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Markets for forest products following a large disturbance: Opportunities and challenges from the mountain pine beetle outbreak in western Canada

Bryan Bogdanski, Lili Sun, Brian Peter, and Brad Stennes

Canada

The Pacific Forestry Centre, Victoria, British Columbia

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Pacific Forestry Centre
506 West Burnside Road
Victoria, British Columbia
V8Z 1M5
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Abstract

The mountain pine beetle outbreak in the Interior forests of British Columbia that began in the late 1990s continues to kill lodgepole and other pine trees across the region and into western Alberta. Beginning in 2001 the provincial government increased available timber supply on Crown-owned lands and encouraged the forest industry to focus harvesting efforts on lodgepole pine. The timber supply uplift and pine-focused harvest strategies raise several questions with regard to the response by the BC industry to the increased supply of pine timber and the impact on timber and product market prices. Following the slowdown in many of BC's major markets, further opportunities to utilize MPB-killed wood inventories need to be examined. This paper describes recent wood market trends and highlights market opportunities and limitations for MPB-killed lodgepole pine. We also highlight key information gaps and uncertainties with regard to fully understanding the possible market and industry impacts of increasing pine harvests to address the mountain pine beetle outbreak, and the subsequent decrease in future timber supply. The appendices include a comprehensive listing of elasticity estimates important to any economic analysis of wood product markets.

Keywords: market demand, market dynamics, mountain pine beetle, lodgepole pine, wood products, timber supply.

Résumé

L'infestation de dendroctone du pin ponderosa qui a débuté vers la fin des années 1990 continue de tuer des pins tordus latifoliés et des pins d'autres espèces dans les forêts de l'intérieur de la Colombie-Britannique et de l'ouest de l'Alberta. Depuis 2001, le gouvernement de la Colombie-Britannique permet une récolte accrue de bois dans les terres de la Couronne et encourage l'industrie forestière à concentrer ses efforts de coupe sur le pin tordu latifolié. Cet accroissement de l'offre de bois associé à une stratégie de récolte axée sur le pin soulève plusieurs questions quant à ses répercussions pour l'industrie forestière de la province et à son impact sur les prix du bois et des autres produits forestiers. Après le ralentissement de la demande observé dans de nombreux marchés importants, la province doit envisager d'autres façons d'utiliser ses stocks de bois tué par le dendroctone. Nous décrivons ici les tendances récentes du marché du bois et soulignons les possibilités et contraintes commerciales associées au bois de pin tué par le dendroctone. Nous cernons également les principales lacunes et incertitudes existant dans l'information requise pour bien comprendre les impacts possibles de l'offre accrue de pin ainsi que de la diminution future de cette offre sur les marchés et sur l'industrie. On trouvera en annexe une liste complète des estimations d'élasticité nécessaires à toute analyse économique des marchés des produits forestiers.

Mots clés : demande du marché, dynamique du marché, dendroctone du pin ponderosa, pin tordu latifolié, produits du bois, offre de bois

Executive Summary

The mountain pine beetle (MPB) outbreak in the Interior of British Columbia has created a massive inventory of standing dead lodgepole pine timber. The outbreak is entering its second and likely final decade in BC, but it has expanded in Alberta. During the first decade of the outbreak, the province of BC increased the available timber for harvest and encouraged industry to harvest more pine. The province hoped new uses for the salvaged timber would develop. Looking back over the past decade, we observe mixed results. Industry remains focused on lumber and panel markets, though there has been investment in the wood pellet sector.

In spite of a number of years of record demand in BC's key lumber market, not all the available timber for harvest was utilized. The recent collapse of the US housing market and decreased demand in other jurisdictions due to the global recession underscored the importance of demand outside BC and Canadian markets. The available timber for harvest is expected to return to pre-outbreak levels over the next 10 years and then fall significantly below these levels after 2020. Due to the immense quantity of timber and the fact that the timber quality decreases from time of death, the economic opportunity to salvage timber for use in wood, paper, or energy products is limited by industry capacity, industry cost structure, and market demand. Limited market demand is a major challenge.

Pre-global recession (pre-2008) market trends point to limited growth of future demand for many wood products. Many of the expanding markets are in developing regions such as China, and countries in Southeast Asia. There may also be opportunities in countries such as Mexico and parts of the Middle East. While the import volume is increasing in these countries, the unit value is typically lower than in BC's traditional markets of the US, Japan, and Europe. Lower product values, high transportation costs, and market development costs will be significant challenges for BC's industry when marketing products derived from salvaged lodgepole pine in these new forest product markets.

A second challenge is that even if BC's traditional markets do rebound significantly, aggressive competition could lead to lower product prices. Strategies to make use of the additional fibre supply domestically would help mitigate this market risk.

There remain several information gaps that, if filled, could help reduce uncertainty and inform policy development over the next few years. These include a better understanding of five issues: factor and market price impacts from increased fibre supply, especially in light of the impacts of the Canada–US Softwood Lumber Agreement; the nature of demand from Chinese and emerging markets for lumber and logs; the most likely uses of standing dead pine after the MPB outbreak; the impacts of decreased green timber supply on existing wood and paper industries; and the impacts of elevated harvesting on non-timber, environmental, and social values.

1. Introduction

Slade et al. (1993) write, "…rational planning for resource-based economies (both producing and consuming) requires accurate projections and an improved understanding of the dynamics of supply and demand." This is especially true for forestry in Canada, as the forest sector is forced to react to large supply and demand shocks. An illustrative example is the mountain pine beetle (MPB) epidemic in western Canada; the largest recorded forest pest outbreak to occur in North America. Although the supply side of this analysis focuses on the declining MPB outbreak in British Columbia (BC), it provides lessons that are applicable to the MPB outbreak in Alberta and any large-scale natural disturbances that create supply shocks in the forest industry.

The MPB outbreak currently covers about 14 million hectares of forests containing pine in the Interior of BC (BCMFR 2007). Over the past decade the MPB has killed 46% (620 000 of 1.35 million m^3) of the merchantable pine in the province (BCMFR 2009a). An additional 730 million m^3 of merchantable pine is vulnerable to MPB, of which 340 million m^3 is projected to be killed over the next decade.

Recent research findings indicate that standing dead timber may hold its merchantable value (shelf life) for between 2 and 15 years, depending on product type (e.g. sawlog, pulpwood, or pole), technology, stand conditions (e.g. wet or dry), tree characteristics (e.g. stem size and pre-attack health) (Lewis et al. 2006; Trent et al. 2006; Orbay and Goudie 2006), and product prices. Currently, the government assumes an average shelf life of 3 years for sawlogs (BCMFR 2007). Given the uncertainty regarding shelf life and the fact that total timber supply will have to decrease sometime, the province faces the problem of trying to capture as much value from the dead trees as possible while accommodating social, environmental, industry, and trade concerns.

A central goal of mitigating the economic impacts of the MPB epidemic is to capture the value of dead pine while minimizing negative impacts on non-pine resources and the industry. The BC Government's strategy to do just this is twofold: 1) redirect harvesting to MPB-affected stands (and away from unaffected stands), and 2) increase the total annual allowable timber harvest (supply) in the Central Interior, with the incremental supply coming from MPB areas.[1] Part two of the strategy was developed with the hope that market demand for roundwood will be sufficient to absorb the incremental timber supply without disrupting traditional downstream lumber markets (by decreasing market prices or creating market access issues). Industry also hopes that markets will not discount products from MPB-killed timber.

In order to reduce the risk of negatively affecting lumber product markets, the province has made access to some of the incremental timber supply conditional on investments in manufacturing capacity designed to use MPB-killed timber for non-lumber products; in particular, panels, poles, and energy products such as wood pellets. The last part of the strategy is consistent with the recommendation, set out in a government-commissioned report, that salvage harvesting should be used as an opportunity to diversify the BC Interior forest industry (R&S Rogers Consulting Inc. 2001).

Once the MPB outbreak has run its course, which is projected to occur sometime between 2015 and 2020, timber supply from living merchantable trees (green trees) will decrease below pre-outbreak levels. Even after the green-timber supply falls, a significant volume of potentially merchantable dead standing trees will remain. This timber may augment the green-timber supply and soften the reduction in total timber supply. The rate of decrease in timber supply over the next 5 to 15 years will hinge on the expected volume of accessible pine timber and its economic shelf life. As this juncture nears, the need for improved understanding of the resource, its potential uses, and market opportunities will become more important. Such information will help industry and policymakers form sound expectations and will support effective and rational industry and government planning during this period of transition.

This report focuses on the industry and market issues related to timber supply and the MPB outbreak. We focus primarily on the situation in BC, where the outbreak is in its second decade and therefore more information is available on its effects. This report aims to give the reader an understanding of both the current market situation and trends and to highlight the potential opportunities for, and limitations to, using dead pine timber.

The following section is a review of the forest economics literature concerning timber supply changes and product markets. This section summarizes findings of recent empirical studies relevant to the mountain pine beetle outbreak. The remainder of the report includes an overview of the current timber supply, timber harvest, and industry structure, followed by a synthesis of current research on potential uses of salvageable pine and a look at global and North American wood product trends. We wrap up with a discussion of the implications of this report and recommendations for further research. The appendices include a detailed listing of elasticity estimates for forest products.

[1] We differentiate MPB versus non-MPB areas throughout the document. MPB areas are those used by the BCMFR in their document "Timber Supply and the Mountain Pine Beetle Infestation in British Columbia, 2007 Update" (BCMFR 2007).

2. Assessing Potential Market and Related Impacts

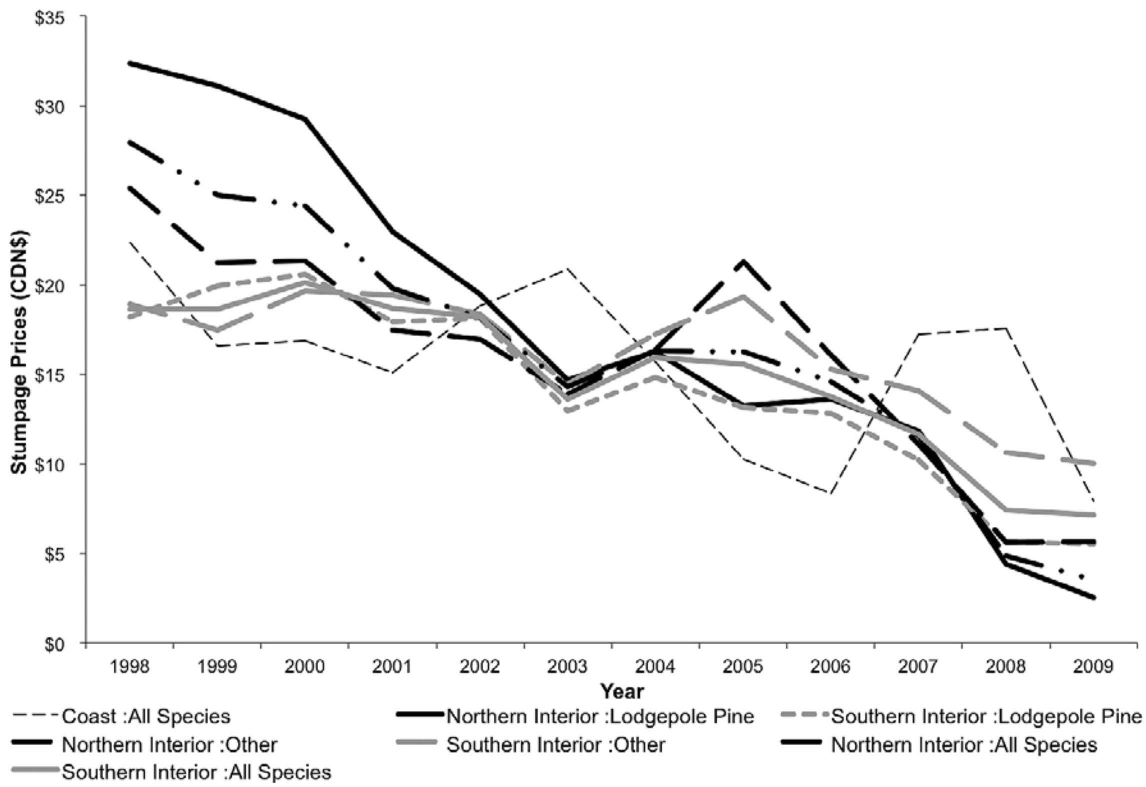
A key question of interest is whether marked shifts in the timber supply of western Canadian spruce-pine-fir impact market prices and outputs. This question is fundamental to understanding the socio-economic and environmental impacts associated with the timber supply changes that inform policy decision-making. A large change in timber supply could impact markets in two ways: increased timber supply could reduce wood costs and provide the sector with a competitive advantage over other producers; and increased product supply could lead to reduced product prices that, in turn, could lead to reduced log and timber prices. Both of these may concern policymakers. A large shift in market share could lead to international or regional trade conflicts. If output prices fall more than input (logs and labour) prices then industry profits will fall. A drop in log prices could trigger a decrease in timber prices and lead to reduced government revenues if the percentage decrease in timber prices is greater than percentage increase in timber harvested. However, not all segments of the forest products industry would be negatively affected by a decrease in market prices. Obviously, a decrease in product prices benefits consumers. The question from society's point of view is: Do total benefits (consumer and producer benefits) increase or decrease through changes in western Canada's timber supply in response to the MPB infestation?

To get a good sense of the answers to these questions we must recognize the key features of the industry and linkages among markets, and gain an understanding of how these features and linkages influence market prices and outputs.

Since 2000 timber harvesting and lumber capacity and production in the Interior of BC have increased significantly. This is consistent with what one might expect from an increase in the availability of raw material (i.e., increased input supply leads to a push in outputs). On the other hand, without accounting for the market response to increased supply (changes in quantity demanded by the market) or tracking changes in market demand shifts, it is difficult to discern the true impact of an increased timber supply in BC from price and quantity data (Figures 1 and 2). This should not be surprising given the many factors that affect both market demand and supply, such as tariffs, exchange rates, technological change, interest rates, reductions in supply in other areas, and overall economic trends. The apparent lack of correlation (Figure 1a) does not indicate that prices are unaffected by timber supply changes. Instead it underscores the point that several different factors affect final, intermediate, and primary product prices.

Between 2000 and 2007 timber prices appear to have drifted down and, with them, government revenues, even though harvest levels increased significantly. These trends could be the result of increased timber supply, increased harvesting and processing costs, changes in products prices (including effects of tariffs and exchange rates on producers' prices), or combinations of several factors. To disentangle the various factors that affect timber prices, we must sort out the possible influences and attempt to measure their individual contribution. This is no small feat; it involves making assumptions with regard to market structure and behaviour, establishing reasonable empirical relationships, and addressing many informational issues. We do not attempt to tackle this problem in this report, but instead try to highlight some of the important attributes of the forest industry as well as key methodological and informational issues.

a)



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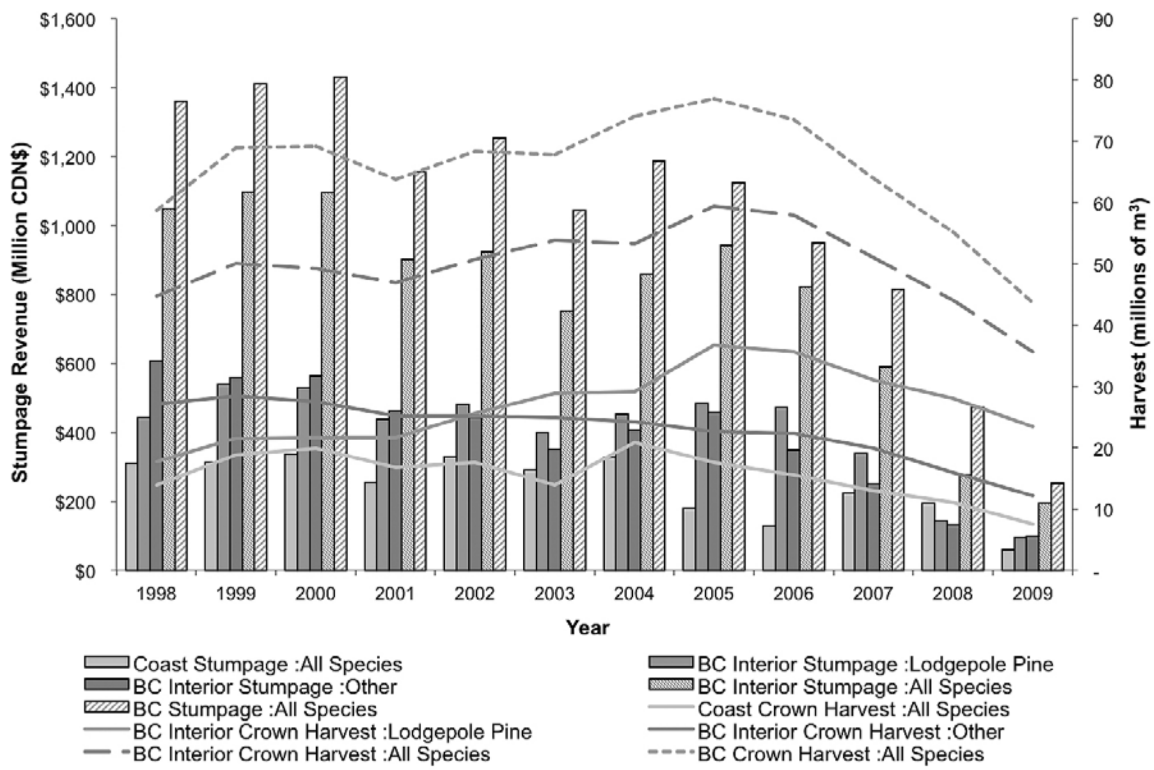


Figure 1. a) Stumpage prices by region and species, and b) stumpage revenues and harvests by species and region. (Source: BCMFR 2010c.)

