwood lumber dispute (e.g., van Kooten 2002; van Kooten and Folmer 2004, pp.409-421; Mogus et al. 2006). The SLA can be analysed with the aid of Figure 11. The British Columbia market is depicted in the figure, with ES referring to the province's excess lumber supply function (the supply relevant to foreign buyers) and D to domestic demand. The excess demand of other regions, principally the United States, is denoted ED. The ad valorem export tax causes the excess demand curve facing BC lumber producers to pivot′,to ED as indicated. ED′ intersects the province's ES schedule at point *r*, so amount E_0 is sold outside BC (exported to the U.S. and other regions). The f.o.b. or border price that foreign (U.S.) consumers pay is p^0, which is determined from the ED schedule for quantity E_0 with ED. The quantity bought by domestic consumers is q_0, which is determined by the intersection of the supply price *m* and the domestic demand schedule.

The surplus accruing to BC lumber producers plus that going to domestic consumers is determined using the excess supply function as it takes into account both consumer and producer surplus. This surplus is given by the area bounded by *nrm*. One can use the domestic demand function D in this case to identify the consumer surplus component, which is given by the area bounded by $bp^{o}d$. There is also a scarcity rent (collected as tax revenue) equal to area p^0mrk, of which p^0p^1yk is paid by foreign consumers while p^1mry comes at the expense of local lumber producers. If the province collects the tax, the overall surplus in the lumber market that accrues to British Columbians is given by area *nrm* plus area p^0mrk.

Now, if free trade is permitted, equilibrium is determined by the intersection at point *e* of the excess supply curve ES with ED. The price to foreigners falls to p^1 and BC exports of lumber increase from E_0 to E_1 as indicated by the arrow; however, the domestic price rises and consumption falls from q_0 to q_1 (also indicated by an arrow). The surplus accruing to British Columbia now equals the area bounded by nep^1, with the consumer surplus now given by *bmc*. The scarcity rent disappears.

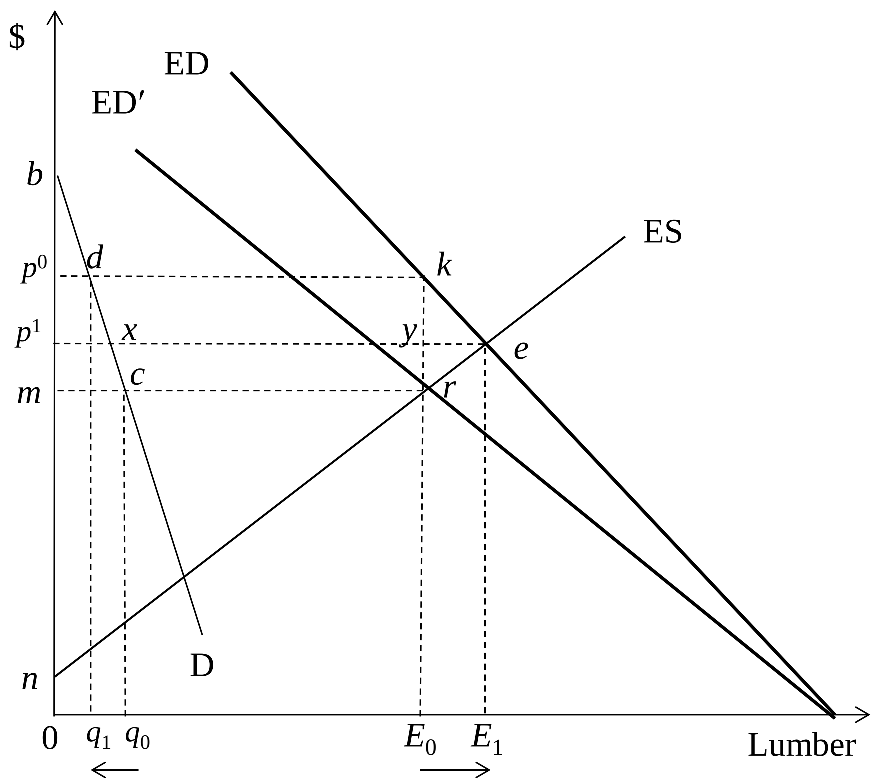

Figure 11: Analysis of the Canada-U.S. softwood lumber dispute

What is the advantage of free trade? This is unclear because it depends on the size of the areas involved. British Columbians gain area p^1mre but lose the tax revenue given by area p^0mrk. The net gain or loss is thus given by ($yre - p^0p^1yk$). (Already included in this calculation is a loss of BC consumers measured by area p_1mcx.) Given the areas involved, it would appear that, when examining only the lumber market, the wellbeing of British Columbians declines when the export tax on lumber exported to the U.S. is removed. U.S. residents also benefit from elimination of the export tax on lumber; the net gain to the U.S. is measured by the area bounded by p^0p^1ek and, since wellbeing is determined from the excess demand function, U.S. consumers gaining more than producers lose. These results are not surprising given that BC lumber production is large enough to impact prices in the United States (see van Kooten 2002).

2.6 Discussion

Whether logs or lumber are considered, the benefits that accrue to a country from imposing export taxes or a quota are limited. One condition for a region to benefit from export restrictions on forest products is the existence of market power – the ability to influence prices in export markets through its policies. For example, van Kooten (2002) found that Canadian lumber producers could increase their overall wellbeing by voluntarily restricting lumber exports to U.S. markets. One obstacle that needed to be overcome, however, was to find a means of preventing other lumber producing regions from exploiting the higher U.S. lumber prices through increased exports. A second and perhaps more important obstacle may well be the (in)ability of Canada's provinces to agree on a method for sharing the resulting quota rents among producers.

The theory is quite simple and is illustrated with the aid of Figure 12 (also see Schmitz et al. 2010, p.103). With linear excess supply and demand schedules, an exporting country could benefit from scarcity rent in the export market; the scarcity rent results from restrictions on exports. As exports are restricted, the scarcity rent rises as indicated by the rent function in the bottom half of the diagram, attain a maximum at q^R, and fall towards zero as exports approach zero. It is easy to demonstrate that the scarcity rent is maximized at the intersection of the excess supply schedule with the marginal revenue function associated with the excess demand schedule. This occurs where $q^R=½q^*$, where q^* is the amount that would be exported under free trade (e.g., see van Kooten 2002). The export level that maximizes the scarcity rent, q^R, can be achieved by a quota or by an export tax. Indeed, the rent could be captured by the importing country through the imposition of a countervail duty, as noted in the previous section.

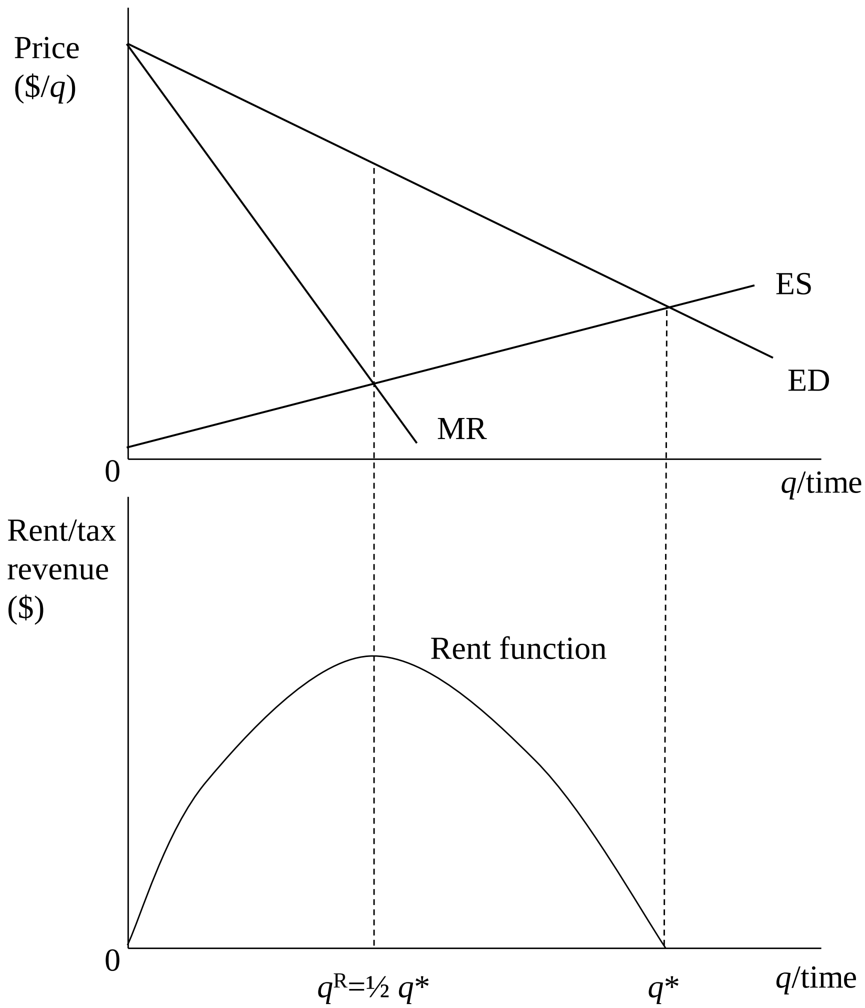

Figure 12: Exercising market power in export markets

A point of clarification is needed. Notice that an export restriction creates scarcity rent, which differs from quasi-rent (producer surplus). Thus, if one compares q^* in Figure 12 with zero exports, q^* is preferred because quasi-rent is positive as opposed to zero if there are no exports. Thus, consider again the case of Russian log exports. In Figures 7 and 8, Russia continued to export logs, even when the tariff rate quota was binding. However, if Russia banned all log exports, it would lose any of the rents available in the Chinese and other markets; logging companies and forestland owners would lose the quasi-rents associated with those log sales, unless the same logs would actually be fully utilized in the domestic market and that the price of logs in the domestic market would be unchanged. It is unlikely, however, that the logs would be fully utilized domestically and, if so, that log prices would remain high. In the worst case scenario, and certainly not an unrealistic one in a global economy, Russian efforts to impose a ban on log exports could simply result in significant welfare losses at home and perhaps abroad.

Finally, the approach discussed above can also be used to analyse government subsidies to wood products manufacturers, subsidies for the production of biomass fuels, and so on. In all cases, however, it is important to provide quantitative estimates of the various impacts. This requires a multi-regional, bilateral, spatial price-equilibrium model. Development of such a model is a more challenging task to which I now turn.

3. MODEL OF GLOBAL TRADE IN LOGS AND LUMBER

Despite their usefulness for evaluating policy, analytic models have deficiencies that can only be addressed with an appropriate numerical model. In the case of forestry, the sheer number of forest products and their inter-relationships makes it difficult to construct a trade model that captures some of these relationships. As a result, most bi-lateral trade models have focused on either logs or one or more final products, usually lumber. One model that does examine multiple products is the Global Forest Products Model (GFPM), which eschews bi-lateral trade flows for more general trade relations – each country trades with the rest of the world, but not with other countries (Buongiorno et al. 2003; Sun et al. 2010). Thus, GFPM sacrifices information on bi-lateral flows for greater product detail. In this section, we describe a trade model that has two products, coniferous logs and softwood lumber, with the former an input into production of the latter. Another is the University of Washington's CINTRAFOR Global Trade Model (CGTM), which has 15 regions (three Canadian regions with the BC Interior and BC Coast constitute two of the regions) (see Perez-Garcia et al 1997). It describes all aspects of forest products production including forest growth, processing and final demand, but is proprietary. Further, no explanation of the link between log and lumber markets, and how welfare is measured, is available in the detail provided below.

Many spatial price equilibrium trade models are sometimes inadequately grounded in economic theory. This is why, in the previous section, I provided a model of forest trade that is rooted in theory. There a trade model was developed that could be explained graphically (as well as mathematically) and that could be used to provide insights into the impacts of forest sector policies on various countries or regions. Now I develop a model of forest log and lumber trade that can be used to estimate the potential quantitative effects of forest policies in one forest jurisdiction on others. The forest model is referred to as the REPA-PFC Forest Trade Model, or RPTM.

The RPTM constitutes a spatial price equilibrium (SPE) model where transaction/ transportation costs and government policies are the only impediment to equalization of prices across regions. The model employs a mathematical programming framework with an objective function and inequality and/or equality constraints. It consists of two products (logs and lumber) and twenty regions. In the model, Canada is divided into five regions – Atlantic Canada, Central Canada, Alberta, BC Interior and BC Coast. The United States is divided into three regions (South, North, West), and Asia is separated into China, Japan and Rest of Asia (including Korea as an important player in log-lumber trade). Chile, Australia and New Zealand are also separate regions, while the remaining six regions comprise Russia, Finland, Sweden, Rest of Europe, Rest of Latin America, and the Rest of the World (ROW). The model runs in a GAMS-Excel environment so no executable code is available. Background information regarding the model is available from van Kooten (2002), Mogus et al. (2006) and Abbott et al. (2009).

I begin in the next section by first examining the link between log markets and lumber markets because this provides the theory and assumptions underlying the surplus measures that are employed in the analysis. Then I examine in more detail how one measures the surpluses accruing to various economic agents in each of the regions; since this information is important only for determining the redistribution of incomes among regions and economic agents, these surplus areas are calculated after the model is actually solved (as discussed below). A mathematical specification of the model itself is provided in section 3.3.

