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Modelling Bi-lateral Forest Product Trade Flows: Experiencing Vertical and Horizontal Chain Optimization

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Modelling Bi-lateral Forest Product Trade Flows: Experiencing Vertical and Horizontal Chain Optimization

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Abstract

This paper serves to document the REPA Forest Trade Model – a global model of forest trade that consists of ten products across two horizontal layers in a vertical chain. The model includes 20 regions: Five Canadian regions (Atlantic Canada, Central Canada, Alberta, BC Interior and BC Coast), three U.S. regions (South, North and West), China, Japan, Rest of Asia, Chile, Rest of Latin America, Australia, New Zealand, Finland, Sweden, Russia, Rest of Europe, and the Rest of the World. The underlying economic theory upon which the model is built is discussed in detail; we demonstrate that changes in region-level forest management policies (e.g., related to harvests) and/or trade policies have a larger impact on income transfers among regions and agents than they have on global welfare. The objective function and constraints to the quadratic programming implementation of the model are developed, and the method used to calibrate the model to existing bilateral trade flows via positive mathematical programming is discussed. Finally, the data sources and actual data are provided, as are the corrections to shipping and handling costs needed to calibrate the model.

Keywords: Forest trade modeling; vertical chains; welfare measurement; mathematical programming; model calibration

JEL categories: C61, D60, F17, Q23, Q27, Q42

1. INTRODUCTION

Since the development of some of the earliest models of forest product trade, research has focused on expanding these models to consider more products in an international context. Utilizing gains in both computational and methodological proficiencies, models have become increasingly more complex, but there often remains confusion regarding the extent to which models are grounded in economic theory. Sometimes descriptions of forest trade models simply fail to provide a theoretical justification for their construction, thereby leading to lack of clarity about their projected welfare measures.

Modelling the global forest products sector is challenging for a number of reasons. Foremost, the forest products industry has emerged as an interconnected global market in which economic regions can best exploit their comparative advantages. Countries' domestic forest product sectors are inevitably linked via international markets. As a result, global trade in forest products reached US$ 224 billion in 2010, an inflation-adjusted increase of $62.5 billion over the previous decade.[1] Although numerical forest product models may be used to assess the development of a domestic wood products processing sector, they must be viewed in the context of their connection to foreign markets.

Not only is the forest products industry connected through international trade, it is also comprised of many interconnected wood products. As wood fiber is generally sourced from the initial harvest of logs, the manufacturing of secondary wood products will not only be affected by the supply of logs, but also by competition for residual fiber. In fact, the initial demand for logs is derived from the demand functions for various manufactured wood products, including

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[1] This figure represents the export value among all 159 countries represented in the FAOSTAT database across all forest products. Values are adjusted using the U.S. annual CPI index from the U.S. Bureau of

primarily lumber. Any structural shifts in the market for one of these products will inevitably impact the others.

The gains from trade in both logs and wood products result in increased economic welfare for both importers and exporters alike – even after adjusting for transportation costs. Forest policies that impact any one market, foreign or domestic, will impact other wood product markets, resulting in international welfare implications. Unravelling the complex effects in all domestic and international markets requires a model that is built upon a transparent economic framework. In this paper, we develop a vertically-integrated, 20-region bilateral trade model that relies on wood fiber from the harvest of timber as the primary input into various products that might be considered on a horizontal plane. We provide a theoretical background to the global forest trade model, a mathematical programming representation of the model, and a discussion of the data used in its construct and how it is calibrated.

We begin in the next section with a background analysis of the techniques used to analyze forest sector trade and its impacts, with particular emphasis on spatial price equilibrium models. This background information is used to justify the methods used here. We then derive our specific modelling framework, which considers the interactions between multiple markets in an integrated supply chain. Then, we outline the mathematical representation of the model, including the application of a precise calibration technique along with the underlying data. Conclusions and recommendations ensue.

2. SPATIAL FOREST PRODUCT MODELS: BACKGROUND

One approach for modelling spatially separated markets is based on econometrics. It has been applied to multiple issues, including forecasting forest product markets and prices, and industry location, as well as examining impacts of technological change. However, there are many problems associated with the econometric approach. For example, time-series forestry data often lack appealing econometric features, such as significant variation and stationarity, and are often collinear (Buongiorno 1996). In fact, the use of econometric models may not necessarily be the most efficient way to study the development of the forest sector, as the sector is based on spatially separated markets with many products (Toppinen and Kuuluvainen 2010). Rather, the greatest contribution of econometric methods might be their ability to provide quantitative information to be used in mathematical programming models. These models can be used for policy analysis and forecasting the future economic development of forest products and trade.

Another commonly used approach is the application of spatial price equilibrium (SPE), mathematical programming models. The SPE approach assumes that, while changes in countries' forest policies will affect prices of goods, they have no discernible impact on the relative prices of goods elsewhere in the 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 shipping and handling goods (e.g., freight, insurance, exchange rate conversion fees), plus tariffs and other non-tariff barriers. It is assumed that, in the absence of trade barriers and transaction costs, prices of homogeneous goods would be the same in every region as a result of spatial arbitrage – the law of one price (LOP) (Vercammen 2011).
One of the earliest formulations of equilibria among spatially separated markets is found in Enke (1951). Utilizing an electric analogue circuit, equilibrium prices and quantities are determined in a static model when three or more jurisdictions engage in the trade of a homogenous good. Spatial separation is made significant through freight costs per unit. Here, the electric circuit is compared to other methods of solution with other electronics. Enke's paper also highlights the important connection between a computable optimization model and traditional theory used

commonly in determining optimal values in two-country trade situations.

Samuelson (1952) was the first to re-formulate Enke's approach into a mathematical linear programming trade model with spatially separated markets. He determined that Enke's complicated proposition could be arranged into a simpler style applying the theorem that the solution to a competitive equilibrium is identical to the maximization of social surplus, defined as the sum of the producer surplus and consumer surplus under perfectly competitive market conditions. In the trade situation, a unique equilibrium could be found by maximizing the total area between the excess demand and excess supply curve in each region, minus the total transportation costs of shipping goods between regions.

Takayama and Judge (1964, 1971) furthered the work of Enke and Samuelson on spatial equilibrium modelling to formulate the seminal quadratic programming problem used in most current mathematical trade models. Using linear regional demand and supply curves, the authors described the general solution for interregional prices and bilateral trade flows of multiproduct, *n*-region problems. We employ their approach in this paper to provide a general framework for solving interregional and international trade.

The approach is more commonly known as the Samuelson-Takayama-Judge (STJ) model (Samuelson 1952; Takayama and Judge 1971), whereby the objective is to maximize a quasi-welfare function (QWF) given as the difference of area below the demand and above the supply function, net of transaction costs. It can be stated as follows:

Maximize:

$$QWF = \sum_{d=1}^{M} \left(\alpha_d - \frac{1}{2} \beta_d x_d^D \right) x_d^D - \sum_{s=1}^{N} \left(a_s + \frac{1}{2} b_s x_s^S \right) x_s^S - \sum_{d=1}^{M} \sum_{s=1}^{N} t_{sd} x_{sd}, \qquad (1)$$

Subject to: Dual Variable

$$x_d^D \le \sum_{s=1}^{N} x_{sd} \qquad P_d^D \qquad (2)$$

$$x_s^S \ge \sum_{s=1}^{M} x_{sd} \qquad P_s^S \qquad (3)$$

In this specification, there are *M* importing regions (denoted *d*) and *N* exporting regions (denoted *s*). As the current model does not distinguish an importing region from an exporting region, there are *M*=*N* known inverse demand and inverse supply equations, written as $P_d^D = \alpha_d - \beta_d x_d^D$ and $P_d^D = a_s + b_s x_s^S$, respectively. Coefficients α_d, β_d, a_s and b_s are known scalars, while demand and supply quantities, $x_d^D = \sum_{d=1}^{M} x_{sd}$ and $x_s^S = \sum_{s=1}^{N} x_{sd}$, with x_{sd} the amount of product *x* shipped from export region *s* to import region *d*. The x_{sd} are unknown and must be endogenously determined. Finally, it is assumed that we have knowledge of the transaction costs of shipping a unit of *x* from *s* to *d*, t_{sd}.

The use of the spatial equilibrium concept in the forest products sector dates back to the early 1960s. Employing a spatial fiber allocation model, Holland and Judge (1963) studied the least cost strategy for transporting hardwood and softwood lumber to 11 demand regions from 18 supply regions within the United States. Holley (1970) used a similar approach to examine lumber and plywood demand, supply and trade in the United States. Holley included logging and manufacturing costs in the objective function to expand upon the work by Holland and Judge (1963). To study optimal location of industry, market shifters were exogenously implemented to provide projections from 1965 to 1975.

Building on the earlier works, Holley et al. (1975) created a linear program to model the least cost trade flows of 11 forest products in North America. Called the Inter-Regional Trade

Model (ITM), timber availability and processing capacities offered constraints to the amount of products that could be consumed. The ITM’s objective was to minimize the cost of supplying fiber for the projected increased demand scenarios.

By the late 1970s, the development of the spatial equilibrium modelling framework allowed for more explicit economic theory in trade modelling through developments in nonlinear programming techniques. The difference between this development and the spatial allocation models previously used can be summarized by two main improvements: first, regional supply and demand are expressed endogenously as functions, rather than pre-determined fixed values; second, the objective function is no longer one of minimizing costs subject to meeting some predetermined demand scenario, but rather it is to maximize the surplus value of trade, or the sum of all consumer and producer surpluses.

With this in mind, Haynes et al. (1978) were among the first to use the spatial equilibrium model to investigate the demand for forest products in the United States as a function of macroeconomic indicators (GNP, housing starts and population). Product prices were determined by substituting the equilibrium quantities consumed in each region into the regional demand functions.

The Timber Assessment Market Model (TAMM) developed by Adams and Haynes (1980) uses the spatial equilibrium modelling framework to provide long-range projections of consumption, production, price and product flows for softwood lumber, plywood and raw materials. Although the focus of the model is mainly on the U.S., it does include an international trade component as Canada is included as a separate region. Demand and supply relations are determined using econometrics, and the model has a high degree of detail regarding production processes.

International trade modelling rapidly expanded in the 1980s with improvements in solution algorithms and computing capacities. Some of the first work on international trade of forest products includes Buongiorno and Gilles (1982). These authors rely on a spatial equilibrium model to analyze the global pulp and paper industry. Although the U.S. was again emphasized, the model incorporated Western Europe, Japan and the Rest of the World in addition to Canada. The authors continued their efforts by developing a model of the North American pulp and paper industry, known as PAPYRUS (Gilles and Buongiorno 1987). Long-term forecasts were developed for production, consumption, imports, exports, prices and fiber use. This mathematical programming model incorporated supply and demand functions for raw materials and final goods. In total, fourteen commodities are recognized in the model, with the United States and Canada represented by eleven supply and nine demand regions, and the rest of the world represented by three net demand regions.

Eventually PAPYRUS evolved into the Price-Endogenous Linear Programming System (PELPS-III) (Zhang et al. 1993), which was a system for modelling economic sectors. PELPS has a static stage and a dynamic phase. The solution to the static stage is based on the prices that clear multiple markets in a spatial equilibrium framework, and equivalent to the maximization of the sum of producer and consumer surpluses, again referred to as the STJ framework and described by equations (1) through (3) above.[2] The equilibriums found in the static phase are achieved simultaneously for several products, industries and regions. The dynamic phase of PELPS simulates the changes in the equilibrium values found in the static phase, but over a

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[2] Notice that these models are often referred to as linear programming (LP) models, but they are really quadratic programming (QP) models. However, since the first derivatives of quadratic equations are linear, QP models can easily be re-specified as an LP. Unlike nonlinear programming (NLP) models, algorithms used by solvers, such as CPLEX, now easily handle QP models, directly providing shadow prices and globally optimal solutions as with LP models.

longer time horizon. In utilizing the PELPS model, the long-term forecast is revealed through the addition of multiple short-term equilibrium solutions (Buongiorno 1996). In this way, the model allows for exogenous changes to the parameters, such as changes in demand due to changing demographics. Capacity is kept endogenous, even over the long term, as capacity is driven by the short-term equilibrium solutions. However, the model is not truly dynamically optimal as it lacks equations (with endogenous variables) that link one period to the next.

Subsequently, the Global Forest Products Model (GFPM) (Buongiorno et al. 2003) was built on the price-endogenous linear programming structure of PAPYRUS (Gilles and Buongiorno 1987) and PELPS-III (Zhang et al. 1993). The GFPM is widely used in the economic modelling of production, consumption and trade in forest products. It was developed as part of the United Nations Food and Agriculture Organization (FAO) work on forest sector outlook studies. The GFPM employs a price endogenous linear programming framework to model 180 countries and 14 products. Each country may produce, consume and trade each of the 14 products. In fact, the PELPS static/dynamic modelling framework underlies the GFPM. Timber supply, processing industries, product demand, and trade are modeled as annual static equilibriums, computed by maximizing social surplus. Year-by-year changes are simulated in a dynamic phase, whereby static phases are linked together to construct the dynamic simulations. As the GFPM relies on the PELPS modelling framework, they are fundamentally similar.

To allow for the complexity of a global trade model with multiple products, the GFPM is constructed from one world model and four regional sub-models (Africa, America, Asia and Europe). These four regional sub-models are constructed with area specific detail, with additional constraints ensuring that aggregate trade flows are consistent with those predicted by the more general world model. Thus, the world model must be solved first to predict consumption, production, prices and trade. Regional models export and import to a hypothetical world region in order to satisfy aggregate demand and supply conditions. Although this simplification allows for the added complexity of multiple products in a global market, it does so at the cost of a transparent, bilateral trade flow analysis.

3. PARTIAL EQUILIBRIUM TRADE MODELLING: THEORETICAL FOUNDATION

To illustrate the development of the forest product trade model used in this study, consider Figures 1 and 2. In the figures, lumber trade is assumed to occur between two countries. The effects of trade can be understood by analyzing the excess supply and excess demand functions. A diagrammatic explanation of spatial price equilibrium trade models, and excess supply (ES) and excess demand (ED) functions, can be found in Just et al. (2004), Schmitz et al. (2010) and, in the context of forestry, van Kooten and Folmer (2004, pp. 409-421).

Autarky and the Excess Supply and Demand Functions

In Figure 1, the domestic supply of lumber is *S* and the demand is *D*. The equilibrium price and quantity for lumber in autarky are p_1 and q_1, respectively. Suppose the price rises above p_1 for whatever reason (e.g., trade). If it were to rise to p_2, the country will produce q_2 but only consume q_3. In other words, the country will supply $q_2 - q_3$ more lumber than it would consume at the given price p_2. The quantity available for export for any price above the autarky price of p_1 is given by the horizontal difference between the quantity supplied and the quantity demanded for a given price. This is how the ES curve is derived. For example, at the price p_2, the excess supply of lumber is q_4, which is exactly equal to $q_2 - q_3$. The area above the ES curve below a given price is a measure of the gains from trade. This gain equals area *a*, which is exactly equal to area *b*, and is the excess of producer surplus gain over the consumer surplus loss as a result of moving from the autarky equilibrium price p_1 to p_2.

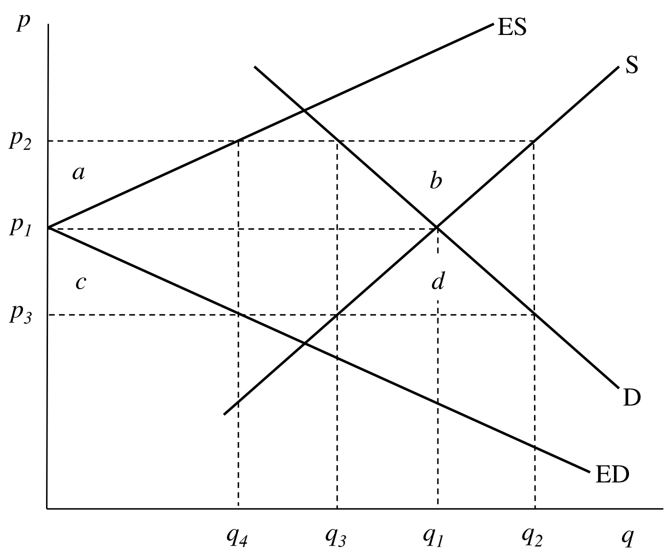


Figure 1: Excess Supply and Excess Demand

Similarly, the excess demand curve is represented in Figure 1 by price deviations below the autarkic price. Suppose, as the result of free trade, price falls from p_1 to p_3. Consumers desire quantity q_2 while producers only supply q_3, so imports of lumber of amount $q_2 - q_3$ occur. The excess demand schedule ED is derived by horizontally subtracting quantities supplied along the supply curve from quantities demanded along the demand curve. For example, if the price were to fall below p_1 to p_3, the country would import q_4, which is exactly equal to $q_2 - q_3$. The area below the ED curve bounded by a given price is a measure of the gains from trade. This area equals *d* (equals area *c*), which is the excess of consumer surplus gain over the producer surplus loss as a result of moving from the autarky equilibrium price p_1 to p_3.

The ES and ED schedules can be derived mathematically. Suppose the (inverse) demand and supply curves in Figure 1 are linear:

$$P^D = \alpha - \beta q,\ \ \alpha,\beta \geq 0, \text{ and} \tag{4}$$

$$P^S = a + bq,\ a,b \geq 0. \tag{5}$$

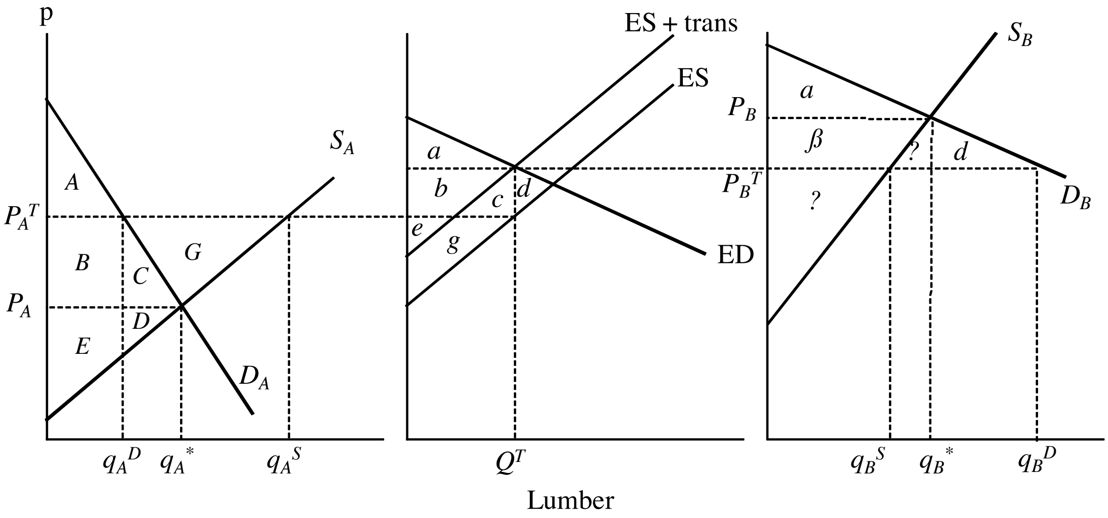
The excess demand and supply curves in the figure are then given by:

$$\mathrm{ED} = \gamma - \delta q, \text{ with } \gamma = \frac{a\beta + b\alpha}{\beta + b} \geq 0 \text{ and } \delta = \frac{b\beta}{\beta + b} \geq 0. \tag{6}$$

$$\mathrm{ES} = \gamma + mq, \text{ with } \gamma = \frac{a\beta + b\alpha}{\beta + b} \geq 0 \text{ and } m = \frac{b\beta}{\beta + b} \geq 0. \tag{7}$$

Notice that γ is the equilibrium domestic price in autarky, such that in the absence of shipping and handling 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 (at least to the choke prices), although ED slopes down and ES slopes up.

For grammatical convenience, consider first lumber trade between only two countries or regions, A and B. The two-country example offers an excellent way to illustrate how spatial price equilibrium trade models can be used to analyze policy. A numerical mathematical programming model would be required to model the real world as it is characterized by bilateral trade among many countries or regions. The two-country spatial price equilibrium lumber trade model is illustrated in Figure 2.



(a) Country A (b) International Market (c) Country B

Figure 2: Two Country Model of Lumber Trade

In the figure, the domestic demand functions in countries A and B are given by D_A and D_B, respectively, while the domestic supply functions for lumber are given by S_A and S_B. Under autarky, an amount q_A* will be supplied and consumed in country A, at a domestic price of P_A (see Fig 2a); in country B, the autarkic price and quantity are P_B and q_B* (Fig 2c). Note that, for trade to take place, the difference between autarkic prices must exceed the cost of transporting the good from one market to the other; that is, $|P_A - P_B| > t$, where t refers to the shipping, handling and other costs.

Economic wellbeing or welfare is always determined as the sum of surpluses (van Kooten 2014; Just et al. 2004); that is, 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 or quasi-rent), plus any surplus that can be attributed to the country's natural resources. In the absence of trade, the consumer surplus associated with the lumber market is given by area $(A + B + C)$ in Figure 2(a) for country A, and area α in Figure 2(c) for country B. The producer surplus in the absence of trade is measured by area $(E + D)$ for country A and $(\gamma +\beta)$ for country B. 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 country B, total surplus in the absence of trade is given by area $(\alpha + \gamma + \beta)$, while it is $(A + B + C + D + E)$ for country A.

Gains from Trade

To demonstrate that trade improves the wellbeing of both countries, it is necessary to show that the total surplus in each region increases as a result of trade. In the absence of trade, the price in country B exceeds that in country A (Fig 2). With trade, the price in country B falls from P_B to P_B^T, while country A's price rises from P_A to P_A^T. Consumers in country B gain as a result of the price decrease; consumption rises from q_B* to q_B^D and consumer surplus increases from area α to area ($\alpha+\beta+\phi+\delta$). However, producers in country B face a lower price, namely, $P_B^T<P_B$ in panel (c), causing them to reduce production from q_B* to q_B^S. An amount $q_B^D–q_B^S$ is purchased from country A, while producer surplus falls from ($\gamma+\beta$) to just γ. The overall wellbeing of country B increases by area ($\phi+\delta$), with consumers (home builders, furniture makers, etc.) as the main beneficiaries of trade.

The situation in country A mirrors that of B. The rise in country A prices causes consumers to purchase less lumber (from q_A* to q_A^D) and reduces their overall consumer surplus by area ($B+C$). Producers in country A now receive a higher price and ramp up their production of lumber from q_A^* to q_A^S, leading to an increase in producer surplus of ($B+C$+G) in the process. The wellbeing of country A as a whole increases by area G, with producers (manufacturers of lumber) the main beneficiaries from trade.