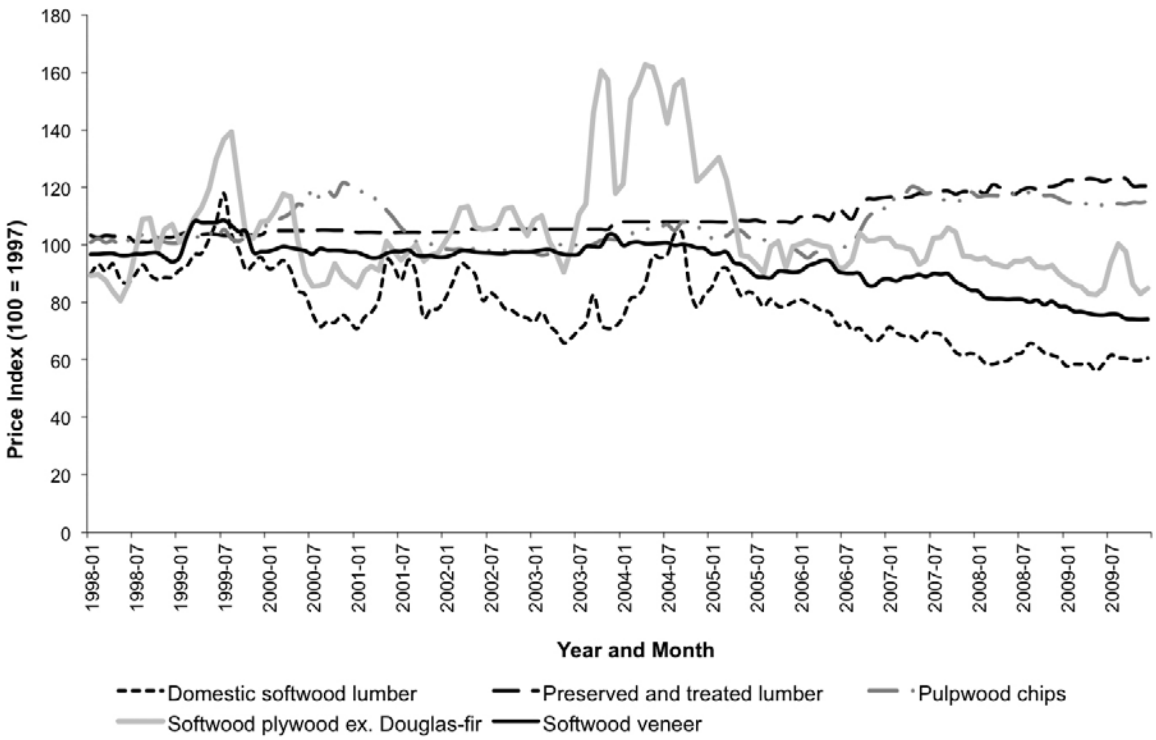


Figure 2. Price indices for major Canadian wood products (100 = 1997). (Source: Statistics Canada n.d.[a] Table 329-0042.)

Figure 3 illustrates some specific elements of the forest industry structure and the linkages between input and output markets. Generally speaking, the demand for timber is derived from the demand for logs, which is derived from the demand for wood, paper, and energy products. Two key aspects of production of wood-based products are evident in the illustration. First, the production of more than one product (joint products) can occur. For example, sawmilling produces lumber and various wood residues. Second, primary and intermediate products may have competing uses. For example, sawmill residues can be used for producing pulp, panels, and energy products or can even be used in agriculture or urban landscaping. The implication of the complex interactions between inputs and outputs is that any analysis must attempt to capture key demand determinants and linkages without making the analysis too complex and incomprehensible.

Prices at each level of production are directly or indirectly linked to final demand factors, and demand for joint products and substitute (complementary) products can also affect demand and supply at various market stages. Given the linkages between markets, it is apparent that changes in supply of timber can, at least theoretically, affect price and production levels in downstream markets, and changes in final demand will likewise affect price and production levels in upstream markets. This prompts two questions: How sensitive are prices to changes in resource supply or final demand? And, is price sensitivity invariant regardless of the source of change? A review of the literature provides qualitative and quantitative insights to these and related questions.

2.1 Review of Applied Studies

Previous studies examined various aspects of the interrelationships between timber, log, and product markets. Some of these studies are directly associated with harvesting in the presence of natural disturbance, though most focus on the general issue of interactions between inputs (logs) and product markets (lumber/paper). All of the studies are founded on the principles of production economics; specifically, the notion that the demand for inputs (e.g., logs) is derived from their use in the production of final consumption goods (e.g., contribution to production of housing services), and employs standard market theory.

The timber market impacts associated with large-scale salvaging have been considered in a series of studies by the

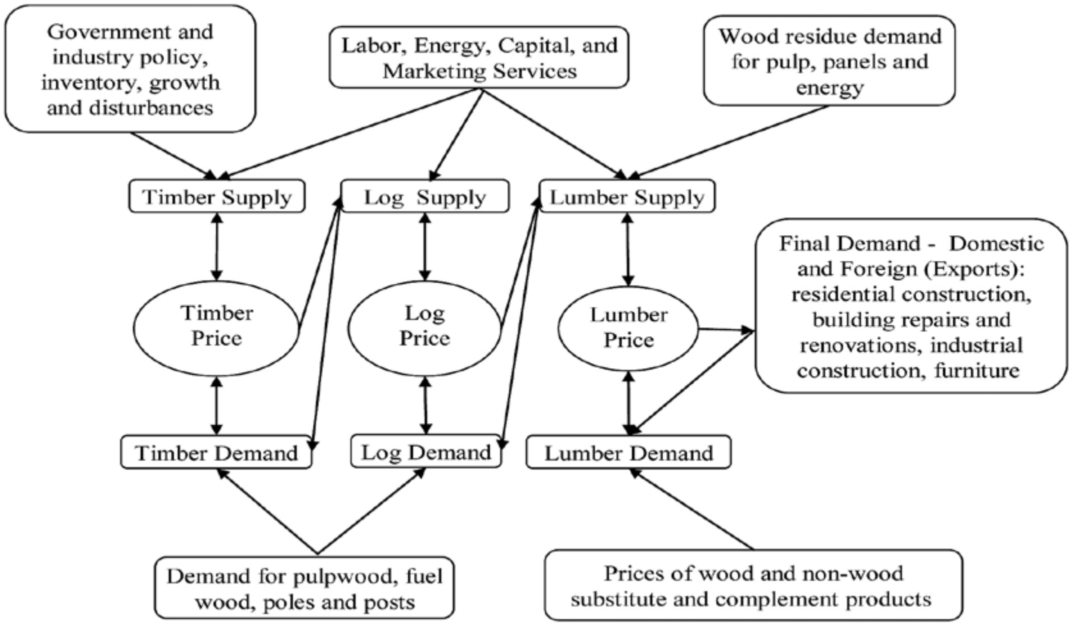


Figure 3. Conceptual model of the market linkages between timber, logs, lumber, and final demand for lumber.

US Department of Agriculture's Forest Service. Holmes (1991) examined the economic impacts of southern pine beetle (*Dendroctonus frontalis*) outbreaks in the southern United States, demonstrating short-run effects on the economic welfare of consumers and holders of damaged and undamaged timber. Holmes (1991) finds that the beetle outbreak provided immediate gains to consumers through lower prices, but timber producers suffer losses in both damaged and undamaged forests due to price effects resulting from the increased supply of salvage logs. In the longer term, timber prices increase due to increased scarcity of timber (Prestemon and Holmes 2000), which benefits holders of un-damaged timber inventory. Prestemon and Holmes (2004) and Prestemon et al. (2004) examined government response to large-scale natural disturbances. They tried to quantify the impacts of two different natural catastrophes on different sectors of the regional economy and found that salvage harvesting improved the welfare of consumers and holders of damaged timber, but negatively affected holders of undamaged timber (relative to the base case of no salvage harvesting). They also found that the expediency of government action can have a large impact on returns to government because dead standing timber is subject to reductions in volume and quality through decay. This body of work provides important insights into the market and welfare effects from natural disturbances and salvaging. Further considerations can also be included such as downstream impacts on product markets, markets outside the region, and markets for substitute products.

Several derived demand studies (often referred to as multi-level studies) that are relevant to large-scale salvage harvesting have been conducted. Based on the seminal paper by Gardner (1975), which looked at the farm–retail price spread in a competitive food industry, Haynes (1977) examined the empirical link between lumber and timber markets using the derived demand framework. Wiseman and Sedjo (1981) extend Haynes' analysis by using the derived demand approach to look at welfare impacts associated with distortions in log export markets (restricted demand). Murray and Wear (1998) used the framework to examine the market impacts from a supply shock, examining changes in timber supply and harvesting in the US Pacific Northwest.

Haynes (1977) uses the derived demand framework to illustrate the interdependence between upstream log markets and downstream lumber markets within a regional US market. The basic graphical model, as found in Klemperer (1996), is illustrated in Figure 4. The model assumes there is a direct relationship between timber and logs and lumber supply and demand. On the supply side of the market, supply for each stage of production represents the marginal cost of production for various levels of lumber output, as measured in roundwood equivalent. On the demand side, demand for inputs reflects the market demand for lumber minus conversion costs. Within the multi-stage market model, it is evident that an increase in timber supply (rightward shift) lowers timber prices that, in turn, lower log and lumber prices. The lower prices are associated with an increased consumption of timber, logs, and lumber.

Haynes (1977) shows that, given assumptions regarding marketing margins and elasticity of final demand, the price elasticity for logs and timber markets can be derived. He concludes that timber price elasticity is more inelastic than lumber price elasticity (i.e., timber prices move relatively less than lumber prices). For example, a 10% decline in lumber prices translates into only a 5% decline in timber prices.

Gardner shows that this result is due to the fixed proportion production assumption (Gardner 1975, p. 405). Does the fixed-factor proportion model reasonably depict the production process for various wood products? What happens to relative prices of products and inputs under different market changes? Gardner (1975) indicates that the source of the change matters. He shows that an increase in the supply of an input results in a relatively larger decrease in the input (logs) than the output (lumber) because more marketing services are needed to use more of the input in question.

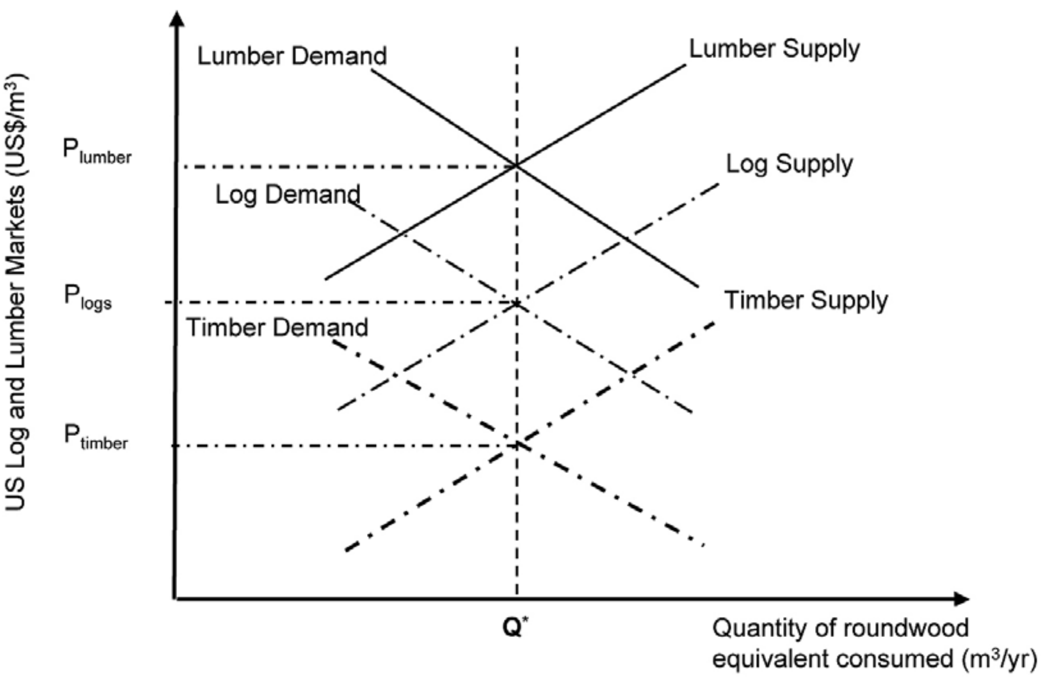


Figure 4. Regional multi-level market for lumber. (Source: Klemperer 1996.)

Wiseman and Sedjo (1981) extend the multi-stage framework of Haynes (1977) by breaking a market up into two distinct markets: a domestic market and an export market. The graphical framework is illustrated in Figure 5, and has been adapted to illustrate the impacts of an increase in Canadian log supply due to salvage logging during the MPB outbreak and the subsequent decrease in supply following the outbreak. The framework is useful for showing the interdependence between the upstream log markets and international downstream lumber market.

Figure 5 shows that an increase in Canadian log supply increases the supply of Canadian lumber in the North American market during the salvage period (2000–2020). The increased Canadian lumber supply, given North American lumber demand (Canadian and US import demand), reduces lumber prices and increases lumber consumption. Canada increases its exports to the US market (the difference between Canadian consumption and North American consumption). After the outbreak, Canadian log supply falls to levels below pre-MPB outbreak levels. This leads to reduced North American lumber supply, increased lumber prices, reduced Canadian exports, and reduced lumber consumption in the post-salvage era (post-2020).