Like previous SPE models, earlier versions of the RPFM were only roughly calibrated. However, recent advances now enable us to calibrate SPE models quite precisely using the method of positive mathematical programming (Paris et al. 2011; Paris 2011), which is explained in section 3.4. Data issues are discussed in section 3.5, which are mitigated to some extent by focusing on coniferous logs and softwood lumber. Further, just as extant forest trade models and the data they rely on tend to be outdated, so are estimates of demand and supply elasticities. This data problem was addressed here by re-considering estimates of supply and demand elasticities (e.g., Pattanayak et al. 2002; Latta and Adams 2000), but there was little evidence to cause us to change the elasticity data employed by Abbott et al. (2009).[9]

Given that log supply in some regions (especially in Canada) is determined by government fiat, a key question will be how accurate the assumed supply elasticity for a region represents the supply responsiveness of public decisions to changes in prices. One might also question the extent to which the uniform logs and lumber employed in the model adequately address differences in species and log quality, and whether softwoods can be modelled separately from hardwoods. The trade model developed here is, in the end, limited by the quality of the data and the validity of the assumptions used in its construction.

3.1 Measuring Welfare Change in a Log-Lumber Trade Model

The objective in the RPTM is to maximize the sum of the net surpluses that accrue in each regional market minus the costs of transporting logs and lumber among the various regions. There are three types of economic surplus to consider: (1) consumer surplus, (2) quasi-rent (producer surplus), and (3) the rent created as a result of policy-induced scarcity or resulting from natural scarcity of timber. Given Harberger's (1971) three postulates of welfare economics, free trade will result in the maximization of social wellbeing. That is, the free market solution maximizes the sum of the consumer plus producer surpluses, while the policy-induced surplus rent must be zero because it is a form of market failure that inhibits free trade. Policy intervention in the way of an export tax, import tariff (countervail duty) or quota restriction results in a divergence between the demand and supply prices.

It should be noted that, as in the discussion of Russian log export restrictions in the previous section, the demand for logs is a derived demand and the area underneath it represents the willingness of lumber (and other wood product) producers to pay for logs. Thus, the surplus area constituting the difference between what downstream producers are willing to pay for logs and what they actually pay is not truly consumer surplus, but more appropriately a quasi-rent that

[9] After considering various estimates of supply elasticities for North America, Abbott et al. (2009) employ elasticities of 1.0 for each of the regions. This is done because, with the exception of elasticity estimates for some regions, such estimates are not availability for the majority regions in the model. Further, the use of a supply elasticity of 1.0 ensures that the supply schedule passes through the origin. With respect to demand elasticities, many of the most recent estimates (e.g., Robert Beach's estimate of -0.14 for the U.S. South as presented at the SOFAC Annual Meeting October 21-22, 2008 at Research Triangle Park, North Carolina) are very close to the estimates we employ.

has a counterpart in the market for lumber (and other wood products).[10]

To motivate discussion of the underlying theory and assumptions that enable us to integrate logs and lumber in a trade model, consider the vertically-integrated industries depicted in Figure 13. Panel (a) represents the market for inputs into the logging sector (panel b) – logging equipment, trucks, fuel, workers, et cetera. Importantly, it also includes the return to the land resource. Input prices are denoted r_{n-1} and quantities by q_{n-1} to indicate the downstream supplier. It is assumed that the input supply schedule facing the logging sector is perfectly elastic, so that input prices are not affected by changes in the demand for such inputs by loggers. All of the logs produced by the logging sector are inputs into lumber production (panel c). Finally, lumber is an input into upstream industries such as (primarily) construction, furniture making and other activities. Prices and quantities in this upstream sector are denoted P_{n+1} and q_{n+1}, respectively, and it is assumed that the demand in this market is perfectly elastic. That is, changes in lumber prices do not affect the prices of houses, buildings, furniture, and so on, because lumber is either too insignificant an input or can readily be substituted by other products.

Following Just et al. (2004, pp.312-322), we employ an asterisk (*) on supply or demand to indicate an equilibrium schedule, one that takes into account the feedback changes in the prices of upstream or downstream markets, as a result of changes in the market under consideration. To determine what is to be measured by the objective function, consider an autarkic situation in which the government seeks to limit lumber production either by a quota or a tax on lumber that causes output to be reduced from L^0 to L^1 in Figure 13(c).

[10] Since the concern is with lumber producers, I ignore other wood product producers in the remaining discussion. Although other wood products are important, sawnwood or lumber is the most valuable product. Timber is rarely harvested except for its lumber or sawnwood value; that is, other wood products (chips for pulp, plywood, oriented strand board, medium density fiber board, veneer panels and biomass for energy) are manufactured only because residuals from harvesting trees for sawmilling and the sawmilling process create an inexpensive source of input.

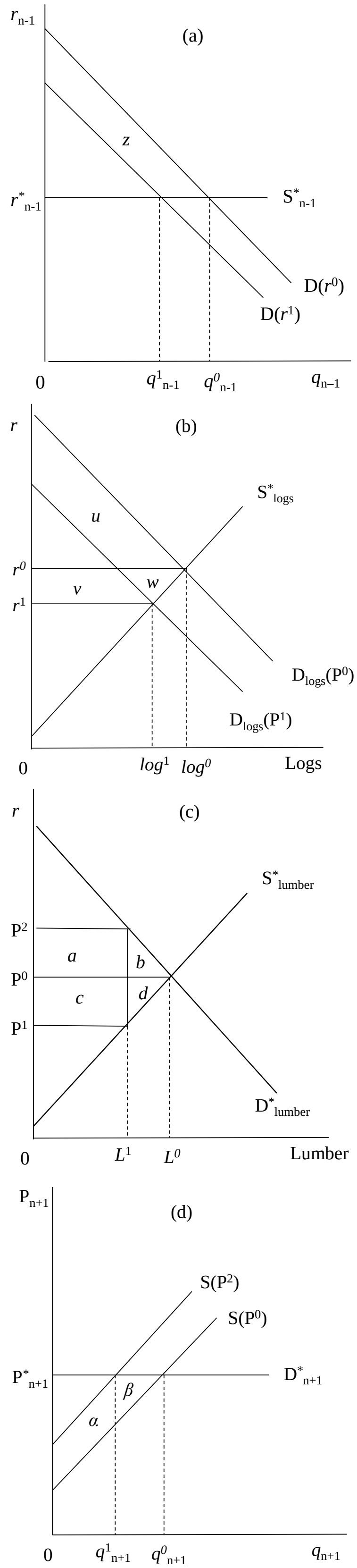

Figure 13: Vertically integrated log and lumber markets

The government policy creates a wedge between the demand price and the supply price. The price upstream users (consumers) of lumber must pay rises from P^0 to P^2, while the price received by the sawmill falls from P^0 to P^1. The function labelled D^*_{lumber} is a derived demand for lumber by upstream processors (home builders, furniture makers, etc.). When the price of lumber goes up from P^0 to P^2, the loss in consumer surplus is given by area $a+b$; this is equivalent to the reduction in quasi-rent available to upstream producers and is given by area $\alpha+\beta$ in panel (d). Note, however, that it is necessary to employ only one measure, say area $a+b$ in the lumber market of panel (c); it is not necessary to estimate the equivalent loss in the upstream market of panel (d).

Now consider the change in quasi-rent experienced by lumber producers as a result of the government policy that created a wedge between the demand and supply prices. Lumber producers experience a loss given by area $c+d$ in Figure 13(c). This same loss can be measured under the derived demand function in Figure 13(b); the equivalent loss in the log market is given by area $u+w–v$. Again, it is only necessary to measure the change in quasi-rent (producer surplus) in the lumber market, not the downstream log market.

There remain two additional surplus measures that need to be taken into account. First, in the log market, suppliers experience a reduced demand for logs because the lower supply price for lumber shifts the derived demand for logs from $D_{logs}(P^0)$ to $D_{logs}(P^1)$. The loss in quasi-rent incurred by log suppliers is given by area $v+w$, which is equivalent to area z in the downstream market in Figure 13(a). And again, it is necessary only to measure this loss in the log market and not the downstream market for q_{n-1}.

Finally, it is necessary to account for the scarcity rent that the government policy has created. This rent could accrue to the government as tax revenue or as revenue from sale of quota, or to the lumber producers if they are permitted to capture this rent. The rent is equal to area $a+c$ in panel (c), and, if it is captured by the lumber producers, they would then benefit by the amount given by area $[(a+c) – (c+d)] = [(a+c) + (v–u–w)]$; this area represents an overall gain to producers (van Kooten 2002). The total change in welfare due to the government policy would equal area $[–(a+b) – (c+d) + (a+c) – (v+w)] = [–(a+b) + (v–u–w) + (a+c) – (v+w)] = –(b+d+v+w) < 0$, which is the deadweight loss due to the policy.

The point of the above analysis is this: the welfare measures appropriate for the forest trade model are the quasi-rent and consumer surplus changes in the lumber market plus the quasi-rent accruing to log suppliers. This is predicated on the assumption that remaining upstream and downstream markets are characterized by perfectly elastic output demand and input supply, respectively. It is also predicated on the assumption that other wood product markets are characterized by a perfectly elastic demand function or that lumber production is the only downstream use of logs.[11]

3.2 Income Redistribution: Measuring Surplus *Ex Post*

If a country exports or imports no logs or lumber, and there are no distortions in the domestic market, then the domestic supply and demand prices and quantities are equal. In that case, the economic surplus in the lumber market is simply given by the area under the demand curve minus the area under supply (e.g., area $a+b+c+d$ in Fig 13c). The surplus to suppliers of logs is given by the equilibrium price of logs multiplied by quantity minus the area under the log supply schedule.

When trade leads a country to be an importer or exporter of lumber (or logs), the quantities demanded and supplied are no longer equal. The situations for each of an importing and an exporting region are shown in Figures 14 and 15, respectively, where the left-hand diagrams represent situations where there is no market failure, while the right-hand diagrams represent the case of an export tax or import tariff (which effectively increases the transportation cost between two or more regions), or a quota restriction. A tax, tariff or quota causes the world price to increase from P_w to P'_w, driving a wedge between the price consumers pay and the domestic cost of production so $P'_w > P^S$, where P^S is the supply price (or marginal cost).

Consider first the case where there is no government policy anywhere to distort prices. Then, the net surplus in an importing country is given by the consumer surplus S_1+S_2 plus the quasi-rent R in Figure 14(a). The net surplus in an exporting country is given by the consumer surplus M plus the quasi-rent $N_1+N_2+N_3$ in Figure 15(a). Notice that, in each region, the supply and demand prices will be identical ($P^S = P^D$), and these prices will be the same across regions once they are adjusted for transportation costs. Thus, one can use either the demand or supply price to calculate the consumer surplus and the quasi-rent. It is only if there is a market distortion

[11] The first assumption amounts to the existence of a parallel (horizontal) market for other wood products at the same level in the marketing chain as the lumber diagram in Figure 14(c), but then with a demand function that is horizontal as in Figure 14(d).

(tax, tariff or quota) that the demand price and supply price might differ.

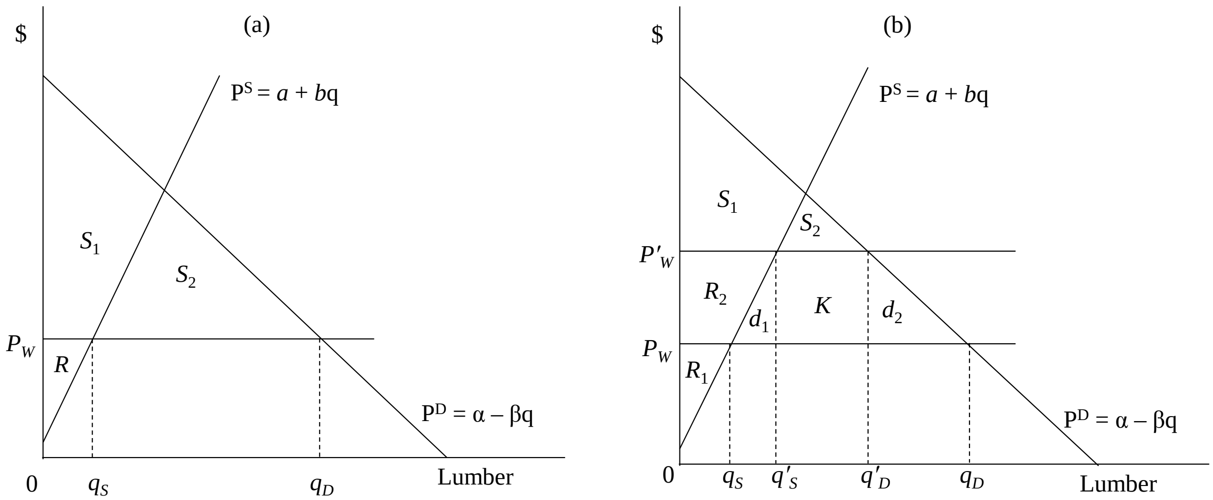

Figure 14: Identifying surplus areas for an importing region

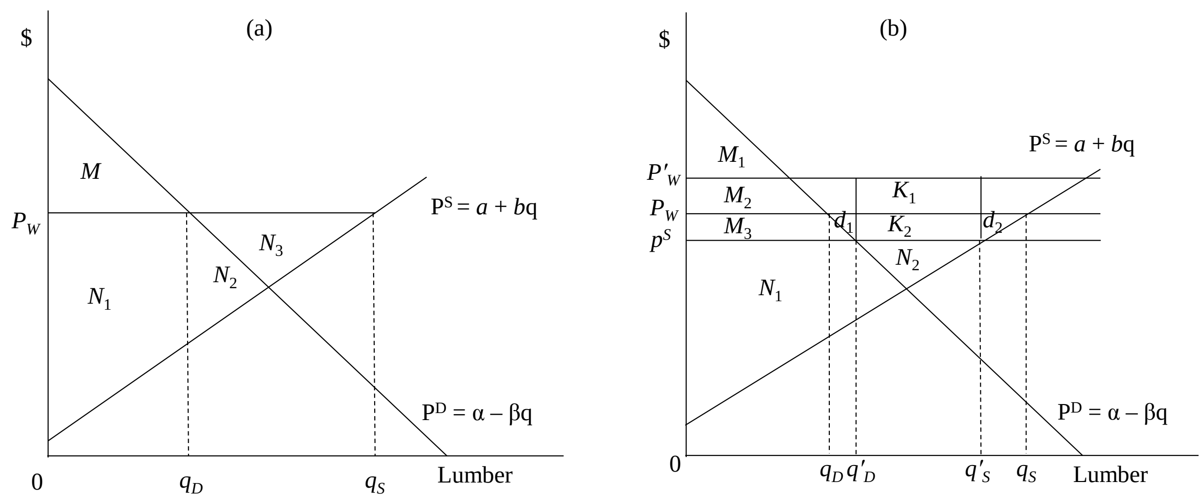

Figure 15: Identifying surplus areas for an exporting region

In the case of an importing country, an import tariff on lumber will raise the domestic price from P_w to P'_w, as indicated in Figure 14(b). The resulting decline in consumer surplus is given by $R_2+d_1+K+d_2$, the quasi-rent accruing to producers increases by R_2 and the government collects K as tariff revenue. The situation is similar if an importing region restricts the amount that can be imported. In this case, however, area K is a quota rent that accrues to foreign producers, an authorized domestic importer or the government acting as importer – that is, the quota creates a scarcity rent that could accrue to any economic agent (and thus could lead to rent seeking behaviour, as demonstrated in the case of U.S. lumber producers). Indeed, this is why countries will voluntarily impose export restrictions (van Kooten 2002; Schmitz et al. 2010, p.103). In both cases, however, the deadweight loss due to the intervention is given by d_1+d_2, with d_1 the result of producing lumber at inefficient domestic mills as opposed to more efficient foreign ones. Area d_2 is the loss to upstream lumber users (i.e., lumber consumers) because they might substitute more expensive construction material for lumber.