The main results can be summarized in the international market, Figure 2(b). The amount traded between A and B is $Q^T = q_A^S–q_A^D = q_B^D – q_B^S$. The net gain to country B is area a, which is equal to area ($\phi+\delta$) in panel (c); the net gain accrues to consumers in country B, and is therefore measured under the excess demand curve. Meanwhile, the net gain to country A is the area ($e+g$), which is equal to area G in panel (a); this gain accrues to the producers of lumber. Note that shipping and handling costs equal to ($b+c$) can also be identified in Figure 2(b).

4. VERTICAL AND HORIZONTAL CHAINS IN FOREST TRADE MODELING

In the preceding discussion, the impacts of changes in the lumber market on vertically- and horizontally-related markets were ignored. In many situations this is not realistic. As an illustration, suppose the government imposes a quota on softwood log exports. Although this will inevitably impact local industrial roundwood prices (reducing them) and thus profits earned by forest landowners, some of the reduced cost will be passed down the marketing chain to processors of logs and, ultimately, consumers of wood products such as lumber, plywood, pulp, et cetera. The reduced price of wood fiber can lead to lower lumber prices that, through competition, could be passed along to home builders, furniture makers and so on. However, the linkages could be complex, but they should be considered when evaluating the impact of any policy affecting the forest products industry.

In this section, we aim to establish a framework for evaluating the welfare effects of price changes in vertically-related markets. The analysis begins by considering a marketing chain for logs used in the production of lumber, ultimately consumed by construction, furniture and other lumber users. Then, in the next section, the analysis is extended to consider multiple users of logs – not just lumber, but producers of plywood, oriented strand board (OSB), medium-density fiber board (MDF), pulp, wood pellets, and others. The fiber from the initial harvest of logs is competitively distributed to multiple processors through horizontally integrated markets. These complex vertical and horizontal relationships suggest a framework for establishing a global trade model of forest products that is rooted in economic theory.

Vertical Chain Integration

To motivate the discussion of the underlying theory and assumptions that enable the integration of vertically connected markets in a trade model, consider the vertically-integrated sectors depicted in Figures 3 and 4. In Figure 3, we are concerned with the derivation of a competitive supply curve for lumber that takes into account the equilibrium adjustments to the input price of logs. With the competitive supply curve in place, we then isolate the welfare consequences of price changes in the vertically-related markets depicted in Figure 4.

As a matter of clarity, we refer to two types of supply and demand curves. An *intermediate* supply or demand curve refers to a relation between price and quantity that does not take into account the effect of changes in the prices of the commodity in question on *related* goods or services. Rather, it does not take into account the rebound effect that the policies in one market have on the prices in related markets that, in turn, affect the demand or supply in the original market. The *general equilibrium* supply and demand function takes these rebound effects into account, as discussed in the next paragraphs. It is appropriate to measure the consumer and producer surpluses as areas under the general equilibrium demand and supply curves, respectively (Just et al. 2004).

To derive the competitive supply curve for lumber that accounts for input prices (denoted with r), consider a competitive lumber industry that uses logs as inputs (Fig 3). The log market is assumed to have a perfectly elastic supply for inputs (fixed input prices);[3] that is, fluctuations in inputs used to produce logs are assumed not to affect the prices of logging equipment, trucks, fuel, workers, et cetera. However, the lumber market depicted in Figure 3(b) is characterized by an upward sloping, intermediate supply curve $S_{lum}(r^0_{log})$, and an initial input price of r^0_{log} and output price of P^0_{lum}. The demand for logs in Figure 3(a) is derived from the downstream manufacturers of lumber, as logs are the single most important input into the production of lumber – the demand for logs by lumber producers is given by the value of the marginal product of logs in the production of lumber, or the marginal physical product of logs in the production of lumber multiplied by the output price of lumber. Given a derived demand of $D_{log}(P^0_{lum})$, the log market has initial price r^0_{log} along its intermediate supply curve S_{log}.

Suppose the output price in the lumber market falls to p^1_{lum} as the result of policy intervention. Initially, manufacturers of lumber adjust their production to q^2_{lum} along their initial intermediate supply curve, as they do not perceive the effects of their decisions on the (related)

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[3] We use r to denote input prices and P to denote prices in downstream markets. Thus, r is used in the case of logs and markets upstream of logs, and P for lumber and markets downstream.

log market. As a result of the price change in the lumber market, the derived demand for logs falls to $D_{log}(P^1_{lum})$, thereby reducing the price of logs to r^1_{log}. In turn, the lower input price leads to a downward shift from $S_{lum}(r^0_{log})$ to $S_{lum}(r^1_{log})$ in the intermediate supply curve for lumber, giving rise to new equilibrium output and price combination of q^1_{lum} and P^1_{lum}. One can then derive a general equilibrium supply curve for lumber (denoted S^*_{lum}) by connecting the original and final equilibriums; the general equilibrium supply function allows for equilibrium adjustments of input use and input price, as output price changes. In Figure 3, S^*_{lum} differs from the intermediate supply curve, say $S_{lum}(r^0_{log})$, as the latter only indicates how the lumber market will respond to price fluctuations under the premise that input prices are fixed.

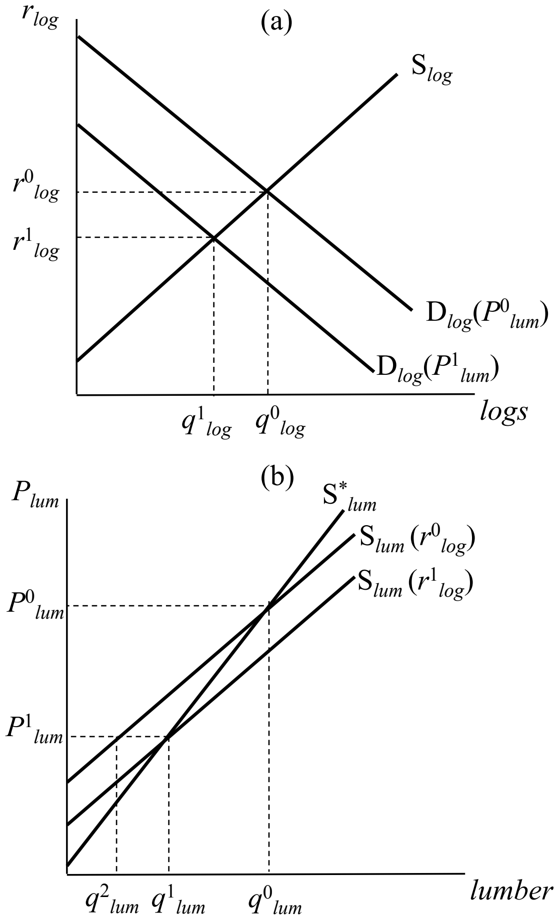

Figure 3: Derivation of the general equilibrium competitive supply curve for lumber in a vertically integrated market chain

To see how one can measure the welfare implications of policy intervention in multiple vertically connected markets, consider Figure 4. Following van Kooten (2013), it is shown that three types of economic surpluses must be considered: (1) consumer surplus, (2) quasi-rent (producer surplus), and (3) the rent created as a result of policy induced scarcity. It is assumed that the input supply schedule $S_{n\text{-}1}$ facing market n-1 (the logging sector) is perfectly elastic so that input prices $r_{n\text{-}1}$ (logging equipment, trucks, fuel, labor, etc.) are not affected by changes in the demand for such inputs as a result in changes in log output. It is assumed that all of the logs produced by the logging sector are inputs into lumber production (panel c). Lumber is an input into downstream industries such as (primarily) construction, furniture making and other activities, where it is assumed that the demand in this market is perfectly elastic, D_{n+1}. 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. The general equilibrium lumber supply curve S^{*}_{lum} allows for equilibrium adjustments of input use and input price as output price changes (as discussed above). Finally, to make the following analytical discussion tractable, it is assumed there are no other wood products using logs as inputs – no markets are horizontal to lumber in Figure 4(c). This assumption will be relaxed later in the discussion of horizontal market integration.

Suppose a quota of q^{1}_{lum} (or an equivalent ad valorem tax) is imposed on the producers of lumber. As a result of reduced lumber production, the price consumers of lumber (construction, furniture making and other users of lumber) must pay rises to P^{1}_{lum}, while the price lumber producers receive falls to P^{2}_{lum}. Since the demand curve for lumber is derived from the demand for these downstream products, the reduction in consumer surplus, as given by area (a+b) in panel (c), is equal to the change in quasi-rent in the market for downstream users of lumber.

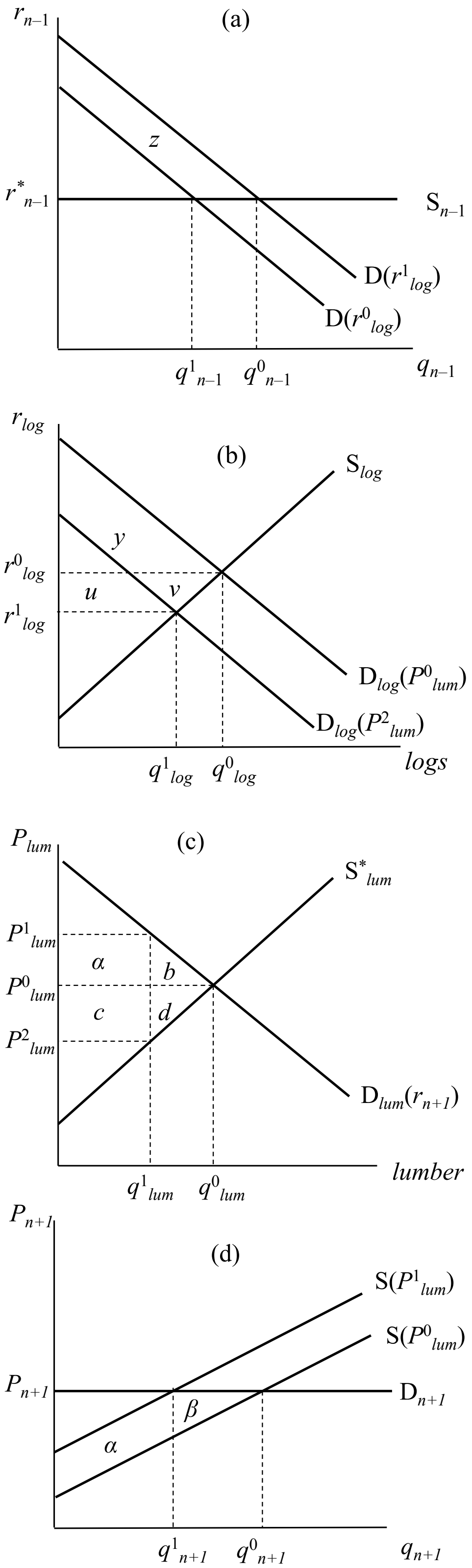

Figure 4: Vertically integrated log and lumber markets

Thus, it is necessary to measure only one of these changes, say area (a+b) in panel (c), and not the equivalent loss of area (α+β) in the downstream market for users of lumber in panel (d).

Now consider the change in consumer surplus in the log market in panel (b). As a result of the government policy that reduced the production of lumber from q^0_{lum} to q^1_{lum} in panel (c), derived demand for logs shifts downward from $\text{D}_{log}(P^0_{lum})$ to $\text{D}_{log}(P^2_{lum})$. Due to this lower demand for logs, the price falls from r^0_{log} to r^1_{log}, causing a change in consumer surplus equal to (u–y). Since it is assumed that all logs are used in the production of lumber, the change in consumer surplus in the log market is equal to the change in quasi-rent in the downstream lumber market. Thus, the change in consumer surplus in the log market equals the loss (c+d) in Figure 4(c). Notice that the general equilibrium, competitive supply curve for lumber S^*_{lum} takes into consideration the effect of the new log price, P^1_{log}, on lumber supply; thus, it is not necessary to have S^*_{lum} shift as a result of this price change as it is inherently incorporated through its derivation (as discussed in conjunction with Fig 3).

There remain two additional surplus measures that need to be taken into account. First, in the log market (Fig 4b), the loss in quasi-rent to log producers is equal to area (u+v), which is equivalent to the change in consumer surplus of area z in the upstream market for logging equipment, trucks, fuel, labour, et cetera (Fig 4a). Again, this area must only be measured once, say in the log market, and not the equivalent measure in the upstream market.

Finally, in the lumber market (Fig 4c), a scarcity rent is created equal to area (a+c), as supply is constrained to be lower than demand as the result of policy intervention. Producers of lumber may capture the scarcity rent if it were created through a quota on production, while if it arose due to an ad valorem tax the government captures it as tax revenue.

The point of the above analysis is this: the welfare measures appropriate for a vertically integrated forest trade model are the consumer surplus, producer surplus (quasi-rent) and scarcity rent. This result hinges 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 (horizontal markets to lumber) are characterized by a perfectly elastic demand function or that lumber production is the only downstream use of logs. We now consider what happens if this is not the case.

Horizontal Chain Integration

So far we have considered the vertical relationship between one input and one output, with additional upstream and downstream markets considered as having respective infinitely-elastic supply (fixed input prices) and demand (fixed output prices). Now consider a vertical chain such as that discussed above, but with several outputs from logs and not just lumber; that is, we consider multiple products that use wood fiber from the harvests of timber. The addition of these other wood product markets horizontal to lumber in the marketing chain adds complexity, but also greater reality, to the model. Although lumber remains the primary use of logs, other wood products, such as plywood, oriented strand board (OSB), particleboard, which includes wafer board, strand board and medium-density fiberboard (MDF), wood pulp, wood pellets, and wood wastes and residuals continue to be a significant part of the global forest products industry.

To add to the challenge of integrating horizontal markets into the discussion, logs are not only an input to downstream processors, but fiber may also flow between two or more horizontal markets. For example, the markets for lumber and wood pellets are on the same horizontal market segment (i.e., downstream of logs in the vertical supply chain), because both utilize fiber that originates with the initial log harvest. However, the lumber manufacture produces, among other things, sawmilling residuals that are commonly used in the production of most other wood products, including wood pellets. Wood pellets and lumber are *complements* in production in the sense that by-products from lumber manufacture are used to produce pellets. The more lumber that is produced, the more fiber becomes available to produce wood pellets. Alternatively, two products may be *substitutes* in production if they compete for the same input. Lumber and plywood manufacturers compete for the same industrial roundwood, with logs used to produce lumber (plywood) not available to produce plywood (lumber). Some products are both complements and substitutes in production. For example, pulp chips are residual to lumber and plywood production, but whole logs can be chipped and used solely to produce pulp. This is true, just as well, for wood chips, OSB and some other products.[4] In practice, the value of logs in lumber is generally much higher than in other uses so that harvests might not even take place unless the roundwood logs are designated to be processed into lumber. Exceptions occur where plantations of fast-growing species such as hybrid poplar have been established to service a biomass power plant or pulp mill.

To demonstrate the importance of the distinction between complements and substitutes in production, consider the expansion of the vertically integrated market structure given in the Figure 4. Here we have K markets horizontal to lumber, differentiated according to whether they are primarily complements or substitutes to the production of lumber. Let i (= 1, …, k) denote wood products that are joint products (complements) in the production of lumber or plywood, and j (= k+1, …, K) denote wood products that are competitive in (substitutes to) the production of lumber. Further, let $S_i^*(P_i; P_{i\text{-}}, P_j, P_{lum})$ and $S_j^*(P_j; P_{j\text{-}}, P_i, P_{lum})$ be the respective supply curves for complements and substitutes that incorporate equilibrium adjustments of log inputs and their prices (as indicated by the asterisk), and $P_{i\text{-}}$ and $P_{j\text{-}}$ denote prices of joint and competitive

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[4] One caveat should be noted. Some logs are not suited to the production of lumber or plywood and might only be worth chipping for pulp purposes or used as a biomass fuel.

products, respectively, other than that of the product under consideration. The equilibrium supply functions do shift, however, with changes in the prices of horizontal products.

A change in the price of lumber will lead to changes in relative prices across *h* horizontal markets. If markets are competitive, an increase in the price of lumber will lead to greater use of fiber in lumber production – (1) logs will be cut more efficiently to produce more lumber, (2) logs will be competed away from other log processors (e.g., plywood manufacturers), and/or (3) harvests of commercial roundwood logs will increase. In the first case, the supply of fiber available to complementary products, such wood pellets and pulp, will decline. In the second case, it is not clear if the amount of residual fiber from plywood manufacture, for example, is more or less than with lumber manufacture. Consider the third case. In modern sawmills, computers are used to obtain the greatest value from logs. In that case, although there will be some shifting of fiber from plywood to lumber, say, it will generally be possible to increase lumber production only by increasing harvests. Thus, the amount of fiber available to complementary horizontal markets will increase. Overall, however, it is unclear as to the effect that an increase in the price of lumber will have on the supply of complementary products:

$$\frac{\partial S_i^*\left(P_i; P_{i-}, P_j, P_{lum}\right)}{\partial P_{lum}} \lessgtr 0, \qquad \forall\, i = 1, \ldots, k. \tag{8}$$

On the other hand, in markets for products that are substitutes in production with lumber, an increase in the price of lumber will reduce fiber available for those products and thus reduce their supply:

$$\frac{\partial S_j^*\left(P_j; P_{j-}, P_i, P_{lum}\right)}{\partial P_{lum}} < 0, \qquad \forall\, j = k{+}1, \ldots, K. \tag{9}$$

One can measure the welfare implications of policy intervention in multiple vertically and horizontally connected markets. Building upon the framework established above, in Figure 5 we add horizontal markets *i* and *j* to the horizontal market segment for lumber in the vertical chain – a market *i* is added to the left of lumber and a market *j* to the right. Again we assume that, in the $(n–1)^{\text{th}}$-level markets upstream from logs, the supply functions are perfectly elastic. This implies that the prices of inputs into the production of logs do not change with changes in the harvests of logs. Likewise, we assume that changes in the supplies of the *K* outputs produced from wood fiber, whether lumber, plywood, OSB, wood pellets, et cetera, do not change the prices in the $(n+1)^{\text{th}}$-level downstream markets in the vertical chain – the demand functions in these markets are perfectly elastic. For example, as the global supply of wood pellets changes, the prices received for electricity in various countries are not impacted. Likewise, as the supplies of lumber and/or plywood change, the prices of residential construction or furniture do not change. Therefore, we ignore these upstream and downstream markets in the discussion of Figure 5.

Now consider the vertically and horizontally integrated forest sectors depicted in Figure 5. Logs are the main input into the processing of forest products. It is assumed that the supply functions of any other inputs into forest products manufacturing are perfectly elastic; thus, increases in the demand for labor, machinery, fuel and so on by the processing sector does not affect the prices of these inputs. As noted above, lumber is the considered the most important product from the processing of logs. Then, in Figure 5, there exist two markets horizontal to lumber in the supply chain: market *j* whose output is considered competitive for fiber in the production of lumber (a substitute), and market *i* whose output is considered a joint product with lumber (complement); that is, product *j* competes with lumber for logs, while product *i* can utilize material directly from logs but relies primarily on residuals from the manufacture of lumber and the manufacture of other wood products *j*. The supply curves for the two markets are assumed to behave in a manner consistent with equations (8) and (9); however, in the discussion pertaining to Figure 5, we simply assume that the supply function for complements in production, *i*, will shift outwards (increase) with an increase in the price of lumber, so the sign in equation (8) is positive. Finally, the demand for logs $D_{log}(P_i, P_j, P_{lum})$ is assumed to be derived from the demands by downstream wood fiber processors.

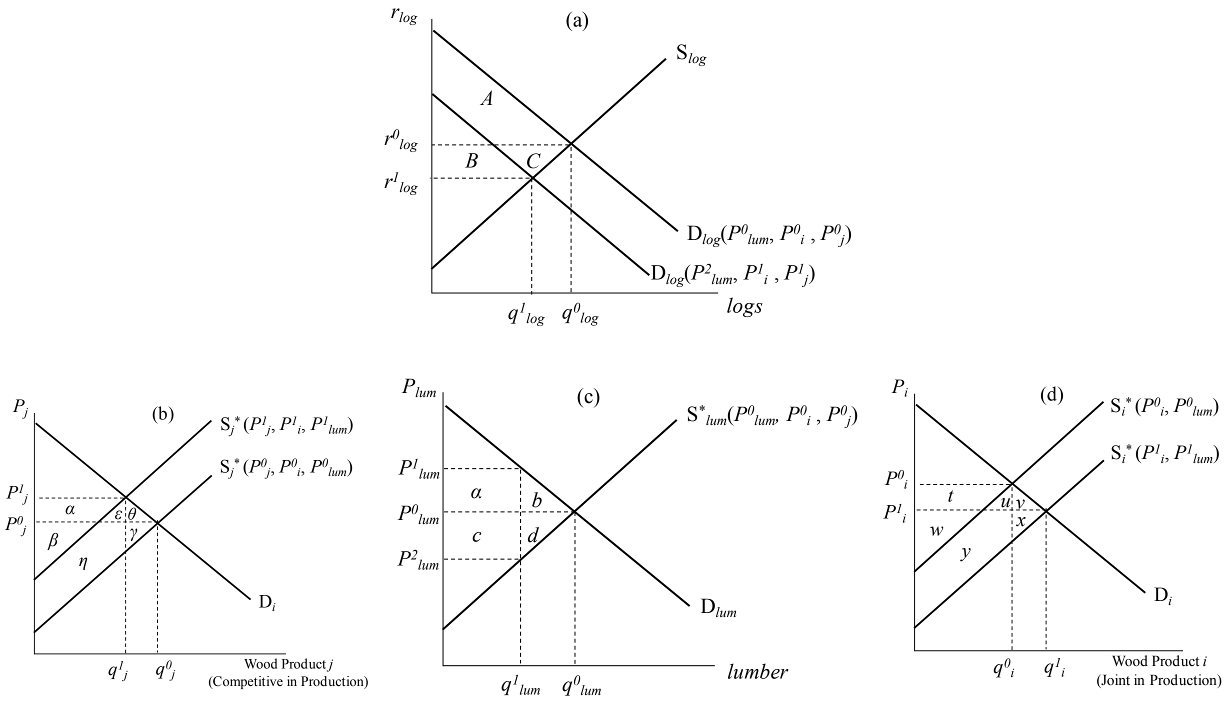

Figure 5: Vertically and horizontally integrated wood product markets

Suppose lumber output is somehow constrained to q^1_{lum} as a result of a quota or a per unit tax ($=P^1_{lum} - P^2_{lum}$). As a result, the marginal cost of producing lumber falls from P^0_{lum} to P^2_{lum} in Figure 5(c), although in the case of a quota lumber producers may actually receive P^2_{lum} or the demand price P^1_{lum} depending on which entity is able to collect the policy-created scarcity rent. Nonetheless, the higher demand price of lumber affects markets that are horizontal to lumber in the supply chain as indicated in panels (b) and (d).