This framework illuminates some essential insights into market impacts: changes in the supply of an input can impact output prices and consumption, as well as export levels and market shares. Wiseman and Sedjo (1981) apply this framework to the case of log export restrictions from the US Pacific Coast. They conclude that restrictions lead to a measurable impact on log and lumber prices, and thereby increase lumber manufacturers' welfare at the expense of timber owners and consumers.

a)

b)

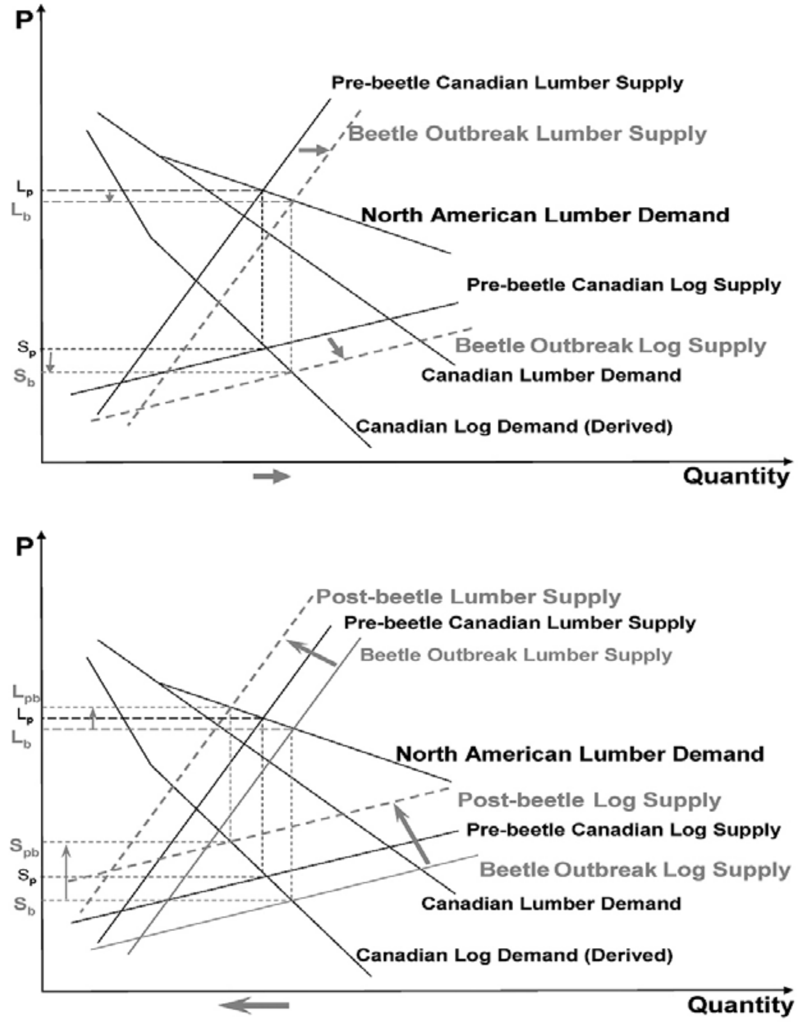


Figure 5. Theoretical impact of a) MPB-related supply increase and b) subsequent decrease on log and lumber equilibrium prices and quantities in North America. Adapted from Wiseman and Sedjo 1981.

Murray and Wear (1998) and Wear and Murray (2004) addressed the issue of interconnectedness between timber supply regions and lumber markets within continental North America. In both papers the authors examined the impact of decreased timber supply from US federal lands in the Pacific Northwest on timber harvesting and lumber markets across regions. They found evidence that lumber markets are interconnected and that a change in timber supply in one region impacts lumber prices in all regional markets.

They also found that price impacts and consequent welfare impacts were muted by changes in timber harvesting in other regions. These results suggest that an increase in BC's timber supply will decrease timber harvesting in other regions and lower lumber prices across all markets. The data seem to support this outcome (Figure 6). Likewise, the finding supports the assertion that harvesting and prices in other regions will increase when BC's timber supply decreases after salvaging of dead pine stops and timber supply is reduced to new, long-run, sustained yield levels.

An underlying question remains: What is the effect of increased timber and product supply on demand? Montgomery (2001) has found that housing demand is not very responsive to the price of wood products, but the price of wood products does affect the allocation of housing investment between new construction and home improvements. In other words, the price of wood products (lumber and panels) has little impact on the quantity of housing demanded but instead on the type of housing demanded (old versus new). This is supported by Gorte (1994) who observed that lumber only makes up about 5% of the cost of new

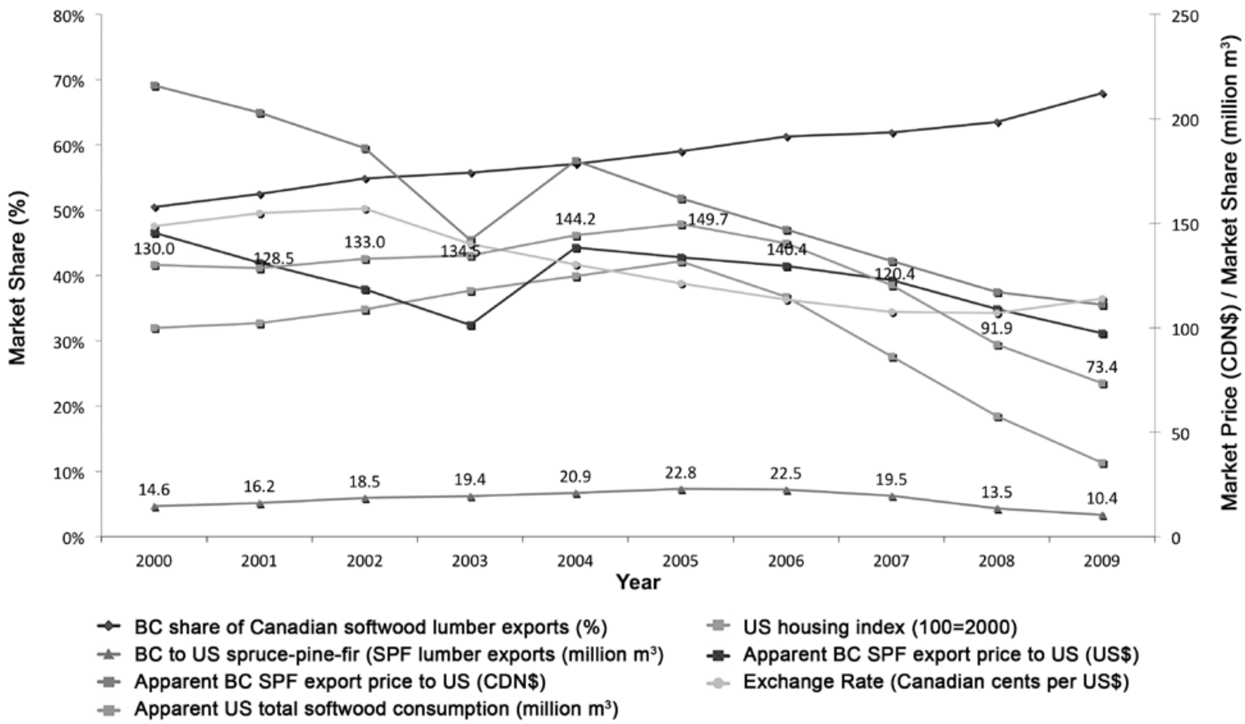


Figure 6. Market shares and market prices in Canada and the US. (Sources: Statistics Canada n.d.[a] and US Census Bureau n.d.)

housing, yet housing (new and old) consumes around 80% of lumber. Consequently, changes in lumber prices (due to a supply shock, for example) have little effect on the quantity of housing demanded, but a change in housing demand has a large impact on the quantity of lumber demanded.

One recent study models and estimates the impacts from a large change in BC timber supply on downstream product markets. The study forms part of the background work for the US Department of Agriculture's Forest Services report, "The 2005 RPA Timber Assessment Update" (Haynes et al. 2007). Specifically, the study considers the impact of an increase in the BC Interior's timber supply due to the MPB outbreak on US timber markets, North American lumber trade, and lumber prices. The study does not consider the impact of increased timber supply on BC's log and timber prices.

The RPA study finds that an 8% average increase in BC timber harvest over the 2005–2020 period leads to an 8.5% increase in BC Interior lumber output, a 0.6% increase in US lumber consumption, and a 3.2% decline in softwood lumber prices. The apparent inconsistency between the large increase in BC output and small increase in US consumption is reconciled by decreased production in the US and other regions of Canada and reduced off-shore imports. Haynes et al. (2007) estimate that half of the increased BC lumber production is offset by decreased US production. These results reflect the current understanding of the North American markets: lumber demand is relatively inelastic and supply from different regions is substitutable. These results form the base case projections in the final RPA report (Haynes et al. 2007); BC lumber production is predicted to increase and US lumber production and prices are predicted to decline over the 2005–2020 period.

All of the studies discussed above involve the use of structural models. These models presume certain relationships and workings of the economy. All of these studies require estimated values of key pieces of information, including estimates of elasticity of demand, supply, income, and substitution. These estimates come from empirical studies of market demand and supply, or are assumed.

Empirical market demand and supply studies are founded on economic theory, where relationships derived from equilibrium conditions predict how changes in supply or demand in one market will affect equilibrium prices in both the output and input markets. The direction and magnitude of changes are summarized by elasticity measures. Elasticity measures are either a principal output of empirical forest product markets studies or an essential input for analytical or simulation market studies. In Appendix 2 we present a summary of empirical studies on elasticity conducted between 1990 and 2010.

There are a few key findings from the survey of empirical studies that are relevant to the discussion and understanding of the impact of an increase in BC's timber supply in response to the MPB outbreak. First, in many cases the range of estimated values is large. This means that inferences made from study results such as Haynes et al. (2007) are uncertain, because very different modelling results may produce different assumed values for key elasticity estimates used in forecasting models. Second, there are no studies that look at the specific problem that we wish to understand. For example, most studies focus on the lumber market; few studies focus on other wood product markets. There are no studies that examine BC timber supply within the context of the 2006 Canada–US Softwood Lumber Agreement. While there have been numerous studies on previous trade agreements, the unique structure of the current agreement, with tariffs that increase when market prices fall below specified thresholds, warrants careful examination. Finally, there are no comprehensive studies on Chinese import demand. It is important to fill these gaps in our understanding to allow BC policymakers to better understand the opportunities and challenges that face developing or expanding lumber and non-lumber production capacity to use more of the standing dead pine killed by the MPB.

3. British Columbia's Response to the Mountain Pine Beetle

3.1 Provincial Response

3.1.1 Increased Timber Supply (Allowable Annual Cuts)

The scale of the current mountain pine beetle outbreak is unprecedented in modern history. Fourteen million ha (an area larger than Greece) of mature lodgepole pine trees, spread over approximately 40 million ha of the BC Interior (an area larger than Japan), are vulnerable to the MPB. Lodgepole pine forests cover approximately 36% of the affected forest area and make up 12% of the total provincial merchantable volume on the timber harvesting land base (BCMFR 2007). The share of lodgepole pine across the BC Interior varies across the landscape, as does the current percentage of dead pine (BCMFR 2009a). As such, the timing and degree of response to the MPB outbreak by the provincial government (in terms of timber supply) has also varied across the affected area.

Since 2000 the allowable annual cut (AAC; permitted rate of annual timber harvest on public forest lands) in the Interior of BC has increased by 15 million m^3 to about 67 million m^3 per year (see Table 1) as the intensity and scale of the MPB outbreak has increased (see Appendix Table A1 for a district-level breakdown). This amounts to a 33% increase in the timber supply in the Interior of the province, and a 21% increase in total BC softwood supply (including the unrelated drop in coastal timber supply). In a Canadian and North American context, the additional supply of softwood timber is equivalent to an increase of 8.6% and 3.2% respectively over 2000 timber supply levels.[2] This compares to a projected decrease of 11 million m^3 below 2000 timber supply levels in the Interior of the province (BCMFR 2007). Using 2000 as a base year, this is equivalent to a decrease of 18.1, 7.2, and 2.7% of BC, Canadian, and North American timber supplies respectively. When and how quickly the timber supply will decrease from current levels is not precisely known. This hinges on the shelf-life of standing dead pine and a myriad of forest stewardship, community, industry, and environmental considerations that, together, influence term-limited timber supply decisions on BC's public lands. A recent BC Ministry of Forest and Range report projects the drop in Interior timber supply will begin any time after 2010 and continue to fall until about 2020, at which point the timber supply is expected to hold steady for a few decades before rising again (BCMFR 2007).

[2] In 2000 the potential Canadian softwood timber supply was reported to be 174 million m^3 (see the National Forest Database Program online at http://nfdp.ccfm.org/supply/background_e.php). The 5-year average industrial roundwood softwood harvest in Canada between 1996 and 2000 was 155 million m3. The US does not have an equivalent supply estimate given the preponderance of private lands. However, in 2000 the US softwood timber harvest reached 295 million m3 and the 5-year average industrial roundwood softwood harvest in the US between 1996 and 2000 was 292 million m3 (Howard 2007).

Table 1. Current, past, and projected Annual Allowable Cut (AAC) (m^3). (Sources: BCMFR 2007, 2010a, and 2010b.)

Region	AAC 2000	AAC 2009	Change from 2000 to 2009	Projected post-MPB AAC (2020–2050)	Change from 2000 to 2009
Coast	19 579 000	17 578 990	-11%	17 578 990	0%
Interior	50 601 600	67 098 520	33%	40 000 000	-20%
Southern Interior	27 534 120	35 005 880	27%	-	-
Northern Interior	22 067 480	32 092 640	39%	-	-
British Columbia	70 199 300	84 667 480	21%	57 519 790	-18%

3.2 Industry Response

3.2.1 Timber Harvest

Over much of the first decade (2000–2009) of the MPB outbreak in the Interior of BC, the forest industry responded to the increased timber supply (Figure 7). The forest industry steadily increased total harvest, and the share of pine harvested as timber supply was ramped up in an effort to salvage more pine timber. However, the importance of the demand for wood products in determining the demand for BC Interior timber was clearly revealed in the final 3 years of the decade. The decline in demand for wood products due to the collapse of the US housing market significantly reduced the demand for BC's timber. In spite of the significant reduction in demand for BC wood products over the past 3 years, the BC industry continues to focus on pine salvage.

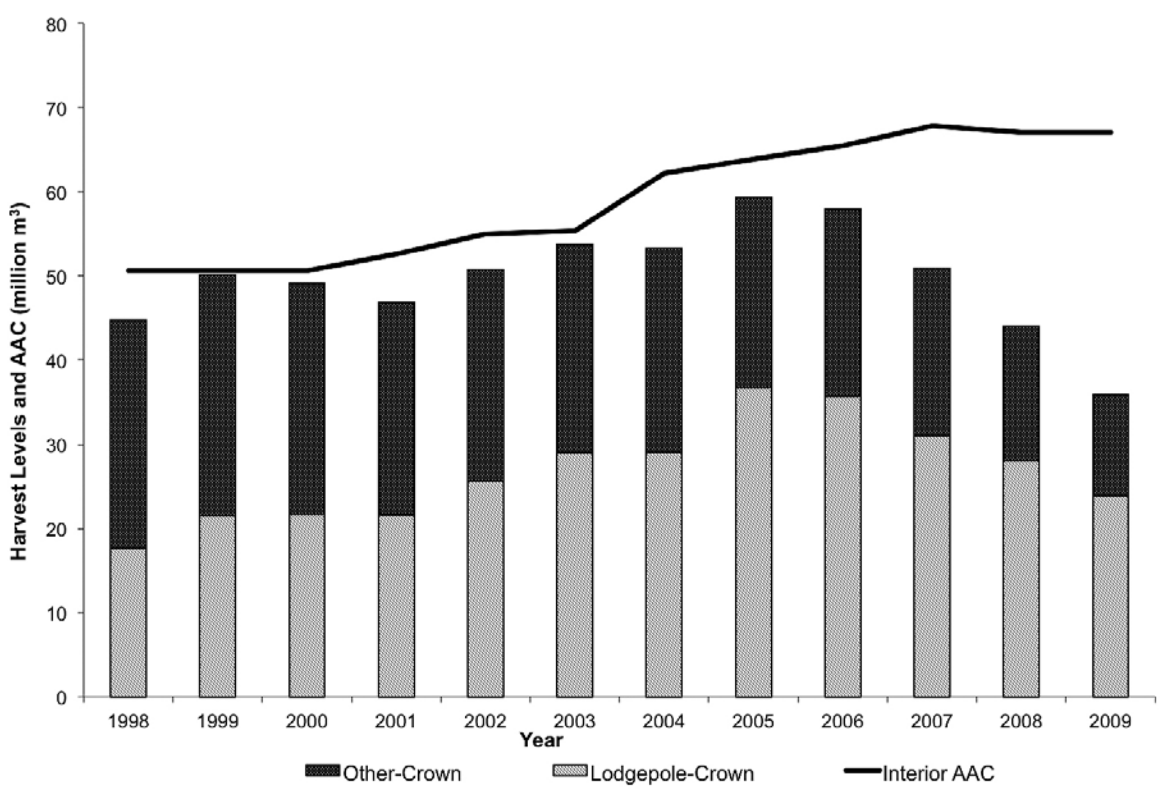


Figure 7. Harvest levels relative to annual allowable cut on Crown lands in the Interior of BC. (Source: BCMFR 2010c.)

Comparisons of the Northern and Southern Interior forest regions reveal different harvesting patterns (Figure 8) among the regions. Comparing 2000 and 2009 harvest levels shows the proportion of pine harvesting has increased from 40 and 50% to 70 and 65% in the Northern and Southern Interior regions respectively.