Now consider the welfare measures for examining the distributional impacts of government policy. For an importing country, the consumer surplus and quasi-rent can be calculated using either the supply or the demand price as both will be equal, both before and after the policy intervention. If the price is P_w, the consumer surplus is $S_1+S_2+R_2+d_1+K+d_2$ and quasi-rent R_1; if the price rises to P'_w because of government policy, the consumer surplus is S_1+S_2 and quasi-rent R_1+R_2.[12] This leaves the policy-induced rent area K in Figure 14(b), but it can be calculated as part of the rent accruing to the exporter (as discussed below).

The situation is different for the case of an exporter. Since there are no imports, it is not possible to place a tariff on them. An export tax, on the other hand, applies to the excess supply function as indicated in Figure 10; it creates a wedge between the price that foreign consumers pay and the supply price, and this wedge exceeds the transportation cost – suppliers would wish to produce more but are prevented because the tax raises the transaction cost of selling lumber into the foreign market, thus lowering the amount foreign consumers purchase. The effect is identical to that of an export quota in that suppliers wish to produce more but are prevented by government regulation. The situation is shown in Figure 15(b).

Initially, consumers and producers in the domestic market face the transportation cost-adjusted global price, P_w. The export tax or quota policy results in an increase in the transaction cost-adjusted world price to P'_w, where the transaction cost includes transportation costs and explicit taxes or the implicit payment for quota. Lumber producers continue to be paid their marginal supply price, although it is now lower than the world price so that $P^S<P_w<P'_w$, but domestic consumers benefit from the export tax or quota because they also pay P^S. Domestic

[12] Notice that areas denoted S_1 and S_2 in panel (b) are not meant to be identical to areas S_1 and S_2 in panel (a), and so on.

consumer surplus increases from (M_1+M_2) to (M_1+M_2+M_3) for a net gain of M_3, while quasi-rent accruing to lumber suppliers in Figure 15(b) declines from (N_1+N_2+M_3+d_1+K_2+d_2) to (N_1+N_2) for a net loss of (M_3+d_1+K_2+d_2). However, there is a policy-created scarcity rent equal to K_1+K_2 and a deadweight loss given by d_1+d_2 (as was the case in Fig 14b). The supply price P^S can be used to calculate the consumer surplus and quasi-rent areas in the exporter's domestic market, both before and after the policy intervention.

This leaves only the calculation of the policy-induced scarcity rent, whether it results from an import tariff, export tax or quota. Who collects the rent is clear from the particular policy under investigation. The scarcity rent accruing to any region is given by the difference between the demand price in any given importing region minus the supply price in the exporting region multiplied by the quantity of lumber transferred between the two regions. The sum of these measures across the various regions engaged in bilateral trade, and then adjusted for transportation costs, constitutes the scarcity rent in the model. In the current model, all regions both consume and produce lumber, so the scarcity rent in any region is simply equal to the difference between the demand and supply prices multiplied by the consumption of lumber.

Finally, we need to consider the log market. As noted in the discussion pertaining to Figure 13, the relevant consumer surplus in the log market simply constitutes an alternative measure of the quasi-rent accruing to lumber suppliers. Hence, the impacts of any policies affecting lumber markets would be captured by the changes in quasi-rent accruing to lumber suppliers. In that case, the only surplus measure of interest would be the quasi-rent accruing to log suppliers as indicated earlier. What about tax or quota policies that affect the availability of logs? In the case of an export or import tax on logs, the policy-induced surplus area is given simply by the tax revenue. Alternatively, the scarcity rent accruing in any region's log market can be calculated by multiplying the shadow price of logs times the quantity of logs produced. The shadow price is useful in this regard because, unless it is zero, the shadow price is indicative of a shortage of logs and it is the value attached to that shortfall.

3.3 Model Specification

Mathematical programming model: Objective function

The RPTM is formulated as a mathematical program where the objective function is maximized subject to a variety of technical and economic constraints. Each region is assumed to have linear (inverse) lumber demand and supply curves similar to those in equations [1] and [2]. Let d = 1, …, D refer to lumber demand regions of which there are D, and s = 1, …, S refer to lumber supply regions of which there are S. Then

[5] $P_d = \alpha_d - \beta_d q_d$, $\alpha, \beta \geq 0,\ \forall d = 1, \ldots, D$, and

[6] $P_s = a_s + b_s q_s$, $a, b \geq 0,\ \forall j = 1, \ldots, S$.

The objective in the forest trade model is to maximize the sum of the consumer surpluses and quasi-rents across all relevant markets, plus any potential rent caused by natural resource scarcity, that is, limits on timber (log) availability.[13] The sum of consumer surpluses and quasi-rents is found by maximizing the sum of the areas under the D demand schedules [5] and subtracting the sum of the areas under the S lumber supply schedules [6]. These respective areas are given by:

[7] $B_d = \int_0^{q_d} (\alpha_d - \beta_d x)dx = \alpha_d q_d - \frac{1}{2}\beta_d q_d^2,\ \forall d = 1, \ldots, D,$

[8] $C_s = \int_0^{q_s} (a_s + b_s x)dx = a_s q_s + \frac{1}{2} b_s q_s^2,\ \forall s = 1, \ldots, S,$

where x is an integration variable, B_d is total benefit (area under demand) in demand region d, and C_s is total cost (area under supply) in supply region s.

In the log market, the area under the demand schedule and above price is an alternative measure of the quasi-rent in the lumber market, as noted in the discussion of Figure 13. Thus, we need not measure consumer surplus in the log market as it is already measured in the lumber market. However, the quasi-rent to log producers needs to be included in the objective function, and it is found as follows. The supply or marginal cost of logs is assumed to be linear: $r = m + nQ$, where Q is the quantity of logs. In each log-supply region, the social cost of providing logs

[13] As noted, the resource scarcity rent in the logs market is difficult to calculate and we might only do so ex post based on shadow prices. Therefore, the log scarcity rent is not explicitly included in the objective function (but see below). As already noted, policy-induced scarcity rent leads to a deadweight loss and income transfers that could benefit one or more regions and/or one or more economic agents. For further discussion of resource rents see van Kooten and Folmer (2004, pp.38-44).

(the quasi-rent) is found by multiplying the marginal cost or supply price r by the market-clearing log quantity and then subtracting the area under the log supply function up to that quantity. Assume there are k=1, …, K log supply regions. The quasi-rent from supplying logs from any one region k is given by:

$$[9] \qquad R_k = r_k\, Q_k - \int_0^{Q_k}(m_k + n_k x)dx = (m_k + n_k Q_k)Q_k - m_k Q_k - \frac{1}{2}n_k Q_k^2 = \frac{1}{2}n_k Q_k^2.$$

Given that a free market leads to the greatest overall wellbeing (Harberger 1971, 1972), any government policy that restricts the sale of lumber or logs (whether a tax/tariff or quota) reduces the overall wellbeing of the regions in the model, although an individual region might be able to enhance its own wellbeing (or that of some agents in that region). In the objective function, we subtract the tax revenue because it results in distortions that violate the Harberger outcome – if taxes were a policy variable in the model, they would be set to zero as this would maximize overall welfare. Finally, the transportation costs associated with log and lumber trade must be subtracted as they are a cost to global society.

Then the objective function can be written as:

$$[10] \qquad W = \sum_{d=1}^{D} B_d - \sum_{s=1}^{S} C_s + \sum_{k=1}^{K} R_k - \sum_{k=1}^{K}\sum_{s=1}^{S} \delta T_{ks} Q_{ks} - \sum_{s=1}^{S}\sum_{d=1}^{D} T_{sd} q_{sd} - \sum_{k=1}^{K}\sum_{s=1}^{S} t_{ks} Q_{ks} - \sum_{s=1}^{S}\sum_{d=1}^{D} t_{sd} q_{sd},$$

where W refers to overall wellbeing, T_{ij} is the cost ($/m^3) of transporting lumber from region i to region j, δ is a parameter that takes into account the extra cost of transporting logs because they occupy more space per cubic meter than lumber, t_{ks} is the tax on logs ($/m^3) originating in log supply region k and sold to lumber producing region s, and t_{sd} the tax on lumber ($/m^3) produced in lumber supply region s and sold in lumber demand region d.

The first two terms in the objective function [10] constitute the overall sum of consumer surpluses plus quasi-rents in the lumber markets, but they also include the scarcity rents due to a tax, tariff or quota. This is clear from the expressions for B_d and C_s given in equations [7] and [8], respectively; these expressions simply calculate the differences between the supply and demand schedules and thus include any rents caused by market distortions. The third term is the sum of the quasi-rent accruing to log suppliers (equation [9]), but it excludes any scarcity rent resulting from policies that restrict log flows among regions. The fourth and fifth terms are the respective costs of transporting logs and lumber between various regions, and the final two terms are the taxes paid on logs and lumber, respectively.

Notice that the policy-induced scarcity rent in the lumber market is included as a benefit, via the first two terms in objective function [10], but also as a cost via the last term in [10]. The scarcity benefits are clearly measured in a different fashion than the costs. The reason for including the two measures – the scarcity rent as a benefit and its collection as a cost – is to ensure that the added transaction costs is appropriately taken into account in determining the optimal lumber flows among regions. In the case of logs, the collection of the scarcity rent through a tax is taken into account in order optimally to allocate logs across regions. However, there is no ability in the model to include the policy-induced scarcity back as a benefit, so this needs to be done *ex post*.

Mathematical programming model: Constraints

Objective [10] is maximized subject to a number of biophysical and economic constraints relating to the availability of timber harvests, log supply, lumber production and demand, and so on. These constraints are specified as follows. First, the quantity of roundwood produced by any log supply region k (Q_k) is constrained by the timber harvest and the region's ability to convert raw timber into roundwood (logs):

[11] $Q_k \leq \phi_k \times h_k, \ \forall k.$

In [11], parameter ϕ_k indicates how much of the timber harvest in region k (denoted h_k) is convertible to coniferous industrial roundwood (logs), which depends on tree species, size of trees and a region's technical skills, among other things. The sale of logs by region k to all other regions, including domestic sales, is limited to what is produced by log supply region k:

[12] $\sum_{s=1}^{S} Q_{sk} \leq Q_k, \ \forall k.$

Lumber production in lumber-supply region s cannot exceed the total of all industrial roundwood that the region can produce or purchase from other regions multiplied by a recovery factor ξ_s that converts roundwood into sawn timber.

[13] $q_s \leq \xi_s \times \sum_{k=1}^{K} Q_{ks}, \forall s.$

However, the ability of a region to convert coniferous roundwood to lumber is constrained by its sawmilling capacity:

[14] $q_s \leq q^*_s, \forall s.$

where q^*_s refers to the sawmilling capacity of region s.

The lumber that region s can then sell to all lumber-demand regions, including domestic buyers of lumber, is constrained by its total production of lumber as follows:

[15] $\sum_{d=1}^{D} q_{ds} \leq q_s, \forall s.$

Finally, the total lumber supplied to any given region must equal or exceed the demand for lumber in that region. Thus,

[16] $\sum_{s=1}^{S} q_{sd} \geq q_d, \forall d.$

The constrained optimization program maximizes objective [10] subject to constraints [11] through [16] plus non-negativity conditions on the decision variables. For each of the relevant regions, the decision variables are roundwood (log) supply (Q_k), flows of logs from log supply regions to lumber producing ones (Q_{ks}), lumber consumption (q_d), lumber supply (q_s), and flows of lumber from producing to consuming regions (q_{sd}).

Notice that no time subscripts are employed in the forgoing discussion. This was done because the model is solved in each period independent of time. That is, the decision maker does not take into account the impact that current decisions have on the evolution of the system. Although timber harvest in one period reduces the timber available in the next period, this change is treated as exogenous to the solution of the model in the next period; population growth, changes in sawmilling capacity, changes in the availability of timber for harvest, and so on are treated as exogenous.[14] Thus, the model outcomes in future periods are sensitive to the assumptions regarding how forests and economies change over time.