First consider the market for substitutes in production in Figure 5(b). The lower willingness to pay for logs by lumber producers will result in less fiber directed towards lumber (as fiber is competitively distributed), allowing for additional resources used in producing *i* substitute products. Consistent with equation (8), this effect is represented as a rightward shift in the supply curve from $S_i^*(P^0_i; P^0_{i-}, P^0_j, P^0_{lum})$ to $S_i^*(P^1_i; P^1_{i-}, P^1_j, P^1_{lum})$, giving rise to a new price and quantity combination P^1_i and q^1_i.

Meanwhile, the fall in lumber production from q^0_{lum} to q^1_{lum} results in fewer by-products (i.e., chips and residuals) available to markets (*j*), whose production is complementary to lumber. That is, production in the *j* market uses residuals from lumber manufacturing as inputs. Consistent with equation (9), this effect is represented through an upward shift in the supply curve of *j* markets from $S_j^*(P^0_j; P^0_{j-}, P^0_i, P^0_{lum})$ to $S_j^*(P^0_j; P^0_{j-}, P^0_i, P^0_{lum})$, giving rise to new price and quantity combination P^1_j and q^1_j. It is important to recall that the supply curves for all downstream markets from logs are denoted with an asterisk (*), as they incorporate equilibrium adjustments to input (log) prices. That is, further consideration of the impact of the price of logs on downstream users need not be represented diagrammatically in Figure 5.

The demand for logs $D_{log}(P_{lum}, P_i, P_j)$ is derived from the demand for downstream wood processors. It will inevitably be affected through the price changes in the markets for lumber, substitutes *i* and complements *j*. As a result of the policy intervention in the lumber market, the derived demand for logs shifts down to $D_{log}(P^2_{lum}, P^1_i, P^1_j)$ giving rise to new price and quantity combination of r^1_{log} and q^1_{log}. This price change for logs is reflected in the downstream supply curves, as they incorporate equilibrium adjustments of input prices.

Before proceeding, it is important to take note of two important points that hinge on the fact that the lumber market is the primary processing sector. First, although prices change in all downstream markets, it is assumed that any shifts in the derived demand for logs will ultimately be driven through changes in the price of lumber. Secondly, in order to make the analytical discussion tractable, it is assumed that the supply curve for lumber remains at $S_{lum}^{*}(P^{0}_{lum}; P^{0}_{i}, P^{0}_{j})$. This may be due to, among other things, the relative magnitude of the lumber market or the offsetting effects of the price changes in markets i and j.

To evaluate the welfare impacts of such a policy, three types of economic surpluses must again be considered: (1) consumer surplus, (2) quasi-rent (producer surplus), and (3) the rent created as a result of policy induced scarcity. In fact, if logs are an essential input in the production of all downstream wood processors (lumber, panels, wood pulp, wood pellets, etc), then the sum of quasi-rents in the downstream sectors must equal the consumer surplus in the log market.

As a result of the policy intervention in the log market, it is assumed that the derived demand curve for logs falls to $D_{log}(P^{2}_{lum}, P^{1}_{i}, P^{1}_{j})$, leading to a change in consumer surplus equal to area $(B–A)$. As mentioned, this may be evaluated through the change in quasi-rents in markets using logs as an essential input in production. First, the price and quantity in the lumber market (panel c) falls to P^{2}_{lum} and $q^{1}_{lum,}$respectively, leading to a fall in quasi-rent equal to area $(c+d)$ accruing to producers of lumber. Next, producers in market i experience a net change in quasi-rent equal to area $(y+x–t)$ as a result of the downward shift in the supply curve. Finally, producers in the j markets complementary to lumber experience a net change in quasi-rent equal to area $(\alpha–\gamma–\eta)$ as a result of the upward shift in the supply curve. Together the sum of the changes in quasi-rents in the markets downstream of logs is equal to area $(y+x+\alpha–\gamma–\eta–t–c–d)$, which is exactly equal to area $(B–A)$. Thus, it is only necessary to evaluate one of these surplus measures, say the sum of quasi-rents in the downstream markets to logs, and not the consumer surplus in the log market itself.

There still remain a number of other welfare measures that must be accounted for when evaluating the effects of policy intervention in the lumber market. First, the change in consumer surplus in markets downstream from logs must be taken into account and, in the case where these markets face perfectly elastic demands for their outputs, will equal the change in quasi-rents in markets consuming such products. Next, one must measure the change in quasi-rent in the upstream log market and, when faced with perfectly elastic supply for inputs, will exactly equal the change in consumer surplus in markets for factors in the production of logs. Finally, the policy induced scarcity-rent must be evaluated in the lumber market, where it may accrue to government or producers of lumber, depending on whether the policy implemented was a tax on consumption or a quota on production, respectively.

In summary, the above analysis shows that integrating additional horizontal markets to lumber will change the welfare analytics compared to the strictly vertical case in three distinct ways. First, markets whose production is either competitive or complementary in production must be considered independent from one another when evaluating the effects of policy in vertically and horizontally connected markets. Second, the appropriate welfare measures include the sum of consumer surpluses, quasi-rents and scarcity-rents in the downstream markets that use logs as inputs, plus the quasi-rent accruing to upstream log suppliers. Finally, the change in consumer surplus in the log market may be evaluated through the sum of quasi-rents in the downstream markets using logs as inputs. Similar to the earlier discussion, the results hinge on the assumption that remaining upstream and downstream markets are characterized by perfectly elastic output demand and input supply, respectively. However, it is no longer predicated on the assumption that other wood product markets (horizontal markets to lumber) are characterized by a perfectly elastic demand function or that lumber production is the only downstream user of logs.

5. MODEL OF GLOBAL FOREST PRODUCTS TRADE

Despite their usefulness for evaluating policy, analytic models have deficiencies that can only be addressed with an appropriate numerical model. Because a country's domestic forest product sector is inevitably linked to international markets, economic policies related to log export policies, sales of log from public forest lands and the domestic wood-products processing sector must be viewed in the context of their impacts on foreign markets. Not only is the forest products industry connected through international trade, it is also comprised of many interconnected wood products. As wood fiber is generally sourced from the initial harvest of logs, the manufacturing of secondary wood products will not only be affected by the supply of logs, but also by competition for residual fiber. Indeed, the initial demand for logs is derived from the demand functions for various manufactured wood products, including lumber. Any structural shifts in the market for one of these products will inevitably impact the others.

As noted earlier, the Global Forest Products Model (GFPM) includes forest products but relies on 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). That is, GFPM sacrifices information on bi-lateral flows for greater product detail. In this section, we describe a trade model in which harvests of timber leads to a supply of industrial roundwood that provides the fiber for a number of downstream products: sawnwood (lumber), plywood, particleboard (OSB, waferboard and strandboard), fiberboard (MDF and hardboard), wood pulp and, wood pellets. Although lumber and plywood are the most lucrative uses of roundwood, their production also provides residuals in the form of chips and sawdust that can be used to produce fiberboard, pulp and wood pellets as indicated in Figure 6. Finally, the harvest and process of industrial roundwood from the initial harvest produces residuals (roadside debris; tree tops, branches, other debris), which may also be used in the production of wood pellets (although this is not done here because transportation costs are often too great).

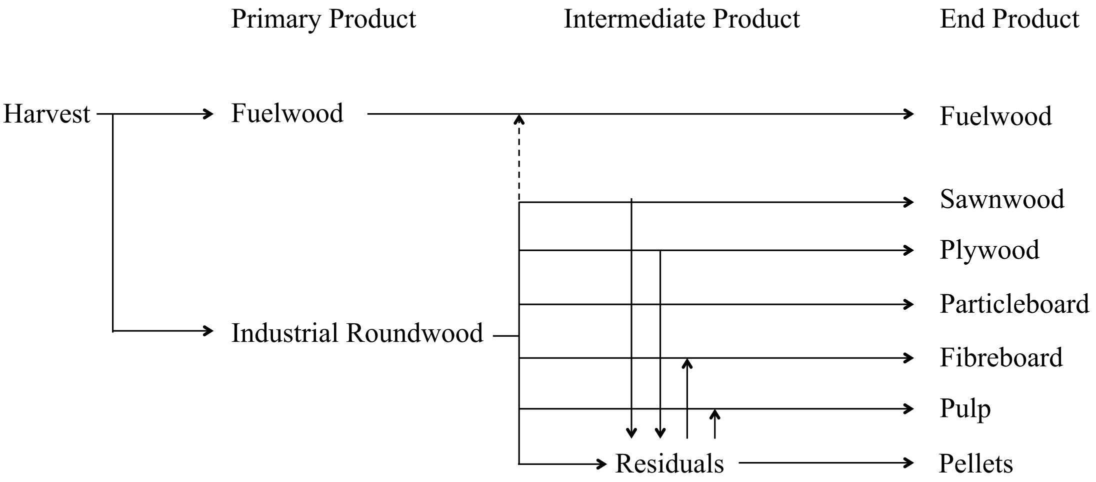

Figure 6: Forest Product Flow Chart

The model assumes that, while changes in countries' forest policies will affect prices of forest products, they have no discernible impact on the relative prices of goods and services elsewhere in the economy. Since it is a spatial price equilibrium (SPE) trade model, it is assumed that, in the absence of trade barriers and transaction costs, prices would be the same in every region as a result of spatial arbitrage – the law of one price (LOP) holds. Differences in prices between regions are thus assumed to be the result of transaction costs, and include costs associated with shipping and handling goods (e.g., freight, insurance, exchange rate conversion fees), plus tariffs and other non-tariff barriers.

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. Chile, Australia, New Zealand, Finland, Sweden and Russia are also separate regions, while the remaining regions comprise Rest of Europe, Rest of Latin America, and the Rest of the World (ROW).

The model calculates production of logs and various wood products and their consumption in each region, and associated bilateral regional trade flows. It is solved numerically in an integrated Excel-R-GAMS environment.

Model Specification

Objective function

Consider first the wood processing sector. Each region is assumed to have a set of linear (inverse) demand and supply curves for each downstream product *k*:

$$P_d^k = \alpha_d^k - \beta_d^k q_d^k,\ \alpha_d^k, \beta_d^k \geq 0,\ \forall d = 1, \ldots, M,\ \forall k, \text{ and} \tag{10}$$

$$P_s^k = a_s^k + b_s^k q_s^k,\ a_s^k, b_s^k \geq 0,\ \forall s = 1, \ldots, N,\ \forall k, \tag{11}$$

where $k \in$ {lumber, plywood, particleboard, fiberboard, pulp, wood pellets}, q_d^k refers to the quantity of commodity *k* consumed in demand region *d*, and q_s^k refers to the quantity of wood product *k* produced by supply region *s*.[5] There are *M* demand (import) regions and *N* supply (export) regions and, for convenience of notation, these are assumed to be the same for each product *k*. One objective of the forest trade model is to maximize the sum of the consumer and producer surpluses across all relevant wood-processing sectors. The consumer and producer surpluses are found by maximizing the sum of the areas under the *M* demand schedules (10) and subtracting the sum of the areas under the *N* supply schedules (11). These respective areas are given by:

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[5] For convenience, we use *d* to denote a net demand region and *s* a net supply region, although a region is simultaneously a supplier and demander of the commodity in question.

$$B_d^k = \int_0^{q_d^k} (\alpha_d^k - \beta_d^k x)\,dx = \alpha_d^k q_d^k - \frac{1}{2}\beta_d^k q_d^{k^2} \text{ , and,} \tag{12}$$

$$C_s^k = \int_0^{q_s^k} (a_s^k + b_x^k x)\,dx = a_s^k q_s^k + \frac{1}{2} b_s^k q_s^{k^2} \text{ ,} \tag{13}$$

where x is an integration variable, B_d^k is the total benefit (area under demand) in demand region d for product k, and C_s^k is the total cost (area under supply) in supply region s for product k.[6]

Now consider the markets for industrial roundwood (pulp logs and coniferous logs). As noted earlier, the demand for logs is a derived demand that depends on the production of downstream lumber, plywood, pellets, pulp, et cetera. For each wood product k, its derived demand is given by its output price multiplied by the marginal physical product of the input (logs) in the production of the k^{th} commodity: $P^k \times \text{MP}_{logs \rightarrow \text{k}}$. The total derived demand for logs is given by the horizontal sum of the individual k derived demands for logs. However, the change in consumer surplus in the log market caused by a policy shock can be evaluated in the downstream markets, namely, as the sum of the changes in the producer surpluses in the downstream wood processing markets – changes in the consumer surplus in the log market are measured by the changes in producer surpluses in the downstream markets. Thus, it is necessary to include in the objective function only the producer surplus in the log market. Assume that the supply (marginal cost) of logs in region u is linear: $r_u = m_u + n_u Q_u$, m_u, $n_u \geq 0$, where Q_u is the quantity of logs in country u. The producer surplus from supplying logs from any region u is:

$$QR_u = r_u Q_u - \int_0^{Q_u} (m_u + n_u x)dx = \frac{1}{2} n_u Q_u^2, \forall u = 1,\ldots,U \text{ ,} \tag{14}$$

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[6] See Vercammen (2011, p.22). Given lack of good data, in the numerical analysis a supply elasticity of one is assumed, which implies that the supply schedules pass through the origin. Vercammen also provides the welfare equation if supply schedules intersect the horizontal axis (have negative intercepts).

where U regions supply logs.[7]

The overall objective in the forest trade model is to maximize the sum of the necessary producer and consumer surpluses provided above, while subtracting the shipping and handling costs and associated taxes. The objective function to be maximized can be written as:

$$W = \sum_{k=1}^{K}\left[\sum_{d=1}^{M} B_d^k - \sum_{s=1}^{N} C_s^k - \sum_{d=1}^{M}\sum_{s=1}^{N}\left(t_{s,d}^k + \tau_{s,d}^k\right) q_{s,d}^k\right] + \sum_{u=1}^{U}\left[QR_u - \sum_{s=1}^{N}\left(\delta t_{u,s} + \tau_{u,s}\right)Q_{u,s}\right], \quad (15)$$

where W refers to the overall global wellbeing from trade in forest products, $t_{s,d}^k$ is the cost ($/m^3) of transporting processed forest product k from supply region s to demand region d, and $\delta t_{u,s}$ is the cost of transporting industrial roundwood (logs) from region u to region s, where δ is a parameter that takes into account the extra cost of transporting logs because they occupy more space per cubic meter than lumber (whose cost of transport from region u to s is given by $t_{u,s}$).[8] Finally, $\tau_{u,s}$ is the tax on logs ($/m^3) originating in log supply region u and sold to wood product producing region s, while $\tau_{s,d}^k$ is the tax on wood product k originating in supply region s and exported to region d.

Objective (15) is maximized subject to a series of biophysical and economic constraints relating to the availability of timber harvests, log supply and wood product manufacturing limits.

Constraints

The essential constraints are material flows and productivity constraints that ensure that total supply equals total demand for each region/country and each product. The model constraints are summarized as follows. First, the quantity of industrial roundwood of each type $L \in \{$saw logs,

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[7] In the current specification, we do not distinguish among different log types; this is done below, in which case the objective function (equation 29 below) will change slightly to include this distinction.

[8] In the current application, $t_{s,d}^k = t_{s,d}^{lum}$ for all k.

veneer logs, pulpwood logs} = {*SL*, *VL*, *PL*} produced by any log producing region u must be no greater than its harvest of logs (h_u), and the region's ability to convert harvested timber into various industrial roundwood components:

$$Q_u = \sum_{L\in\{SL,VL,PL\}} Q_u^L \leq \phi_u^L \times h_u, \forall u. \tag{16}$$

The parameter ϕ_u^L indicates how much coniferous industrial roundwood of each type is recovered from the timber harvest in region u, which depends on size and species of trees, as well as the region's technical skills, capital and other factors. The aggregate of the various log types in region u is denoted Q_u. The sale of logs by region u to log consuming regions s, including domestic sales, must not exceed the total supply of logs in region u:

$$\sum_{s=1}^{N} Q_{u,s}^L \leq Q_u^L, \forall u, L. \tag{17}$$

The quantity of logs supplied to region s must be greater than or equal to the amount required for the production of downstream wood products:

$$\sum_{u=1}^{U} Q_{u,s}^L \geq Q_s^L, \forall\, s, L. \tag{18}$$

Logs are used as inputs into the production of the K downstream wood products. It follows that the sale of downstream wood products from supplying region s to all consuming regions must be no larger than what is produced in region s:

$$\sum_{d=1}^{M} q_{s,d}^k \leq q_s^k, \forall\, s, k. \tag{19}$$

Similarly, the supply of downstream products from all supply regions to region d, and including domestic supply, must be greater than or equal to the demand of region d:

$$\sum_{s=1}^{N} q_{s,d}^{k} \geq q_{d}^{k}, \forall\, d, k. \tag{20}$$

We distinguish between primary and secondary wood products processed from logs on the basis of value – primary products generally tend to be quite a bit more valuable than secondary products (but not always).[9] Lumber and plywood must necessarily be considered primary products for sawlogs (*SL*) and veneer logs (*VL*), while wood pulp is the primary product from pulp logs (*PL*). In addition, secondary products (particleboard, fiberboard and wood pellets) can employ wood fiber from logs in direct competition with the primary products, with wood pulp also considered a secondary product when it comes to non-pulp logs. Therefore, in what follows, we denote $f \in \{\text{particleboard, fiberboard, pulp, pellets}\} \subset K$ and $nf \in \{\text{lumber, plywood}\} \subset K \ni f \cup nf = K$.

Secondary products will rely on chips and residuals from sawmilling and plywood manufacture for the most part. For simplicity, however, we assume that industrial roundwood gets allocated to each of our six (primary plus secondary) products so that all of the roundwood is utilized. This can be described using the following relation:

$$q_{s}^{k,L} \leq \rho_{s}^{k,L} \times \eta_{s}^{k,L} \times Q_{s}^{L}, \forall\, k, s, L. \tag{21}$$

In equation (21), the total available output in processing region *s* of wood product *k* from logs of type *L*, $q_s^{k,L}$, is determined by the proportion of the logs of type *L* used to produce *k*, denoted $\rho_s^{k,L}$, multiplied by the recovery factor $\eta_s^{k,L}$ that converts logs into product and the amount of logs of type *L* available in region *s*. To ensure that all of the wood fiber is fully used we require

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[9] A secondary product may be more valuable depending on the quality of logs and the location of processing facilities. Consider as an example fast-growing pine plantations located next to a power plant; the pine is grown primarily to be used as a biomass fuel. Alternatively, such trees might be best used to produce pulp if no sawmills are in the vicinity.

$$\sum_{k=1}^{K} \rho_s^{k,L} = 1. \tag{22}$$

The manufacture of lumber and plywood results in chips and other residuals (sawdust, planer shavings, residues) that are joint products which can be used to produce particleboard, fiberboard, wood pulp and wood pellets. The total amount of wood chips and residuals produced in region s depends on the production of lumber and plywood, and can be determined from the following relation.

$$R_s^z = \sum_{nf} \left(q_s^{nf} \times v_s^{nf,z} \right), \forall\ s, z \in \{\text{wood chips, other residuals}\}, \tag{23}$$

where R_s^z is the amount of z (wood chips, sawdust, planer shavings or other residuals) produced in region s and $v_s^{nf,z}$ is the region's ability to recover residual z from each of the sawmilling and plywood manufacturing sectors.

The production of products f directly from logs in region s is denoted $q_s^{f,L}$ and is determined from equation (21). In addition, we find the amount of product f produced from chips and residual fiber using the following relationship:

$$q_s^{f_R} = \sum_{z} \left(w_{s,f}^z \times \theta_f^z \times R_s^z \right), \forall s, \tag{24}$$

where $q_s^{f_R}$ denotes the quantity of wood product f produced from residual fiber (and not directly from logs). In addition, $w_{s,f}^z$ refers to the proportion of residual fiber of type z in region s that is used to produce product f, while θ_f^z is a parameter that converts residual fiber of type z into product f. The condition requiring that all residual fiber is exhausted is given by:

$$\sum_{f} w_{s,f}^z, \forall s, z. \tag{25}$$

Pulp mills use chips from sawmilling and manufacture of plywood to the extent that such chips are not used for OSB or other products. Particleboard, fiberboard and pellets can employ wood chips and other residuals from sawmilling and plywood production.

Finally, the total amount of product *k* produced by region *s* can now be determined as follows:

$$q_s^k = q_s^{f_R} + \sum_{L \in \{\mathrm{SL,VL,PL}\}} q_s^{k,L}, \forall s, k, f \in k. \tag{26}$$

The constrained optimization program maximizes objective (15) subject to constraints (16) through (26) plus non-negativity conditions on the decision variables. For each of the relevant regions, the decision variables are the supply of industrial roundwood (sawlogs and veneer logs) and pulpwood (Q_u^L); bilateral flows of logs from supplying to wood processing regions ($Q_{u,s}^L$); production and consumption of product *k* in each region (q_s^k and q_d^k, respectively); and the bilateral trade flows of product *k* ($q_{s,d}^k$). The proportions of the logs of type *L* used to produce *k* ($\rho_s^{k,L}$), and the proportions of residual fiber of type *z* used in *f* ($w_{s,f}^z$) can also be determined endogenously in the model, although, in the current application, these are exogenously provided.

Model Calibration: Positive Mathematical Programming

It is important that the forest trade model is calibrated so that the user can be confident that model projections are realistic. The calibration must be based on observed values and must be rooted in economic theory. Although trade models rely on observed data, it is often the case that computational deficiencies require an aggregation of firm and market characteristics. As a result, mathematical programming models of trade often experience extreme specialization in supply responses. As well, discrepancies between modelled and observed optimal values may arise due to mis-specified parameters, often originating from transaction costs per unit of product traded between two countries (e.g., non-tariff trade barriers). To deal with such problems, several calibration techniques have evolved.

One method is referred to as the historical mixes approach, which attempts to address the problem of extreme solutions (McCarl 1982; Önal and McCarl 1991). This approach is based on the fact that optimal solutions are often found at corners (extreme points), particularly when working with aggregate representative producers.[10] Since aggregation may bias the data, and hence the original problem, a region may be assigned a subset of possible production 'mixes' based on observed levels. This last point is justified as observed mixes must be optimal, or why would they have occurred in the first place? This calibration method takes historical choices (mixes) into account by constraining the current optimal values to be a weighted average of those observed choices. The weights may be determined endogenously within the mathematical programming framework, with the sum of the weights equaling 1. Chen and Önal (2012) extend this method by including decisions that are not historically observable. Simulated mixes of the 'new' decision variables are added to the historical mixes, allowing the optimization procedure to choose the weights, and again constraining the sum of the historical and synthetic weights to equal 1.

A second calibration method based on an approach originally proposed by Howitt (1995), referred to as positive mathematical programming (PMP), is increasingly applied to problems in agriculture and forestry (see de Frahan et al. 2007; Paris 2011, pp.340-411; Heckelei et al. 2012). 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

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[10] The simplex method that is used in solving linear and quadratic programming problems finds only corner solutions.