At the district level, harvest patterns are more variable but the general trend is similar. Since 2000 the proportion of lodgepole pine to total harvest generally increased across all districts affected by the MPB outbreak and increased sharply over the last few years of the decade.

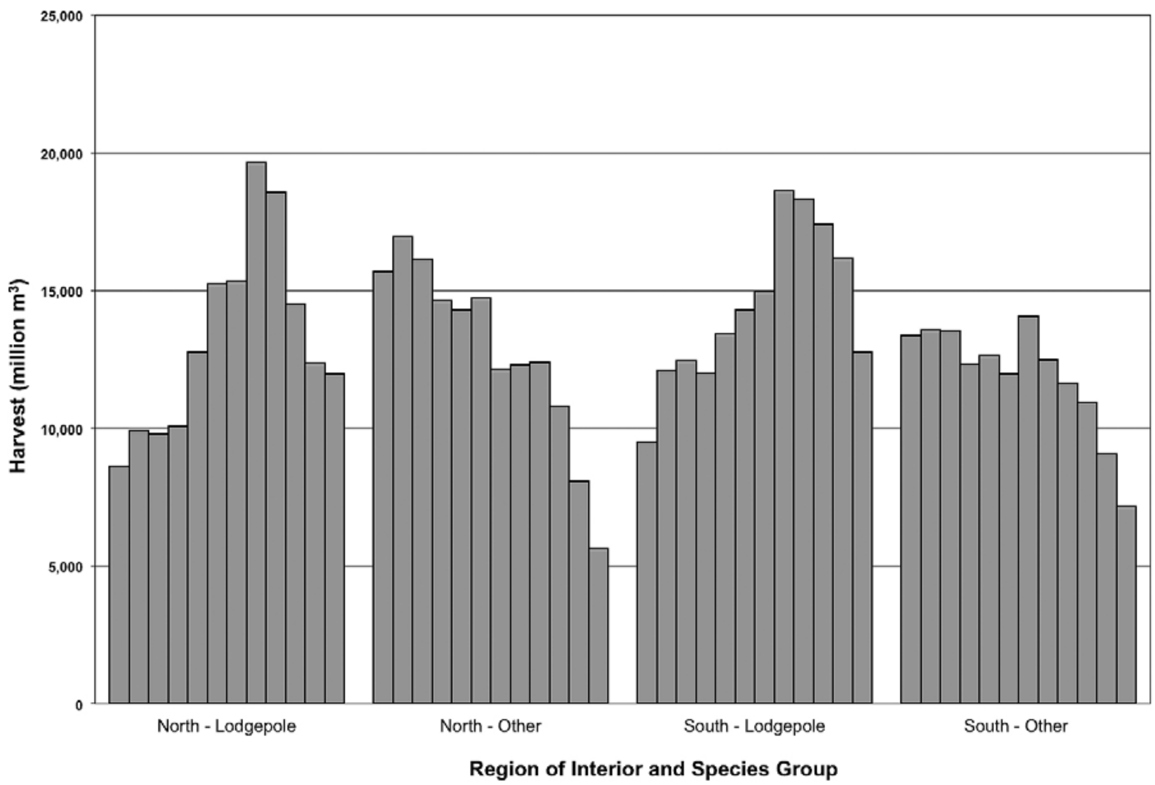


Figure 8. Regional harvests on Interior Crown lands from 1998 to 2009 by species group. Within each grouping, one bar represents one year, beginning on the left with 1998 and advancing chronologically through 2009 on the right. (Source: BCMFR 2010c.)

3.2.2 Industry Capacity and Structure

There is evidence to suggest that the increased availability of timber supply in MPB-affected areas played a part in inducing some small structural changes in the BC Interior forest sector. Based on mill data between 2000 and 2008 (the most complete data available), it is evident that either the number of mills or their capacity changed in MPB *vis-à-vis* non-MPB areas. Tables 2 and 3 summarize the number of mills and mill capacity, respectively, over the years from 2000 through 2008, organized by region and areas with elevated timber supply to address the MPB outbreak (see Appendix Table A1 for district AAC changes). It is important to note that wood product demand over this period was increasing. From late 2000 through late 2009, demand for wood products declined sharply due to the US housing crisis and the global recession. These events have had a significant impact on the forest industry in BC and other regions of Canada (see NRCan 2010). While changes in available timber can lead to changes in industry size and structure, industry expansion and restructuring is unlikely to occur without concurrent changes in demand. We elaborate further on the importance of demand later in this report.

Table 2. Number of mills in the BC Interior from 2000 through 2008. (Sources: BCMF 2001 and BCMFR 2005–2010d.)

Region	Mill Type	MPB	2000	2001	2002	2003	2004	2005	2006	2007	2008
North	Chips	MPB[a]	2	2	2	2	2	-	-	-	-
		Non	7	6	4	2	2	2	2	2	2
	Lumber	MPB	22	23	24	23	24	25	25	24	22
		Non	18	20	12	13	11	12	10	9	7
	Pellet Mills	MPB	-	-	-	-	-	3	4	3	3
		Non	-	-	-	-	-	-	-	-	-
	Pole & Post	MPB	2	2	2	3	2	2	2	3	3
		Non	2	1	1	-	-	-	-	-	-
	Pulp & Paper	MPB	4	4	4	4	4	4	4	4	4
		Non	7	6	6	6	7	7	7	7	7
	Other Veneer	MPB	2	2	2	1	2	2	2	2	2
	& Panel	Non	5	5	5	5	5	5	6	6	6
South	Chips	MPB	5	5	5	5	5	4	3	4	4
		Non	1	1	-	-	-	-	-	-	-
	Lumber	MPB	38	38	39	43	40	42	38	36	33
		Non	19	19	18	17	16	15	15	13	11
	Pellet Mills	MPB	-	-	-	-	-	4	4	5	5
		Non	-	-	-	-	-	-	-	-	-
	Pole & Post	MPB	20	19	16	14	18	17	17	20	20
		Non	11	9	9	7	5	5	6	6	6
	Pulp & Paper	MPB	4	4	4	4	4	4	4	4	4
		Non	1	1	1	1	1	1	1	1	1
	Other Veneer	MPB	19	18	19	19	20	19	17	17	17
	& Panel	Non	5	6	5	5	5	5	5	4	4

[a] 'MPB' refers to management units within the provincial MPB management zone, and 'Non' refers to management units not within that area.

Table 3. Industry capacity for different mill types and regions of British Columbia, 2000–2008. (Sources: BCMF 2001 and BCMFR 2005–2010d.)

Region/Mill Type	MPB	2000	2001	2002	2003	2004	2005	2006	2007	2008
Northern										
Chips (thousand BDU)	MPB[a]	254	252	252	255	192	-	-	-	-
	Non	1058	998	511	312	422	430	432	432	720
Lumber (MMbf)	MPB	4085	4267	4413	4143	4697	4772	4673	4779	4627
	Non	1879	2248	1822	2130	2191	2327	2070	1687	1313
Pellet Mills	MPB	-	-	-	-	-	359	530	440	482
(thousand Tonnes)	Non	-	-	-	-	-	-	-	-	-
Pole & Post	MPB	60	61	59	57	49	42	44	85	1274
(thousand pieces)	Non	524	14	14	-	-	-	-	-	-
Pulp & Paper	MPB	1213	1213	1102	1108	1113	1113	1119	1141	1118
(thousand Tonnes)	Non	1865	1702	1684	1698	1984	1943	1929	1954	1492
Panels (mill ft^2, 3/8″ basis)	MPB	396	286	277	277	299	299	302	304	-
	Non	1228	1310	1215	1229	1539	1539	2337	2338	1912
Southern										
Chips (thousand BDU)	MPB	346	468	325	308	498	222	178	373	403
	Non	46	12	-	-	-	-	-	-	-
Lumber (MMbf)	MPB	3761	3860	4392	4758	4863	5049	5136	5087	4801
	Non	1534	1528	1561	1407	1347	1430	1303	1145	923
Pellet Mills	MPB	-	-	-	-	-	354	280	411	453
(thousand Tonnes)	Non	-	-	-	-	-	-	-	-	-
Pole & Post	MPB	4559	4230	5649	13 180	7027	5090	6382	9084	6740
(thousand pieces)	Non	1402	948	1701	1986	275	287	863	870	246
Pulp & Paper	MPB	1377	1373	1366	1383	1375	1383	1389	1384	1366
(thousand Tonnes)	Non	414	414	428	420	431	431	449	466	466
Panels (mill ft^2, 3/8″ basis)	MPB	2728	2996	2925	3127	3400	3356	3372	3120	2567
	Non	600	619	634	575	748	769	740	649	309

[a] ‘MPB’ refers to management units within the provincial MPB management zone, and ‘Non’ refers to management units not within that area.

While there were capacity and structural changes in several industries during the 2000–2008 period, the most notable changes occurred in the sawmilling industry. The number of mills, industry capacity, distribution of capacity across mill size classes, and average mill size changed in many ways across the Interior region (Figure 9 and Table 4). In the Northern Interior region, the number of mills and total industry capacity grew in the areas affected by the mountain pine beetle. The number of very small mills and very large mills increased, resulting in a slightly decreased average mill size. In the areas not affected by MPB timber policies, the number of mills declined significantly, while the industry capacity remained relatively unchanged, reflecting a shift to larger mills. In the Southern Interior region, more pronounced changes occurred. In the areas affected by MPB timber policies, the number of mills decreased while the industry capacity increased. The disappearance of smaller mills and the shift to larger mills resulted in a substantial increase in the average mill size in this area. In the areas of the Southern Interior region not affected by MPB timber policies, the number of mills decreased by half and the industry capacity decreased by about 20%, resulting in a significant increase in average mill size, albeit much smaller than the average in other regions.

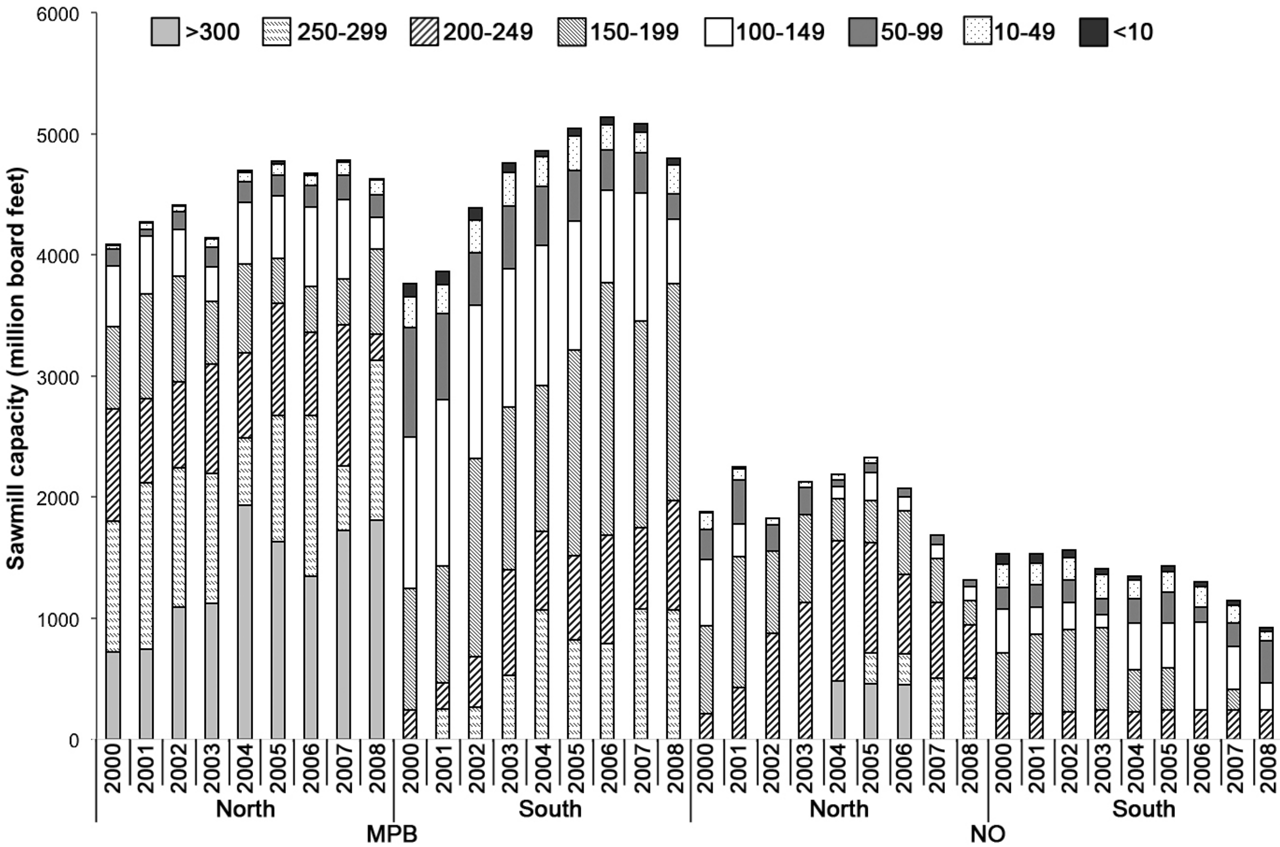


Figure 9. Sawmill capacity by mill size class across a region and presence of MPB timber policy, 2000 to 2008. (Sources: BCMF 2001 and BCMFR 2005–2010d.)

Table 4. Average lumber mill size (million board feet per year) by region and presence of MPB timber policy. (Sources: BCMF 2001 and BCMFR 2005–2010d.)

	2000	2001	2002	2003	2004	2005	2006	2007	2008
MPB Area									
North	186	186	184	180	196	184	180	177	185
South	64	63	74	79	92	87	97	102	109
All MPB management areas	96	97	106	107	124	117	124	128	137
Non-MPB Area									
North	104	112	152	164	199	194	207	187	188
South	28	44	54	52	59	62	59	60	51
All non-MPB management areas	59	69	83	88	104	107	105	101	89
All BC Interior	80	86	98	101	118	114	119	121	124

During the 2000–2007 period, there was a decline in the number and capacity of wood chip mills that supply chips to pulp and paper mills and panel mills. These changes were sharper in the Northern Interior region than in the Southern Interior. This is not surprising as the increased supply of chips produced by lumber mills meant decreased demand on dedicated mills to produce chips. The opposite occurred in 2008 because lumber production fell as the US housing crisis began to unfold.

In terms of value-added wood manufacturers, the sector was surveyed at the end of the 1990s and again in 2007 (for the 2006 period) with analysis of regional changes (Stennes and Wilson 2008). One particular group of value-added wood product firms that performed well in the most heavily affected MPB areas were the log home and timber frame manufacturers. The strongest growth was found in the Northern Interior and Cariboo regions, where the number of firms doubled between 1999 and 2006 (from 19 to 38 firms).

Likewise, pole and post mills increased in number and capacity in the MPB area, with significant capacity increases in the Southern Interior region, while decreases were experienced in the non-MPB area. Again, this reflects the relative increase in available logs for pole and post manufacturing in MPB areas.

One of the most dramatic changes in the interior forest sector was the emergence and rapid growth of the wood-fuel pellet industry starting in about 2005. This expansion was established in the MPB area, reflecting the increased availability of low-cost residual fibre generated from expanded primary processing in these areas. In fact, when the expansion began there were large surpluses of residual wood products, especially in the Northern Interior (Stennes et al. 2010). This sector has considerable dependence on co-products from primary log breakdown, and the slowdown in harvests and primary breakdown are challenges for the continued expansion of pellet production.

There was little change in the capacity and structure of the pulp and paper industry over this period (Tables 2 and 3). There were some changes in the wood panel industries, though the most notable changes occurred in the Northern Interior area unaffected by MPB timber policies. Here the principal change was the expansion of oriented strand board (OSB) milling capacity. The notable changes in areas affected by MPB policies were the increased mill capacity to produce OSB, other panels (medium-density fibreboard), and plywood and veneer in the Southern Interior region.

Together, the changes suggest that the industry's general capital structure remains focused on lumber, pulp and paper, and panel production. This is consistent with the general North American trend. According to Spelter et al. (2007), 2007 lumber capacity levels in BC, the US South, and US West were 8, 5, and 6 million m^3 greater than 2001 levels, respectively. Eastern Canada was the only region in North America to reduce lumber capacity (by 1 million m^3) during this period.