[14] This is similar to what is done in many energy models, integrated assessment models for climate change, et cetera.

Income distribution: Surplus areas

Consider first the surpluses that accrue in the lumber market. When measuring the consumer surplus and quasi-rent for a particular region, it is necessary to determine the status of that region. For an importing region and especially a region that produces no lumber of its own, the consumer surplus (CS) must be calculated using the demand price (as there might be no supply price). In that case, the consumer surplus is calculated as follows:

[17] $$\text{CS}=\int_0^{q_d}(\alpha_d - \beta_d x)dx - P^D q_d = \left(\alpha_d q_d - \frac{1}{2}\beta_d q_d^2\right) - (\alpha_d - \beta_d q_d)q_d = \frac{1}{2}\beta_d q_d^2.$$

where P^D is the demand price in the domestic market and q_d refers to the quantity consumed.

For an exporting country, we employ the supply price as argued in conjunction with Figure 15(b). Again the consumer surplus (CS) is given by total area under the demand curve (equation [7]) minus what the consumers pay. In this case, however, we use the supply price to determine what consumers pay. In that case, the consumer surplus is calculated as follows:

[18] $$\text{CS}=\int_0^{q_s^D}(\alpha_s - \beta_s x)dx - P^S q_s^D = \left(\alpha_s q_s^D - \frac{1}{2}\beta_s {q_s^D}^2\right) - (a_s + b_s q_s^D)q_s^D$$
$$= (\alpha_s - a_s)q_s^D - \left(\frac{1}{2}\beta_s + b_s\right){q_s^D}^2,$$

where P^S is the supply price in the market of exporting (supply) region *s* and q_s^D refers to the quantity demanded or sold in that exporting region. Similarly, the quasi-rent (*QR*) is given by:

[19] $$QR_s = P^S q_s - \int_0^{q_s}(a + bx)dx = (a_s + b_s q_s)q_s - \left(a_s q_s + \frac{1}{2}b_s q_s^2\right) = \frac{1}{2}b_s q_s^2.$$

where q_S is the quantity of lumber produced domestically in region *s* and sold domestically or exported.

Finally, the policy-induced scarcity rent (*SR*) in the lumber market is given by:

[20] $$SR_s = (P^D - P^S)(q_s - q_s^D) = [(\alpha_s - \beta_s q_s^D) - (a_s + b_s q_s)](q_s - q_s^D).$$

In the log market, the quasi-rent is given by equation [9]. To this must be added any resource scarcity rent or policy-induced scarcity rent. The policy-induced scarcity rent in the log market is simply equal to the tax revenue that is collected by a government that imposes an export tax on logs. It can also be calculated ex post as the shadow price of logs times the volume produced. It should be noted, however, that a tax is used in the RPTM to implement a quota.

3.4 Model Calibration

It is increasingly important that trade models are appropriately calibrated, with economic theory guiding the calibration. There are essentially two methods of calibration that can be employed. First, models can be calibrated using the historical mixes approach (McCarl 1982; Önal and McCarl 1991). This approach is based primarily on the observation that optimal results to a linear program are found at corner solutions (extreme points). Since a linear combination of the optimal corner solutions is also optimal, it is possible to find solution 'mixes' that consist of a weighted combination of the activities (decision variables). Now assume that the historical mix of activities was optimal: Otherwise why would decision makers have chosen this mix of activities? The historical choices can be taken into account by constraining the current decision to be a weighted average of past decisions, with the weights determined endogenously within the mathematical programming model and the sum of the weights constrained to equal 1. Chen and Önal (2012) extend this method by including decisions not available in the past. They do this by adding synthetic (or simulated) mixes of the decision variables to the historical mixes, allowing the optimization procedure to choose the weights, and constraining the sum of the historical and synthetic weights to equal 1.

A second method was proposed by Howitt (1995) and is known as positive mathematical programming (PMP). It has steadily gained acceptance among economists engaged in mathematical modelling (see de Frahan et al. 2007; Paris 2011, pp.340-411; Heckelei et al. 2012), including its use in spatial price equilibrium trade modelling (Paris et al. 2011). Positive mathematical programming uses the notion that any calibration constraint can be represented in the objective function (e.g., a linear calibration constraint might be represented as a nonlinear cost function in the objective). Rather than adding arbitrary calibration constraints to ensure that the optimal solution to a mathematical program replicates what is observed, the PMP method uses the shadow prices associated with such constraints to re-specify the objective function. The calibrated model is then solved to replicate the observed values exactly. The objective function that is derived using PMP takes into account forest quality heterogeneity (e.g., stand quality, previous management decisions), decision makers' risk, political nuances and unobserved costs that are not otherwise taken into account. In SPE trade models, calibrated parameters represent those that represent the 'effective' transaction costs between export and import regions that model the observed flows of logs and lumber.

In the current trade model, the PMP method is used to calibrate the model to both the observed log and lumber trade flows among the twenty regions in the model. PMP is required because the available transaction (transportation) cost data that explain differences in prices between regions are not fully available. Effective transaction costs include the effects of missing policy instruments, such as implicit or even explicit export subsidies, and thus are not included in the transaction cost data available to the researcher. For example, transportation cost data are of a less than desirable quality and assume a fixed factor relation between the costs of transporting logs and those of transporting lumber that may not indeed be true. The PMP method corrects for available transaction cost data for unobserved transaction costs. In the context of the current trade model, it is necessary to adjust the transportation or transaction costs in the fourth and fifth terms of the objective function [10], namely, T_{ts} and T_{sd}.

PMP is implemented in three stages using the approach described in Paris et al. (2011). First, the quadratic program (QP) that constitutes the trade model described in section 4.3 is solved to maximize objective function [10] subject to all of the accompanying constraints plus the following calibration constraints:

[21] $$Q_{ks} = \bar{Q}_{ks},\ \forall k,s$$ (Log flows calibration constraint)

[22] $$q_{sd} = \bar{q}_{sd},\ \forall s,d$$ (Lumber flows calibration constraint)

where $\bar{Q}_{ks}$ and $\bar{q}_{sd}$ represent, respectively, the observed trade flow in logs between timber producing region k and lumber producing region s and the trade flow in lumber between supply region s and demand region d. In both cases, the potentials of a region to sell logs and/or lumber to itself (k=s and s=d) are included. The number of calibration constraints is equal to $t \times s$ plus $s \times d$.[15] Associated with the calibration constraints [21] and [22] are the dual (shadow) prices, λ_{ts} and λ_{sd}, which are found by solving the original model with the calibration constraints included.

The second phase of the PMP method is that of finding the shadow prices. Although quite

[15] In the current model there are twenty regions, so 400 calibration constraints are required.

straightforward in the current context, in other settings it might require the use of a maximum entropy algorithm (Paris and Howitt 1998; see also Jansson and Heckelei 2009). Because [21] and [22] are equality constraints, the shadow prices (λ_{ts} and λ_{sd}) can be positive or negative, and are used to adjust the transportation costs in the original objective function. That is, the relevant term in objective function [10] is now expressed as:

$$[23] \quad \sum_{k=1}^{K} \sum_{s=1}^{S} \delta(T_{ks} + \lambda_{ks})Q_{ks} - \sum_{s=1}^{S} \sum_{d=1}^{D} (T_{sd} + \lambda_{sd})q_{sd}.$$

In the third stage, the modified objective function is maximized subject to the original constraints. With this modification, the inter-regional lumber trade flows are precisely duplicated by the model.

The fact that the shadow prices λ_{sd} can be negative indicates that the original transaction cost data fail to include missing policy instruments such as export subsidies, for example. Indeed, Paris et al. (2011) indicate that, in some instances, the overall effective transaction costs between two countries might even be negative, as when export subsidies are larger than the sum of other transaction costs. In some circumstances, this may provide additional insight into the potential restrictiveness of trade measures that are otherwise difficult to quantify, such as non-tariff trade barriers (e.g., phytosanitary standards).

3.5 Model Data

The underlying data for the model come from a variety of sources. Forestry statistics from the Food and Agricultural Organization of the United Nations (FAO 2012a, 2012b) constituted the primary source of data, with supplementary data available from the Government of Canada (2012), BC Statistics (2013), Random Lengths (various years), the University of Washington's Center for International Trade in Forest Products (CintraFor),[16] the Global Forest Products Model at the University of Wisconsin,[17] the U.S. Forest Service (e.g., Howard 2001;

[16] See http://www.cintrafor.org/research/currentprojects.shtml.

[17] Data are available from Joseph Buongiorno at http://labs.russell.wisc.edu/buongiorno/ (viewed 22 January 2013). Although it includes a plethora of forest products, the University of Wisconsin's forest trade model was not used because of its drawbacks. For the current purposes, these include its lack of small, sub-country regions. Further, each country trades with a central auctioneer rather than amongst each other, so there is no bilateral trade information (e.g., see Sun et al. 2010).

Oswalt et al. 2009; Warren 2011) and other sources (e.g., Cardellichio and Binkley 2008). Supplementary data were required when FAO data were unavailable or observations were missing (see below). Although it is recognized that, in some cases, the quality of the FAO data is less than desirable, the data are used here because of the completeness and consistency of their global coverage. Consistent production, consumption and trade data are needed to ensure that country- and/or region-level statistics on imports and exports add up to consumption and production as this is important for model calibration.

Given that FAO relies on surveys of forestry agencies in member countries, forest sector production, consumption and trade data for developed countries (with highly-competent government statistical agencies) are better than for developing countries. For example, over a ten-year period, the FAO's log export data tracked within a 1½% band of official Canadian data. For Ethiopia, on the other hand, loss of land due to deforestation turned out to exceed the area covered by forests in the same period.

The FAO data had to be adjusted by relevant data from Canada and the U.S. to separate those countries' forest sector economies into five and three regions, respectively. Further, data from Canada and the U.S. were used to backfill FAO data where the FAO data were missing or not yet available.

The data analysis began with country-level harvest statistics. Model constraint [11] is a sustainability constraint in the sense that production of logs is determined by each region's harvest or annual allowable cut (AAC), which is the maximum amount that can be sustainably harvested in any year, and a parameter that converts harvests into coniferous industrial roundwood. Data on AAC are available from FAO, the U.S. Forest Service (Howard 2001; Oswalt et al. 2009), and the Canadian Forest Service's National Forestry Database (Government of Canada 2012). Factors converting harvested timber into industrial roundwood and then sawnwood were determined by taking ratios of each region's harvests to production of roundwood, and so on.

The FAO provides country-level data on the destinations of various forest product exports and on the origins of imports.[18] Export and import data for coniferous industrial

[18] Available from http://faostat.fao.org/DesktopDefault.aspx?PageID=628&lang=en (viewed 19 January 2013).

roundwood and lumber were reconciled with respective FAO country-level coniferous industrial roundwood and sawnwood production data to create separate matrices for trade flows of these commodities among the twenty countries/regions in the RPTM.[19] The difference between a country's total production of coniferous industrial roundwood, plus imports minus exports, was taken as its domestic consumption of logs; the difference between a country's total production of sawnwood, plus imports minus exports, was taken as its domestic consumption of lumber.

For Canada and the United States, regional consumption of logs was determined by production, while regional exports of logs were allocated using various statistical sources (e.g., BC Statistics 2013) and trade publications (Random Lengths).[20] Regional lumber consumption, on the other hand, was determined by allocating total consumption across regions by their proportion of population. The same was done with respect to regional imports – national imports were allocated across regions according to population. Exports from any Canadian or U.S. region to any other country/region in the model were derived by allocating national exports to those countries/regions by regional production, but then making adjustments based on other sources of information (such as expert opinion). The final trade matrices for logs and lumber that are used in the model are found in Tables 1 and 2, respectively. The model is first calibrated to the trade flows indicated in these tables using positive mathematical programming.

The base-year AAC and log and lumber production and consumption data are provided in Table 3, with log and lumber recovery factors and production costs, and base-year lumber demand prices in Table 4. For simplicity and because data are not available for most regions, log and lumber supply elasticities are assumed to equal 1.0;[21] then the slope of these schedules is simply the ratio of the base production (manufacturing) cost found in Table 4 and the associated level of production from Table 3. The price and income elasticities of lumber demand are provided in Table 5, as are assumptions about each region's expected growth in AAC and gross domestic product (GDP). The latter assumptions are used when looking at changes over time.

[19] Available from (viewed 19 January 2013): http://faostat3.fao.org/home/index.html.
[20] Regional production of sawnwood was first based on regional production of coniferous roundwood using forestry statistics from the Government of Canada (2012) and BC Statistics (2013) for Canada, and Howard (2001), Oswalt et al. (2009) and Warren (2011) for the U.S. Population data are from Statistics Canada and the U.S. Census Bureau, while world population data are from the FAO (2012a).
[21] Supply elasticity estimates for some regions range from 0.8 to 1.1, but it was not clear if these were statistically different from 1.0 rather than 0.0 as indicated in tests of statistical significance.