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 (as in the historical mixes approach), 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.

In trade models, the PMP-calibrated ‘transportation’ costs represent the ‘effective’ transaction costs between export and import regions. They are derived from the shadow prices on the calibration constraints relating to the observed flows of logs and lumber. Again the calibration is motivated by the fact that there is a discrepancy between the true transaction costs and the observed transaction costs, as determined by shipping, loading/unloading, insurance and administrative costs, plus tariffs and non-tariff barriers. The main reason for this discrepancy occurs because (observed) transaction costs are measured with a significant degree of uncertainty (Paris et al. 2011). To deal with and measure the hidden or unknown transaction costs (bribes, non-tariff barriers, etc.), one can utilize a two-phase positive mathematical programming model (Paris et al. 2011).

The phase I PMP specification maximizes objective (15) subject to constraints (16)-(26), with the addition of the following constraints:

Dual Variable

$$Q^L_{u,s} = \overline{Q}^L_{u,s} \qquad \lambda^L_{u,s} \tag{27}$$

$$q^k_{s,d} = \overline{q}^k_{s,d} \qquad \lambda^k_{s,d} \tag{28}$$

In this specification, it is assumed we observe trade flows for industrial roundwood and *k* downstream wood products, $\overline{Q}^L_{u,s}$ and $\overline{q}^k_{s,d}$, as well as their respective transaction costs $\delta t_{u,s}$ and

$t_{s,d}^{k}$.

Upon obtaining the shadow prices $\lambda_{u,s}^{L}$ and $\lambda_{s,d}^{k}$ associated with the primal model, the objective function for the phase II problem can be specified as follows:

$$\text{Maximize } W = \sum_{k=1}^{K}\left[\sum_{d=1}^{D} B_d^k - \sum_{s=1}^{S} C_s^k - \sum_{d=1}^{D}\sum_{s=1}^{S} T_{s,d}^k q_{s,d}^k\right] + \sum_{L\in\{SL,VL,PL\}}\sum_{u=1}^{U}\left[QR_u - \sum_{s=1}^{S}\delta T_{u,s}^L Q_{u,s}^L\right], \quad (29)$$

where $T_{s,d}^{k}$ now equals $t_{s,d}^{k} + \tau_{s,d}^{k} + \lambda_{s,d}^{k}$, and $T_{u,s}$ equals $t_{u,s} + \tau_{u,s} + \lambda_{u,s}^{L}$. In the second stage, the modified objective function (29) is maximized subject to the original constraints (16)-(26). With this modification, the model precisely duplicates the inter-regional fiber trade flows.

The fact that the shadow prices $\lambda_{u,s}^{L}$ and $\lambda_{s,d}^{k}$ can be negative indicates that the original transaction cost data fail to include missing policy instruments, such as export subsidies. 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).

Economic Surplus and Income Redistribution

As discussed in Section 2, the appropriate welfare areas are the consumer surplus and quasi-rent (producer surplus) in the downstream markets, plus the quasi-rent and resource rent accruing in the log markets. In addition, there may be policy-induced scarcity rents that accrue to governments in the form of tariffs or taxes and to other economic agents as quota rents; some of this rent is simply wasted in rent-seeking activities or lost due to other inefficiencies. In the model these welfare measures and income transfers are calculated ex post – after the model has solved the optimal bilateral trade flows. The following equations provide the mathematical derivation of these welfare measures.

Wood Processing Sector

Consider first the *k* downstream wood processing markets in the vertical supply chain. The consumer surpluses in each of these markets and each commodity are given by:

$$CS_d^k = \int_0^{q_d^k} \left(\alpha_d^k - \beta_d^k x\right) dx - P_d^k q_d^k = \left(\alpha_d^k q_d^k - \frac{1}{2}\beta_d^k (q_d^k)^2\right) - \left(\alpha_d^k - \beta_d^k q_d^k\right) q_d^k = \frac{1}{2}\beta_d^k (q_d^k)^2,\ \forall s,k, \qquad (30)$$

where P_d^k is the demand price for product *k* in the domestic market, and q_d^k is the quantity of product *k* consumed. Likewise, the producer surpluses or quasi-rents in these *k* downstream markets are given by:

$$QR_s^k = P_s^k q_s^k - \int_0^{q_s^k} \left(a_s^k + b_s^k x\right) dx = \left(a_s^k + b_s^k q_s^k\right) q_s^k - \left(a_s^k q_s^k + \frac{1}{2} b_s^k (q_s^k)^2\right) = \frac{1}{2} b_s^k (q_s^k)^2,\ \forall s,k, \qquad (31)$$

where P_s^k is the supply price for product *k* in the domestic market, and q_s^k is the quantity of product *k* produced.[11]

In each of the downstream markets, a variety of distortions might exist. These consist of tariff and non-tariff trade barriers, export taxes, illegal fees, quotas and so on. These distortions to trade are captured in the PMP calibration process so that they are included in the revised shipping, handling and other transaction costs (see below). However, when we examine the impact of various policies (e.g., tariff or export tax, quota), income transfers will occur and these can be measured in two ways. First, with tariffs or taxes, the income accrues to government and

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[11] It might be worth recalling that, in principle, a region might only be a supply or demand region, but in practice regions both supply and demand each of the *k* products. Further, given the regions in the model are quite large, each supplies some amount of harvested timber to its domestic market for processing.

is calculated simply as the quantity affected (traded or sold) multiplied by the tariff/tax rate. Second, some policies create distortions that result in a wedge between the demand price and the supply price (or marginal cost). This leads to a policy-induced scarcity rent that is calculated as follows:

$$SR_y^k = (P_y^{k,Demand} - P_y^{k,Supply})\overline{q}_y^k = \left\{\left(\alpha_y^k - \beta_y^k \overline{q}_y^k\right) - \left(a_y^k + b_y^k \overline{q}_y^k\right)\right\}\overline{q}_y^k,\ \forall k, y \in \{s,d\}, s \neq d, \quad (32)$$

where $\overline{q}_y^k$ refers to the quantity of k consumed in market y. In essence, since the producer surplus calculated in equation (33) does not include the policy-induced scarcity rent, it is necessary to include this rent as a transfer, although it is not clear who captures this rent; it is simply determined by the size of the wedge between the demand and supply prices multiplied by the quantity sold in market y ($\overline{q}_y^k$).

Upstream Log Markets

Now turn to the market for logs. As noted earlier, because the demand for logs is a derived demand, the consumer surpluses in the log markets are measured as quasi-rents in the *K* downstream markets. It is necessary, therefore, only to measure the producer surplus or quasi-rent in the log markets. The best measure of the quasi rent in any log market is given by equation (14) and is similar to equation (33); it is given by:

$$QR_u^L = \frac{1}{2} n_u^L (Q_u^L)^2, \forall u, L, \quad (33)$$

where n_u^L is the slope of the type-*L* log supply curve in region *u*.

To this, must be added any scarcity rent associated with resource scarcity or the result of the introduction of policy that creates a wedge between the demand and supply price of logs. Because we do not explicitly include demand functions for logs in the trade model, we rely on the shadow prices of logs. The shadow price of logs gives the addition to global wellbeing, as defined in the objective function (15), if an additional log were available. Therefore, policy-induced rent plus the rent from resource scarcity in the log market can be calculated by the shadow price of logs times the volume produced:

$$SR_u^L = \lambda_u^L \overline{Q}_u^L, \forall u, L, \tag{34}$$

where λ_u^L is the shadow price and $\overline{Q}_u^L$ is the equilibrium production of logs of type L in region u.

The surpluses in equations (30)-(34) are summed to obtain the total surplus from trade.

Model Data

The underlying data come from a variety of sources and are provided in Appendix A. The Food and Agriculture Organization of the United Nations (FAO 2014) constitute the primary source of forestry statistics, while supplementary data are 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),[12] the Global Forest Products Model at the University of Wisconsin (GFPM),[13] the U.S. Forest Service (e.g., Howard 2001; Oswalt et al. 2009; Warren 2011), the United Nations Economic Commission for Europe (UNECE),[14] and van Kooten and Johnston (2014). Where FAO data were either unavailable, or observations were missing, supplementary data were used.

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[12] Center for International Trade in Forest Products. University of Washington School of Environmental Forest Services. http://www.cintrafor.org/research/tradedata.shtml (Accessed January 10, 2014). See also Perez-Garcia (1993).

[13] Data are available from 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).

[14] United Nations Economic Commission for Europe. http://www.unece.org/fileadmin/DAM/timber/docs/dp/dp-30.pdf (Accessed December 12, 2013).

The FAO provides annual production and trade data for a number of forest products dating back to 1961. The data are collected through annual questionnaires conducted by the FAO Forestry Department in partnership with the International Tropical Timber Organization, the Statistical Office of the European Communities (Eurostat), and the UNECE. In cases where countries fail to provide information through the questionnaire, the FAO estimates production and trade of wood products through trade journals, statistical yearbooks and other sources. Where data are unavailable, the FAO repeats historical information from the previous years. Although, in some instances the quality of the FAO data may be less than desired (Buongiorno et al. 2001), they are nonetheless consistently available at a country level, and provide information on the destinations of various forest product exports and the origins of imports. Having this information is critical for implementing the positive mathematical programming calibration method on country-to-country trade flows. Since Canada and the U.S. are broken down into five and three sub-regions, respectively, the FAO data had to be adjusted using local information. Further, information from Canada and the U.S. was used to reconcile missing observations from the FAO dataset.

The data analysis began with the collection and calculation of each region's technical ability to produce logs and wood products. First, a region's ability to produce logs is a function of the annual allowable cut (AAC), which is the amount of wood permitted to be sustainably harvested, and a region's ability to convert coniferous logs into 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 coniferous timber into industrial roundwood were determined by taking ratios of each region's production of roundwood to harvests. Industrial roundwood is assumed to be broken down into two sub-categories: (1) sawlogs and veneer logs, and (2) round and split pulpwood. For both categories, the FAO provides regional production and trade flows. However, in the current model we are not concerned to replicate pulpwood trade as there is simply too little trade of pulpwood.

Next, the ability to recover coniferous wood products (lumber, plywood, particleboard, fiberboard, pulp and wood pellets) from their respective log inputs is calculated as the ratio of production to inputs. The FAO differentiates coniferous from non-coniferous lumber allowing for a simple calculation of regional coniferous lumber recovery factors. This is not the case for other wood products, however. First, plywood and veneer sheets are reported as an aggregate of coniferous and non-coniferous fiber by the FAO. Thus, to estimate regional coniferous plywood and veneer sheet production, the reported aggregate data were adjusted by taking the proportion of coniferous sawlogs and veneer logs consumed in a region multiplied by total regional production of plywood and veneer sheet. A similar adjustment was applied to particleboard. Fiberboard and pulp were also reported as an aggregate of softwood and hardwood by the FAO. As these products primarily use fiber from pulpwood, they were adjusted using the reported proportion of regional coniferous pulpwood consumption multiplied by the total aggregated production of the respective product. Wood pellet data were collected irrespective of whether pellets were produced using coniferous or non-coniferous fiber. The FAO does not currently report on wood pellet statistics directly; thus, we rely on other sources (e.g., Lamers et al. 2012; Government of Canada 2012; EuroStat 2013) and adjust regional production based on the proportion of coniferous industrial roundwood consumption by each region. Finally, a region's ability to recover chips and residuals from sawmilling is determined from a variety of sources (BC Government 2009; UNECE 2010; Government of Canada 2010).

Regional consumption of logs and wood products is based on apparent consumption (production + imports – exports) since the FAO only reports production and trade. For Canada and the United States, regional consumption of logs is determined by production, while regional exports of logs are allocated on the basis of various statistical sources (e.g., BC Statistics 2013) and trade publications (*Random Lengths*).[15] Regional wood product consumption in Canada and the U.S., 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.

It is important to note that, in many circumstances, bi-lateral trade flows of wood products are reported by the FAO as an aggregate of coniferous and non-coniferous products. Thus, the trade matrices for aggregated products were adjusted in a similar fashion to production. Specifically, exports from a given country were adjusted based on the proportion of coniferous inputs used in the respective region. The trade matrices are provided in Appendix Tables A-7 to A-13. At this time, there is too little information on the country-to-country trade flows of wood pellets to be included in the calibration component of the model.

Data on prices come primarily from *Random Lengths* and the timber database of the UNECE (2014), reported in Table A-3. The base-year AAC and production of logs and wood

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[15] Various issues of *Random Lengths* are employed. Regional production of lumber 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 (2014). The authors can provide data and calculations upon request.

products are provided in Table A-1, while consumption is provide in Table A-2. The price elasticities of demand for wood products are derived from a variety of sources (FAO 2014; BC Stats 2013; Oswalt et al. 2009; van Kooten and Johnston 2014) and are reported in Table A-5. As noted earlier, for simplicity and because data are not available for most regions, log and lumber supply elasticities are assumed to equal 1.0; then the slopes of these schedules are simply given by the ratios of the base production (manufacturing) costs provided in Table A-4 and outputs. The manufacturing costs come primarily from UNECE (2012) or van Kooten and Johnston (2014).

The shadow prices associated with the calibration constraints in the first phase of the PMP procedure are provided in Tables B-1 to B-6. The shadow prices are then used to adjust the observed transportation and other transaction costs (Table A-6) to calculate the effective transportation costs, which are provided in Tables C-1 to C-6. For log shipments, the transportation costs are identical to those for lumber, but are multiplied by δ (=1.27) to account for the extra volume required to transport logs compared to lumber. Because constraints (29) and (30) are equality constraints, the associated shadow prices may be either positive or negative. As noted earlier, a positive shadow price indicates that the effective transportation and other transaction costs are higher than observed, perhaps because transportation costs have been underestimated or there exist unobserved non-tariff costs (as noted earlier). Likewise, there may be subsidies or other policies that not taken into account, in which case the shadow prices are negative.

6. CONCLUSIONS

In this paper, we provided the theoretical foundation for a spatial, price-equilibrium forest trade model that included upstream log harvesting and downstream wood processing – a vertical chain with horizontal layers. We then developed a mathematical representation of the trade model; this took the form of a constrained optimization model or, more specifically, a quadratic programming model. The model tracks nine different forest products and their associated country-to-country trade flows. The products consisted of three different log types and six final products, plus an intermediate product (residuals) derived during the processing stage that is not traded.[16] Residuals took various forms but could be inputs into four final products, although these products could also be produced directly from logs. In addition, the model has 20 regions, of which five are in Canada and three in the United States. Since data are generally provided at a country-level, a method was developed to allocate supply and demand to regions within a country.

The model differs from previously models in several important ways. Although the majority of the forest product trade models have employed the same spatial price equilibrium framework employed here, the documentation included with most models has lacked a clear explanation of the underlying economic theory upon which the model is built, or the documentation is unavailable. In the development of a model with vertical and horizontal chains, it is important to determine how markets relate and how welfare changes are measured. In the current application, policies that affect one market might result in large changes in wellbeing of economic agents in various markets, but these are often income transfers and not true measures of the global change in welfare (see van Kooten 2014). That is, many trade policies that countries or regions pursue are best considered to be of the 'beggar-thy-neighbor' type.

Further, positive mathematical programming is used to calibrate country-to-country trade flows to observed bilateral trade in some base period. This contrast with previous models of

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[16] In the numerical model and because of data limitations, sawlogs and veneer logs are treated as a single log type.

forest trade that generally calibrate trade flows by minimizing the difference between observed and estimated values. Ad hoc constraints are then employed to achieve a ‘best’ calibration. The PMP method is rooted in economic theory and reduces the remaining error to zero without the need for ad hoc constraints: that is, the PMP-calibrated model can reproduce observed trade flows exactly. Further, PMP is useful where there are no observable data, particularly where transaction costs and/or policies are not properly taken into account. It should be noted, however, that if the underlying model data are sparse, or incorrectly taken into account, the PMP method may still prove to lead to errors. Indeed, one line of future research would be to use the PMP approach not only to calibrate bilateral trade flows to those observed in a given period, but also use it to calibrate the model to replicate the output of forest products to the base period.

The quality of the data underlying the model is open to criticism. Although much effort has been expended to ensure that the data are the best available, the data provided by the primary source (FAO 2014) are based on the completion of surveys by various country forest ministries. Depending on the quality of data available in any given country, whether the survey has been sent to the appropriate ministry or office that has access to the data, and the effort of the person responsible for responding will determine the quality of data. The result is uneven quality of data. Yet, the FAO database is the only readily available comprehensive forest data that provides distinct country-to-country trade flows, which is critical in implementing the PMP calibration.

Finally, the current model employs fixed country-specific recovery factors. Making the factors endogenous would alleviate some of the rigidity in the model, facilitating greater flexibility. The model would also greatly benefit from the inclusion of dynamic considerations, although making the model truly a dynamic optimization (requiring equations that tie one year to another, say through investment) is likely beyond the current state of the art in forest trade modeling. Rather, a dynamic model is more likely to rely on exogenous variables to relate periods over time. Clearly, future research is required and it could start with the current model.

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8. APPENDIX

A: Input Data

Table A1: Global Coniferous AAC and Forest Product Production in 2011

Country/Region	AAC ('000 m^3)	Industrial Roundwood ('000 m^3)	Sawlogs + Veneer Logs ('000 m^3)	Pulpwood ('000 m^3)	Sawnwood ('000 m^3)	Plywood + Veneer[1] ('000 m^3)	Particleboard[1] ('000 m^3)	Fibreboard[1] ('000 m^3)	Pulp[2] ('000 Mt)	Wood Pellets ('000 Mt)
Australia	29,788	14,912	8,988	5,632	3,826	213	773	474	491	204
BC Coast	45,802	13,729	12,316	1,144	4,451	371	607	111	1,915	0
BC Interior	62,246	53,225	48,074	4,107	15,984	1,331	2,181	399	6,877	1,196
Alberta	15,780	14,839	13,403	1,145	4,457	58	883	162	1,917	76
Atlantic Canada	13,052	10,393	9,388	802	3,121	88	5	1	474	237
Rest of Canada	33,268	31,285	28,257	2,414	9,395	287	2,621	480	1,427	355
Chile	47,215	26,454	15,523	10,412	6,631	1,281	521	958	2,125	38
China	291,251	42,587	37,613	4,139	17,918	30,539	8,180	31,575	6,340	384
Finland	50,952	39,122	18,763	19,592	9,700	1,013	163	96	7,812	275
Japan	17,281	16,306	13,877	2,109	9,294	2,518	949	825	4,059	30
New Zealand	21,956	11,788	8,245	3,312	3,934	1,053	145	674	1,432	59
Russia	173,000	94,013	65,700	26,470	29,055	2,799	5,204	1,491	5,267	1,265
Sweden	70,200	62,960	33,600	28,125	16,400	112	507	96	10,342	1,332
US North	23,505	13,901	8,645	4,983	3,138	535	806	416	1,893	894
US South	218,289	129,093	80,282	46,281	29,144	4,970	7,482	3,860	17,577	1,076
US West	98,861	58,465	36,359	20,960	13,199	2,251	3,388	1,748	7,960	246
Rest of Latin America	443,222	5,472	5,009	356	2,621	713	410	120	0	3
Rest of Europe	347,306	181,725	122,032	56,130	73,755	3,941	31,570	12,935	10,399	6,089
Rest of Asia	697,010	6,008	3,871	2,019	6,148	951	243	435	439	1
Rest of World	734,894	113,090	82,552	28,321	37,628	35,254	14,298	38,087	6,295	9
TOTAL	**3,434,878**	**939,368**	**652,495**	**268,454**	**299,799**	**90,278**	**80,936**	**94,943**	**95,042**	**13,769**

Source: FAO (2014), BC Statistics (2013), Government of Canada (2012), Oswalt et al. (2009), van Kooten and Johnston (2014), UNECE (2012)

[1] Calculated by the authors based on proportion of coniferous sawlogs + veneer logs out of total sawlogs + veneer logs multiplied by total plywood + veneer production from FAOSTAT - Forestry database

[2] Calculated by the authors based on proportion of coniferous pulpwood out of total pulpwood multipled by total pulp production within a given country from FAOSTAT - Forestry database.

[3] Calculated by the authors based on the proportion of coniferous industrial roundwood out of total industrial roundwood production within the given country from FAOSTAT - Forestry database.

Table A2: Global Coniferous Forest Product Consumption in 2011

Country/Region	Industrial Roundwood ('000 m^3)	Sawlogs + Veneer Logs ('000 m^3)	Pulpwood ('000 m^3)	Sawnwood ('000 m^3)	Plywood + Veneer[1] ('000 m^3)	Particleboard[1] ('000 m^3)	Fibreboard[1] ('000 m^3)	Pulp[2] ('000 Mt)	Wood Pellets ('000 Mt)
Australia	14,912	8,196	5,632	4,394	489	811	205	654	0
BC Coast	13,729	9,554	1,144	1,686	316	630	166	1,335	0
BC Interior	53,225	47,789	4,107	1,943	866	2,169	410	4,742	49
Alberta	14,839	13,667	1,145	1,771	120	904	216	1,119	4
Atlantic Canada	10,393	9,460	802	1,492	105	23	36	54	11
Rest of Canada	31,285	29,561	2,414	9,367	701	2,778	798	273	17
Chile	26,454	15,472	10,412	4,546	166	539	824	434	38
China	42,587	49,533	4,139	28,179	25,523	8,169	29,957	13,624	384
Finland	39,122	20,336	19,592	5,037	261	224	207	6,022	182
Japan	16,306	16,241	2,109	15,549	3,449	384	562	5,010	158
New Zealand	11,788	5,901	3,312	1,708	554	103	291	660	10
Russia	94,013	47,855	26,470	16,898	1,485	5,282	1,749	4,075	392
Sweden	62,960	35,070	28,125	5,861	231	791	259	8,935	1,869
US North	13,901	8,958	4,983	30,254	1,649	1,599	1,237	309	552
US South	129,093	77,615	46,281	15,831	5,001	7,914	4,025	12,737	567
US West	58,465	35,225	20,960	12,729	2,453	3,711	1,882	4,870	152
Rest of Latin America	5,472	5,148	356	3,500	1,450	417	847	979	0
Rest of Europe	181,725	119,368	56,130	88,283	4,672	27,178	7,033	5,688	9,316
Rest of Asia	6,008	12,718	2,019	7,062	1,744	898	1,254	13,052	2
Rest of World	113,090	84,829	28,321	43,711	39,044	16,413	42,987	10,470	1
TOTAL	**939,368**	**652,495**	**268,454**	**299,799**	**90,278**	**80,936**	**94,943**	**95,042**	**13,704**

Source: FAO (2014), BC Statistics (2013), Government of Canada (2012), Oswalt et al. (2009), van Kooten and Johnston (2014), UNECE (2012)

[1] Calculated by the authors based on proportion of coniferous sawlogs + veneer logs out of total sawlogs + veneer logs multiplied by total plywood + veneer production from FAOSTAT - Forestry database

[2] Calculated by the authors based on proportion of coniferous pulpwood out of total pulpwood multipled by total pulp production within a given country from FAOSTAT - Forestry database.