3.2.3 Employment

In spite of the steady increase in provincial harvest levels after 2001, total forest sector direct employment has trended down over the same period in all sub-sectors of the forest economy (Figure 10). This loss of employment accelerated after early 2007 due to harvest reduction and mill closures, but continued investment in labour-saving capital improvements has been reducing labour per unit of output over the entire period of our analysis.

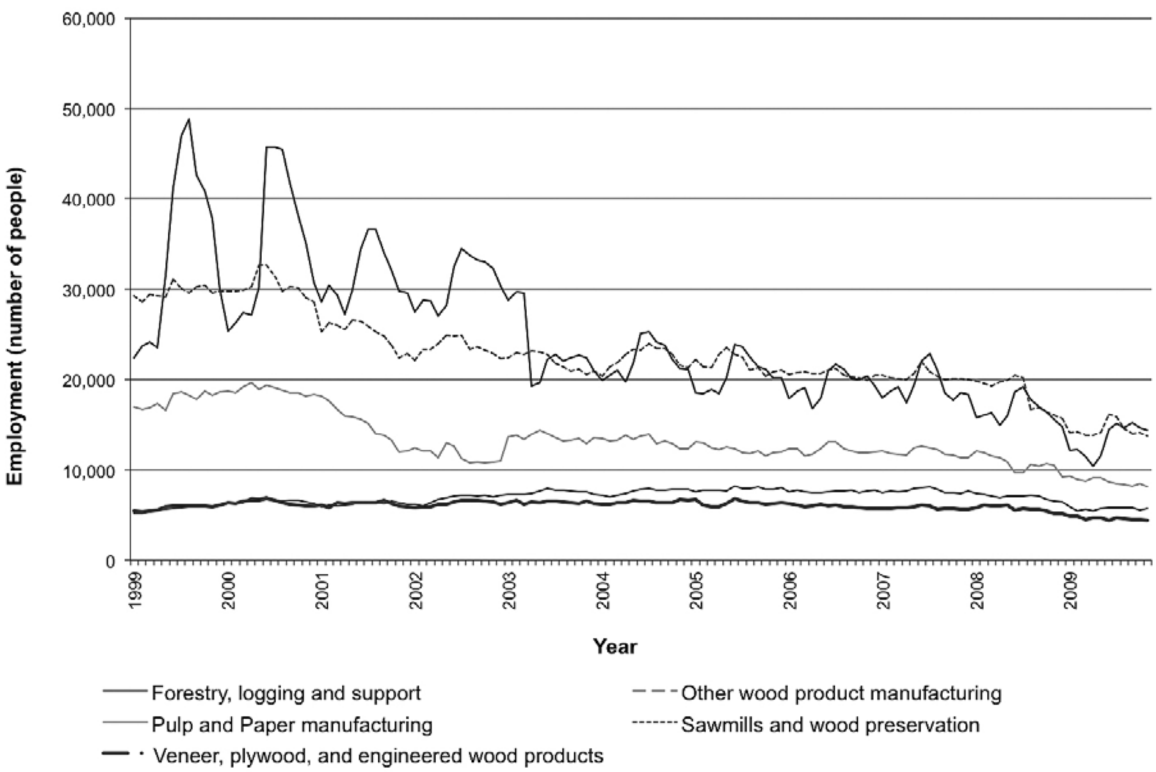


Figure 10. Total employment in BC's forest industries, 1999–2009. (Source: Statistics Canada n.d.[a] Table 281-0023.)

3.2.4 Industry Utilization of Logs from Salvaged Lodgepole Pine

In accord with industry capacity changes, the bulk of the increased timber supply has been used to make lumber and, to a lesser extent, panels. According to BCMFR data (BCMFR 2005–2010d), log use in sawmills and panel mills increased over 2004 levels in 2005 and 2006 before falling somewhat in 2007 (Table 5). On the other hand, use of logs in chip mills and other mills decreased over the 3-year period after 2004. Log use in pulp mill wood rooms decreased over 2005 and 2006 before increasing in 2007. Given that industry's capacity is geared toward sawn lumber (75–80%), a given percentage increase or decrease in log harvest is generally associated with an equivalent percentage increase or decrease in lumber production.

Table 5. Primary log use by the Interior processing sector, 2004–2008 (thousands of m^3) (Source: BCMFR (2005–2010d).)

	2004	2005	2006	2007	2008
Lumber Mills	49 030	51 901	51 542	48 185	35 471
Veneer/Panel Mills	4000	6191	6409	6024	4313
Pulp Mill Wood Rooms	848	766	789	924	872
Chip Mills	2309	1329	1363	1256	1365
Shake and Shingle Mills	17	17	14	7	7
Other Mills	841	511	492	551	573
Log Exports	379	386	361	417	449
Total Log Use	57 424	61 101	60 970	57 363	43 049

Since the inception of MPB uplifts in 2000, lumber production has steadily increased in both regions of the Interior. Table 6 shows the lumber production for the two Interior production regions of BC *vis-à-vis* other regions of North America. While improved log utilization (lumber recovery) increases lumber supply, this factor alone cannot account for the entire increase in lumber production between 2000 and 2007. Between 2000 and 2007 the average lumber recovery factor (LRF) in Interior BC sawmills increased 7% while total lumber output increased 25%, indicating that improved lumber recovery accounted for one-quarter of the increased lumber output. The other three-quarters of the increased output are a result of increased throughput of logs.

Use of logs for veneer, plywood, and OSB has also increased. (Though output data for panel products are not tracked, estimates of primary log use by BC mills suggest that this may be the case.) Based on data from Statistics Canada (2000b–2003b; 2004c–2007c) and information provided in Spelter et al. (2006), we calculate that 2007 plywood production in the Interior increased by 11% over 2001 levels (Table 7). However, while any species can be used to make plywood and veneer (Haygreen and Bowyer 1996), the preferred species is Douglas-fir. Therefore, it is uncertain whether veneer production has been boosted by increased availability of lodgepole pine. Lodgepole pine has seen significant use in OSB production in both BC and the US. Mixtures of chips and sawdust/shavings containing salvaged lodgepole pine are used in the production of pulp, medium density fibreboard (MDF), wood-fuel pellets, and are burned directly for energy.

Table 6. BC regional softwood lumber production from 2000 to 2009. The Southern Interior region includes south and central BC production areas (million m^3). (Sources: Statistics Canada 2000a–2009a; Spelter et al. 2007; Random Lengths 2009.)

Region	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Coast	8.1	7.5	6.1	5.9	6.3	5.9	5.5	3.9	3.2	2.4
Interior	26.3	25.2	29.4	30.1	33.6	35.1	35.4	32.8	25.0	20.6
Northern Interior	14.1	13.1	15.3	15.5	16.9	17.0	17.0	15.6	11.5	10.5
Southern Interior	12.2	12.0	14.2	14.6	16.7	18.1	18.5	17.2	13.5	10.0
BC Total	34.3	32.6	35.5	36.0	39.9	41.0	41.1	36.7	28.2	23.0
Canada total	74.2	72.1	77.9	77.5	82.8	81.2	79.2	72.0	57.2	45.3
BC % share	46%	45%	46%	46%	48%	50%	52%	51%	49%	51%
Interior BC % share	35%	35%	38%	39%	41%	43%	45%	46%	44%	45%
North America total	159.1	1153.4	162.0	163.4	174.5	176.7	170.6	153.5	125.8	100.2
BC % share	22%	21%	22%	22%	23%	23%	24%	24%	22%	23%
Interior BC % share	17%	16%	18%	18%	19%	20%	21%	21%	20%	21%

Table 7. Plywood production (m^3). (Sources: Statistics Canada 2000b–2003b; 2004c–2007c; Spelter et al. 2006.)

Year	BC	BC Interior (estimated)
2000	1 541 493	1 252 620
2001	1 563 795	1 215 925
2002	1 680 792	1 347 610
2003	1 733 007	1 392 489
2004	1 863 057	1 520 268
2005	1 852 861	1 511 948
2006	1 794 769	1 464 545
2007[a]	1 651 937	1 354 589

a Estimated from the Canadian total using BC's 2006 share of production.

4. Product Opportunities from Dead Pine

As discussed in the previous section, the industry's capacity continues to be geared toward core products (lumber and panels) and much of the increased timber supply has gone to making these products. This may be a rational and efficient response by industry to market conditions and the characteristics of salvaged lodgepole pine. However, the question of what, if any, alternative products can be made from this fibre basket remains. In this section, we briefly discuss some of the product opportunities. These opportunities are divided into four groups: lumber and lumber-derived products; structural panel products and engineered products; non-structural panels and other wood products; and pulp and energy.

4.1 Lumber and Lumber-based Products

While lumber is an obvious use for salvaged lodgepole pine logs, the usefulness of a standing dead pine tree for lumber declines over time due to checking and decay (Lewis and Hartley 2005; Lewis et al. 2006). A recent study by Barrett and Lam (2007) underscores this point. In comparing 5-year-old dead lodgepole pine logs with green lodgepole pine logs, they found that 12.5% less lumber was recovered from dead logs, with an additional 6% loss in aggregate value due to decreased lumber grades resulting from visible imperfections (fungal stains) and different piece size mixes. This suggests that, due to increased logging costs and transport costs (more logs needed to make the same amount of lumber) and reduced product value, the economic value of standing dead pine for lumber will diminish over time. How quickly sawlog value diminishes depends greatly on the local climatic conditions; quality declines relatively slowly in dry areas and more quickly in wet areas (Lewis and Hartley 2005; Lewis et al. 2006).

Research is underway in many areas to discover how reduced lumber grades can be compensated for. Two possible strategies are using the lumber to make products such as glulam (pieces of lumber glued together to make beams), or treating the lumber with stains and preservatives (to address issues of appearance) for subsequent use in fencing and decking. While these strategies address the issue of lost lumber grade value, the products have limited volume market opportunities and do not offer a strategy that matches the scale of the MPB outbreak. In addition, the strategies do not address the issue of reduced lumber recovery from the logs or the increase in harvesting and transportation costs.

4.2 Structural Panel and Engineered Products

Wang et al. (2007) conclude that MPB-killed logs can be used to make veneer and plywood, which in turn can be used to produce laminated veneer lumber (LVL), I-joists, headers and beams, flooring, decking, and concrete forms. Though technically feasible, this would require that suitable logs be sorted from unsuitable logs, and manufacturing parameters related to drying, grading, gluing, and hot-pressing would need to be adjusted to ensure efficient production (Wang et al. 2007). Xu et al. (2008) also concluded that dead MPB-attacked logs (with and without bluestain present) can be used to make plywood but changes to the process are required to reduce delamination due to glue dry-out.

OSB is another possible use for MPB-killed timber. It is made by chipping log bolts into wafer strands that are then configured into layers and bonded together with resins. Aspen (*Populus* spp.) and southern yellow pine (*Pinus* spp.) are the most common species groups used to make OSB in North America, but any low-density species can be used (Haygreen and Bowyer 1996). While OSB is a possible use for salvaged lodgepole pine logs, there are still outstanding issues regarding resin consumption (due to high permeability of the wood) and associated increased costs (Byrne et al. 2006) that may prevent widespread utilization of dead lodgepole pine for OSB.

4.3 Non-structural Panels and Other Wood Products

Other panel products such as medium-density fibreboard (MDF), particleboard (excluding OSB), and hardboard could be produced using particles derived directly from salvaged pine or from sawmill residues. Any species can be used to make these products (Haygreen and Bowyer 1996). Nevertheless, since the processes to make these products are energy intensive (Haygreen and Bowyer 1996), the cost of fibre and marketing costs will weigh heavily in determining the feasibility of using salvaged pine logs to make these products. A study in New Hampshire found that the business case for an MDF plant using low-cost, whole logs, with and without a cogeneration facility, was very poor, even with very high electrical power prices (INRS 2001). The long-term availability of wood fibre is also an issue. New greenfield projects involve millions of dollars of investments and require several years to pay back (INRS 2001). The uncertainty of a continued fibre supply for a long enough period poses a significant risk to this type of investment.

Other less traditional products using wood fibre from salvage pine include composite cement–wood and plastic–wood products (Hartley and Pasca 2006). Other products using dead lodgepole (and ponderosa) pine solid wood include log homes, treated and untreated fence posts and utility poles (Byrne et al. 2006), and direct use in making furniture and minor wood products such as bowls and utensils. Though these are potential uses of salvaged pine, the market size is limited.

One successful use of beetle-killed logs in other jurisdictions is the log home sector in Montana. This sector was one of three case studies in a report on forest product manufacturing clusters published by Cintrafor (Braden et al. 1998). One of the factors that led to the formation of this industry in Montana was the availability of standing dead lodgepole pine trees. This is also one of the sectors in BC that has performed well in rural parts of the province, and provides high levels of employment and revenues per m^3 of wood used (Stennes and Wilson 2008). Similar to many other value-added products, this is not a product that will consume vast amounts of timber. In BC, lodgepole pine is still a relatively minor species in log home manufacturing, comprising just 14% of roundwood used in 2006.

4.4 Pulp

Lodgepole pine trees killed by the MPB can be used (after some processing) to make pulp. However, depending on how long the tree has been dead, fibre derived from salvaged lodgepole pine may have increased resins or low moisture content. Both of these factors may require changes in the pulping process, resulting in increased processing costs (Watson 2006). Increased input and increased processing costs will both lower operating margins on pulp and reduce the competitiveness of mills. Fortunately, recent research findings suggest that the changes in the mechanical and chemical properties of the wood may be minor for several years after the tree dies (Kadla et al. 2008), so impacts on pulp and papermaking may also be minor (Bicho et al. 2008; Dalpke et al. 2008). However, because of the large capital investments required to increase pulping capacity at an existing pulp mill or to build a new mill, the uncertainty of continued long-term wood fibre supply poses a significant risk. On the other hand, the large standing inventory of dead lodgepole pine may be an alternative source of fibre for existing pulp and paper mills for many years after the outbreak in the BC Interior and other parts of western Canada.

4.5 Energy and Energy Products

The product opportunity that has received the most attention for its potential to use MPB-killed pine is bioenergy. In addition to expanding economic opportunities in the MPB-affected areas, drivers for bioenergy expansion include provincial policies to increase renewable energy sources and the expectation that energy from biomass will be considered carbon neutral. Most biomass energy is produced and used by pulp producers or (to a smaller extent) sawmills for internal energy demands, but there are examples of stand-alone energy or energy feedstock production as well.

There are several ways to produce energy and energy products from salvaged lodgepole pine trees. In terms of commercial-scale alternatives, the simplest and most widely used option has been the production of wood pellets, which are generally transported and burned for energy in other jurisdictions. The main market for wood pellet exports from BC is northern Europe, where burning biomass receives favourable treatment through a number of government support measures (see Stennes and McBeath [2006] for more detail). There are also stand-alone facilities that burn woody feedstock for energy production and sell back to the electricity grid, including a well-established facility in Williams Lake, BC that has been in operation for two decades. Both pellet producers and stand-alone energy plants have been successful using co-product streams from sawmills and, to a lesser degree, roadside residuals, but the jump in costs associated with switching to dedicated harvests of MPB-killed trees for energy is not feasible at current energy prices (Stennes and McBeath 2006).

Solid wood can also be transformed (through mechanical and chemical processes) into liquid fuel products, though the commercial-scale technology to do this is still developing (Sims et al. 2008). Some of the more complex energy systems also produce chemical streams that can offer additional revenue streams. Any of the capital-intensive systems, especially those exhibiting economies of scale, are not appropriate for a temporary feedstock source such as MPB-killed pine unless they can transition to another source of feedstock when the MPB-killed pine is gone. As the lowest-cost feedstock streams move from surplus to scarcity, such facilities have the potential to bid fibre away from existing users such as pellet producers, panel mills, and pulp mills (Stennes et al. 2010).

4.6 Discussion: Product Opportunities

The sections above provide an overview of the potential products and uses that can be derived from salvaged pine timber. As the standing timber degrades, so does the expected log quality. As the quality of logs decreases, the number or quality of potential products is diminished. In addition to reduced product scope, the overall potential market size generally declines in volume or value.

While there are potential products and uses of salvaged lodgepole pine, there is no guarantee that demand for the products will exist or be significant enough to justify expansion or development of the industry. The dramatic change in the US wood product market between 2006 and present day (discussed further in the next section) emphasizes this point. Success in developing new markets to utilize a greater volume of pine, or increase value derived from pine, will depend on the specific attributes of the stands, the products, extraction and production costs, market access, transportation costs, marketing and distribution costs, and consumers' preferences. As long as the trees can produce sawlog-quality logs, most of the emphasis will continue to be on lumber. The challenge for the BC Interior sawmill industry will be to maintain a competitive cost structure in the face of increased log processing costs and reduced lumber value recovery (Barrett and Lam 2007).