Table 1: Bilateral Coniferous Industrial Roundwood Trade Flows, Twenty Model Regions, 2010 (‘000s m^3)[a]

Export to import region	Australia	BC Coast	BC Interior	Alberta	Atlantic Canada	Rest of Canada	Chile	China	Finland	Japan	New Zealand	Russian Fed	Sweden	US North	US South	US West	Rest LA	Rest Europe	Rest Asia	ROW	TOTAL Productio
Australia	13,288.0	0.0	0.0	0.0	0.0	0.0	0.0	935.0	0.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	200.0	25.0	**14,498.0**
BC Coast	0.0	11,650.0	0.0	0.0	0.0	0.0	0.0	1,680.0	0.0	1,142.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	921.0	0.0	**15,393.0**
BC Interior	0.0	0.0	45,245.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**45,245.0**
Alberta	0.0	0.0	0.0	13,667.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	**13,667.6**
Atlantic Canada	0.0	0.0	0.0	0.0	11,152.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**11,152.2**
Rest of Canada	0.0	0.0	0.0	0.0	0.0	27,346.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**27,346.2**
Chile	0.0	0.0	0.0	0.0	0.0	0.0	22,905.9	30.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	300.0	0.0	0.0	0.0	**23,335.9**
China	0.0	0.0	0.0	0.0	0.0	0.0	0.0	65,414.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**65,414.8**
Finland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	38,309.4	0.0	0.0	0.0	290.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**38,599.4**
Japan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14,749.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**14,749.9**
New Zealand	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2,298.0	0.0	750.0	14,713.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3,720.9	0.0	**21,482.6**
Russian Federation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13,203.0	1,324.0	500.0	0.0	65,729.9	57.0	0.0	0.0	0.0	0.0	500.0	8,508.6	2,500.0	**92,322.5**
Sweden	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	110.0	0.0	0.0	0.0	59,419.0	0.0	0.0	0.0	0.0	1,115.0	0.0	0.0	**60,644.0**
US North	0.0	0.0	0.0	0.0	0.0	141.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14,000.0	0.0	0.0	0.0	30.0	120.0	0.0	**14,291.5**
US South	0.0	0.0	0.0	0.0	0.0	1,905.7	0.0	0.0	0.3	1,070.1	0.0	0.0	0.0	0.0	122,800.0	0.0	150.0	250.0	1,200.0	150.0	**127,526.2**
US West	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	600.0	0.0	0.0	0.0	0.0	0.0	56,400.0	60.0	0.0	800.0	100.0	**57,960.0**
Rest LA	0.0	0.0	0.0	0.0	0.0	0.0	100.0	55.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50,970.0	0.0	300.0	0.0	**51,425.3**
Rest Europe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,196.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	181,710.2	0.0	0.0	**182,906.9**
Rest Asia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	200.8	0.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7,716.1	0.0	**7,966.9**
ROW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70.0	200.0	27,117.7	**27,387.7**
TOTAL Consumption	**13,288.0**	**11,650.0**	**45,245.0**	**13,667.0**	**11,152.2**	**29,393.4**	**23,005.9**	**83,816.9**	**40,940.5**	**19,012.1**	**14,713.8**	**65,729.9**	**59,766.0**	**14,000.0**	**122,800.0**	**56,400.0**	**51,480.7**	**183,675.2**	**23,686.5**	**29,892.7**	**913,315.8**

[a] Calculated by the author using data from FAO (2012b), BC Statistics (2013), Government of Canada (2012), Oswalt et al. (2009) and internet sources.

Table 2: Bilateral Sawnwood Trade Flows, Twenty Model Regions, 2010 (‘000s m^3)[a]

Export to import region	Australia	BC Coast	BC Interior	Alberta	Atlantic Canada	Rest of Canada	Chile	China	Finland	Japan	New Zealand	Russia	Sweden	US North	US South	US West	Rest LA	Rest Europe	Rest Asia	ROW	Total Production
Australia	4,515.0	0.0	0.0	0.0	0.0	0.1	0.6	42.1	0.0	4.6	2.8	0.0	0.0	0.0	0.0	0.3	0.0	0.4	36.5	0.4	4,602.7
BC Coast	7.9	208.2	55.2	217.7	135.8	1,369.1	0.6	472.3	0.2	274.9	4.0	0.0	0.4	769.3	607.2	394.3	2.2	45.1	15.7	23.0	4,603.0
BC Interior	28.2	747.5	198.3	781.6	487.5	4,916.4	2.2	1,695.9	0.7	987.0	14.5	0.0	1.4	2,762.6	2,180.3	1,416.0	7.9	161.8	56.5	82.5	16,528.9
Alberta	7.9	208.4	55.3	217.9	135.9	1,370.7	0.6	472.8	0.2	275.2	4.0	0.0	0.4	770.2	607.9	394.8	2.2	45.1	15.8	23.0	4,608.3
Atlantic Canada	5.5	146.0	38.7	152.6	95.2	960.0	0.4	331.2	0.1	192.7	2.8	0.0	0.3	539.5	425.8	276.5	1.6	31.6	11.0	16.1	3,227.6
Rest of Canada	16.6	439.4	116.6	459.4	286.6	2,889.8	1.3	996.8	0.4	580.2	8.5	0.0	0.8	1,623.8	1,281.6	832.3	4.7	95.1	33.2	48.5	9,715.4
Chile	17.0	0.9	0.3	1.0	0.6	6.2	3,769.3	322.0	1.5	289.0	1.5	0.0	0.0	122.5	96.7	62.8	468.3	96.3	197.6	409.2	5,862.7
China	0.7	0.0	0.0	0.0	0.0	0.0	0.0	25,027.9	0.0	77.4	0.2	0.1	0.0	0.3	0.2	0.2	2.0	4.0	21.0	11.7	25,145.7
Finland	10.0	0.0	0.0	0.0	0.0	0.2	0.0	74.0	3,960.5	623.0	0.0	0.3	9.4	0.4	0.3	0.2	0.1	2,313.5	29.8	1,986.1	9,008.0
Japan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.5	0.0	15,492.8	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	2.1	1.2	15,508.9
New Zealand	275.0	0.0	0.0	2.0	0.0	2.0	0.1	683.0	2.4	131.0	1,677.6	0.0	0.6	82.5	65.1	42.3	0.0	107.0	326.2	549.7	3,946.6
Russian Fed	0.1	0.0	0.0	0.0	0.0	0.0	0.0	4,344.0	287.2	843.0	0.0	11,302.1	11.2	0.5	0.0	1.5	0.0	2,919.9	213.4	3,544.5	23,467.5
Sweden	26.0	2.8	0.8	3.0	1.8	18.6	0.1	72.0	25.3	743.0	0.1	0.0	5,462.5	14.3	11.3	7.3	0.1	6,902.8	15.9	2,865.3	16,173.2
US North	1.0	5.8	1.5	6.0	3.8	37.9	0.0	33.5	0.0	24.0	0.0	0.1	0.0	1,670.2	1,318.2	856.1	51.8	5.6	4.6	6.4	4,026.3
US South	9.6	53.5	14.2	55.9	34.9	351.6	0.1	310.8	0.1	223.0	0.2	0.6	0.4	15,510.4	12,241.4	7,950.1	480.7	51.6	43.0	59.5	37,391.7
US West	4.4	24.2	6.4	25.3	15.8	159.3	0.1	140.8	0.0	101.0	0.1	0.3	0.2	7,024.5	5,544.0	3,600.5	217.7	23.4	19.5	26.9	16,934.3
Rest LA	0.3	0.4	0.1	0.4	0.3	2.7	2.2	128.6	0.0	1.6	1.1	0.2	0.1	185.5	146.4	95.1	13,859.3	1.3	3.5	0.4	14,429.2
Rest Europe	245.1	0.4	0.1	0.4	0.2	2.4	0.0	215.5	66.2	881.8	0.6	6.4	144.7	64.9	51.2	33.3	32.2	60,611.4	6.4	156.3	62,519.5
Rest Asia	0.5	0.0	0.0	0.0	0.0	0.0	0.0	20.1	0.0	17.6	0.4	0.0	0.0	0.4	0.3	0.2	23.9	131.2	15,296.8	6.5	15,497.9
ROW	0.3	0.0	0.0	0.0	0.0	0.1	0.0	11.0	0.1	0.8	2.1	0.0	1.4	0.3	0.2	0.1	153.4	3,500.5	63.2	19,272.8	23,006.3
TOTAL consumption	5,171.1	1,837.4	487.5	1,923.3	1,198.4	12,087.3	3,777.7	35,406.6	4,345.1	21,763.7	1,720.5	11,310.2	5,633.8	31,142.2	24,578.2	15,963.9	15,308.2	77,047.5	16,411.6	29,089.8	**316,203.9**

[a] Calculated by the author using data from FAO (2012b), BC Statistics (2013), Government of Canada (2012), Oswalt et al. (2009) and internet sources.

Table 3: Timber Available for Harvest, Coniferous Industrial Roundwood Production and Consumption, Sawnwood Production and Consumption, by Region, 2010 ('000s m^3)[a]

Country/Region	AAC or Harvest	Roundwood Production	Roundwood Consumption	Sawnwood Production	Sawnwood Consumption
Australia	29,788.0	14,498.0	13,288.0	4,602.7	5,171.1
BC Coast	25,600.0	15,393.0	11,650.0	4,603.0	1,837.4
BC Interior	62,246.0	45,245.0	45,245.0	16,528.9	487.5
Alberta	18,689.7	13,667.6	13,667.0	4,608.3	1,923.3
Atlantic Canada	13,052.3	11,152.2	11,152.2	3,227.6	1,198.4
Rest of Canada	33,267.9	27,346.2	29,393.4	9,715.4	12,087.3
Chile	47,215.0	23,335.9	23,005.9	5,862.7	3,777.7
China	291,251.0	65,414.8	83,816.9	25,145.7	35,406.6
Finland	50,952.0	38,599.4	40,940.5	9,008.0	4,345.1
Japan	17,281.0	14,749.9	19,012.1	15,508.9	21,763.7
New Zealand	21,956.0	21,482.6	14,713.8	3,946.6	1,720.5
Russia	173,000.0	92,322.5	65,729.9	23,467.5	11,310.2
Sweden	70,200.0	60,644.0	59,766.0	16,173.2	5,633.8
US North	23,505.4	14,291.5	14,000.0	4,026.3	31,142.2
US South	218,288.8	127,526.2	122,800.0	37,391.7	24,578.2
US West	98,860.8	57,960.0	56,400.0	16,934.3	15,963.9
Rest Latin America	443,222.0	51,425.3	51,480.7	14,429.2	15,308.2
Rest of Europe	347,306.0	182,906.9	183,675.2	62,519.5	77,047.5
Rest of Asia	697,010.0	7,966.9	23,686.5	15,497.9	16,411.6
Rest of World	734,894.0	27,387.7	29,892.7	23,006.3	29,089.8
TOTAL	**3,417,585.9**	**913,315.8**	**913,315.8**	**316,203.9**	**316,203.9**

[a] Calculated by the author using data from FAO (2012b), BC Statistics (2013), Government of Canada (2012), Oswalt et al. (2009) and internet sources. The production and consumption values are identical to those in Table 1 (roundwood) and Table 2 (sawnwood).

Table 4: Log and Lumber Recovery Factors, Prices and Production Costs, 2010[a]

Region	Coniferous industrial roundwood recovery factor	Lumber recovery factor	Base-year lumber manufacturing cost ($/m^3)	Base-year lumber price ($/m^3)	Base-year log costs ($/m^3)
Australia	0.4891	0.347	200.00	225.97	140.00
BC Coast	0.6043	0.396	180.00	204.33	107.00
BC Interior	0.7305	0.366	175.00	195.07	102.00
Alberta	0.7349	0.341	175.00	196.07	102.00
Atlantic Canada	0.8587	0.290	185.00	214.68	125.00
Rest of Canada	0.8261	0.332	190.00	225.41	140.00
Chile	0.4967	0.255	183.00	211.11	111.70
China	0.2257	0.400	240.50	255.00	215.00
Finland	0.7614	0.220	195.00	227.80	140.00
Japan	0.8578	0.818	295.00	325.00	230.00
New Zealand	0.9833	0.268	183.00	212.00	116.00
Russia	0.5363	0.357	190.00	211.11	97.00
Sweden	0.8682	0.271	205.00	248.73	138.00
US North	0.6110	0.294	195.00	227.18	146.30
US South	0.5871	0.305	165.00	193.05	110.00
US West	0.5892	0.302	182.00	212.54	138.00
Rest Latin America	0.1166	0.282	175.00	205.00	150.00
Rest of Europe	0.5293	0.340	245.00	275.00	230.00
Rest of Asia	0.0115	0.660	205.00	229.96	185.00
Rest of World	0.0375	0.775	198.00	208.90	165.00

[a] Calculated by the author using data from FAO (2012b), BC Statistics (2013), Government of Canada (2012), Oswalt et al. (2009) and internet sources. Prices are from Abbott et al. (2009), who used data from Buongiorno's Global Forest Trade Model, Random Lengths (2012), Warren (2011) and Canada's Department of Foreign Affairs and International Trade (at: http://www.international.gc.ca/controls-controles/softwood-bois_oeuvre/index.aspx?lang=eng&view=d viewed 11 February 2013).

Table 5: Lumber Price and Income Elasticities, and Rates of Growth in Available Harvests (AAC) and Gross Domestic Product (GDP)

Region	Price Elasticity of Lumber Demand[a]	Income Elasticity of Lumber Demand[a]	Rate of Growth in AAC or Available Harvest	Average Rate of Growth in GDP
Australia	-0.16	0.32	0.031	0.0274
BC Coast	-0.16	0.32	0.015	0.0237
BC Interior	-0.16	0.32	0.000	0.0237
Alberta	-0.16	0.32	0.015	0.0237
Atlantic Canada	-0.16	0.32	0.015	0.0237
Rest of Canada	-0.16	0.32	0.029	0.0237
Chile	-0.21	0.46	0.032	0.0341
China	-0.21	0.45	0.007	0.0300
Finland	-0.16	0.32	0.014	0.0217
Japan	-0.16	0.4	0.019	0.0300
New Zealand	-0.16	0.32	0.009	0.0162
Russia	-0.14	0.92	0.026	0.0191
Sweden	-0.16	0.32	0.037	0.0158
US North	-0.16	0.32	0.032	0.0237
US South	-0.16	0.32	0.032	0.0237
US West	-0.16	0.32	0.032	0.0273
Rest of Latin America	-0.56	0.38	0.018	0.0206
Rest of Europe	-0.17	0.34	0.014	0.0192
Rest of Asia	-0.21	0.46	0.006	0.0300
Rest of World	-0.20	0.44	0.000	0.0300

[a] Sources Mogus et al. (2006) and Abbott et al. (2009) (see footnote on Table 4).