[3] Calculated by the authors based on the proportion of coniferous industrial roundwood out of total industrial roundwood production within the given country from FAOSTAT - Forestry database.

Table A3: Global Coniferous Forest Product Prices in 2011, $USD

Country/Region	Industrial Roundwood ('000 \$/m^3)	Sawlogs + Veneer Logs ('000 \$/m^3)	Pulpwood ('000 \$/m^3)	Sawnwood ('000 \$/m^3)	Plywood + Veneer ('000 \$/m^3)	Particleboard ('000 \$/m^3)	Fibreboard ('000 \$/m^3)	Pulp[1] ('000 \$/Mt)	Wood Pellets ('000 \$/Mt)
Australia	98,153	78,304	27,037	217,213	505,570	344,480	371,493	823,264	156,803
BC Coast	105,092	98,230	33,917	198,100	470,286	211,707	391,781	636,171	126,720
BC Interior	86,000	85,418	29,493	172,262	407,584	206,897	353,341	635,890	125,440
Alberta	99,408	85,856	29,644	173,146	432,686	235,388	408,427	735,026	129,280
Atlantic Canada	108,285	94,003	32,457	189,576	465,788	250,872	414,898	800,661	158,355
Rest of Canada	103,845	98,704	34,080	199,055	464,231	251,127	426,657	767,834	153,698
Chile	98,153	78,304	27,037	186,428	433,917	295,658	371,493	697,743	152,145
China	106,333	84,829	29,290	220,770	536,000	344,500	498,000	669,668	153,698
Finland	118,230	95,780	33,071	239,890	518,319	309,455	485,749	772,917	156,803
Japan	115,875	92,442	31,918	211,007	491,125	334,638	438,568	581,117	156,803
New Zealand	98,153	78,304	27,037	186,428	433,917	295,658	371,493	577,564	153,698
Russia	100,405	88,660	30,612	186,428	378,629	215,401	396,192	638,602	153,698
Sweden	100,518	93,367	32,237	237,310	605,960	510,498	1,266,862	876,937	158,355
US North	153,502	115,000	39,707	275,000	526,350	471,807	295,257	623,257	166,600
US South	137,162	110,000	37,980	255,000	535,216	421,585	263,828	631,074	152,510
US West	153,721	125,000	43,160	265,000	527,101	472,479	295,678	707,259	129,280
Rest of Latin America	98,153	78,304	27,037	199,977	465,452	317,145	371,493	669,497	156,803
Rest of Europe	92,132	73,500	25,378	168,120	663,000	301,000	455,000	692,209	153,698
Rest of Asia	110,422	88,092	30,416	226,027	526,086	358,459	417,930	533,782	153,698
Rest of World	78,030	62,250	21,493	203,771	474,283	323,162	295,329	660,012	158,355

Source: FAO (2014), BC Statistics (2013), Government of Canada (2012), Oswalt et al. (2009), van Kooten and Johnston (2014), UNECE (2012), UNECE/FAO TIMBER database

[1] Calculated by the authors based on a weighted average composite of regional prices for mechanical, chemical, and semi-chemical pulp prices.

Table A4: Global Coniferous Forest Product Manufacturing Cost in 2011, $USD

Country/Region	Sawnwood ('000 \$/m^3)	Plywood + Veneer ('000 \$/m^3)	Particleboard ('000 \$/m^3)	Fibreboard ('000 \$/m^3)	Pulp ('000 \$/Mt)	Wood Pellets ('000 \$/Mt)
Australia	170,124	214,419	125,989	216,645	308,247	106,519
BC Coast	94,047	240,262	140,895	233,902	388,527	105,454
BC Interior	81,780	225,168	137,850	225,151	317,945	97,378
Alberta	82,200	225,685	141,866	240,578	367,513	101,050
Atlantic Canada	90,000	242,858	147,715	261,269	400,330	107,804
Rest of Canada	94,500	244,716	145,032	249,785	383,917	106,926
Chile	111,704	214,419	125,989	216,645	308,247	100,519
China	167,691	232,287	136,488	234,699	333,934	98,979
Finland	88,181	262,273	154,108	264,996	376,775	113,011
Japan	152,871	253,133	148,737	255,761	363,902	106,015
New Zealand	127,375	214,419	125,989	216,645	308,247	104,519
Russia	108,459	242,776	142,652	245,297	297,695	94,891
Sweden	54,655	255,664	150,225	258,319	405,435	102,953
US North	146,322	263,915	148,905	260,916	353,126	134,000
US South	146,322	258,025	147,716	257,500	315,537	116,000
US West	146,402	275,696	151,281	267,746	353,630	126,000
Rest of Latin America	93,659	214,419	125,989	216,645	308,247	98,519
Rest of Europe	134,956	201,264	118,260	203,354	377,500	104,972
Rest of Asia	167,691	241,221	141,738	243,726	346,778	101,709
Rest of World	119,134	170,458	100,159	172,228	245,050	91,007

Source: FAO (2014), BC Statistics (2013), Government of Canada (2012), Oswalt et al. (2009), van Kooten and Johnston (2014), UNECE (2012), as well as calculations from the authors.

Table A5: Global Coniferous Forest Product Domestic Price Elasticity of Demand

Country/Region	Sawnwood	Plywood + Veneer	Particleboard	Fibreboard	Pulp	Wood Pellets
Australia	-0.17	-0.59	-0.43	-0.71	-0.34	-1.10
BC Coast	-0.17	-0.59	-0.43	-0.71	-0.34	-1.10
BC Interior	-0.17	-0.59	-0.43	-0.71	-0.34	-1.10
Alberta	-0.17	-0.59	-0.43	-0.71	-0.34	-1.10
Atlantic Canada	-0.17	-0.59	-0.43	-0.71	-0.34	-1.10
Rest of Canada	-0.17	-0.59	-0.43	-0.71	-0.34	-1.10
Chile	-0.21	-0.59	-0.43	-0.71	-0.34	-1.10
China	-0.21	-0.59	-0.43	-0.71	-0.34	-1.10
Finland	-0.17	-0.37	-0.43	-0.58	-0.34	-1.10
Japan	-0.17	-0.59	-0.43	-0.71	-0.34	-1.10
New Zealand	-0.17	-0.59	-0.43	-0.71	-0.34	-1.10
Russia	-0.17	-0.59	-0.43	-0.71	-0.34	-1.10
Sweden	-0.17	-0.37	-0.43	-0.58	-0.34	-1.10
US North	-0.17	-0.59	-0.43	-0.71	-0.34	-1.10
US South	-0.17	-0.59	-0.43	-0.71	-0.34	-1.10
US West	-0.17	-0.59	-0.43	-0.71	-0.34	-1.10
Rest of Latin America	-0.56	-0.59	-0.43	-0.71	-0.34	-1.10
Rest of Europe	-0.17	-0.56	-0.36	-0.63	-0.34	-1.10
Rest of Asia	-0.21	-0.59	-0.43	-0.71	-0.34	-1.10
Rest of World	-0.20	-0.59	-0.43	-0.71	-0.34	-1.10

Source: van Kooten and Johnston (2014), UNECE (2012)

Table A6: Inter-regional Transportation Costs, Twenty Regions, \$/m^3, 2011[a]

Export/Import	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	0.0	60.6	62.3	63.9	75.5	81.6	55.0	43.4	75.7	38.0	10.5	70.3	73.7	77.6	67.0	58.5	64.8	78.0	43.4	53.4
BC Coast	60.6	0.0	9.6	12.8	43.7	33.3	51.2	40.6	73.1	39.6	55.1	81.8	72.1	38.6	31.6	17.5	53.6	72.1	40.6	79.8
BC Interior	62.3	9.6	0.0	6.6	40.4	30.1	60.6	49.6	82.3	48.3	63.1	90.0	81.1	35.5	29.9	18.4	60.5	81.1	49.6	88.1
Alberta	63.9	12.8	6.6	0.0	37.1	27.0	63.2	52.6	85.2	52.0	67.1	94.0	84.1	32.3	28.1	19.3	65.3	84.1	52.5	94.5
Atlantic Canada	75.5	43.7	40.4	37.1	0.0	12.9	42.3	82.3	38.5	78.5	73.4	46.8	34.5	9.8	32.1	46.9	37.7	43.2	64.4	58.3
Rest of Canada	81.6	33.3	30.1	27.0	12.9	0.0	51.8	94.9	40.8	90.1	85.4	58.8	46.5	6.0	21.0	34.6	49.7	54.8	76.4	72.6
Chile	55.0	51.2	60.6	63.2	42.3	51.8	0.0	49.5	65.4	50.0	46.9	68.5	63.5	43.7	36.4	40.1	21.5	60.5	49.0	68.5
China	43.4	40.6	49.6	52.6	82.3	94.9	49.5	0.0	100.2	8.2	50.5	52.7	96.1	94.7	78.5	56.5	85.4	97.2	3.0	62.8
Finland	75.7	73.1	82.3	85.2	38.5	40.8	65.4	100.2	0.0	92.2	80.8	8.4	4.0	43.2	41.2	65.2	54.8	12.0	99.0	50.8
Japan	38.0	39.6	48.3	52.0	78.5	90.1	50.0	8.2	92.2	0.0	42.9	56.7	95.0	88.7	77.6	64.5	72.9	96.2	10.2	71.5
New Zealand	10.5	55.1	63.1	67.1	73.4	85.4	46.9	50.5	80.8	42.9	0.0	78.6	82.5	78.9	68.8	66.9	68.3	86.6	50.5	57.1
Russian Fed	70.3	81.8	90.0	94.0	46.8	58.8	68.5	52.7	8.4	56.7	78.6	0.0	11.3	48.2	48.2	69.3	57.2	15.2	22.2	69.2
Sweden	73.7	72.1	81.1	84.1	34.5	46.5	63.5	96.1	4.0	95.0	82.5	11.3	0.0	43.2	41.2	64.3	53.0	9.8	98.0	50.3
US North	77.6	38.6	35.5	32.3	9.8	6.0	43.7	94.7	43.2	88.7	78.9	48.2	43.2	0.0	22.8	38.9	44.7	48.9	73.0	60.9
US South	67.0	31.6	29.9	28.1	32.1	21.0	36.4	78.5	43.2	77.6	68.8	48.2	41.2	22.8	0.0	22.1	38.3	43.9	67.2	47.0
US West	58.5	17.5	18.4	19.3	46.9	34.6	40.1	56.5	65.2	64.5	66.9	69.3	64.3	38.9	22.1	0.0	48.1	68.0	44.8	77.9
Rest LA	64.8	53.6	60.5	65.3	37.7	49.7	21.5	85.4	54.8	72.9	68.3	57.2	53.0	44.7	38.3	48.1	0.0	49.2	57.4	45.8
Rest Europe	78.0	72.1	81.1	84.1	43.2	54.8	60.5	97.2	12.0	96.2	86.6	15.2	9.8	48.9	43.9	68.0	49.2	0.0	98.0	48.2
Rest Asia	43.4	40.6	49.6	52.5	64.4	76.4	49.0	3.0	99.0	10.2	50.5	22.2	98.0	73.0	67.2	44.8	57.4	98.0	0.0	62.8
ROW	53.4	79.8	88.1	94.5	58.3	72.6	68.5	62.8	50.8	71.5	57.1	69.2	50.3	60.9	47.0	77.9	45.8	48.2	62.8	0.0

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

Table A7: Bilateral Coniferous Industrial Roundwood Trade Flows, Twenty Model Regions, (‘000 m^3) 2011

Export/Import	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 Production
Australia	13,267.9	0.0	0.0	0.0	0.0	0.0	0.0	935.0	0.0	2.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.0	253.5	23.0	14,483.0
BC Coast	0.0	11,559.8	0.0	0.0	0.0	0.0	0.0	1,680.0	0.0	1,142.0	0.0	0.0	0.0	788.7	0.0	0.0	0.0	0.0	132.0	8.8	15,311.3
BC Interior	0.0	0.0	44,620.8	300.0	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	44,920.8
Alberta	0.0	0.0	0.0	12,971.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	89.6	5.8	13,067.3
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	1.4	0.0	188.9	12.3	27,548.7
Chile	0.0	0.0	0.0	0.0	0.0	0.0	22,905.9	30.0	0.0	22.3	0.0	0.0	0.0	0.0	0.0	0.0	49.0	0.0	0.0	0.0	23,007.2
China	3.4	0.0	0.0	0.0	0.0	0.0	0.0	65,411.4	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	39.0	24.7	65,479.6
Finland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	38,309.4	1.0	0.0	0.0	290.0	0.0	0.0	0.0	0.0	0.0	0.0	7.6	38,609.0
Japan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.4	0.0	14,749.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.6	0.1	14,827.0
New Zealand	17.1	0.0	0.0	0.0	0.0	0.0	4.8	2,298.0	0.0	737.0	14,713.8	0.0	0.0	0.0	0.0	0.0	0.0	1.4	3,720.9	64.5	21,557.4
Russian Fed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13,203.0	1,324.0	437.0	0.0	65,729.9	57.0	0.0	0.0	0.0	0.0	492.1	8,508.6	3,094.8	92,846.3
Sweden	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	110.0	0.6	0.0	0.0	59,419.0	0.0	0.0	0.0	0.0	1,114.8	0.0	22.1	60,667.6
US North	0.0	0.0	0.0	0.0	63.7	141.5	0.0	0.0	0.0	115.2	0.6	0.1	0.0	13,220.3	0.0	0.0	15.5	26.9	108.3	14.4	13,706.6
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	1.1	0.1	0.0	122,774.1	0.0	144.2	249.4	1,006.0	134.1	127,285.0
US West	0.0	90.0	24.0	94.6	59.0	481.0	0.0	0.0	0.0	484.6	0.0	0.5	0.0	0.0	0.0	55,717.6	65.3	112.9	455.6	60.7	57,645.9
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	0.3	9.4	4.8	7.4	50,963.7	32.4	116.2	1.9	51,291.5
Rest Europe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	577.0	1,196.7	30.0	6.8	28.3	3,054.4	10.1	5.2	7.9	3.9	181,710.2	305.3	1,274.3	188,210.3
Rest Asia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	200.8	0.0	12.5	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	7,716.1	50.6	7,981.0
ROW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.4	0.0	0.0	0.0	0.0	0.0	0.3	0.2	0.3	0.7	70.1	65.7	27,117.7	27,263.3
TOTAL Consumption	13,288.5	11,649.8	44,644.8	13,365.8	11,275.0	29,874.4	23,010.7	84,427.5	40,940.5	18,805.9	14,721.2	65,760.0	62,820.7	14,028.8	122,784.2	55,734.2	51,244.4	183,811.1	22,756.2	31,917.4	916,861.2

Table A8: Bilateral Coniferous Sawlog Trade Flows, Twenty Model Regions, (‘000 m^3) 2011

Export/Import	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 Production
Australia	8,188.5	0.0	0.0	0.0	0.0	0.0	0.0	615.2	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	166.8	15.2	8,988.0
BC Coast	0.0	9,500.2	0.0	0.0	0.0	0.0	0.0	1,261.0	0.0	857.2	0.0	0.0	0.0	592.0	0.0	0.0	0.0	0.0	99.1	6.6	12,316.0
BC Interior	0.0	0.0	47,774.5	299.6	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	48,074.0
Alberta	0.0	0.0	0.0	13,311.3	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	85.8	5.6	13,403.3
Atlantic Canada	0.0	0.0	0.0	0.0	9,387.6	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	9,387.6
Rest of Canada	0.0	0.0	0.0	0.0	0.0	28,063.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	180.8	11.7	28,257.1
Chile	0.0	0.0	0.0	0.0	0.0	0.0	15,460.4	18.6	0.0	13.8	0.0	0.0	0.0	0.0	0.0	0.0	30.3	0.0	0.0	0.0	15,523.0
China	2.0	0.0	0.0	0.0	0.0	0.0	0.0	37,573.6	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.4	14.2	37,612.9
Finland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	18,613.8	0.5	0.0	0.0	144.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	18,762.6
Japan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.0	0.0	13,809.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	44.1	0.1	13,877.0
New Zealand	5.9	0.0	0.0	0.0	0.0	0.0	1.6	788.8	0.0	253.0	5,895.8	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1,277.3	22.1	8,245.0
Russian Fed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8,698.3	872.3	287.9	0.0	47,835.4	37.6	0.0	0.0	0.0	0.0	324.2	5,605.5	2,038.9	65,700.0
Sweden	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	63.3	0.3	0.0	0.0	32,881.7	0.0	0.0	0.0	0.0	641.3	0.0	12.7	33,600.0
US North	0.0	0.0	0.0	0.0	37.7	83.8	0.0	0.0	0.0	68.2	0.4	0.1	0.0	8,356.7	0.0	0.0	9.2	15.9	64.2	8.5	8,644.7
US South	0.0	0.0	0.0	0.0	0.0	1,128.7	0.0	0.0	0.2	633.8	0.0	0.7	0.0	0.0	77,609.9	0.0	85.4	147.7	595.8	79.4	80,281.6
US West	0.0	53.3	14.2	56.0	34.9	284.9	0.0	0.0	0.0	287.0	0.0	0.3	0.0	0.0	0.0	35,216.7	38.7	66.9	269.8	36.0	36,358.7
Rest LA	0.0	0.0	0.0	0.0	0.0	0.0	10.2	5.6	0.0	0.0	0.0	0.0	0.0	1.0	0.5	0.8	4,975.7	3.3	11.8	0.2	5,009.0
Rest Europe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	379.1	786.2	19.7	4.5	18.6	2,006.7	6.6	3.4	5.2	2.6	117,761.4	200.6	837.2	122,031.8
Rest Asia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	119.6	0.0	7.5	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	3,713.2	30.1	3,871.0
ROW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48.9	0.0	0.0	0.0	0.0	0.0	1.9	1.0	1.5	4.0	406.4	381.0	81,707.1	82,551.8
TOTAL Consumption	8,196.3	9,553.5	47,788.7	13,666.9	9,460.2	29,560.6	15,472.2	49,532.8	20,335.8	16,240.9	5,900.6	47,855.1	35,070.0	8,958.2	77,614.8	35,224.8	5,147.8	119,368.1	12,718.1	84,829.5	652,495.0

Table A9: Bilateral Coniferous Lumber Trade Flows, Twenty Model Regions, (‘000 m^3) 2011

Export/Import	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 Production
Australia	3,738.3	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	3,826.0
BC Coast	7.9	56.5	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	4,451.3
BC Interior	28.2	747.5	1,653.7	781.6	487.5	2,916.4	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	15,984.3
Alberta	7.9	208.4	55.3	66.1	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	4,456.5
Atlantic Canada	5.5	146.0	38.7	152.6	388.9	560.0	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	3,121.3
Rest of Canada	16.6	439.4	116.6	459.4	286.6	2,569.7	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	9,395.3
Chile	17.0	0.9	0.3	1.0	0.6	6.2	4,537.4	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	6,630.8
China	0.7	0.0	0.0	0.0	0.0	0.0	0.0	17,800.2	0.0	77.4	0.2	0.1	0.0	0.3	0.2	0.2	2.0	4.0	21.0	11.7	17,918.0
Finland	10.0	0.0	0.0	0.0	0.0	0.2	0.0	74.0	4,652.5	623.0	0.0	0.3	9.4	0.4	0.3	0.2	0.1	2,313.5	29.8	1,986.1	9,700.0
Japan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.5	0.0	9,277.9	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	2.1	1.2	9,294.0
New Zealand	275.0	0.0	0.0	2.0	0.0	2.0	0.1	683.0	2.4	131.0	1,665.0	0.0	0.6	82.5	65.1	42.3	0.0	107.0	326.2	549.7	3,934.0
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	16,889.6	11.2	0.5	0.0	1.5	0.0	2,919.9	213.4	3,544.5	29,055.0
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	5,689.3	14.3	11.3	7.3	0.1	6,902.8	15.9	2,865.3	16,400.0
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	782.1	1,318.2	856.1	51.8	5.6	4.6	6.4	3,138.3
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	3,994.1	7,950.1	480.7	51.6	43.0	59.5	29,144.3
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	5,044.0	365.4	217.7	23.4	19.5	26.9	13,199.2
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	2,050.6	1.3	3.5	0.4	2,620.6
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	71,846.7	6.4	156.3	73,754.8
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	5,946.9	6.5	6,148.0
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	33,894.2	37,627.7
TOTAL Consumption	4,394.4	1,685.7	1,942.9	1,771.5	1,492.0	9,367.2	4,545.7	28,178.9	5,037.1	15,548.8	1,707.9	16,897.7	5,860.6	30,254.1	15,830.8	12,728.8	3,499.6	88,282.8	7,061.7	43,711.2	299,799.4

Table A10: Bilateral Coniferous Plywood + Veneer Trade Flows, Twenty Model Regions, (‘000 m^3) 2011