As the quantity of salvageable pine sawlogs declines over time, the challenge is to find non-lumber uses for the rest of the timber resource. One aspect of this challenge is the cost of harvesting and transportation. Eventually costs of harvesting and transportation will become a major hurdle in the pursuit of exploiting pine stands killed by the mountain pine beetle.

Although there are various options such as fibreboards (structural and non-structural), pulp, other wood products, and energy, all of these options have different production costs and final market prices. For example, pulp has a high product price but involves high production costs. These high production costs often mean that the cost of fibre is critical to the profitability of a pulp mill. Though the BC pulp and paper industry does process whole logs (in pulpwood rooms located at pulp mills or via chip mills located off-site), this is a secondary source of chips. On average, chips derived directly from logs have constituted about 10% of the total fibre used in BC pulp mills. The reason is obvious: direct chip production is generally more costly than acquiring chips from nearby sawmills that produce chips as a by-product. Whole-log chipping is feasible only if there is high pulp and paper demand (high output prices) or during periods of low supply from sawmills (due to either low lumber demand or log supply shortages). In these cases, the market price of chips must be high enough to justify their production from whole logs.

The cost of feedstock is also an issue for energy options. Many energy options such as a cogeneration plant or stand-alone power plant involve high capital costs and low product values. Therefore, the cost of energy feedstock is critical. Stennes and McBeath (2006) found that under reasonable economic conditions the use of standing lodgepole pine timber as a feedstock for the production of electrical power is not feasible. They conclude that the most economical energy opportunity is producing wood pellets, which have low production costs (particularly fixed costs) and are easily transported to markets that offer the best prices. However, that said, the business model is generally unfavourable if fibre must be sourced directly from the forest.

Note that production of hardboard and MDF involves production of fibres using a mechanical process, similar to that used in mechanical pulping facilities (Haygreen and Bowyer 1996). Therefore, there may be opportunities to exploit synergies between mechanical pulping facilities and MDF and hardboard facilities, and even energy facilities such as pellet plants.

However, due to high capital costs, these opportunities will be more likely to occur in locations where the infrastructure already exists.

Public sector decisions will play an important role in determining the extent of salvageable pine use over time. Government decisions, timber supply projections, and policies that affect log costs will affect also the level, type, and timing of capital investment in the BC Interior. For example, if timber supply is fixed for a known time, say 5 years, the industry will consider capital investments consistent with this period and timber supply level (i.e., investments with a 5-year payback period). However, uncertain timber supply levels and duration will tend to influence investment decisions negatively. Similarly, policy on salvage and reforestation can affect the amount and quality of salvage-timber supply and thus the type and scale of economic activity. For example, aggressive reforestation targets for young MPB-killed stands could result in a reliable supply of small-diameter trees for a known period. The small-diameter tree supply could be used for chip production for pulp or energy, or for minor wood products such as posts. The extent of the opportunity will depend on policies that define stand development (road access) and reforestation cost obligations. Again, uncertain salvage and reforestation targets will negatively affect industry strategy and investment that targets small-diameter wood.

5. Market Opportunities for Pine Products

In the previous section, we discussed possible products and uses of lodgepole pine killed by the mountain pine beetle. Here we discuss the market opportunities for these products. The discussion here is cursory. For a more in-depth understanding of some of the trends in wood markets, the reader is encouraged to consult two recent reports by Wood Markets (2007a; 2007b), recent reports by the United Nations (UNECE and FAO 2008; UNECE and FAO 2009; UNECE and FAO 2010), and two USDA reports (Haynes et al. 2007; Ince et al. 2007). Specifically, we outline the current global and regional market trends and identify the limits in terms of market size, location, and competition. Because the pulp and paper industry is largely a by-product of the wood industry in western Canada, this discussion focuses on wood product markets. We start with a global perspective, using data from the UN Food and Agriculture Organization (FAO), and then move to a North American perspective using data from Statistics Canada, the US Department of Agriculture, and other sources. In reviewing these trends, it is important to keep in mind the size of the markets, their growth, and their geographical locations. All of these considerations are relevant to discussions regarding the feasibility of using more salvageable lodgepole pine to produce new products or expand production of existing products.

5.1 Global Markets and Trends

At an aggregate level, there appears to be ambiguous evidence to support the claim that forest products are becoming increasingly scarce in the world. Recently, global production of industrial roundwood increased significantly from 2001 levels, peaking at a level of 1.7 billion m^3, before falling dramatically in 2008 (Figure 11b). However, in a historical context, roundwood consumption is at a level similar to levels experienced in the late 1980s and early 1990s.[3] The nominal and real value of aggregate global forest product imports has increased over the last 25 years (Figure 11a). Most of the increase in value occurred in the 1980s, and since 1989 the real value of forest product imports has increased at an annual rate of only 1% per annum. Together, these trends do not provide a clear view of whether global timber resources are becoming more scarce, at least at the aggregate level.

[3] Although the drop in global production and consumption in the early 1990s resulted from the dissolution of the Soviet Union, little of this production entered global markets. The overall drop in global sawnwood production from former Soviet Union countries between 1990 and 2000 was approximately 80 million m^3.

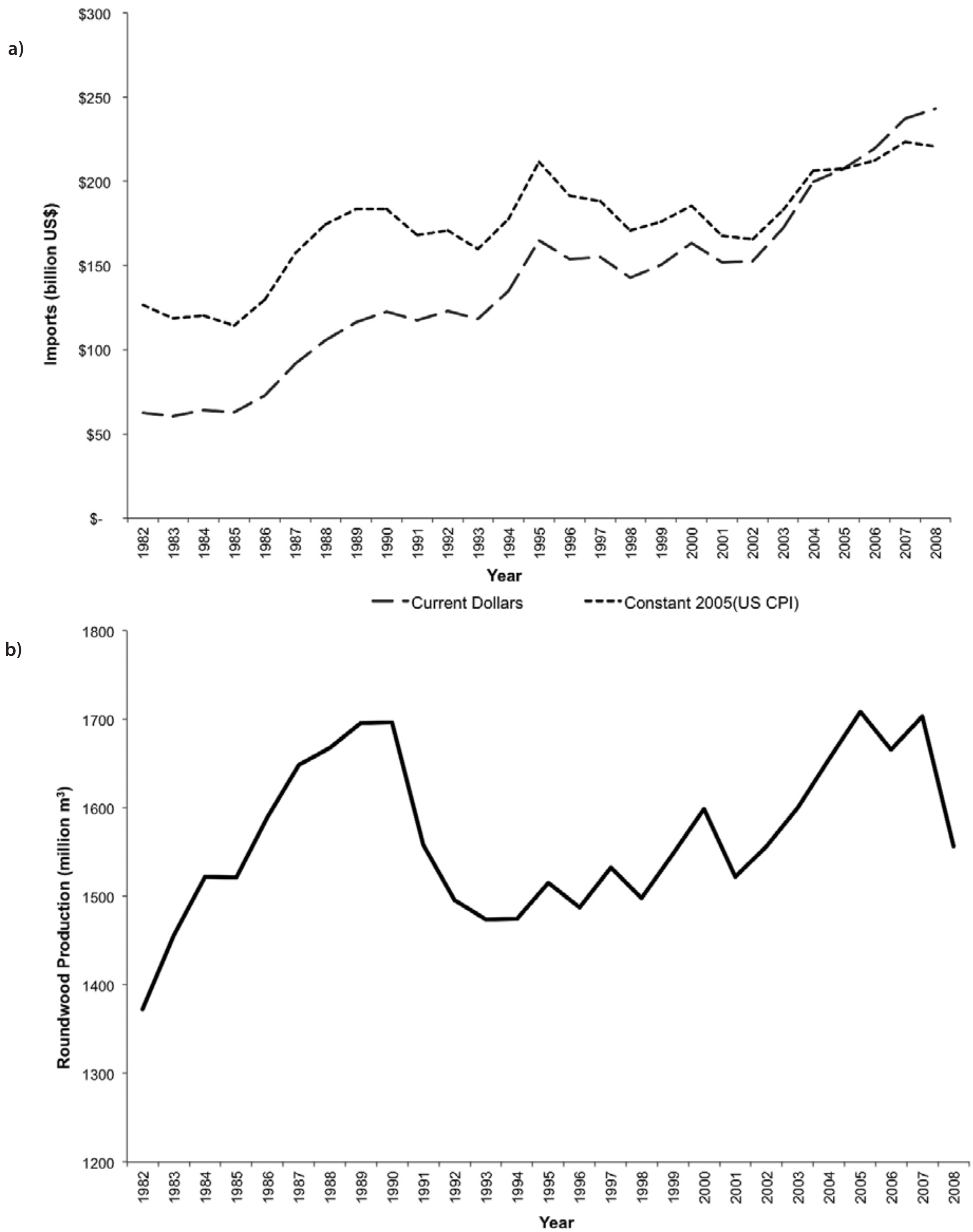


Figure 11. a) World aggregate forest product imports (current US$ and constant US$[2005]) and b) industrial roundwood production (m^3). (Sources: FAOSTAT n.d. and World Bank n.d.)

Turning to broad aggregate groups of solid wood forest products, the picture is a little clearer. The quantity and nominal value of all major wood product groups has increased in recent years (Figures 12), a trend consistent with global economic growth (World Bank n.d.). However, in spite of increased consumption, nominal import prices have been relatively flat for most wood product categories over the past 25 years. Real prices are, in fact, lower now than 25 years ago for all products except veneer (Figure 13). This does not lend much support for the notion that wood products and timber are becoming more scarce.

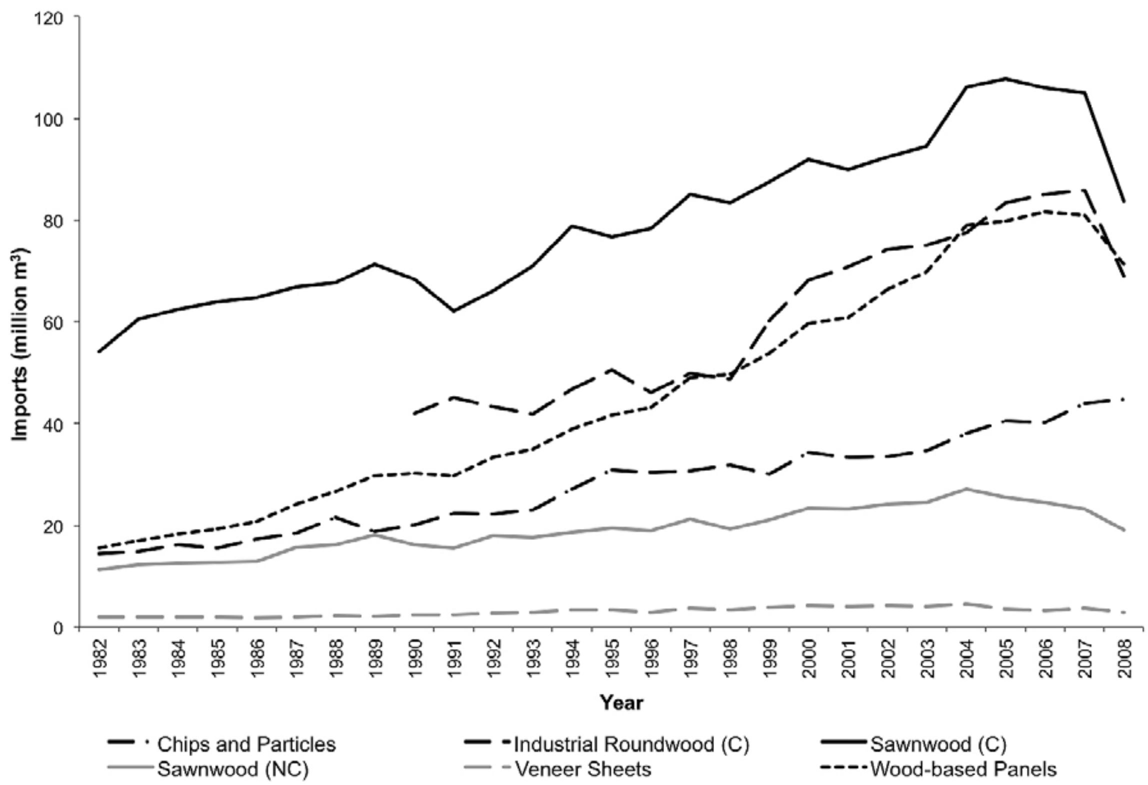


Figure 12. World import quantity of major wood product groups, 1977 to 2008. (C) denotes coniferous and (NC) denotes non-coniferous sawnwood. (Source: FAOSTAT n.d.)

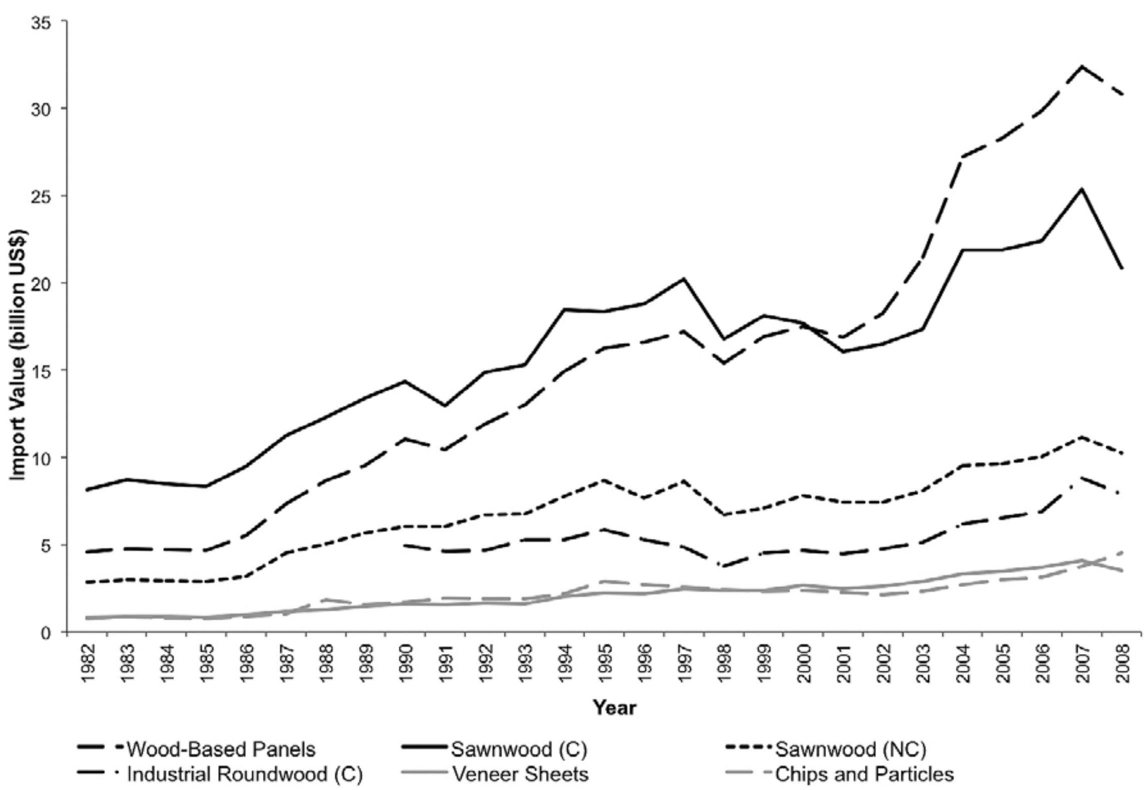
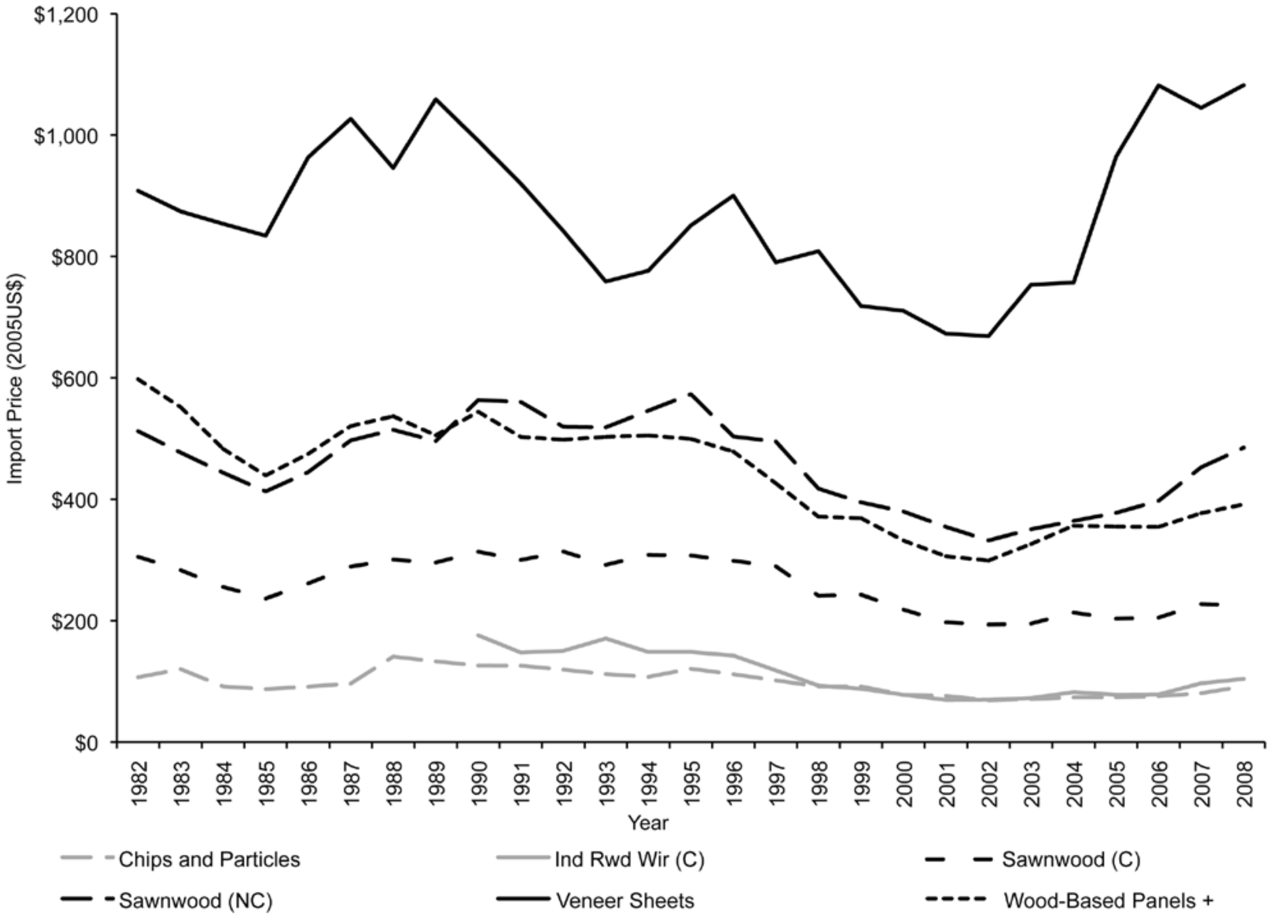