Methods for determining transportation costs between regions are described by Cardellichio and Binkley (2008), and are employed here. The transportation cost data for lumber are provided in Table 6. Transportation costs for industrial roundwood are simply assumed to be 1.27 times those of lumber. This factor is based on the ratio of volume of lumber to that of roundwood contained in a cubic meter. Lumber is assumed to fill the volume fully, while roundwood is assumed to be perfectly cylindrical (which is highly unlikely). Finally, British Columbia's log export policies impose costs upon forest companies that export those logs. These costs relate to transaction costs, fees in lieu of employing the logs in local mills, and so on. To represent these costs in the trade model, we simply assume an export tax equivalent of these costs equal to 25%, the same export tax that Russia imposes on exports of logs.

Table 6: Inter-regional Transportation Costs for Lumber, Twenty Regions, $/m^3, 2010[a]

Export to Import Region	Australia	BC Coast	BC Interior	Alberta	Atlantic Canada	Rest of Canada	Chile	China	Finland	Japan	New Zealand	Russia	Sweden	US North	US South	US West	Rest of Latin America	Rest of Europe	Rest of Asia	Rest of World
Australia	0.00	60.63	62.26	63.89	75.50	81.57	55.03	43.41	75.66	37.97	10.45	70.33	73.74	77.56	67.02	58.54	64.79	78.02	43.41	53.41
BC Coast	60.63	0.00	9.64	12.84	43.70	33.26	51.19	40.63	73.12	39.63	55.08	81.77	72.12	38.59	31.58	17.49	53.60	72.12	40.63	79.76
BC Interior	62.26	9.64	0.00	6.64	40.42	30.11	60.61	49.63	82.34	48.32	63.08	90.00	81.12	35.46	29.86	18.40	60.46	81.12	49.60	88.13
Alberta	63.89	12.84	6.64	0.00	37.14	26.95	63.19	52.63	85.20	52.00	67.10	94.00	84.12	32.32	28.15	19.32	65.32	84.12	52.53	94.50
Atlantic Canada	75.50	43.70	40.42	37.14	0.00	12.88	42.26	82.26	38.45	78.52	73.39	46.83	34.45	9.84	32.08	46.87	37.71	43.18	64.37	58.28
Rest of Canada	81.57	33.26	30.11	26.95	12.88	0.00	51.82	94.92	40.84	90.08	85.36	58.84	46.45	5.96	20.96	34.61	49.71	54.84	76.37	72.56
Chile	55.03	51.19	60.61	63.19	42.26	51.82	0.00	49.50	65.39	49.97	46.89	68.53	63.47	43.65	36.35	40.05	21.45	60.50	49.00	68.52
China	43.41	40.63	49.63	52.63	82.26	94.92	49.50	0.00	100.15	8.20	50.48	52.67	96.10	94.65	78.52	56.45	85.35	97.15	3.00	62.84
Finland	75.66	73.12	82.34	85.20	38.45	40.84	65.39	100.15	0.00	92.15	80.81	8.38	4.02	43.18	41.18	65.25	54.83	11.99	99.00	50.83
Japan	37.97	39.63	48.32	52.00	78.52	90.08	49.97	8.20	92.15	0.00	42.88	56.67	95.00	88.65	77.60	64.45	72.87	96.15	10.17	71.49
New Zealand	10.45	55.08	63.08	67.10	73.39	85.36	46.89	50.48	80.81	42.88	0.00	78.59	82.51	78.86	68.83	66.90	68.31	86.64	50.48	57.10
Russia	70.33	81.77	90.00	94.00	46.83	58.84	68.53	52.67	8.38	56.67	78.59	0.00	11.33	48.18	48.18	69.25	57.24	15.18	22.15	69.16
Sweden	73.74	72.12	81.12	84.12	34.45	46.45	63.47	96.10	4.02	95.00	82.51	11.33	0.00	43.18	41.18	64.25	52.99	9.81	98.00	50.29
US North	77.56	38.59	35.46	32.32	9.84	5.96	43.65	94.65	43.18	88.65	78.86	48.18	43.18	0.00	22.83	38.94	44.71	48.88	73.02	60.94
US South	67.02	31.58	29.86	28.15	32.08	20.96	36.35	78.52	43.18	77.60	68.83	48.18	41.18	22.83	0.00	22.07	38.27	43.88	67.20	46.97
US West	58.54	17.49	18.40	19.32	46.87	34.61	40.05	56.45	65.25	64.45	66.90	69.25	64.25	38.94	22.07	0.00	48.06	67.95	44.82	77.87
Rest of Latin America	64.79	53.60	60.46	65.32	37.71	49.71	21.45	85.35	54.83	72.87	68.31	57.24	52.99	44.71	38.27	48.06	0.00	49.21	57.35	45.77
Rest of Europe	78.02	72.12	81.12	84.12	43.18	54.84	60.50	97.15	11.99	96.15	86.64	15.18	9.81	48.88	43.88	67.95	49.21	0.00	98.00	48.16
Rest of Asia	43.41	40.63	49.60	52.53	64.37	76.37	49.00	3.00	99.00	10.17	50.48	22.15	98.00	73.02	67.20	44.82	57.35	98.00	0.00	62.84
Rest of World	53.41	79.76	88.13	94.50	58.28	72.56	68.52	62.84	50.83	71.49	57.10	69.16	50.29	60.94	46.97	77.87	45.77	48.16	62.84	0.00

[a] Calculated by the author using data from Abbott et al. (2009) and internet sources.

3.6 Model Calibration Again

The first step in solving the trade model is to calibrate the transaction costs for trading logs and lumber among various regions, including one's own region. By including calibration constraints [21] and [22] for logs and lumber, we find the shadow prices associated with the equilibrium constraints. Only the shadow prices for sawnwood are provided in Table 7. As noted in Section 3.4, shadow prices adjust the observed transportation and other transaction costs reported in Table 6; for lumber, the shadow values in Table 7 are simply added to the values in Table 6 to obtain the effective transaction costs, which are provided in Table 8.

The situation for logs differs because there are so many instances where there are no bi-lateral flows of logs between regions (see Table 1). For those zero bi-lateral flows, the shadow price turns out to equal the negative of the associated transportation or transaction costs. Then the adjusted transaction costs are zero, but the use of these adjusted transaction costs leads to unreasonable flows of logs (e.g., from Sweden to British Columbia) in some policy scenarios. To prevent this and still obtain bi-lateral log flows close to those observed in Table 1, the shadow price associated with bi-lateral trade between any timber supply region and the following regions is arbitrarily set at \$250/m^3 to prevent such bi-lateral log flows: British Columbia, Alberta, the Scandinavian countries, Australia/New Zealand/Chile and Russia. This is done after the PMP phase of the model, but before scenario analysis. The 're-calibrated' trade flows in logs and lumber for the base-case scenario are provided in Table 9.

Comparisons between Tables 1 and 9, and between Tables 2 and 10, indicate that the new re-calibration results in bi-lateral trade flows that are relatively close to the observed flows. Unfortunately, they do not duplicate the observed trade flows exactly. Indeed, when only the shadow prices derived from the calibration constraints are used, the calibration is exact even though the adjusted transaction costs have a large number of zeros. But these adjusted transaction costs lead to unreasonable trade flows in logs in many policy scenarios, indicating that out of sample prediction is particularly problematic. Nor is the issue resolved by calibrating the model only to bi-lateral lumber flows; indeed, such a calibration leads to even less desirable outcomes during policy analysis – less desirable in terms of illogical bi-lateral flows of both logs and lumber. Without further investigation, the ad hoc adjustments to the shadow prices derived from the calibration constraints on log flows appear to be the least objectionable approach.

Table 7: Adjustments Required to the Transaction Costs Matrix for Sawnwood Trade Flows, Shadow Prices, 20 Regions ($/m^3)[a]

Export to import region	Australia	BC Coast	BC Interior	Alberta	Atlantic Canada	Rest of Canada	Chile	China	Finland	Japan	New Zealand	Russian Fed	Sweden	US North	US South	US West	Rest LA	Rest Europe	Rest Asia	ROW
Australia	47.09	-32.65	-60.12	-60.87	-56.05	-52.64	-56.10	7.24	-8.07	-1.43	-5.01	-75.75	-8.73	27.32	17.86	36.34	-34.94	-80.02	12.49	-19.77
BC Coast	52.63	104.05	68.57	66.26	51.83	71.74	25.34	86.09	70.74	73.37	27.39	-9.20	69.16	116.81	103.82	127.91	52.33	1.95	91.35	29.96
BC Interior	64.56	106.68	90.48	84.73	67.37	87.17	30.26	89.36	74.05	77.46	32.95	-2.58	72.69	135.54	121.13	142.60	57.74	5.22	94.65	33.86
Alberta	62.47	103.06	83.42	90.95	70.23	89.90	27.19	85.94	70.76	73.34	28.47	-7.09	69.26	128.01	112.19	131.02	52.46	1.80	91.30	27.07
Atlantic Canada	42.23	64.40	41.84	46.00	99.58	96.18	39.00	48.51	109.54	38.70	13.56	30.64	110.96	175.16	132.92	128.13	72.26	34.94	71.66	55.49
Rest of Canada	31.19	70.34	47.65	51.69	82.20	104.56	24.19	31.35	102.56	22.45	-3.38	13.18	94.37	159.41	124.41	120.77	55.76	18.78	55.16	36.71
Chile	41.16	35.20	-0.05	-1.75	35.61	35.54	74.72	59.57	60.93	45.60	18.51	-12.45	60.27	119.65	106.95	113.25	66.82	-4.08	65.32	8.64
China	-4.93	-10.22	-45.06	-47.17	-60.37	-63.56	-48.42	53.08	-30.16	30.70	-42.78	-56.01	-28.69	12.65	8.79	40.86	-53.07	-96.72	55.34	-26.76
Finland	41.38	36.80	1.74	-0.24	62.94	70.03	13.67	32.44	151.71	25.88	5.44	65.88	142.71	143.64	125.64	111.57	56.97	67.95	38.85	64.76
Japan	15.82	5.60	-28.93	-31.72	-41.81	-43.90	-33.29	59.70	-7.24	58.14	-19.88	-44.21	-12.67	33.48	24.53	47.68	-25.76	-80.90	62.99	-20.59
New Zealand	70.06	15.64	-18.19	-21.33	-11.19	-13.68	-2.76	42.91	29.84	37.02	59.05	-38.18	25.56	68.76	58.79	70.72	4.29	-45.90	48.17	19.30
Russia	29.10	7.87	-26.20	-29.31	34.29	31.76	-5.48	59.64	121.19	42.15	-9.94	77.97	115.66	118.36	98.36	87.29	34.28	44.48	95.42	-20.46
Sweden	76.95	71.32	36.49	34.37	100.47	97.95	49.32	70.01	178.84	56.61	37.40	96.71	182.65	177.16	159.16	146.09	92.33	103.66	73.37	98.83
US North	-20.42	13.19	-9.52	-5.50	33.41	46.77	-25.54	-20.21	47.64	-29.46	-52.50	-35.57	45.06	128.68	85.85	79.74	8.95	-27.08	6.68	-3.49
US South	-8.88	20.20	-3.92	-1.32	11.18	31.77	-16.64	-4.07	47.84	-18.01	-41.47	-33.57	47.26	105.85	108.68	96.61	15.38	-22.08	12.51	10.48
US West	-0.98	34.21	7.46	7.43	-3.69	18.05	-21.22	17.92	25.59	-5.14	-40.12	-55.72	24.01	89.66	86.53	118.60	5.51	-46.23	34.81	-20.50
Rest Latin America	48.76	50.84	18.14	14.17	58.21	55.68	55.32	41.76	89.40	40.48	14.46	15.53	88.66	136.63	123.07	123.28	106.32	25.25	75.02	64.34
Rest Europe	-4.17	-8.98	-43.81	-45.93	11.44	9.26	-22.48	-11.34	91.26	-23.46	-43.57	19.48	90.86	91.16	76.16	62.09	15.81	33.16	-6.93	20.65
Rest Asia	-5.19	-10.22	-45.03	-47.07	-42.48	-45.01	-48.35	50.08	-29.06	28.62	-43.04	-26.02	-30.64	34.28	20.11	52.49	-25.06	-97.57	58.34	-26.76
ROW	34.48	-0.79	-35.00	-40.49	12.16	7.36	-17.52	38.80	67.89	16.31	0.01	-22.24	65.85	94.93	88.90	68.00	35.07	0.83	44.05	84.64

[a] Shadow prices associated with the log calibration constraint [22]. These are the adjustments required to Table 6 to achieve the observed lumber trade flows in Table 2.