Export/Import	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 Production
Australia	124.6	0.0	0.0	0.0	0.0	0.1	0.0	1.3	0.0	0.1	0.0	0.0	0.0	0.3	0.3	0.2	0.0	0.3	84.0	1.9	213.2
BC Coast	2.6	235.5	0.0	0.2	0.1	1.2	0.0	0.5	0.0	1.2	0.0	0.0	0.1	49.2	38.8	25.2	0.3	3.1	0.9	11.6	370.6
BC Interior	9.2	0.7	844.5	0.7	0.4	4.3	0.1	1.9	0.1	4.4	0.0	0.0	0.3	176.7	139.5	90.6	0.9	11.2	3.4	42.1	1,330.9
Alberta	0.4	0.0	0.0	36.1	0.0	0.2	0.0	0.1	0.0	0.2	0.0	0.0	0.0	7.8	6.2	4.0	0.0	0.5	0.2	1.8	57.5
Atlantic Canada	0.7	0.0	0.0	0.1	52.2	0.3	0.0	0.1	0.0	0.3	0.0	0.0	0.0	13.1	10.3	6.7	0.1	0.8	0.3	3.1	88.1
Rest of Canada	2.2	0.2	0.0	0.2	0.1	171.6	0.0	0.5	0.0	1.1	0.0	0.0	0.1	42.5	33.6	21.8	0.2	2.7	0.8	9.1	286.8
Chile	52.1	2.5	0.7	2.7	1.7	16.8	127.4	5.6	3.2	3.2	1.0	0.0	13.1	122.5	96.7	62.8	235.3	308.2	4.0	221.7	1,281.1
China	39.1	16.6	4.4	17.4	10.8	109.2	12.2	25,422.3	11.6	469.3	0.7	34.3	52.3	685.3	540.9	351.3	149.8	1,650.0	961.7	0.1	30,539.0
Finland	0.7	0.1	0.0	0.1	0.1	0.8	0.1	4.3	169.1	3.0	0.0	1.6	35.7	5.5	4.4	2.8	0.1	365.0	13.1	406.9	1,013.4
Japan	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	2,508.5	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	2.1	4.5	2,518.3
New Zealand	134.2	0.0	0.0	0.0	0.0	0.1	0.1	7.1	0.0	142.0	543.2	0.0	0.0	0.9	0.7	0.5	0.0	0.7	97.2	126.8	1,053.5
Russian Fed	0.7	1.1	0.3	1.1	0.7	7.1	0.0	23.9	45.7	146.7	0.0	1,417.3	16.0	49.5	39.0	25.3	1.0	406.7	11.9	604.5	2,798.7
Sweden	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	57.4	0.1	0.1	0.1	3.1	36.6	0.2	14.2	112.0
US North	6.7	4.0	1.1	4.2	2.6	26.3	0.1	1.4	0.1	0.2	0.4	0.1	0.2	435.3	0.0	0.0	18.0	9.9	2.0	22.5	535.2
US South	62.0	37.2	9.9	38.9	24.2	244.4	1.0	12.6	1.2	1.9	3.5	1.4	2.1	0.0	4,042.8	0.0	167.1	92.0	18.8	209.0	4,969.9
US West	28.1	16.8	4.5	17.6	11.0	110.7	0.5	5.7	0.5	0.9	1.6	0.6	1.0	0.0	0.0	1,830.9	75.7	41.7	8.5	94.6	2,250.8
Rest LA	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.3	0.0	0.0	0.0	0.0	0.2	9.3	7.3	4.7	674.3	0.4	0.2	16.0	712.8
Rest Europe	3.3	0.6	0.2	0.6	0.4	4.0	5.1	5.5	23.1	2.4	0.0	27.8	48.4	9.9	7.8	5.1	24.9	1,017.7	14.8	2,739.7	3,941.3
Rest Asia	7.4	0.1	0.0	0.1	0.0	0.4	0.0	24.2	0.1	162.9	0.0	0.0	0.0	10.4	8.2	5.3	7.7	23.4	505.9	194.8	950.9
ROW	14.6	0.5	0.1	0.5	0.3	3.2	19.7	4.2	6.3	0.3	3.6	0.4	4.0	30.7	24.2	15.7	91.0	701.2	13.6	34,319.5	35,253.8
TOTAL Consumption	488.5	315.9	865.8	120.4	104.7	700.9	166.5	25,523.4	261.0	3,448.6	553.9	1,485.0	230.8	1,649.1	5,000.7	2,453.1	1,449.5	4,672.1	1,743.7	39,044.3	90,277.9

Table A11: Bilateral Coniferous Particleboard (PB & OSB)Trade Flows, Twenty Model Regions, (‘000 m^3) 2011

Export/Import	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 Production
Australia	771.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	772.7
BC Coast	0.0	602.0	0.0	0.0	0.0	0.2	0.3	0.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	2.7	607.4
BC Interior	0.1	0.1	2,161.8	0.1	0.1	0.6	1.0	3.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	4.0	0.0	9.6	2,180.9
Alberta	0.0	0.0	0.0	875.2	0.0	0.2	0.4	1.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	3.9	883.0
Atlantic Canada	0.0	0.0	0.0	0.0	4.6	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	4.6
Rest of Canada	0.1	0.1	0.0	0.1	0.1	2,597.1	1.4	4.1	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	5.3	0.0	12.2	2,621.4
Chile	0.1	0.0	0.0	0.0	0.0	0.0	461.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.6	22.5	0.1	29.9	520.7
China	0.7	0.0	0.0	0.0	0.0	0.2	0.9	8,008.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	22.6	1.5	143.8	8,180.4
Finland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	139.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.6	0.0	11.6	163.0
Japan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5	0.0	32.5	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	421.8	488.4	948.6
New Zealand	23.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	103.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.8	144.6
Russian Fed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.3	0.0	0.0	0.0	4,997.1	0.0	0.0	0.0	0.0	0.0	65.8	0.2	123.9	5,204.3
Sweden	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0	476.0	0.0	0.0	0.0	0.0	16.1	0.0	13.2	507.1
US North	0.0	1.9	0.5	1.9	1.2	12.2	0.7	0.3	0.0	0.0	0.0	0.0	0.0	782.8	0.0	0.0	0.2	2.7	0.1	1.0	805.6
US South	0.0	17.3	4.6	18.1	11.3	113.7	6.8	3.1	0.0	0.0	0.0	0.1	0.0	0.0	7,269.8	0.0	1.9	25.3	0.6	9.1	7,481.6
US West	0.0	7.8	2.1	8.2	5.1	51.5	3.1	1.4	0.0	0.0	0.0	0.1	0.0	0.0	0.0	3,292.4	0.9	11.4	0.3	4.1	3,388.3
Rest LA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	102.5	0.0	0.0	0.0	0.0	0.0	0.0	265.7	19.3	0.0	22.6	410.3
Rest Europe	15.0	0.4	0.1	0.4	0.3	2.5	18.2	81.2	80.5	38.5	0.0	135.8	249.2	14.4	11.4	7.4	13.1	26,010.7	110.0	4,780.6	31,569.5
Rest Asia	0.1	0.0	0.0	0.0	0.0	0.1	0.0	22.4	0.0	0.0	0.0	0.1	1.4	0.0	0.0	0.0	0.2	13.4	163.5	41.9	243.1
ROW	0.0	0.0	0.0	0.0	0.0	0.0	44.5	19.8	0.0	210.3	0.2	149.2	64.4	801.2	632.3	410.7	125.8	944.7	199.7	10,695.6	14,298.4
TOTAL Consumption	811.4	629.7	2,169.1	904.1	22.6	2,778.5	538.7	8,168.6	223.8	383.8	103.5	5,282.4	791.0	1,598.6	7,913.6	3,710.5	416.8	27,178.3	897.6	16,412.8	80,935.5

Table A12: Bilateral Coniferous Fiberboard (MDF) Trade Flows, Twenty Model Regions, (‘000 m^3) 2011

Export/Import	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 Production
Australia	126.1	0.4	0.1	0.4	0.3	2.5	0.0	56.0	0.0	0.0	0.0	2.9	1.5	9.8	7.7	5.0	1.5	57.7	17.7	184.5	474.1
BC Coast	0.0	110.0	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	0.5	0.0	0.6	111.2
BC Interior	0.0	0.0	394.9	0.0	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.7	0.0	2.2	399.3
Alberta	0.0	0.0	0.0	157.3	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.7	0.0	2.2	161.7
Atlantic Canada	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.8
Rest of Canada	0.1	0.2	0.1	0.2	0.1	432.3	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	19.8	0.0	23.7	480.0
Chile	0.1	4.2	1.1	4.4	2.7	27.6	756.2	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	46.2	11.5	0.9	100.7	957.6
China	22.0	6.8	1.8	7.2	4.5	45.0	9.8	29,743.0	0.2	2.6	0.0	0.6	0.6	350.0	124.0	36.0	16.8	20.4	201.7	982.1	31,575.2
Finland	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	88.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.1	3.7	95.9
Japan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.6	0.0	226.5	0.0	9.9	0.0	0.0	0.0	0.0	1.0	13.1	4.7	565.2	824.9
New Zealand	22.8	0.3	0.1	0.3	0.2	2.0	0.0	90.1	0.0	0.0	290.3	0.0	0.0	0.0	0.0	0.0	6.9	0.1	69.2	191.7	674.3
Russian Fed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.0	0.0	1,402.4	0.0	0.0	0.0	0.0	0.0	52.0	0.3	32.6	1,490.6
Sweden	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	5.4	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.2	15.5	1.3	43.6	96.5
US North	0.4	2.2	0.6	2.3	1.4	14.2	0.1	0.3	0.1	0.0	0.0	0.0	0.2	376.7	0.0	0.0	0.4	1.5	0.1	15.3	415.7
US South	4.2	20.0	5.3	20.9	13.0	131.6	0.8	3.1	0.6	0.0	0.0	0.0	2.2	0.1	3,497.9	0.0	3.4	14.3	1.0	141.8	3,860.3
US West	1.9	9.1	2.4	9.5	5.9	59.6	0.4	1.4	0.3	0.0	0.0	0.0	1.0	0.0	0.0	1,584.1	1.6	6.5	0.5	64.2	1,748.3
Rest LA	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	2.9	0.0	25.8	32.9	1.4	1.1	0.7	31.2	21.0	2.2	0.0	119.8
Rest Europe	18.6	10.8	2.9	11.3	7.1	71.2	45.2	37.5	108.1	300.7	0.4	136.8	169.7	67.2	53.1	34.5	32.4	6,174.3	307.9	5,345.5	12,935.1
Rest Asia	2.3	0.0	0.0	0.0	0.0	0.1	0.0	8.7	0.0	0.0	0.0	0.4	1.4	0.0	0.0	0.0	0.2	4.8	415.5	1.9	435.5
ROW	6.0	1.7	0.4	1.7	1.1	10.9	11.6	6.9	0.4	29.3	0.5	170.5	19.6	431.9	340.9	221.4	702.8	613.3	230.4	35,285.1	38,086.6
TOTAL Consumption	204.8	165.7	409.7	215.6	36.5	797.6	824.5	29,956.8	206.8	562.1	291.2	1,749.4	259.2	1,237.1	4,024.7	1,881.8	846.5	7,033.1	1,253.7	42,986.5	94,943.4

Table A13: Bilateral Coniferous Pulp Trade Flows, Twenty Model Regions, (‘000 Mt) 2011

Export/Import	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 Production
Australia	477.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.5	0.0	0.1	12.5	491.2
BC Coast	3.1	1,319.4	0.0	0.0	0.0	0.0	0.0	129.4	0.1	26.1	0.0	0.2	178.2	1.3	1.0	0.7	9.2	2.9	47.3	196.3	1,915.2
BC Interior	11.2	0.0	4,738.0	0.0	0.0	0.0	0.0	464.6	0.4	93.8	0.0	0.7	639.9	4.6	3.7	2.4	33.1	10.3	169.8	704.9	6,877.5
Alberta	6.9	0.0	0.0	1,102.1	0.0	0.0	0.0	285.3	0.2	57.6	0.0	0.4	293.0	2.8	2.2	1.5	20.3	6.3	44.3	94.5	1,917.5
Atlantic Canada	3.5	0.0	0.0	0.0	43.7	0.0	0.0	145.4	0.1	29.4	0.0	0.2	150.3	1.5	1.1	0.7	10.4	3.2	53.1	31.2	474.0
Rest of Canada	9.0	0.0	0.0	0.0	0.0	169.2	0.0	371.0	0.3	74.9	0.0	0.6	511.1	3.7	2.9	1.9	26.5	8.2	135.6	111.8	1,426.7
Chile	10.6	0.1	0.0	0.1	0.0	0.3	413.6	576.0	5.1	37.5	0.5	11.1	11.7	0.8	0.6	0.4	47.1	34.2	557.3	418.3	2,125.4
China	0.1	0.0	0.0	0.0	0.0	0.0	0.0	6,298.2	2.2	0.0	0.0	0.0	0.0	0.3	0.2	0.1	2.9	0.2	1.3	34.9	6,340.5
Finland	0.0	0.0	0.0	0.0	0.0	0.1	0.0	322.0	5,684.6	20.2	14.1	74.8	3.5	32.3	25.5	16.5	119.0	2.9	1,382.6	114.2	7,812.3
Japan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	159.9	0.0	3,843.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	55.4	4,058.6
New Zealand	88.2	0.0	0.0	0.0	0.0	0.0	0.0	254.2	0.0	209.0	611.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.8	260.9	1,431.9
Russian Fed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	841.0	14.5	73.3	0.0	3,706.0	6.8	15.1	11.9	7.8	50.3	48.9	437.3	54.4	5,267.4
Sweden	0.0	0.0	0.0	0.0	0.0	0.0	0.0	180.2	50.7	29.0	1.1	0.0	6,983.8	16.1	12.7	8.3	85.8	65.9	2,727.4	180.5	10,341.6
US North	0.3	0.7	0.2	0.8	0.5	4.9	1.3	65.8	0.0	20.6	1.3	2.4	0.0	123.2	4.0	2.6	22.7	37.0	74.9	1,529.5	1,892.6
US South	3.2	6.9	1.8	7.2	4.5	45.6	11.9	845.0	0.4	191.4	12.1	22.6	0.0	46.8	12,623.7	24.0	210.5	343.3	870.4	2,305.4	17,576.5
US West	1.5	3.1	0.8	3.3	2.0	20.6	5.4	382.7	0.2	86.7	5.5	10.2	0.0	21.2	16.7	4,783.5	95.3	155.5	394.2	1,971.9	7,960.2
Rest LA	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	0.0	0.0	0.0	0.0
Rest Europe	0.8	0.0	0.0	0.0	0.0	0.2	0.0	545.4	67.0	41.9	4.5	225.1	17.0	22.7	17.9	11.6	184.6	4,875.2	4,300.0	85.2	10,399.2
Rest Asia	0.1	0.0	0.0	0.0	0.0	0.0	0.0	78.5	0.0	9.1	0.0	0.0	0.5	0.1	0.1	0.1	1.8	0.0	276.1	72.7	439.2
ROW	37.9	4.9	1.3	5.1	3.2	32.1	1.4	1,678.5	196.5	166.1	9.3	20.2	139.5	16.5	13.0	8.5	58.6	94.0	1,573.0	2,235.1	6,294.6
TOTAL Consumption	653.5	1,335.2	4,742.2	1,118.6	54.0	273.0	433.6	13,623.9	6,022.3	5,010.0	660.4	4,074.7	8,935.4	309.0	12,737.4	4,870.5	978.6	5,688.1	13,052.3	10,469.6	95,042.2

B: Shadow Prices on the Calibration Constraints

Table B1: Adjustments required to the Transaction Cost Matrix for Industrial Roundwood, Twenty Model Regions, ($/m^3)

Export/Import	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	-176.5	-253.5	-255.5	-257.6	-272.4	-280.1	-246.4	-231.6	-272.6	-224.7	-189.7	-265.8	-270.1	-275.0	-261.6	-250.8	-258.8	-275.6	-231.6	-244.3
BC Coast	-222.2	-145.2	-157.4	-161.5	-200.7	-187.4	-210.2	-196.8	-238.0	-195.5	-215.1	-249.0	-236.8	-194.2	-185.3	-167.4	-213.2	-236.8	-196.8	-246.5
BC Interior	-195.1	-128.3	-116.1	-124.5	-167.4	-154.3	-193.0	-179.1	-220.6	-177.4	-196.2	-230.4	-219.1	-161.1	-154.0	-139.4	-192.8	-219.1	-179.0	-228.0
Alberta	-213.6	-148.8	-140.9	-132.5	-179.6	-166.7	-212.7	-199.3	-240.7	-198.5	-217.7	-251.9	-239.3	-173.5	-168.2	-157.0	-215.4	-239.3	-199.2	-252.5
Atlantic Canada	-240.5	-200.1	-196.0	-191.8	-144.6	-161.0	-198.3	-249.1	-193.4	-244.3	-237.8	-204.1	-188.4	-157.1	-185.4	-204.1	-192.5	-199.5	-226.4	-218.6
Rest of Canada	-241.2	-179.8	-175.8	-171.8	-153.9	-137.6	-203.4	-258.1	-189.4	-252.0	-246.0	-212.3	-196.6	-145.1	-164.2	-181.5	-200.7	-207.2	-234.6	-229.7
Chile	-269.6	-264.7	-276.7	-280.0	-253.4	-265.5	-193.5	-262.6	-282.8	-263.2	-259.3	-286.8	-280.3	-255.2	-245.9	-250.6	-227.0	-276.6	-262.0	-286.7
China	-254.2	-250.6	-262.1	-265.9	-303.5	-319.6	-261.9	-199.0	-326.2	-209.4	-263.1	-265.9	-321.1	-319.2	-298.7	-270.7	-307.4	-322.4	-202.8	-278.8
Finland	-387.4	-384.2	-395.9	-399.5	-340.1	-343.2	-374.4	-418.5	-291.3	-408.3	-393.9	-302.0	-296.4	-346.2	-343.6	-374.2	-360.9	-306.5	-417.0	-355.9
Japan	-258.4	-260.5	-271.5	-276.2	-309.9	-324.6	-273.6	-220.6	-327.2	-210.2	-264.6	-282.1	-330.8	-322.7	-308.7	-292.0	-302.7	-332.3	-223.1	-300.9
New Zealand	-190.9	-247.6	-257.7	-262.8	-270.8	-286.0	-237.2	-241.7	-280.2	-232.1	-177.6	-277.4	-282.4	-277.8	-265.0	-262.6	-264.4	-287.7	-241.7	-250.1
Russian Fed	-285.0	-299.6	-310.0	-315.1	-255.2	-270.4	-282.7	-262.6	-206.4	-267.7	-295.5	-173.5	-210.1	-256.9	-256.9	-283.7	-268.4	-215.0	-223.8	-283.5
Sweden	-310.5	-308.4	-319.9	-323.7	-260.6	-275.8	-297.4	-338.9	-221.9	-337.5	-321.6	-231.2	-216.8	-271.7	-269.1	-298.4	-284.1	-229.3	-341.3	-280.7
US North	-387.4	-337.9	-333.9	-329.9	-301.4	-296.5	-344.3	-409.1	-343.7	-401.5	-389.0	-350.1	-343.7	-288.9	-317.9	-338.4	-345.7	-351.0	-381.6	-366.3
US South	-342.8	-297.8	-295.6	-293.4	-298.4	-284.3	-303.8	-357.4	-312.5	-356.2	-345.1	-318.8	-310.0	-286.7	-257.7	-285.7	-306.3	-313.4	-343.0	-317.3
US West	-374.1	-321.9	-323.1	-324.3	-359.3	-343.7	-350.6	-371.4	-382.6	-381.6	-384.7	-387.7	-381.3	-349.2	-327.8	-299.7	-360.8	-386.0	-356.7	-398.6
Rest LA	-229.9	-215.7	-224.4	-230.6	-195.5	-210.7	-174.9	-256.0	-217.2	-240.2	-234.4	-220.3	-214.9	-204.4	-196.2	-208.7	-147.6	-210.1	-220.4	-205.7
Rest Europe	-267.5	-260.0	-271.4	-275.2	-223.2	-238.0	-245.2	-291.7	-183.6	-290.5	-278.4	-187.6	-180.8	-230.4	-224.1	-254.7	-230.9	-168.4	-292.8	-229.5
Rest Asia	-337.5	-334.0	-345.4	-349.1	-364.1	-379.4	-344.6	-286.2	-408.1	-295.3	-346.5	-310.5	-406.9	-375.1	-367.7	-339.3	-355.2	-406.9	-282.4	-362.2
ROW	-194.8	-228.3	-238.9	-247.0	-201.0	-219.1	-214.0	-206.8	-191.5	-217.8	-199.5	-214.8	-190.9	-204.4	-186.6	-225.9	-185.1	-188.2	-206.8	-127.0

Table B2: Adjustments required to the Transaction Cost Matrix for Lumber, Twenty Model Regions, ($/m^3)

Export/Import	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	-6.8	-86.6	-114.0	-114.8	-109.9	-106.5	-110.0	-46.7	-62.0	-55.3	-58.9	-129.6	-62.6	-26.6	-36.0	-17.6	-88.8	-133.9	-41.4	-73.7
BC Coast	-7.1	44.4	8.9	6.6	-7.9	12.1	-34.3	26.4	11.1	13.7	-32.3	-68.9	9.5	53.0	40.0	64.1	-7.4	-57.7	31.7	-29.7
BC Interior	16.5	58.6	42.4	36.6	19.3	39.1	-17.8	41.3	26.0	29.4	-15.1	-50.7	24.6	83.8	69.4	90.9	9.7	-42.9	46.6	-14.2
Alberta	8.7	49.3	29.7	37.2	16.5	36.2	-26.6	32.2	17.0	19.6	-25.3	-60.8	15.5	67.8	51.9	70.8	-1.3	-52.0	37.5	-26.7
Atlantic Canada	-23.9	-1.8	-24.3	-20.2	33.4	30.0	-27.2	-17.7	43.4	-27.5	-52.6	-35.5	44.8	109.0	66.7	61.9	6.1	-31.2	5.5	-10.7
Rest of Canada	-24.7	14.5	-8.2	-4.2	26.3	48.7	-31.7	-24.5	46.7	-33.4	-59.2	-42.7	38.5	108.7	73.7	70.1	-0.1	-37.1	-0.7	-19.2
Chile	-18.6	-24.6	-59.9	-61.5	-24.2	-24.3	14.9	-0.2	1.1	-14.2	-41.3	-72.2	0.5	59.8	47.1	53.4	7.0	-63.9	5.5	-51.2
China	-42.7	-48.0	-82.9	-85.0	-98.2	-101.4	-86.2	15.3	-68.0	-7.1	-80.6	-93.8	-66.5	-25.1	-29.0	3.1	-90.9	-134.5	17.5	-64.6
Finland	-29.6	-34.1	-69.2	-71.2	-8.0	-0.9	-57.3	-38.5	80.8	-45.1	-65.5	-5.1	71.8	72.7	54.7	40.6	-14.0	-3.0	-32.1	-6.2
Japan	-29.2	-39.4	-74.0	-76.8	-86.9	-88.9	-78.3	14.7	-52.3	13.1	-64.9	-89.3	-57.7	-11.6	-20.5	2.6	-70.8	-125.9	17.9	-65.6
New Zealand	13.4	-41.0	-74.8	-78.0	-67.8	-70.3	-59.4	-13.7	-26.8	-19.6	2.4	-94.8	-31.1	12.1	2.1	14.1	-52.4	-102.5	-8.5	-37.4
Russian Fed	-34.0	-55.3	-89.3	-92.5	-28.9	-31.4	-68.6	-3.5	58.0	-21.0	-73.1	14.8	52.5	55.2	35.2	24.1	-28.9	-18.7	32.3	-83.6
Sweden	18.7	13.1	-21.7	-23.9	42.2	39.7	-8.9	11.8	120.6	-1.6	-20.8	38.5	124.4	118.9	100.9	87.9	34.1	45.4	15.1	40.6
US North	-112.7	-79.1	-101.8	-97.8	-58.9	-45.6	-117.9	-112.5	-44.7	-121.8	-144.8	-127.9	-47.3	36.4	-6.5	-12.6	-83.4	-119.4	-85.6	-95.8
US South	-90.9	-61.8	-85.9	-83.3	-70.8	-50.3	-98.7	-86.1	-34.2	-100.0	-123.5	-115.6	-34.8	23.8	26.7	14.6	-66.6	-104.1	-69.5	-71.5
US West	-103.6	-68.4	-95.1	-95.2	-106.3	-84.5	-123.8	-84.7	-77.0	-107.7	-142.7	-158.3	-78.6	-12.9	-16.1	16.0	-97.1	-148.8	-67.8	-123.1
Rest LA	-5.3	-3.2	-35.9	-39.9	4.2	1.6	1.3	-12.3	35.4	-13.6	-39.6	-38.5	34.6	82.6	69.0	69.2	52.3	-28.8	21.0	10.3
Rest Europe	-55.3	-60.1	-95.0	-97.1	-39.7	-41.9	-73.6	-62.5	40.1	-74.6	-94.7	-31.7	39.7	40.0	25.0	10.9	-35.4	-18.0	-58.1	-30.5
Rest Asia	-47.5	-52.6	-87.4	-89.4	-84.8	-87.4	-90.7	7.7	-71.4	-13.7	-85.4	-68.4	-73.0	-8.1	-22.2	10.1	-67.4	-139.9	16.0	-69.1
ROW	20.1	-15.1	-49.3	-54.8	-2.2	-7.0	-31.9	24.5	53.6	2.0	-14.3	-36.6	51.5	80.6	74.6	53.7	20.7	-13.5	29.7	70.3