Figure 13. World import value (current US$) of major wood product groups, 1977 to 2008. (C) denotes coniferous and (NC) denotes non-coniferous sawnwood. (Source: FAOSTAT n.d.)



non-coniferous sawnwood. (Sources: FAOSTAT n.d. and World Bank n.d.)

5.2 Regional Markets and Demand Trends for Softwood Products

Europe, Asia, and North America are the largest regional markets of wood products. These same markets have also exhibited the largest increases in absolute growth across all commodities, with few exceptions. Europe is a significant net importer of chips and particles and plywood, and a significant net exporter of MDF, particleboard, and sawnwood. Asia is the largest net importer of chips and particles, roundwood, MDF, and particleboard, and a significant net importer of sawnwood. This region is the largest net exporter of plywood. North America is a significant net importer of all panel products and sawnwood (the US is the single largest net importer for both products), and a significant net exporter of roundwood and chips and particles. Africa is a net importer of most panel and board products and conifer sawnwood, and net exporter of chips and particles and plywood. Oceania is a net exporter of all wood products except plywood. Latin America (excluding Mexico) is a net exporter of all products.

Sawnwood is the largest wood product market for coniferous (softwood) timber. The largest markets for sawnwood are Europe, North America, and Asia (Figure 15). Sawnwood trade has increased over the past 25 years, with a significant rise in recent years (Figure 15). Several important trends and events have occurred in this product market at the sub-region and country levels that are important to highlight. First, most of the increased demand for imports has occurred in Asia and most of the supply increase has come from Europe and Central and South America (Figure 15). On the demand side of the Asian market, despite decreased consumption, Japan has been the single largest import market by volume, because domestic production has been declining faster than consumption. China is a growing net importer and now rivals Japan as the largest single market by volume (Figure 16). Coincidentally, due to the divergent trends of these two large importers, the combined import volume of these two markets has been rather flat over the past decade. In fact, most of the positive increase in aggregate Asian imports has occurred outside of these two markets. More and more of the supply is coming from Latin America, Oceania, and Europe, indicating that Asian markets are hotly contested by many supplier regions. Second, the collapse and rebuilding of former Soviet Union (USSR) countries (most notably the Russian Federation) has had, and will continue to have, a significant direct impact on European and Asian markets and indirect impacts on other markets. These countries have vast timber resources, and if economic development is successful over the coming years these countries will become more and more important in forest product trade (Figure 16).

Outside of Europe, Canada, and the United States, the most important markets for sawnwood are: Eygpt, Algeria, and Morocco in Africa (Figure 17a); Japan, China, Saudi Arabia, and Iran in Asia (Figure 17b); Mexico in the Americas (Figure 17c); and Australia in Oceania (not shown). Out of all of these countries, the highest and most consistent growth markets between 2000 and 2008 were in Mexico and China, where import demand grew by about 2.5 and 3 million m^3 respectively over this period. According to data collected by the International Tropical Trade Organization, China surpassed Japan as the largest Asian sawnwood importer (in terms of volume of imports) as of 2009 (ITTO 2010).

In terms of importing BC lumber, China has been the main growth market in recent years. Lumber exports from BC to China have gone from 250 million m^3 in 2005 to 2.5 billion m^3 in 2009. For the first 4 months of 2010, BC exports to China are up a further 72%, the bulk of which is spruce-pine-fir lumber produced in the BC Interior.

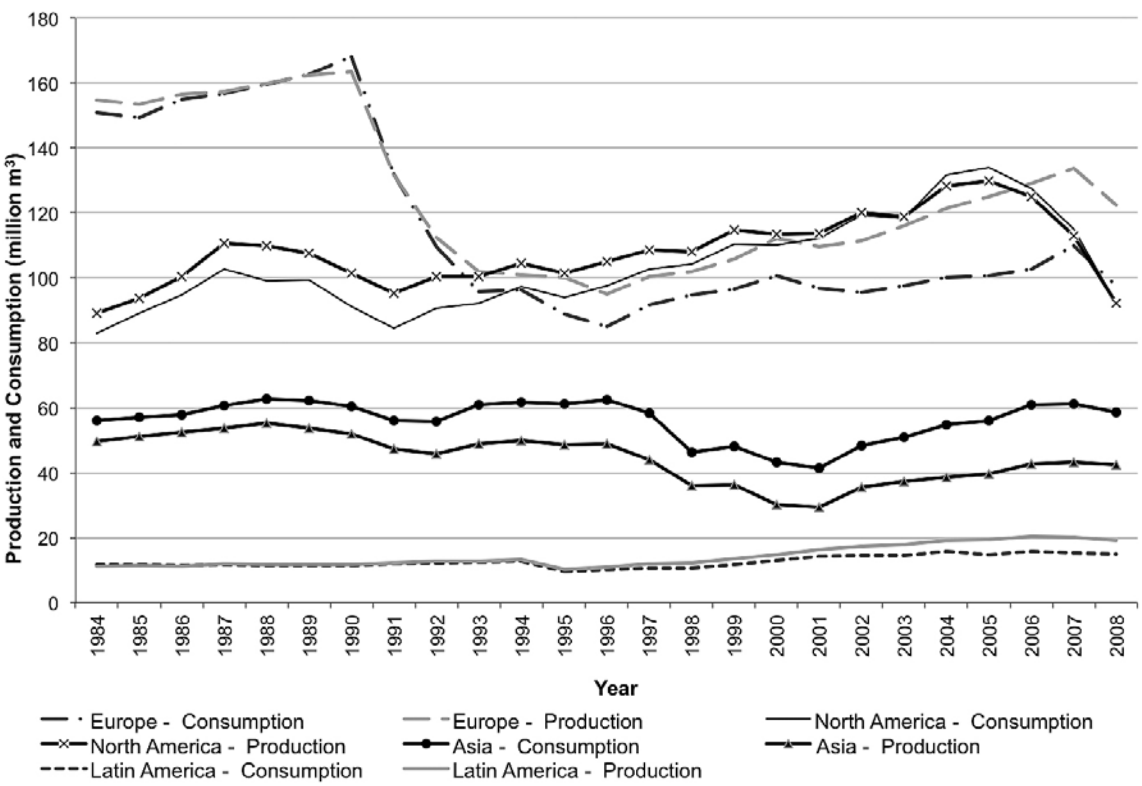


Figure 15. Coniferous sawnwood production and consumption trends, 1984–2008. (Source: FAOSTAT n.d.)

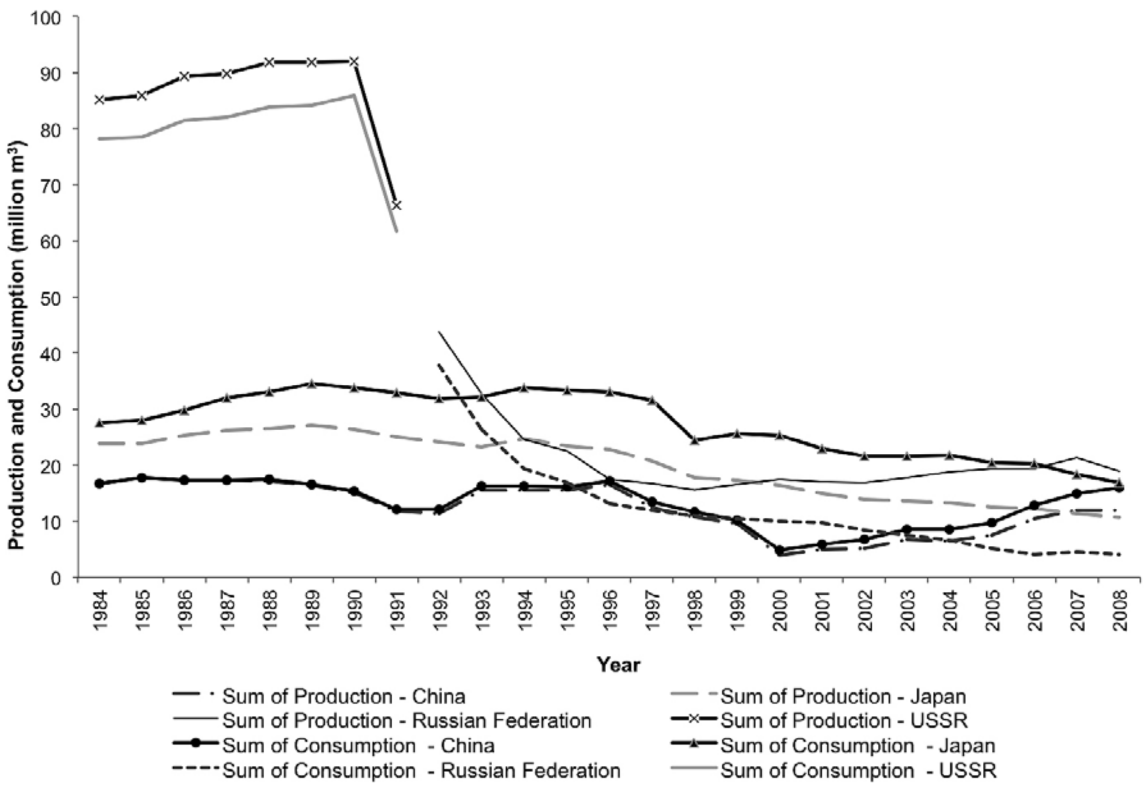


Figure 16. Coniferous sawnwood production and consumption trends in the former Soviet Union (USSR), Russian Federation, and Japan, 1984–2008. (Source: FAOSTAT n.d.) Note: Data for USSR ends in 1991; data for the Russian Federation begins in 1992.

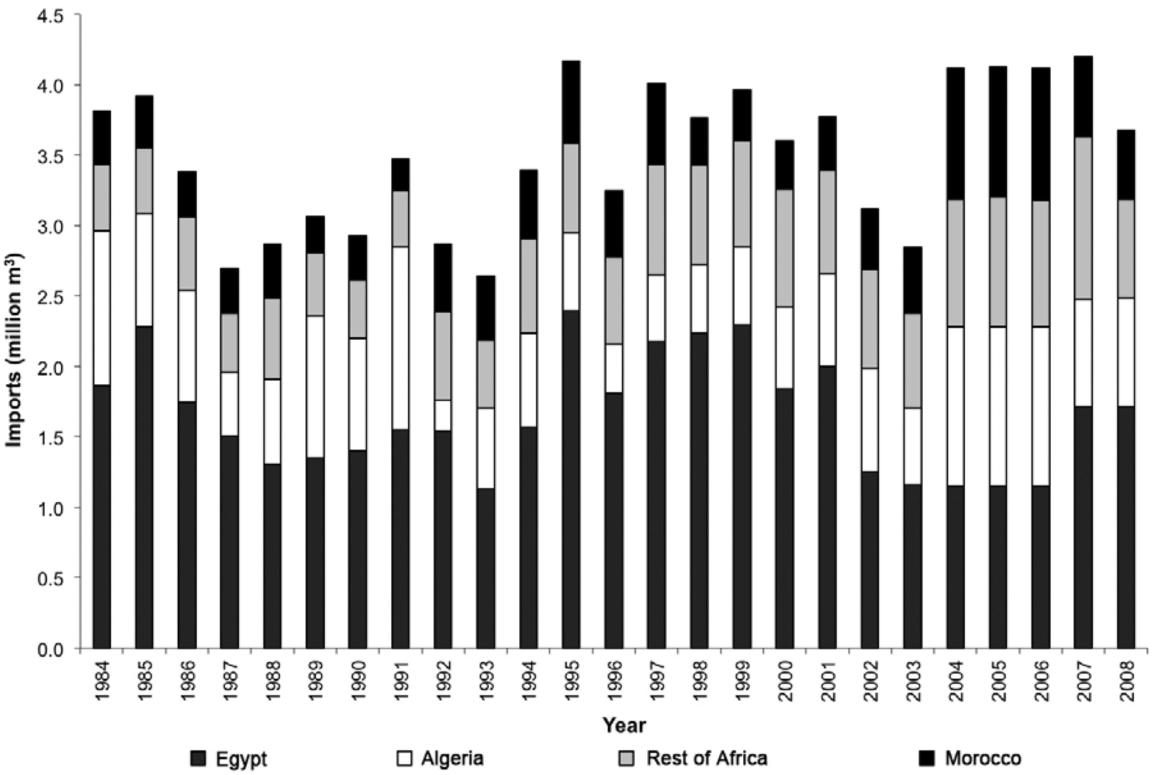
Wood-based panels are the second-largest wood product market in terms of volume of wood consumed. This market includes particleboard, OSB, plywood, MDF, hardboard, and insulating board. The last two markets consume relatively little wood fibre and are therefore excluded from the analysis and discussion.

In 2008 over 100 million m^3 of particleboard was produced and consumed in the world, according to official statistics from the FAO (FAOSTAT n.d.). This is up from over 40 million m^3 consumed and produced in 1984. The amount of inter-regional trade has likewise grown from insignificant amounts in 1984 to about 20 million m^3 in 2008. The largest markets are Europe and North America. Factoring out intra-regional trade between the United States and Canada, the amount of import demand in North America is only about 10 million m^3. Outside of North America most of the import demand is from east Asian and northern European countries (Figure 18). This demand is supplied mainly by other European and southeast Asian countries (Figure 19). These trends suggest that while markets outside North America are growing, they are small, fragmented, and highly contested.