Table 8: Effective Transaction Costs Matrix for Sawnwood Trade Flows ($\$/m^3$)[a]

Export to import region	Australia	BC Coast	BC Interior	Alberta	Atlantic Canada	Rest of Canada	Chile	China	Finland	Japan	New Zealand	Russian Fed	Sweden	US North	US South	US West	Rest LA	Rest Europe	Rest Asia	ROW
Australia	47.09	27.98	2.14	3.02	19.45	28.93	-1.07	50.65	67.59	36.54	5.44	-5.42	65.01	104.88	84.88	94.88	29.85	-2.00	55.90	33.65
BC Coast	113.26	104.05	78.21	79.10	95.53	105.01	76.53	126.72	143.86	113.00	82.48	72.57	141.28	155.40	135.40	145.40	105.93	74.07	131.98	109.72
BC Interior	126.82	116.32	90.48	91.37	107.80	117.28	90.87	138.99	156.39	125.78	96.03	87.42	153.81	171.00	151.00	161.00	118.20	86.34	144.25	121.99
Alberta	126.36	115.90	90.06	90.95	107.38	116.86	90.38	138.57	155.96	125.34	95.57	86.91	153.38	160.34	140.34	150.34	117.78	85.92	143.83	121.57
Atlantic Canada	117.73	108.10	82.26	83.15	99.58	109.06	81.26	130.77	147.99	117.22	86.95	77.47	145.41	185.00	165.00	175.00	109.98	78.12	136.03	113.77
Rest of Canada	112.76	103.60	77.76	78.65	95.08	104.56	76.00	126.27	143.40	112.53	81.98	72.02	140.82	165.37	145.37	155.37	105.48	73.62	131.53	109.27
Chile	96.19	86.40	60.56	61.44	77.87	87.35	74.72	109.07	126.32	95.57	65.40	56.08	123.74	163.30	143.30	153.30	88.27	56.42	114.32	77.15
China	38.48	30.41	4.57	5.46	21.89	31.36	1.08	53.08	69.99	38.90	7.70	-3.34	67.41	107.31	87.31	97.31	32.29	0.43	58.34	36.08
Finland	117.04	109.92	84.08	84.96	101.39	110.87	79.06	132.59	151.71	118.03	86.25	74.26	146.73	186.82	166.82	176.82	111.80	79.94	137.85	115.59
Japan	53.79	45.23	19.39	20.28	36.71	46.18	16.68	67.90	84.91	58.14	23.01	12.46	82.33	122.13	102.13	112.13	47.11	15.25	73.16	50.90
New Zealand	80.52	70.72	44.89	45.77	62.20	71.68	44.14	93.39	110.65	79.90	59.05	40.41	108.07	147.62	127.62	137.62	72.60	40.74	98.65	76.40
Russia	99.43	89.64	63.80	64.69	81.12	90.60	63.05	112.31	129.57	98.82	68.65	77.97	126.99	166.54	146.54	156.54	91.52	59.66	117.57	48.70
Sweden	150.69	143.44	117.61	118.49	134.92	144.40	112.79	166.11	182.86	151.61	119.91	108.04	182.65	220.34	200.34	210.34	145.32	113.47	171.37	149.12
US North	57.14	51.78	25.94	26.82	43.25	52.73	18.11	74.45	90.82	59.19	26.36	12.61	88.24	128.68	108.68	118.68	53.66	21.80	79.71	57.45
US South	58.14	51.78	25.94	26.82	43.25	52.73	19.71	74.45	91.02	59.59	27.36	14.61	88.44	128.68	108.68	118.68	53.66	21.80	79.71	57.45
US West	57.56	51.70	25.86	26.74	43.17	52.65	18.83	74.37	90.84	59.31	26.78	13.53	88.26	128.60	108.60	118.60	53.57	21.72	79.63	57.37
Rest Latin America	113.56	104.44	78.60	79.49	95.92	105.40	76.77	127.11	144.23	113.35	82.77	72.77	141.65	181.34	161.34	171.34	106.32	74.46	132.37	110.11
Rest Europe	73.85	63.14	37.31	38.19	54.62	64.10	38.02	85.81	103.25	72.69	43.07	34.66	100.67	140.04	120.04	130.04	65.02	33.16	91.07	68.81
Rest Asia	38.22	30.41	4.57	5.46	21.89	31.36	0.65	53.08	69.94	38.80	7.44	-3.87	67.36	107.31	87.31	97.31	32.29	0.43	58.34	36.08
ROW	87.89	78.97	53.13	54.01	70.44	79.92	50.99	101.64	118.72	87.80	57.11	46.92	116.14	155.87	135.87	145.87	80.84	48.99	106.89	84.64

[a] Based on summing the calculated shadow prices and observed transportation/transaction costs.

Table 9: Bi-Lateral Flows of Logs after Re-Calibration

				Importing Region																	
Exporting Region	Australia	BC Coast	BC Interior	Alberta	Atlantic Canada	Rest of Canada	Chile	China	Finland	Japan	New Zealand	Russian Fed	Sweden	US North	US South	US West	Rest LA	Rest Europe	Rest Asia	ROW	**TOTAL**
Australia	12,321	0	0	0	0	758	0	935	0	50	0	0	0	0	0	281	0	0	200	25	**14,570**
BC Coast	0	10,973	0	0	141	0	0	1,680	0	1,142	0	0	0	0	0	613	0	0	921	0	**15,470**
BC Interior	0	0	41,724	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**41,724**
Alberta	0	0	0	12,522	0	0	0	0	0	0	0	0	0	0	0	557	0	0	0	658	**13,736**
Atlantic Canada	0	0	0	0	11,208	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**11,208**
Rest of Canada	0	0	0	0	128	27,346	0	0	0	0	0	0	0	0	0	0	9	0	0	0	**27,483**
Chile	0	0	0	0	0	0	20,897	30	0	100	0	0	0	0	0	0	67	0	2,358	0	**23,453**
China	0	0	0	0	0	0	0	65,415	0	0	0	0	0	100	199	0	0	28	0	0	**65,742**
Finland	0	0	0	0	0	0	0	0	36,667	0	0	0	0	0	2,125	0	0	0	0	0	**38,792**
Japan	0	0	0	0	0	0	0	0	0	14,750	0	0	0	0	0	0	0	74	0	0	**14,824**
New Zealand	0	0	0	0	0	0	0	2,298	0	750	13,268	0	0	0	0	0	1,553	0	3,721	0	**21,590**
Russian Federation	0	0	0	0	0	0	0	13,203	0	500	0	58,469	0	0	0	0	0	4,674	8,509	2,500	**87,855**
Sweden	0	0	0	0	0	0	0	0	0	0	0	0	55,220	0	0	0	0	1,115	0	0	**56,335**
US North	0	0	0	0	0	141	0	0	0	0	0	0	0	14,000	0	0	71	30	120	0	**14,363**
US South	0	0	0	0	0	1,906	0	0	0	1,070	0	0	0	0	122,800	0	150	250	1,200	150	**127,526**
US West	0	0	0	0	0	0	0	0	0	600	0	0	0	0	0	56,400	60	0	800	100	**57,960**
Rest LA	0	0	0	0	0	0	0	55	0	0	0	0	0	0	0	0	50,970	0	300	0	**51,325**
Rest Europe	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	181,710	0	0	**181,710**
Rest Asia	0	0	0	0	0	0	0	0	0	368	0	0	0	0	1,825	0	0	0	5,814	0	**8,007**
ROW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	70	200	27,118	**27,388**
TOTAL	**12,321**	**10,973**	**41,724**	**12,522**	**11,477**	**30,152**	**20,897**	**83,616**	**36,667**	**19,330**	**13,268**	**58,469**	**55,220**	**14,100**	**126,949**	**57,851**	**52,881**	**187,951**	**24,142**	**30,550**	**901,061**

Table 10: Bi-Lateral Flows of Lumber after Re-Calibration

				Importing Region																	
Exporting Region	Australia	BC Coast	BC Interior	Alberta	Atlantic Canada	Rest of Canada	Chile	China	Finland	Japan	New Zealand	Russian Fed	Sweden	US North	US South	US West	Rest LA	Rest Europe	Rest Asia	ROW	**TOTAL**
Australia	3,778	0	39	0	0	0	408	42	0	5	0	0	0	0	0	0	0	0	0	0	**4,272**
BC Coast	8	208	55	218	136	1,369	1	472	0	275	14	0	0	769	607	183	2	0	0	23	**4,340**
BC Interior	0	747	198	51	0	4,869	2	1,696	0	987	0	0	222	2,763	2,180	1,416	0	0	56	82	**15,271**
Alberta	8	208	55	218	136	1,371	1	473	0	275	4	0	0	0	1,311	124	2	45	16	23	**4,270**
Atlantic Canada	0	146	0	153	95	960	0	331	0	193	3	0	147	539	426	277	0	32	11	16	**3,328**
Rest of Canada	17	431	117	459	287	2,890	1	997	0	580	8	0	0	1,341	558	832	5	95	33	1,359	**10,010**
Chile	0	1	0	1	1	6	3,340	322	2	289	1	0	0	0	0	0	468	0	490	409	**5,330**
China	1	0	0	0	0	0	0	25,028	0	77	0	0	0	0	0	0	0	4	21	617	**25,749**
Finland	777	0	0	61	0	0	0	74	2,064	623	0	0	9	0	0	0	0	2,451	30	1,986	**8,076**
Japan	0	0	0	0	0	0	0	12	0	15,319	0	0	0	0	0	477	0	0	2	1	**15,812**
New Zealand	275	0	0	0	0	0	0	683	0	131	1,678	85	52	0	65	42	0	0	0	550	**3,561**
Russian Federation	0	0	0	0	0	0	0	4,176	287	843	0	10,978	0	1	0	0	0	2,920	213	1,469	**20,887**
Sweden	26	3	0	3	2	19	0	72	0	0	0	0	5,037	0	11	7	0	6,903	16	2,865	**14,965**
US North	1	6	0	6	4	38	0	33	0	0	0	197	0	1,670	1,318	856	0	6	5	6	**4,145**
US South	10	53	14	56	35	352	0	311	0	223	0	1	0	16,842	12,241	7,950	456	52	43	59	**38,699**
US West	4	24	6	25	16	159	0	141	0	638	0	0	0	7,025	5,544	3,601	218	23	19	27	**17,471**
Rest LA	0	0	0	663	0	3	2	129	0	2	1	0	0	0	146	95	13,859	0	3	0	**14,905**
Rest Europe	245	0	0	0	0	2	0	216	1,538	882	1	6	145	65	51	33	32	60,611	6	156	**63,991**
Rest Asia	0	0	0	0	0	0	0	20	436	18	0	0	0	0	0	0	24	131	15,297	7	**15,934**
ROW	0	0	0	0	482	0	0	11	0	344	2	0	0	0	0	0	0	3,500	63	19,273	**23,676**
TOTAL	**5,150**	**1,829**	**485**	**1,914**	**1,193**	**12,038**	**3,756**	**35,238**	**4,327**	**21,702**	**1,713**	**11,267**	**5,613**	**31,016**	**24,461**	**15,895**	**15,067**	**76,773**	**16,325**	**28,929**	**314,691**

4. FOREST PRODUCTS TRADE POLICY ANALYSIS

In this section, two forest policies are examined to illustrate the use of the forest trade model described in the previous section. I first consider removal of Russia's log export restrictions and then removal of the export taxes on Canadian lumber under the longstanding Canada-U.S. trade dispute in softwood lumber. These situations were discussed in Sections 2.3 and 2.5, respectively. Removal of Russian restriction on log exports (represented in the base scenario by a 25% export tax) should benefit China and Finland more than other countries because of their proximity to Russia, with Japan, South Korea (included in 'Rest of Asia'), Sweden and other European countries ('Rest of Europe') perhaps benefitting as well. However, repercussions of this policy are likely to be felt throughout global log and lumber markets, which the RPTM will demonstrate.

The same is thought to be true of the softwood lumber dispute. If Canada was free to sell as much lumber into the United States as economically feasible, all regions of Canada outside Atlantic Canada (which is not affected by the current Softwood Lumber Agreement) should benefit. However, the actual outcome may not always be that rosy and the extent to which Canada would benefit from free trade in lumber might be disappointing, not because free trade fails to improve overall wellbeing, but because other factors related to global trade stand in the way. Thus, for example, I had previously demonstrated that Canada can gain substantially from U.S. restrictions on free trade in lumber, but only if Canada could collect the scarcity rents that such restrictions would provide (van Kooten 2002).

4.1 Removal of Russian Log Export Restrictions

Russia is the world's dominant exporter of logs. Hence, a removal of the current effective 25% tax that Russia imposes on log exports will have a major impact on global trade in forest products. Recall that Russia imposed log restrictions to stimulate domestic production of lumber, even though its mills are less efficient than those of its major trading partners. The impact of removing the log tax should be greater global production of both logs and lumber and enhanced global wellbeing. As indicated in Table 11, the RPTM results partially support this intuition as global wellbeing increases as does production of logs, but global lumber production declines contrary to what one might expect.

Table 11: Effects on Production, Consumption, Prices and Economic Welfare of Removing Russian Restrictions on Log Exports

	Change in:			Change in prices:		
Country/Region	Log production (m^3)	Lumber production (m^3)	Lumber consumption (m^3)	Lumber demand ($\$/m^3$)[a]	Lumber supply ($\$/m^3$)	Log supply ($\$/m^3$)
British Columbia	1,182,858	550,139	-8,428	4.58	4.58	0.00
Alberta	-859,815	120,702	-7,194	4.58	4.58	-6.42
Rest of Canada	-192,492	314,346	-43,420	9.17	9.17	-1.33
United States	-71,457	1,559,847	-248,989	4.58	4.58	-0.24
China	-55,906	479,243	-133,651	4.58	4.58	-0.18
Japan	-73,750	240,971	-49,111	4.58	4.58	-1.15
Russia	4,409,647	-7,818,538	-34,379	4.58	-63.30	4.63
Rest of World	-2,284,479	3,351,221	-676,900	4.58	4.58	-1.58
TOTAL	**2,054,606**	**-1,202,070**	**-1,202,070**			

	Welfare changes in lumber market:			Welfare change in logs:		
Country/Region	Consumers ($ mil)	Producers ($ mil)	Scarcity rent ($ mil)	Producers ($ mil)	Scarcity rent ($ mil)	TOTAL ($ mil)
British Columbia	-10.6	91.2	-0.3	112.8	0.0	193.1
Alberta	-8.8	19.8	-0.3	-85.4	0.0	-74.6
Rest of Canada	-60.5	61.9	-1.5	-26.2	0.0	-26.4
United States	-326.6	280.0	-7.5	-10.5	0.0	-64.5
China	-161.2	119.1	-1.9	-12.1	0.0	-56.1
Japan	-99.4	73.0	-1.5	-17.0	0.0	-44.8
Russia	-51.6	-1,074.7	760.9	419.7	2,250.0	2,304.3
Rest of World	-721.1	716.8	-19.3	-261.2	0.0	-284.7
TOTAL	**-1,439.7**	**287.2**	**728.5**	**120.2**	**2,250.0**	**1,946.2**

From Table 11, Russian log production increases by 4.4 million m^3 while its lumber production declines by 7.8 million m^3 and consumption by an insignificant amount. Not unexpectedly, its log exports rise by 26.3 million m^3 while lumber exports fall by 3.0 million m^3 (Table 12), with domestic consumption of logs falling by 21.9 million m^3 (although not shown in the tables). Despite everything, overall Russian wellbeing increases by some $2.3 billion, with the gains accruing as quasi-rents to log producers ($0.4 billion) and scarcity rent to timberland owners ($2.3 billion). Lumber producers could lose $1.1 billion in producer surplus and consumers could potentially be better off by $0.7 billion. In this regard, it is important to note that Russia is a net exporter of logs and lumber both before and after the policy change, and thus consumers collect some of the scarcity rents in the lumber market. Clearly, Russia gains by exporting logs and producing somewhat less lumber domestically.