Table B3: Adjustments required to the Transaction Cost Matrix for Plywood + Veneer, Twenty Model Regions, ($/m^3)

Export/Import	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	237.5	141.6	77.3	100.8	122.3	114.6	110.9	224.6	174.6	185.1	155.4	40.3	264.2	180.8	200.2	200.5	132.6	317.0	214.7	152.8
BC Coast	146.6	171.9	99.6	121.5	123.7	132.6	84.4	197.0	146.8	153.1	80.5	-1.5	235.5	189.4	205.3	211.3	113.5	292.5	187.1	96.2
BC Interior	170.9	188.2	135.1	153.6	152.9	161.7	100.9	213.9	163.5	170.4	98.4	16.2	252.4	218.5	232.9	236.3	132.6	309.4	204.0	113.7
Alberta	162.0	177.8	121.3	153.0	149.0	157.6	91.1	203.7	153.4	159.5	87.1	5.0	242.2	214.4	227.4	228.1	120.5	299.2	193.9	100.1
Atlantic Canada	125.7	122.2	62.8	91.1	161.4	147.0	87.3	149.3	175.5	108.2	56.1	27.4	267.1	212.1	198.7	175.8	123.3	315.4	157.3	111.6
Rest of Canada	123.0	136.0	76.5	104.7	151.9	163.2	81.1	140.1	176.5	100.0	47.5	18.8	258.5	219.4	213.2	191.5	114.7	307.1	148.7	100.7
Chile	180.4	149.0	76.8	99.4	153.4	142.3	163.8	216.4	182.8	171.0	116.9	40.0	272.4	212.6	228.7	216.9	173.9	332.4	207.0	135.6
China	179.2	146.7	74.9	97.1	100.5	86.3	101.4	253.0	135.2	199.9	100.4	43.0	226.9	148.7	173.7	187.6	97.1	282.8	240.1	128.4
Finland	100.9	68.2	-3.7	18.5	98.4	94.4	39.5	106.9	189.3	70.0	24.1	41.3	273.0	154.2	165.0	132.9	81.6	322.0	98.1	94.5
Japan	157.8	120.9	49.5	70.9	77.5	64.4	74.2	218.0	116.4	181.3	81.3	12.2	201.2	127.9	147.8	152.9	82.8	257.1	206.1	93.0
New Zealand	226.1	146.2	75.5	96.6	123.4	109.9	118.0	216.5	168.5	179.2	164.9	31.0	254.4	178.5	197.4	191.2	128.1	307.4	206.6	148.2
Russian Fed	134.8	88.0	17.1	38.2	118.5	104.9	64.9	182.9	209.5	134.0	54.9	78.2	294.2	177.7	186.6	157.4	107.7	347.3	203.5	104.7
Sweden	120.2	86.5	14.8	36.9	119.7	106.1	58.8	128.3	202.7	84.5	39.8	55.7	294.3	171.5	182.4	151.2	100.8	341.5	116.4	112.3
US North	77.4	81.1	21.5	49.8	105.3	107.7	39.7	90.7	124.5	51.9	4.4	-20.2	212.2	175.7	161.8	137.5	70.1	263.5	102.4	62.7
US South	103.2	103.4	42.4	69.2	98.4	107.9	62.2	122.2	139.8	78.2	29.8	-4.9	229.5	168.2	199.9	169.7	91.9	283.8	123.6	92.0
US West	80.9	86.7	23.0	47.2	52.8	63.5	27.7	113.4	86.9	60.5	0.9	-56.8	175.6	121.3	147.0	161.0	51.3	228.9	115.1	30.3
Rest LA	172.7	148.6	79.0	99.3	160.0	146.4	144.4	182.6	195.4	150.2	97.5	53.3	284.9	213.6	228.9	211.0	197.4	345.7	200.7	160.4
Rest Europe	175.8	146.4	74.7	96.8	170.8	157.6	121.6	187.1	254.5	143.2	95.5	111.7	344.4	225.7	239.6	207.4	164.5	411.2	176.3	174.3
Rest Asia	167.2	134.7	63.0	85.2	106.4	92.9	89.9	238.0	124.3	186.0	88.4	61.5	213.0	158.3	173.0	187.3	113.1	270.0	231.1	116.5
ROW	249.3	187.6	116.6	135.3	204.6	188.8	162.5	270.3	264.6	216.7	173.9	106.6	352.8	262.5	285.4	246.3	216.8	412.0	260.4	271.4

Table B4: Adjustments required to the Transaction Cost Matrix for Particleboard, Twenty Model Regions, ($/m^3)

Export/Import	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	185.0	-8.4	-14.8	12.0	15.9	10.1	81.2	141.6	74.3	137.2	125.7	-14.4	277.3	234.8	195.1	254.5	92.9	63.5	155.6	110.3
BC Coast	111.6	39.4	25.0	50.3	34.9	45.6	72.2	131.6	64.1	122.7	68.3	-38.6	266.1	261.0	217.7	282.7	91.3	56.6	145.6	71.1
BC Interior	117.0	36.8	41.7	63.5	45.2	55.8	69.8	129.6	61.9	121.1	67.3	-39.8	264.1	271.1	226.5	288.8	91.4	54.6	143.6	69.8
Alberta	102.9	21.2	22.6	57.7	36.1	46.5	54.8	114.2	46.6	105.0	50.9	-56.3	248.7	261.8	215.8	275.5	74.2	39.2	128.3	51.0
Atlantic Canada	99.5	-1.4	-3.0	28.8	81.4	68.8	83.9	92.8	101.6	86.7	52.8	-0.9	306.6	292.5	220.1	256.2	110.0	88.4	124.6	95.4
Rest of Canada	79.8	-4.6	-6.3	25.4	54.9	68.1	60.8	66.5	85.5	61.5	27.2	-26.5	281.0	282.8	217.6	254.8	84.4	63.1	99.0	67.5
Chile	143.3	14.4	0.2	26.1	62.5	53.2	149.5	148.9	97.9	138.5	102.6	0.7	300.9	282.0	239.1	286.3	149.6	94.4	163.3	108.5
China	81.8	-48.2	-62.0	-36.5	-50.7	-63.1	26.9	125.2	-10.0	107.2	25.9	-56.6	195.1	157.9	123.8	196.7	12.5	-15.4	136.2	41.0
Finland	88.0	-42.3	-56.3	-30.7	31.6	29.4	49.4	63.5	128.6	61.6	34.0	26.2	325.6	247.8	199.6	226.4	81.5	108.2	78.6	91.5
Japan	76.2	-58.2	-71.7	-46.9	-57.9	-69.2	15.4	106.0	-13.0	104.4	22.5	-71.5	185.2	152.9	113.7	177.8	14.0	-25.4	118.0	21.4
New Zealand	180.8	3.4	-9.4	15.0	24.2	12.5	95.5	140.8	75.4	138.5	142.4	-16.4	274.7	239.7	199.5	252.3	95.6	61.1	154.7	112.8
Russian Fed	115.4	-28.8	-41.9	-17.4	45.3	33.5	68.3	133.1	142.3	119.2	58.3	56.6	340.4	264.8	214.6	244.5	101.1	127.0	177.5	95.2
Sweden	93.1	-38.1	-51.9	-26.4	38.8	27.0	54.5	70.8	127.8	62.0	35.5	26.4	332.9	251.0	202.8	230.6	86.5	113.5	82.8	95.2
US North	83.8	-10.0	-11.7	20.0	57.9	62.1	68.9	66.7	83.2	62.9	33.7	-15.9	284.2	288.7	215.7	250.4	89.3	69.0	102.3	79.1
US South	98.1	0.8	-2.3	27.9	39.5	50.8	80.0	86.6	86.9	77.7	47.5	-12.1	290.0	269.6	242.2	271.1	99.5	77.8	111.9	96.9
US West	123.3	31.6	25.9	53.4	41.4	53.9	93.0	125.4	81.6	107.6	66.1	-16.5	283.6	270.2	236.9	309.9	106.5	70.4	151.0	82.7
Rest LA	120.6	-1.0	-12.7	10.9	54.0	42.3	115.1	100.0	95.5	102.6	68.2	-1.0	298.4	268.0	224.2	265.3	158.0	92.7	142.0	118.3
Rest Europe	118.1	-8.8	-22.6	2.9	59.3	47.9	86.8	99.0	149.1	90.1	60.6	51.8	352.3	274.6	229.3	256.2	119.6	152.6	112.1	126.6
Rest Asia	115.2	-14.8	-28.6	-3.0	0.6	-11.1	60.8	155.6	24.6	138.6	59.3	7.3	226.6	212.9	168.5	241.8	73.9	17.1	172.6	74.4
ROW	99.8	-59.3	-72.5	-50.3	1.4	-12.7	35.9	90.4	67.4	71.9	47.3	-45.0	269.0	219.6	183.4	203.4	80.1	61.6	104.4	131.9

Table B5: Adjustments required to the Transaction Cost Matrix for Fiberboard, Twenty Model Regions, ($/m^3)

Export/Import	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	124.1	83.8	43.7	97.1	92.0	97.7	69.1	207.2	162.7	153.2	113.7	78.5	945.7	-29.7	-50.6	-10.3	59.3	129.6	127.1	-5.5
BC Coast	48.1	129.1	81.0	132.9	108.5	130.7	57.6	194.7	149.9	136.2	53.7	51.7	932.0	-6.1	-30.5	15.5	55.2	120.2	114.6	-47.1
BC Interior	58.9	131.8	103.0	151.5	124.2	146.2	60.6	198.1	153.1	139.9	58.1	55.9	935.4	9.5	-16.3	27.0	60.7	123.6	118.0	-43.1
Alberta	34.1	105.5	73.2	135.0	104.3	126.2	34.8	171.9	127.1	113.1	30.9	28.7	909.3	-10.5	-37.8	2.9	32.7	97.4	91.9	-72.6
Atlantic Canada	14.8	66.8	31.7	90.0	133.7	132.5	48.0	134.5	166.1	78.8	16.9	68.1	951.2	4.2	-49.5	-32.4	52.5	130.6	72.3	-44.2
Rest of Canada	5.2	73.8	38.5	96.7	117.3	141.9	34.9	118.4	160.2	63.8	1.4	52.6	935.7	4.6	-41.9	-23.7	37.1	115.4	56.8	-62.0
Chile	81.3	105.4	57.6	110.1	137.5	139.7	136.3	213.4	185.2	153.5	89.5	92.5	968.2	16.5	-7.7	20.5	114.9	159.4	133.8	-8.3
China	17.3	40.4	-7.0	45.0	21.9	21.0	11.2	187.2	74.8	119.6	10.3	32.8	860.0	-110.2	-125.4	-71.5	-24.6	47.1	104.2	-78.3
Finland	6.3	29.1	-18.6	33.7	86.9	96.3	16.5	108.3	196.2	56.9	1.1	98.3	973.3	-37.5	-66.9	-59.1	27.1	153.5	29.4	-45.1
Japan	2.9	21.5	-25.6	25.8	5.7	5.9	-9.1	159.1	62.9	107.9	-2.0	8.9	841.2	-124.0	-144.4	-99.4	-32.0	28.2	77.1	-106.8
New Zealand	119.4	95.0	48.6	99.7	99.8	99.6	82.9	205.8	163.3	154.0	129.8	75.9	942.7	-25.3	-46.7	-12.9	61.5	126.7	125.8	-3.4
Russian Fed	41.1	49.9	3.2	54.3	108.0	107.7	42.9	185.2	217.3	121.8	32.8	136.1	995.4	-13.0	-44.5	-33.7	54.1	179.7	135.7	-33.9
Sweden	14.2	36.2	-11.3	40.8	96.9	96.7	24.5	118.4	198.2	60.1	5.5	101.4	983.4	-31.4	-60.9	-52.1	35.0	161.7	36.4	-38.5
US North	1.6	60.9	25.6	83.8	112.7	128.4	35.5	111.0	150.2	57.6	0.3	55.7	931.4	2.9	-51.3	-35.6	34.5	113.8	52.6	-57.9
US South	17.9	73.7	36.9	93.7	96.3	119.1	48.6	132.9	156.0	74.4	16.1	61.5	939.1	-14.1	-22.7	-12.9	46.7	124.6	64.2	-38.2
US West	34.8	96.1	56.8	110.9	89.9	113.9	53.3	163.4	142.3	96.0	26.4	48.8	924.4	-21.9	-36.4	17.5	45.3	108.9	94.9	-60.7
Rest LA	59.6	91.1	45.8	96.0	130.1	129.9	103.0	165.6	183.8	118.6	56.1	91.9	966.8	3.5	-21.5	0.5	124.4	158.7	113.5	2.5
Rest Europe	62.5	88.6	41.2	93.3	140.7	140.8	80.0	169.8	242.7	111.4	53.8	150.0	1,026.0	15.4	-11.1	-3.3	91.3	224.0	88.9	16.2
Rest Asia	43.8	66.9	19.4	71.6	66.2	66.0	38.2	210.7	102.5	144.1	36.7	89.7	884.6	-62.1	-87.7	-33.4	29.8	72.7	133.6	-51.8
ROW	62.2	56.1	9.3	58.0	100.7	98.2	47.1	179.3	179.0	111.2	58.5	71.1	960.7	-21.6	-39.0	-38.1	69.8	150.9	99.2	39.4

Table B6: Adjustments required to the Transaction Cost Matrix for Pulp, Twenty Model Regions, ($/m^3)

Export/Import	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	399.8	152.1	150.2	247.7	301.7	262.8	219.3	202.8	273.8	119.7	143.7	144.8	379.8	122.3	140.6	225.3	181.3	190.8	66.9	183.2
BC Coast	259.6	133.1	123.2	219.2	253.9	231.5	143.5	126.0	196.8	38.5	19.5	53.8	301.8	81.6	96.5	186.7	112.9	117.1	-9.9	77.2
BC Interior	346.0	211.5	220.9	313.3	345.2	322.7	222.1	205.0	275.5	117.8	99.4	133.6	380.8	172.8	186.2	273.8	194.0	196.1	69.1	156.8
Alberta	271.5	135.4	141.3	247.1	275.6	253.0	146.6	129.1	199.8	41.2	22.6	56.7	304.9	103.0	115.0	200.0	116.3	120.2	-6.7	77.6
Atlantic Canada	250.4	95.1	98.1	200.5	303.3	257.6	158.1	90.0	237.1	5.2	6.8	94.4	345.1	116.0	101.6	163.0	134.4	151.6	-28.0	104.3
Rest of Canada	230.7	91.9	94.8	197.1	276.8	256.9	135.0	63.8	221.1	-19.9	-18.8	68.8	319.5	106.3	99.1	161.7	108.8	126.4	-53.6	76.5
Chile	371.1	187.9	178.2	274.7	361.3	318.9	300.6	223.1	310.4	134.0	133.6	173.0	416.4	182.5	197.6	270.1	250.9	234.6	87.7	194.4
China	229.2	44.9	35.6	131.8	167.8	122.3	97.6	119.0	122.1	22.3	-23.5	35.3	230.2	-22.0	1.9	100.2	33.5	44.4	-19.8	46.5
Finland	258.9	74.4	64.9	161.1	273.5	238.3	143.7	80.8	284.2	0.3	8.1	141.5	384.2	91.4	101.2	153.3	126.0	191.5	-53.9	120.5
Japan	202.4	13.7	4.7	100.2	139.3	94.9	64.9	78.6	97.9	-1.7	-48.2	-0.9	199.1	-48.3	-29.4	59.9	13.8	13.2	-59.3	5.7
New Zealand	401.7	169.9	161.7	256.8	316.1	271.3	239.7	208.0	281.0	127.1	166.4	148.9	383.3	133.3	151.1	229.2	190.0	194.4	72.2	191.8
Russian Fed	373.2	174.7	166.1	261.3	374.1	329.2	249.5	237.3	384.8	144.7	119.2	258.9	485.9	195.3	203.1	258.3	232.5	297.3	131.9	211.1
Sweden	239.7	54.2	44.9	141.1	256.4	211.5	124.4	63.7	259.1	-23.7	-14.8	117.4	367.1	70.2	80.1	133.2	106.7	172.6	-74.1	99.9
US North	248.3	100.2	103.0	205.3	293.4	264.4	156.7	77.6	232.3	-5.0	1.3	93.0	336.3	125.8	110.8	170.9	127.4	145.9	-36.7	101.7
US South	309.7	158.0	159.5	260.3	322.0	300.3	214.8	144.6	283.2	56.9	62.2	143.9	389.2	153.9	184.5	238.6	184.7	201.8	20.0	166.5
US West	311.8	165.8	164.6	262.8	300.9	280.3	204.8	160.3	254.8	63.8	57.8	116.5	359.8	131.4	156.1	254.4	168.5	171.4	36.1	129.3
Rest LA	335.7	159.8	152.7	246.9	340.2	295.3	253.5	161.5	295.3	85.5	86.5	158.6	401.2	155.8	170.0	236.4	246.7	220.2	53.7	191.5
Rest Europe	262.2	81.0	71.7	167.9	274.4	230.0	154.2	89.5	277.9	1.9	7.9	140.4	384.1	91.3	104.2	156.3	137.2	209.2	-47.3	128.8
Rest Asia	290.6	106.3	97.1	193.3	247.1	202.3	159.5	177.5	184.7	81.7	37.9	127.2	289.7	61.0	74.7	173.2	122.9	105.0	44.6	108.0
ROW	305.9	92.5	83.8	176.6	278.4	231.3	165.3	142.9	258.1	45.7	56.5	105.5	362.7	98.4	120.2	165.5	159.8	180.1	7.0	196.1

C: Effective Transaction Costs

Table C1: Effective Transaction Cost Matrix for Industrial Roundwood, Twenty Model Regions, ($/m^3)

Export/Import	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	-176.5	-192.8	-193.3	-193.7	-196.9	-198.5	-191.3	-188.2	-196.9	-186.7	-179.3	-195.5	-196.4	-197.4	-194.6	-192.3	-194.0	-197.5	-188.2	-190.9
BC Coast	-161.5	-145.2	-147.8	-148.6	-157.0	-154.2	-159.0	-156.1	-164.9	-155.9	-160.0	-167.2	-164.6	-155.6	-153.7	-149.9	-159.6	-164.6	-156.1	-166.7
BC Interior	-132.9	-118.7	-116.1	-117.8	-127.0	-124.2	-132.4	-129.5	-138.3	-129.1	-133.1	-140.4	-138.0	-125.6	-124.1	-121.0	-132.4	-138.0	-129.4	-139.9
Alberta	-149.7	-135.9	-134.3	-132.5	-142.5	-139.8	-149.5	-146.7	-155.5	-146.5	-150.6	-157.9	-155.2	-141.2	-140.1	-137.7	-150.1	-155.2	-146.7	-158.0
Atlantic Canada	-165.0	-156.4	-155.5	-154.6	-144.6	-148.1	-156.0	-166.8	-155.0	-165.8	-164.4	-157.3	-153.9	-147.3	-153.3	-157.3	-154.8	-156.3	-162.0	-160.4
Rest of Canada	-159.6	-146.6	-145.7	-144.9	-141.1	-137.6	-151.6	-163.2	-148.6	-161.9	-160.6	-153.5	-150.1	-139.2	-143.2	-146.9	-151.0	-152.4	-158.2	-157.2
Chile	-214.6	-213.6	-216.1	-216.8	-211.1	-213.7	-193.5	-213.1	-217.4	-213.2	-212.4	-218.2	-216.9	-211.5	-209.5	-210.5	-205.5	-216.1	-213.0	-218.2
China	-210.8	-210.0	-212.4	-213.2	-221.2	-224.7	-212.4	-199.0	-226.1	-201.2	-212.7	-213.3	-225.0	-224.6	-220.2	-214.3	-222.1	-225.3	-199.8	-216.0
Finland	-311.7	-311.1	-313.5	-314.3	-301.7	-302.3	-309.0	-318.4	-291.3	-316.2	-313.1	-293.6	-292.4	-303.0	-302.4	-308.9	-306.1	-294.5	-318.0	-305.0
Japan	-220.4	-220.9	-223.2	-224.2	-231.4	-234.5	-223.6	-212.4	-235.0	-210.2	-221.7	-225.5	-235.8	-234.1	-231.1	-227.6	-229.8	-236.1	-212.9	-229.5
New Zealand	-180.4	-192.5	-194.7	-195.7	-197.4	-200.7	-190.3	-191.3	-199.4	-189.2	-177.6	-198.8	-199.9	-198.9	-196.2	-195.7	-196.1	-201.0	-191.3	-193.0
Russian Fed	-214.7	-217.8	-220.0	-221.1	-208.4	-211.6	-214.2	-209.9	-198.0	-211.0	-216.9	-173.5	-198.8	-208.7	-208.7	-214.4	-211.2	-199.8	-201.7	-214.4
Sweden	-236.7	-236.3	-238.7	-239.5	-226.1	-229.4	-234.0	-242.8	-217.9	-242.5	-239.1	-219.9	-216.8	-228.5	-228.0	-234.2	-231.1	-219.5	-243.3	-230.4
US North	-309.8	-299.3	-298.5	-297.6	-291.6	-290.5	-300.7	-314.5	-300.6	-312.8	-310.2	-301.9	-300.6	-288.9	-295.1	-299.4	-301.0	-302.1	-308.6	-305.3
US South	-275.8	-266.2	-265.7	-265.3	-266.3	-263.3	-267.5	-278.9	-269.3	-278.6	-276.2	-270.7	-268.8	-263.8	-257.7	-263.6	-268.0	-269.5	-275.8	-270.3
US West	-315.5	-304.5	-304.7	-305.0	-312.4	-309.1	-310.6	-315.0	-317.4	-317.1	-317.8	-318.4	-317.1	-310.3	-305.7	-299.7	-312.7	-318.1	-311.8	-320.8
Rest LA	-165.1	-162.1	-163.9	-165.2	-157.8	-161.0	-153.4	-170.7	-162.4	-167.3	-166.1	-163.1	-161.9	-159.7	-157.9	-160.6	-147.6	-160.9	-163.1	-160.0
Rest Europe	-189.4	-187.8	-190.3	-191.1	-180.0	-183.2	-184.7	-194.6	-171.6	-194.3	-191.8	-172.5	-171.0	-181.6	-180.2	-186.7	-181.7	-168.4	-194.8	-181.4
Rest Asia	-294.1	-293.4	-295.8	-296.6	-299.8	-303.0	-295.6	-283.2	-309.1	-285.1	-296.0	-288.4	-308.9	-302.1	-300.5	-294.5	-297.9	-308.9	-282.4	-299.4
ROW	-141.4	-148.5	-150.8	-152.5	-142.7	-146.6	-145.5	-144.0	-140.7	-146.3	-142.4	-145.7	-140.6	-143.4	-139.7	-148.0	-139.4	-140.0	-144.0	-127.0