Table 12: Change in Exports as a Result of Russian Liberalization of Log Exports

Country/Region	Logs ('000s m^3)	Lumber ('000s m^3)
British Columbia	-296.4	550.1
Alberta	-1,213.8	120.7
Rest of Canada	-292.0	686.3
United States	-71.5	1,559.8
China	-55.9	479.2
Japan	-73.7	241.0
Russia	26,296.7	-2,991.1
Rest of World	-5,929.50	6,251.60
TOTAL	**18,363.8**	**6,897.6**

The impacts of Russia's unilateral liberalization of log exports are also felt in other regions. The United States imports more logs to produce 1.6 million m^3 more lumber, but its overall wellbeing declines by an insignificant $64.5 million although its lumber producers benefit by $280 million. British Columbia produces 1.2 million m^3 more logs to produce slightly more lumber for export, thereby gaining $193 million in additional wellbeing. However, Canada as a whole produces very few extra logs to produce less than 1 million m^3 of lumber for export, thereby enhancing wellbeing by $92.1 million. The same story can be told for other regions. Overall, the Russian trade liberalization affects Russia, but, as indicated by the magnitudes of the changes occurring elsewhere, other regions are not similarly impacted. The changes that occur in other places constitute less than 1%, and sometimes much less, of the base case situation. Even the change in global wellbeing, nearly $2 billion, constitutes only 0.6% of the total surplus that accrues in global the log and lumber markets.

4.2 Expiration of the Softwood Lumber Agreement

By removing the export tax on Canadian lumber destined for the U.S., with the exception of Atlantic Canada, lumber production in Canada increases significantly, while lumber production in the U.S. falls, as predicted (Table 13). In Canada, lumber production soars by some 3.2 million m^3, of which 2.0 million m^3 comes from British Columbia; only production in

Atlantic Canada declines (by about 94,000 m^3) because it was never part of the SLA. When it comes to lumber exports, however, the changes in volume and destination are quite dramatic.

Table 13: Effects on Production, Consumption, Prices and Economic Welfare of Removing Taxes on Canadian Lumber Exports to the United States – Expiry of the Canada-U.S. Softwood Lumber Agreement

	Change in:			**Change in prices:**		
Country/Region	Log production (m^3)	Lumber production (m^3)	Lumber consumption (m^3)	Lumber demand (\$/m^3)[a]	Lumber supply (\$/m^3)	Log supply (\$/m^3)
British Columbia	3,746,804	2,020,364	2,754	-1.50	19.95	0.00
Alberta	0	414,117	2,349	-1.50	15.73	0.00
Rest of Canada	0	690,638	14,178	-2.99	9.95	0.00
United States	-71,457	-907,560	81,299	-1.50	-2.12	-0.24
China	0	-57,597	43,646	-1.50	-0.55	0.00
Japan	0	-63,416	16,031	-1.50	-1.21	0.00
Russia	-4,691,630	-184,909	11,239	-1.50	-1.50	-4.93
Rest of World	-435,783	-1,564,173	175,966	-1.39	-2.25	-0.11
TOTAL	**-1,452,067**	**347,463**	**347,463**			

	Welfare changes in lumber market:			**Welfare change in logs:**		
Country/Region	Consumers (\$ mil)	Producers (\$ mil)	Scarcity rent (\$ mil)	Producers (\$ mil)	Scarcity rent (\$ mil)	TOTAL (\$ mil)
British Columbia	3.5	350.1	-56.9	368.3	149.1	814.0
Alberta	2.9	70.4	-32.9	0.0	91.5	131.9
Rest of Canada	19.8	142.0	-197.8	0.0	8.2	-27.8
United States	106.9	-157.4	45.3	-10.5	0.0	-15.7
China	52.8	-14.2	-32.7	0.0	6.3	12.1
Japan	32.5	-19.0	-5.8	0.0	3.2	10.8
Russia	16.9	-31.1	0.5	-421.5	0.0	-435.2
Rest of World	163.4	-323.1	172.3	-55.6	18.9	-24.0
TOTAL	**398.6**	**17.6**	**-108.0**	**-119.4**	**277.2**	**466.0**

The major effect of the removal of the lumber export tax is that Canadian lumber displaces lumber produced by the U.S., although there is an increase in lumber flowing into Canada from the U.S. as well. Overall lumber exports from British Columbia increase by 2.4 million m^3 (see Table 14), but exports to the United States increase by 13.7 million m^3 as exports to other regions decline – British Columbia reduces lumber exports to Asia by 3.5 million m^3 and sales of lumber within Canada by 8.3 million m^3 (although not shown in the tables). As a result, Canada imports 5.5 million m^3 of additional lumber from the U.S., although net lumber flows are north to south. Some of Canada's exports to regions in Asia are partly covered by increased sales to those markets by U.S. producers, especially those in the U.S. South.

Lumber producers in the U.S. lose some $157.4 million in quasi-rent, although they possibly recover $45.4 million in scarcity rent, so that the net loss might only be $112.0 million. U.S. consumers, on the other hand, gain $106.8 million, which is less than what producers lose. This is contrary to what is expected from a theoretical standpoint, although the theory does not take into account other markets. Since the supply prices of lumber fall in other markets (see Table 12), U.S. lumber producers lose quasi-rent in those markets just as well as in the domestic market. This might account for the higher loss to producers compared to what consumers gain, and is evident of a second best solution given that other trade barriers in forestry (e.g., taxes on lumber imports by Japan, log export restrictions by Russia) remain.

Table 14: Change in Exports as a Result of Liberalization of Lumber Trade between Canada and the U.S.

Country/Region	Logs ('000s m^3)	Lumber ('000s m^3)
British Columbia	-1,641.0	2,426.9
Alberta	-1,214.4	632.0
Rest of Canada	55.8	3,580.4
United States	-71.5	10,195.1
China	0.0	3,499.5
Japan	0.0	-237.6
Russia	-4,174.0	-477.2
Rest of World	-817.4	2,685.4
TOTAL	**-7,862.5**	**22,304.6**

As to log exports, British Columbia will export some 1.6 million m^3 fewer logs (primarily at the expense of the Chinese market), using these domestically to produce lumber (Table 14). In total, British Columbia will process an additional 5.4 million m^3 of logs as a result of removing export taxes on lumber shipped to the U.S. Alberta will also process 1.4 million m^3 of logs domestically, selling an additional 3.2 million m^3 of lumber into the U.S. at the expense of domestic sales. Interestingly, Canada ships 1.2 million m^3 less logs to the U.S. (with over half coming from the BC Coast). This perhaps surprising outcome suggests that BC mills are more efficient than U.S. ones and that, contrary to statements often made by the U.S. Lumber

Coalition,[22] free trade in logs accompanied by free trade in lumber might even enhance flow of logs north of the border. This is a conclusion reached by Berck (2005) as well.[23]

Finally, it is safe to say that, based on results from the current trade model, the removal of export taxes on Canadian lumber destined for the U.S. plays a minor role in global log and lumber markets, with the exception of the impacts on Canada and the U.S., and perhaps Russia. Global lumber production increases by a mere 350,000 m^3, with the entire increase attributable to increased Canadian output as lumber production in all other regions declines slightly. Global log production meanwhile declines by almost 1.5 million m^3, but the decline occurs primarily in Russia (down by 4.7 million m^3 or 5.3%); this suggests that the removal of lumber export taxes on Canadian lumber increases the overall global efficiency at which log are processed into lumber. The fact that overall global wellbeing increases by $466 million supports this conclusion, although the change amounts to only 0.14% of total surplus. The removal of the restrictions under the Canada-U.S. Softwood Lumber Agreement would have a smaller impact on global log and lumber markets than unilateral liberalization of Russian log exports.

5. DISCUSSION AND CONCLUSIONS

Mathematical programming or constrained optimization (e.g., linear and nonlinear programming) have been looked upon as normative methods compared with econometrics. However, econometrics begins with economic theory and then generates a function to be estimated. The researcher collects data on the dependent and explanatory variables, estimates the unknown parameters and the error terms, whose sum one seeks to minimize. Mathematical programming begins with an objective function to be optimized subject to constraints; this is much like the underlying theory used in the econometric approach to specify the underlying function that is to be estimated. Thus, while in mathematical programming the objective function and constraints are known, with econometrics the function and underlying data are known. Traditional mathematical programming has no observed data. Positive mathematical

[22] U.S. Lumber Coalition press release, "U.S. Lumber Coalition Seriously Concerned by British Columbia Log Export Policy Changes", February 26, 2013.

[23] Berck (2005) came to this conclusion using simple regression analysis in the context of a log-lumber framework for analysis.

programming solves this problem by introducing the observations as a calibration constraint in the form $\boldsymbol{x} = \boldsymbol{x}_{\text{observed}}$. The solution requires this constraint to be met exactly; the equivalent in the econometric approach is the attempt to minimize the differences between observed and estimated values. The only difference is that PMP reduces the remaining error to zero.

While econometric (or statistical) methods of estimating functions and using these for policy analysis, the data are often lacking. The big advantage of positive mathematical programming is its usefulness in situations where available data are few. This is certainly the reason why PMP is used in the REPA-PFC Forest Trade Model (RPTM). To date, the current model is the only one to employ PMP to calibrate log and lumber flows among regions in the model. However, this has one drawback. If the observed data underlying the calibration are sparse, inaccurate, out-of-date, et cetera, or the policy to be investigated with the calibrated mathematical programming model is significantly 'outside the observed range' (in the sense that log or lumber flows required to satisfy the constraints lie outside anything experienced), the model may perform just as poorly as a forecast from a regression model that lies well outside the data upon which the regression was based. It is important to recognize that this may well have occurred in the quantitative analyses provided in Section 4.

Although spatial price equilibrium trade models are built upon a theoretically appropriate economic foundation, it is also important to remember that a number of theoretically-based assumptions are built into the model. For example, in the current model, it is assumed that the supply function for inputs into the production of timber is infinitely elastic – that forestland owners and logging companies are price takes in the input market. It is also assumed that the demand for final products made from softwood lumber is also infinitely elastic, which implies that there exist sufficient substitutes for lumber in construction, furniture making and so on. Of course, it also is assumed that global welfare is maximized only when markets are competitive.

One also has to accept that the data upon which the trade model depends are not perfect. Although a great deal of effort has been expended to ensure that the best available data are employed in the calibration of the model and the determination of regional consumption and production of lumber and logs, the volumes of logs and lumber that are traded between regions, the timber available for softwood logs, the construction of the various regional lumber supply and demand schedules and the regional log supply function, and so on. The problem is that the data are suspect, partly because they are based on a single year when forest product markets were somewhat flat but also because they rely almost entirely on information collected by the FAO.

With these caveats in place, it is clear that global log and lumber markets are intertwined. Hence, upon examining a U.S. ban on log exports from public lands, Perez-Garcia et al. (2005) conclude that: "Evaluating the gains and losses associated with an export ban is not straightforward [as] … several important interactions complicate the analysis. For example, one must evaluate the impact of a ban on regional log supply behavior, international market impacts, economic feedback effects, and the existence of multiregional trade flows" (p.87). A similar comment could be made regarding the removal of export restrictions on Russian logs. Likewise, changes in restrictions on lumber imports – under the guise of export restrictions in the case of Canada-U.S. lumber trade – can have adverse consequences outside the regions or countries directly impacted (as indicated in Section 4.2). There it turns out that U.S. demand for lumber is the main driver in Canada's commercial forest sector. However, as indicated in this study, the impact of any one of these two policy initiatives to liberalize trade is extremely small, although important for the countries involved. Yet, it would be difficult to examine the case of total free trade with the current model because this requires projecting well outside the range used to calibrate the current model – an important caveat to keep in mind.

Finally, it is important to point to future work. More time and effort need to be devoted to data collection and analysis for the purposes of improving the forest trade model and thereby the reliability of its predictions. Second, the current model links logs only to lumber. It is necessary to include several more categories of output and, rather than using a fixed log to lumber conversion factor, the conversion factors to lumber and other products should be variable within the model. Mills need to respond to changes in wood product prices by changing the conversion of logs into lumber. Third, while the model can be modified to make it dynamic, there was insufficient time to include this feature. Future work needs to facilitate the examination of impacts over a longer period of time, bringing into the analysis growth in available harvest (AAC), growth in demand, expected downfalls in harvest due to such factors as the mountain pine beetle, and so on.

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