Table C2: Effective Transaction Cost Matrix for Lumber, Twenty Model Regions, ($/m^3)

Export/Import	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	-6.8	-25.9	-51.8	-50.9	-34.4	-25.0	-55.0	-3.3	13.7	-17.4	-48.5	-59.3	11.1	51.0	31.0	41.0	-24.0	-55.9	2.0	-20.3
BC Coast	53.6	44.4	18.5	19.4	35.8	45.3	16.8	67.0	84.2	53.3	22.8	12.9	81.6	91.6	71.6	81.6	46.2	14.4	72.3	50.0
BC Interior	78.7	68.2	42.4	43.3	59.7	69.2	42.8	90.9	108.3	77.7	48.0	39.3	105.7	119.3	99.3	109.3	70.1	38.3	96.2	73.9
Alberta	72.6	62.1	36.3	37.2	53.6	63.1	36.6	84.8	102.2	71.6	41.8	33.2	99.6	100.1	80.1	90.1	64.0	32.2	90.1	67.8
Atlantic Canada	51.6	41.9	16.1	17.0	33.4	42.9	15.1	64.6	81.8	51.0	20.8	11.3	79.2	118.8	98.8	108.8	43.8	11.9	69.8	47.6
Rest of Canada	56.9	47.7	21.9	22.8	39.2	48.7	20.1	70.4	87.5	56.7	26.1	16.2	85.0	114.7	94.7	104.7	49.6	17.8	75.7	53.4
Chile	36.4	26.6	0.8	1.6	18.1	27.6	14.9	49.3	66.5	35.8	5.6	-3.7	63.9	103.5	83.5	93.5	28.5	-3.4	54.5	17.4
China	0.7	-7.4	-33.2	-32.3	-15.9	-6.4	-36.7	15.3	32.2	1.1	-30.1	-41.1	29.6	69.5	49.5	59.5	-5.5	-37.4	20.5	-1.7
Finland	46.1	39.0	13.1	14.0	30.5	39.9	8.1	61.7	80.8	47.1	15.3	3.3	75.8	115.9	95.9	105.9	40.9	9.0	66.9	44.7
Japan	8.7	0.2	-25.7	-24.8	-8.3	1.1	-28.4	22.9	39.9	13.1	-22.0	-32.6	37.3	77.1	57.1	67.1	2.1	-29.8	28.1	5.9
New Zealand	23.9	14.1	-11.8	-10.9	5.5	15.0	-12.5	36.7	54.0	23.3	2.4	-16.2	51.4	91.0	71.0	81.0	15.9	-15.9	42.0	19.7
Russian Fed	36.3	26.5	0.7	1.5	18.0	27.4	-0.1	49.2	66.4	35.7	5.5	14.8	63.8	103.4	83.4	93.4	28.4	-3.5	54.4	-14.4
Sweden	92.5	85.2	59.4	60.3	76.7	86.2	54.6	107.9	124.6	93.4	61.7	49.8	124.4	162.1	142.1	152.1	87.1	55.2	113.1	90.9
US North	-35.2	-40.5	-66.4	-65.5	-49.1	-39.6	-74.2	-17.9	-1.5	-33.1	-66.0	-79.7	-4.1	36.4	16.4	26.4	-38.7	-70.5	-12.6	-34.9
US South	-23.9	-30.2	-56.1	-55.2	-38.8	-29.3	-62.3	-7.6	9.0	-22.4	-54.7	-67.4	6.4	46.7	26.7	36.7	-28.4	-60.2	-2.3	-24.6
US West	-45.0	-50.9	-76.7	-75.8	-59.4	-49.9	-83.8	-28.2	-11.7	-43.3	-75.8	-89.1	-14.3	26.0	6.0	16.0	-49.0	-80.9	-23.0	-45.2
Rest LA	59.5	50.4	24.6	25.4	41.9	51.3	22.7	73.1	90.2	59.3	28.7	18.7	87.6	127.3	107.3	117.3	52.3	20.4	78.3	56.1
Rest Europe	22.7	12.0	-13.9	-13.0	3.5	12.9	-13.1	34.6	52.1	21.5	-8.1	-16.5	49.5	88.9	68.9	78.9	13.9	-18.0	39.9	17.6
Rest Asia	-4.1	-11.9	-37.8	-36.9	-20.5	-11.0	-41.7	10.7	27.6	-3.6	-34.9	-46.2	25.0	65.0	45.0	55.0	-10.1	-41.9	16.0	-6.3
ROW	73.6	64.6	38.8	39.7	56.1	65.6	36.7	87.3	104.4	73.5	42.8	32.6	101.8	141.5	121.5	131.5	66.5	34.7	92.6	70.3

Table C3: Effective Transaction Cost Matrix for Plywood + Veneer, Twenty Model Regions, ($/m^3)

Export/Import	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	237.5	202.3	139.6	164.7	197.8	196.2	165.9	268.0	250.3	223.1	165.9	110.6	337.9	258.3	267.2	259.1	197.4	395.0	258.1	206.3
BC Coast	207.2	171.9	109.2	134.3	167.4	165.9	135.6	237.6	220.0	192.8	135.6	80.3	307.6	228.0	236.9	228.7	167.1	364.6	227.7	175.9
BC Interior	233.1	197.8	135.1	160.2	193.3	191.8	161.5	263.6	245.9	218.7	161.5	106.2	333.5	253.9	262.8	254.7	193.0	390.6	253.6	201.8
Alberta	225.9	190.6	127.9	153.0	186.1	184.6	154.2	256.3	238.6	211.5	154.2	99.0	326.3	246.7	255.5	247.4	185.8	383.3	246.4	194.6
Atlantic Canada	201.2	165.9	103.2	128.3	161.4	159.8	129.5	231.6	213.9	186.7	129.5	74.2	301.6	222.0	230.8	222.7	161.1	358.6	221.7	169.9
Rest of Canada	204.6	169.3	106.6	131.7	164.8	163.2	132.9	235.0	217.3	190.1	132.9	77.6	304.9	225.3	234.2	226.1	164.4	362.0	225.1	173.3
Chile	235.4	200.2	137.5	162.6	195.7	194.1	163.8	265.9	248.2	221.0	163.8	108.5	335.8	256.2	265.1	257.0	195.3	392.9	256.0	204.2
China	222.6	187.3	124.6	149.7	182.8	181.2	150.9	253.0	235.3	208.1	150.9	95.6	323.0	243.3	252.2	244.1	182.4	380.0	243.1	191.3
Finland	176.6	141.3	78.6	103.7	136.8	135.2	104.9	207.0	189.3	162.1	104.9	49.6	277.0	197.4	206.2	198.1	136.5	334.0	197.1	145.3
Japan	195.8	160.5	97.8	122.9	156.0	154.5	124.1	226.2	208.5	181.3	124.1	68.9	296.2	216.6	225.4	217.3	155.7	353.2	216.3	164.5
New Zealand	236.6	201.3	138.6	163.7	196.8	195.2	164.9	267.0	249.3	222.1	164.9	109.6	337.0	257.3	266.2	258.1	196.4	394.0	257.1	205.3
Russian Fed	205.1	169.8	107.1	132.2	165.3	163.8	133.4	235.5	217.8	190.7	133.4	78.2	305.5	225.9	234.7	226.6	165.0	362.5	225.6	173.8
Sweden	193.9	158.6	95.9	121.0	154.1	152.6	122.3	224.4	206.7	179.5	122.3	67.0	294.3	214.7	223.6	215.5	153.8	351.4	214.4	162.6
US North	155.0	119.7	57.0	82.1	115.2	113.6	83.3	185.4	167.7	140.5	83.3	28.0	255.3	175.7	184.6	176.5	114.8	312.4	175.5	123.7
US South	170.2	135.0	72.3	97.4	130.5	128.9	98.6	200.7	183.0	155.8	98.6	43.3	270.6	191.0	199.9	191.8	130.1	327.7	190.8	139.0
US West	139.4	104.1	41.4	66.5	99.7	98.1	67.8	169.9	152.2	125.0	67.8	12.5	239.8	160.2	169.1	161.0	99.3	296.9	159.9	108.1
Rest LA	237.5	202.2	139.5	164.6	197.7	196.2	165.8	267.9	250.2	223.1	165.8	110.6	337.9	258.3	267.1	259.0	197.4	394.9	258.0	206.2
Rest Europe	253.8	218.5	155.8	180.9	214.0	212.4	182.1	284.2	266.5	239.3	182.1	126.8	354.2	274.6	283.4	275.3	213.7	411.2	274.3	222.5
Rest Asia	210.6	175.3	112.6	137.7	170.8	169.2	138.9	241.0	223.3	196.1	138.9	83.6	311.0	231.4	240.2	232.1	170.5	368.0	231.1	179.3
ROW	302.7	267.4	204.7	229.8	262.9	261.3	231.0	333.1	315.4	288.2	231.0	175.7	403.1	323.5	332.3	324.2	262.6	460.1	323.2	271.4

Table C4: Effective Transaction Cost Matrix for Particleboard, Twenty Model Regions, ($/m^3)

Export/Import	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	185.0	52.2	47.4	75.9	91.4	91.7	136.2	185.0	150.0	175.2	136.2	55.9	351.0	312.3	262.1	313.0	157.7	141.5	199.0	163.7
BC Coast	172.2	39.4	34.6	63.1	78.6	78.9	123.4	172.2	137.2	162.4	123.4	43.1	338.2	299.5	249.3	300.2	144.9	128.7	186.2	150.9
BC Interior	179.2	46.5	41.7	70.2	85.6	85.9	130.4	179.3	144.2	169.4	130.4	50.2	345.3	306.6	256.3	307.2	151.9	135.8	193.2	157.9
Alberta	166.8	34.0	29.2	57.7	73.2	73.5	118.0	166.8	131.8	157.0	118.0	37.7	332.8	294.1	243.9	294.8	139.5	123.3	180.8	145.5
Atlantic Canada	175.0	42.3	37.4	65.9	81.4	81.7	126.2	175.0	140.0	165.2	126.2	45.9	341.0	302.4	252.1	303.0	147.7	131.5	189.0	153.7
Rest of Canada	161.4	28.6	23.8	52.3	67.8	68.1	112.6	161.4	126.4	151.6	112.6	32.3	327.4	288.7	238.5	289.4	134.1	117.9	175.4	140.1
Chile	198.4	65.6	60.8	89.3	104.7	105.0	149.5	198.4	163.3	188.5	149.5	69.3	364.4	325.7	275.5	326.4	171.0	154.9	212.3	177.0
China	125.2	-7.6	-12.4	16.1	31.6	31.8	76.4	125.2	90.2	115.4	76.4	-3.9	291.2	252.5	202.3	253.2	97.9	81.7	139.2	103.9
Finland	163.6	30.9	26.1	54.5	70.0	70.3	114.8	163.7	128.6	153.8	114.8	34.6	329.7	291.0	240.7	291.6	136.3	120.2	177.6	142.3
Japan	114.2	-18.6	-23.4	5.1	20.6	20.9	65.4	114.2	79.2	104.4	65.4	-14.9	280.2	241.5	191.3	242.2	86.9	70.7	128.2	92.9
New Zealand	191.2	58.5	53.7	82.1	97.6	97.9	142.4	191.3	156.2	181.4	142.4	62.2	357.3	318.6	268.3	319.2	163.9	147.8	205.2	169.9
Russian Fed	185.7	52.9	48.1	76.6	92.1	92.3	136.9	185.7	150.7	175.9	136.9	56.6	351.7	313.0	262.8	313.7	158.4	142.2	199.7	164.4
Sweden	166.8	34.1	29.3	57.7	73.2	73.5	118.0	166.9	131.8	157.0	118.0	37.8	332.9	294.2	243.9	294.8	139.5	123.4	180.8	145.5
US North	161.4	28.6	23.8	52.3	67.8	68.0	112.6	161.4	126.4	151.5	112.6	32.3	327.4	288.7	238.5	289.4	134.0	117.9	175.4	140.1
US South	165.1	32.4	27.6	56.1	71.5	71.8	116.3	165.2	130.1	155.3	116.3	36.1	331.2	292.5	242.2	293.1	137.8	121.7	179.1	143.8
US West	181.9	49.1	44.3	72.8	88.2	88.5	133.0	181.9	146.8	172.0	133.0	52.8	347.9	309.2	259.0	309.9	154.5	138.4	195.8	160.5
Rest LA	185.4	52.6	47.8	76.3	91.7	92.0	136.5	185.4	150.3	175.5	136.5	56.3	351.4	312.7	262.5	313.4	158.0	141.9	199.3	164.0
Rest Europe	196.1	63.3	58.5	87.0	102.5	102.8	147.3	196.1	161.1	186.3	147.3	67.0	362.1	323.4	273.2	324.1	168.8	152.6	210.1	174.8
Rest Asia	158.6	25.8	21.0	49.5	65.0	65.2	109.8	158.6	123.6	148.7	109.8	29.5	324.6	285.9	235.7	286.6	131.2	115.1	172.6	137.3
ROW	153.2	20.5	15.7	44.2	59.6	59.9	104.4	153.3	118.2	143.4	104.4	24.2	319.3	280.6	230.4	281.2	125.9	109.8	167.2	131.9

Table C5: Effective Transaction Cost Matrix for Fiberboard, Twenty Model Regions, ($/m^3)

Export/Import	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	124.1	144.4	106.0	161.0	167.5	179.3	124.1	250.6	238.4	191.2	124.1	148.8	1,019.5	47.9	16.4	48.3	124.1	207.6	170.5	47.9
BC Coast	108.8	129.1	90.6	145.7	152.2	163.9	108.8	235.3	223.0	175.9	108.8	133.5	1,004.1	32.5	1.1	33.0	108.8	192.3	155.2	32.6
BC Interior	121.2	141.5	103.0	158.1	164.6	176.3	121.2	247.7	235.4	188.3	121.2	145.9	1,016.6	44.9	13.5	45.4	121.2	204.7	167.6	45.0
Alberta	98.0	118.3	79.9	135.0	141.4	153.2	98.0	224.5	212.3	165.1	98.0	122.7	993.4	21.8	-9.6	22.2	98.0	181.5	144.5	21.9
Atlantic Canada	90.3	110.5	72.1	127.2	133.7	145.4	90.3	216.8	204.5	157.3	90.3	115.0	985.6	14.0	-17.4	14.4	90.3	173.8	136.7	14.1
Rest of Canada	86.8	107.1	68.6	123.7	130.2	141.9	86.8	213.3	201.0	153.8	86.8	111.5	982.1	10.5	-20.9	10.9	86.8	170.3	133.2	10.6
Chile	136.3	156.6	118.2	173.3	179.8	191.5	136.3	262.9	250.6	203.4	136.3	161.0	1,031.7	60.1	28.7	60.5	136.3	219.9	182.8	60.2
China	60.7	81.0	42.6	97.7	104.1	115.9	60.7	187.2	175.0	127.8	60.7	85.4	956.1	-15.5	-46.9	-15.1	60.7	144.2	107.2	-15.4
Finland	81.9	102.2	63.8	118.9	125.3	137.1	81.9	208.4	196.2	149.0	81.9	106.6	977.3	5.7	-25.7	6.1	81.9	165.4	128.4	5.8
Japan	40.8	61.1	22.7	77.8	84.2	96.0	40.8	167.3	155.1	107.9	40.8	65.5	936.2	-35.4	-66.8	-35.0	40.8	124.3	87.3	-35.3
New Zealand	129.8	150.1	111.7	166.8	173.2	185.0	129.8	256.3	244.1	196.9	129.8	154.5	1,025.2	53.6	22.2	54.0	129.8	213.3	176.3	53.7
Russian Fed	111.4	131.7	93.2	148.3	154.8	166.5	111.4	237.9	225.6	178.5	111.4	136.1	1,006.8	35.1	3.7	35.6	111.4	194.9	157.8	35.2
Sweden	88.0	108.3	69.8	124.9	131.4	143.2	88.0	214.5	202.2	155.1	88.0	112.7	983.4	11.8	-19.7	12.2	88.0	171.5	134.4	11.8
US North	79.2	99.5	61.0	116.1	122.6	134.3	79.2	205.7	193.4	146.2	79.2	103.9	974.5	2.9	-28.5	3.3	79.2	162.7	125.6	3.0
US South	84.9	105.2	66.8	121.9	128.4	140.1	84.9	211.5	199.2	152.0	84.9	109.6	980.3	8.7	-22.7	9.1	84.9	168.5	131.4	8.8
US West	93.3	113.6	75.2	130.3	136.7	148.5	93.3	219.8	207.6	160.4	93.3	118.0	988.7	17.1	-14.3	17.5	93.3	176.8	139.8	17.2
Rest LA	124.4	144.7	106.3	161.3	167.8	179.6	124.4	250.9	238.7	191.5	124.4	149.1	1,019.8	48.2	16.7	48.6	124.4	207.9	170.8	48.2
Rest Europe	140.5	160.8	122.3	177.4	183.9	195.6	140.5	267.0	254.7	207.6	140.5	165.2	1,035.8	64.2	32.8	64.7	140.5	224.0	186.9	64.3
Rest Asia	87.2	107.5	69.0	124.1	130.6	142.4	87.2	213.7	201.5	154.3	87.2	111.9	982.6	11.0	-20.5	11.4	87.2	170.7	133.6	11.0
ROW	115.6	135.9	97.5	152.5	159.0	170.8	115.6	242.1	229.9	182.7	115.6	140.3	1,011.0	39.4	7.9	39.8	115.6	199.1	162.0	39.4

Table C6: Effective Transaction Cost Matrix for Pulp, Twenty Model Regions, ($/m^3)

Export/Import	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	399.8	212.7	212.5	311.6	377.2	344.4	274.3	246.2	349.5	157.7	154.1	215.2	453.5	199.8	207.7	283.8	246.1	268.8	110.4	236.6
BC Coast	320.2	133.1	132.9	232.0	297.6	264.8	194.7	166.6	269.9	78.1	74.5	135.6	373.9	120.2	128.1	204.2	166.5	189.2	30.8	157.0
BC Interior	408.2	221.1	220.9	320.0	385.6	352.8	282.7	254.6	357.9	166.1	162.5	223.6	461.9	208.2	216.0	292.2	254.5	277.2	118.7	245.0
Alberta	335.4	148.3	148.0	247.1	312.8	279.9	209.8	181.8	285.0	93.2	89.7	150.7	389.0	135.3	143.2	219.4	181.6	204.3	45.9	172.1
Atlantic Canada	325.9	138.8	138.5	237.6	303.3	270.4	200.3	172.3	275.5	83.7	80.2	141.2	379.5	125.9	133.7	209.9	172.1	194.8	36.4	162.6
Rest of Canada	312.3	125.2	124.9	224.1	289.7	256.9	186.8	158.7	261.9	70.1	66.6	127.6	366.0	112.3	120.1	196.3	158.5	181.2	22.8	149.0
Chile	426.2	239.1	238.8	337.9	403.6	370.7	300.6	272.6	375.8	184.0	180.5	241.5	479.8	226.2	234.0	310.2	272.4	295.1	136.7	262.9
China	272.6	85.5	85.3	184.4	250.0	217.2	147.1	119.0	222.3	30.5	26.9	88.0	326.3	72.6	80.4	156.6	118.9	141.6	-16.8	109.4
Finland	334.6	147.5	147.2	246.3	312.0	279.1	209.1	181.0	284.2	92.4	88.9	149.9	388.2	134.6	142.4	218.6	180.8	203.5	45.1	171.3
Japan	240.4	53.3	53.0	152.2	217.8	185.0	114.9	86.8	190.1	-1.7	-5.3	55.7	294.1	40.4	48.2	124.4	86.6	109.3	-49.1	77.1
New Zealand	412.1	225.0	224.7	323.9	389.5	356.7	286.6	258.5	361.8	170.0	166.4	227.5	465.8	212.1	219.9	296.1	258.4	281.1	122.6	248.9
Russian Fed	443.5	256.4	256.1	355.3	420.9	388.1	318.0	289.9	393.2	201.4	197.8	258.9	497.2	243.5	251.3	327.5	289.8	312.5	154.0	280.3
Sweden	313.4	126.3	126.0	225.2	290.8	258.0	187.9	159.8	263.1	71.3	67.7	128.8	367.1	113.4	121.2	197.4	159.7	182.4	23.9	150.2
US North	325.8	138.8	138.5	237.6	303.2	270.4	200.3	172.2	275.5	83.7	80.1	141.2	379.5	125.8	133.7	209.8	172.1	194.8	36.4	162.6
US South	376.7	189.6	189.3	288.5	354.1	321.3	251.2	223.1	326.3	134.5	131.0	192.0	430.4	176.7	184.5	260.7	222.9	245.6	87.2	213.4
US West	370.4	183.3	183.0	282.1	347.8	314.9	244.9	216.8	320.0	128.2	124.7	185.7	424.0	170.4	178.2	254.4	216.6	239.3	80.9	207.1
Rest LA	400.5	213.4	213.1	312.3	377.9	345.1	275.0	246.9	350.1	158.3	154.8	215.8	454.2	200.5	208.3	284.5	246.7	269.4	111.0	237.2
Rest Europe	340.2	153.1	152.8	252.0	317.6	284.8	214.7	186.6	289.9	98.1	94.5	155.6	393.9	140.2	148.0	224.2	186.5	209.2	50.7	177.0
Rest Asia	334.1	147.0	146.7	245.8	311.4	278.6	208.5	180.5	283.7	91.9	88.4	149.4	387.7	134.0	141.9	218.0	180.3	203.0	44.6	170.8
ROW	359.3	172.2	172.0	271.1	336.7	303.9	233.8	205.7	309.0	117.2	113.6	174.7	413.0	159.3	167.1	243.3	205.6	228.3	69.8	196.1