Plywood production and consumption increased significantly over the past few years to around 75 million m^3 after years of consumption below 60 million m^3. Trade in plywood has also surged in recent years. However, most of the increased demand for imports has been concentrated in the United States, with supply increasingly coming from Asia and Latin America (Figures 20 and 21). Excluding demand for plywood in North America, import demand for plywood has actually been decreasing since the late 1990s, and more and more regions are becoming net exporters of plywood, signifying that markets outside of North America are becoming increasingly contested. The most notable new competitors that produce softwood plywood are China, Brazil, and The Russian Federation. Underscoring this new competition is the fact that Canada, which has historically been a net exporter of plywood, became a net importer of plywood in 2007 and 2008.

Of all the panel products, MDF production and consumption has increased the most dramatically over the past several years. This has largely been due to its expanded use in making furniture, but also in making other products such as flooring and mouldings. Even though consumption has increased greatly, trade has not (Figures 22 and 23). This is likely because many types of wood (coniferous and non-coniferous) can be used to make MDF, resulting in a highly fractured market with many importers and exporters.

a)



b)

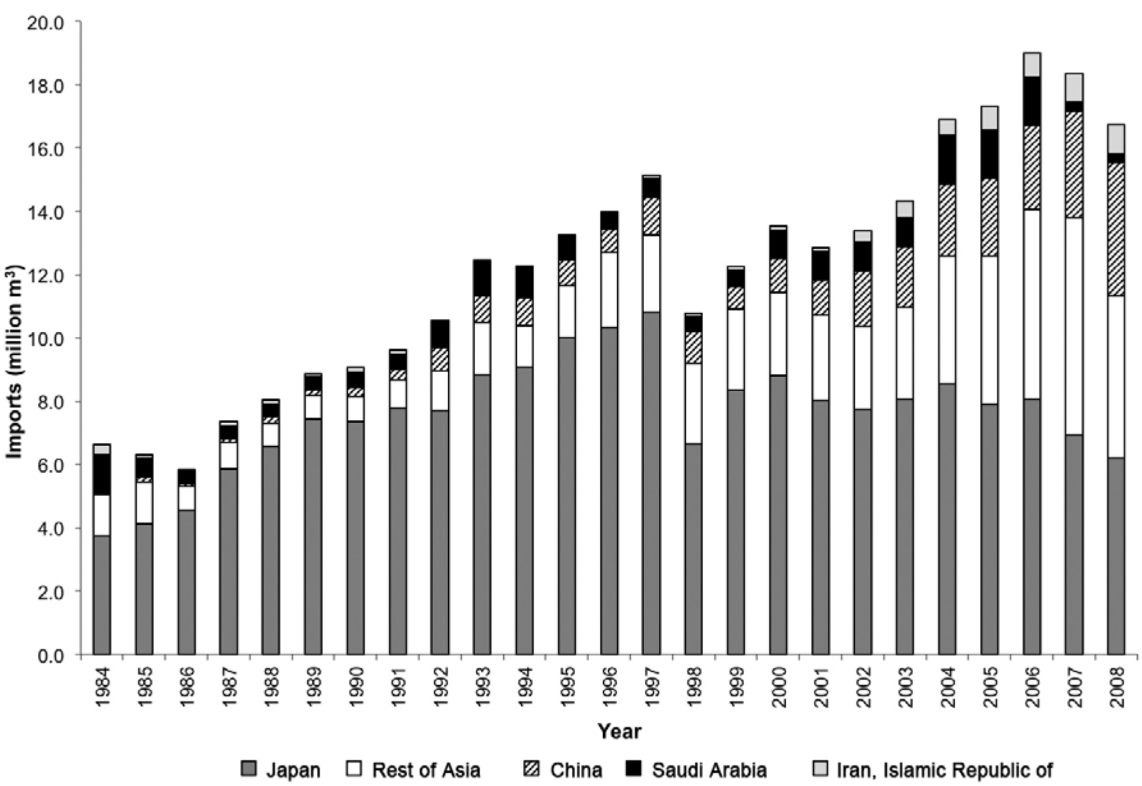


Figure 17. Main import markets for softwood sawnwood in a) Africa and b) Asia, 1984–2008 (million m^3). (Source: FAOSTAT n.d.)

c)

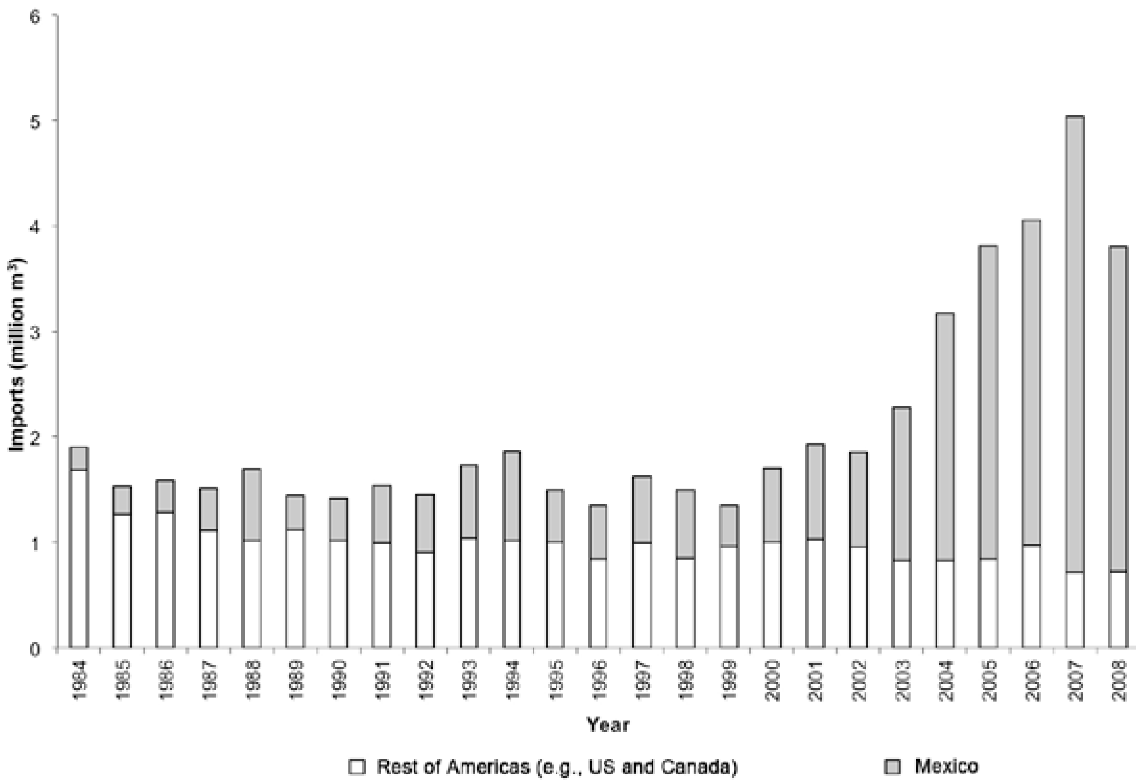


Figure 17 (continued). Main import markets for softwood sawnwood in c) the Americas (excluding Canada and the US), 1984–2008 (million m^3). (Source: FAOSTAT n.d.)

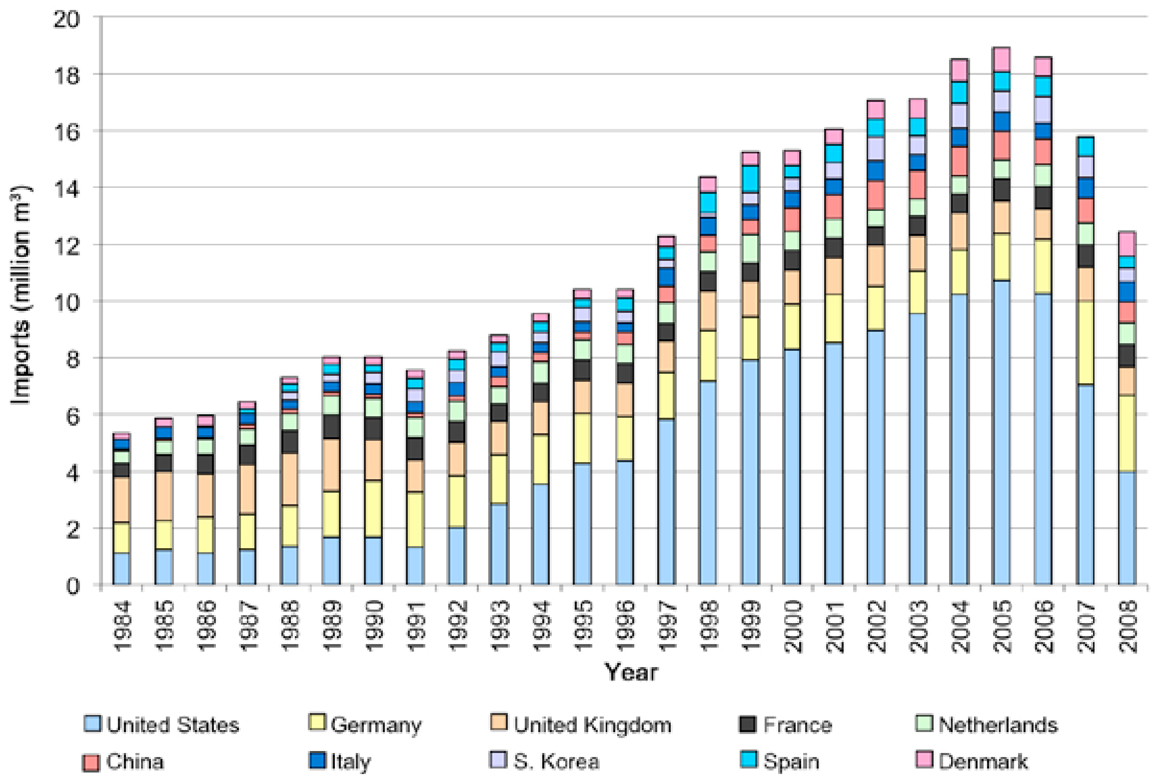


Figure 18. Top particleboard import markets, 1984–2008. (Source: FAOSTAT n.d.)

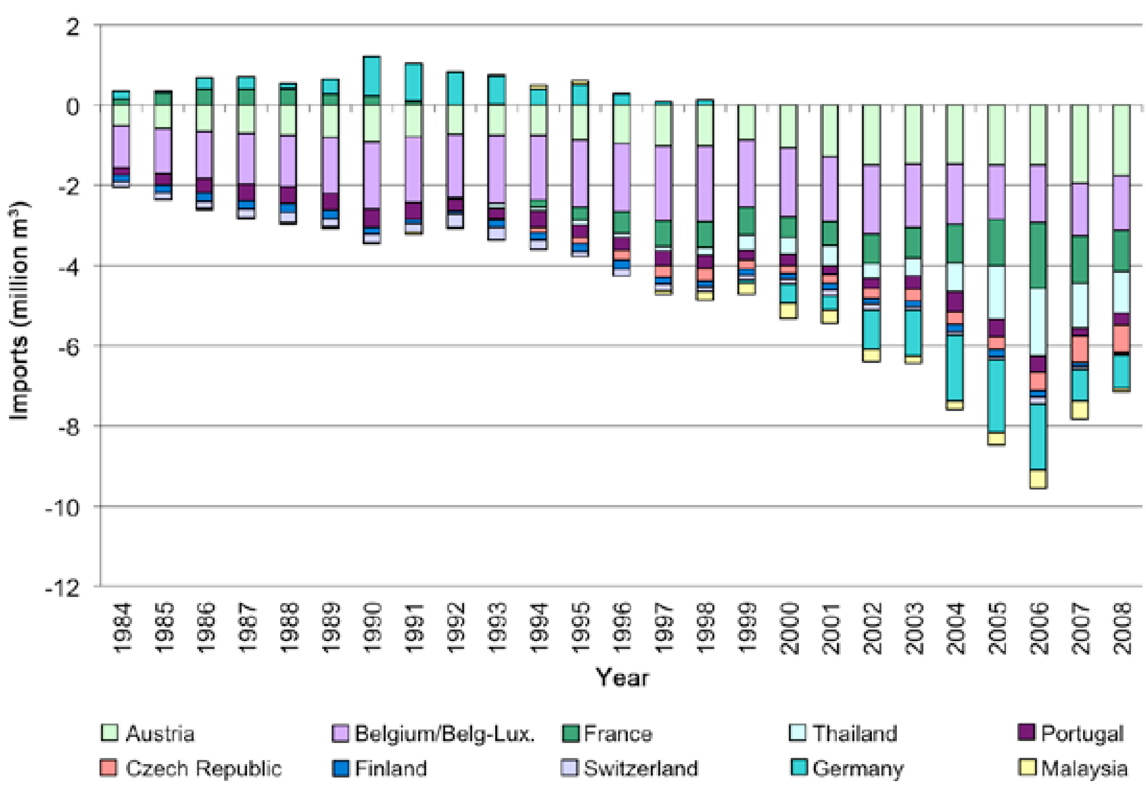


Figure 19. Top net exporters of particleboard in Europe and Asia, 1984–2008. (Source: FAOSTAT n.d.)

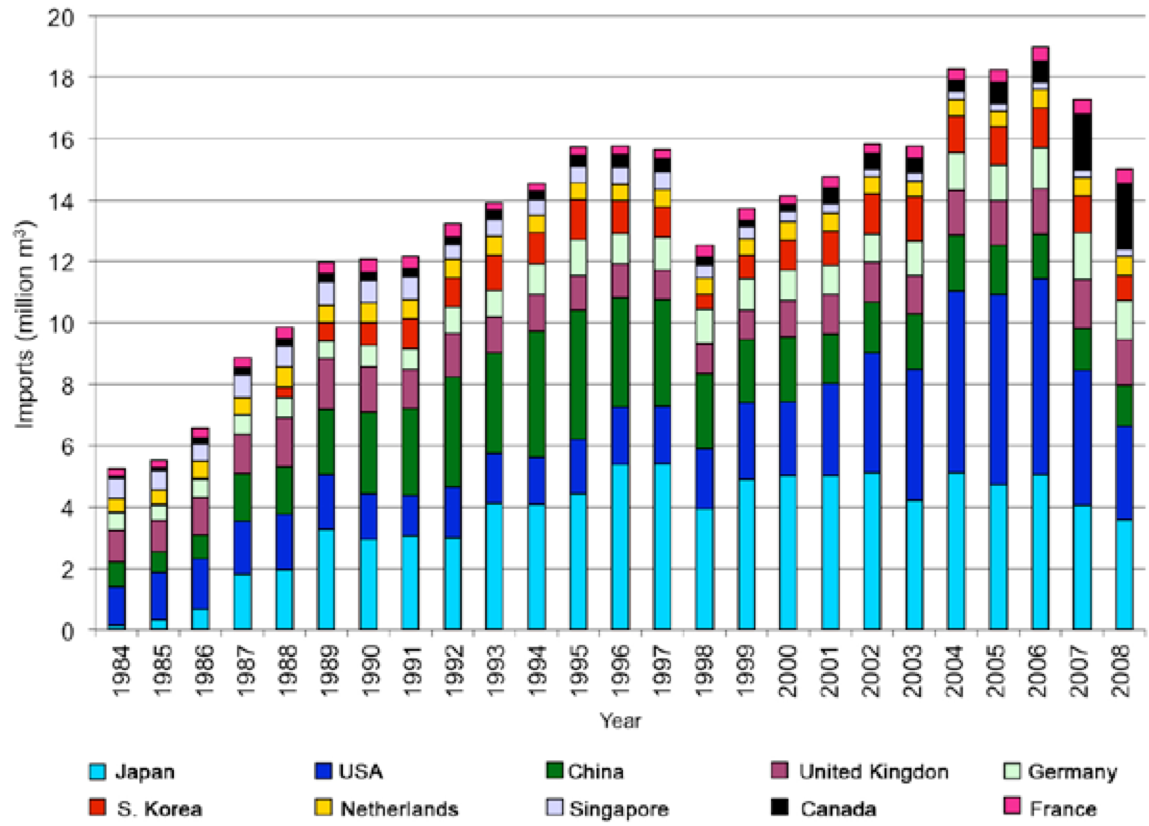


Figure 20. Top plywood import markets, 1984–2008. (Source: FAOSTAT n.d.)

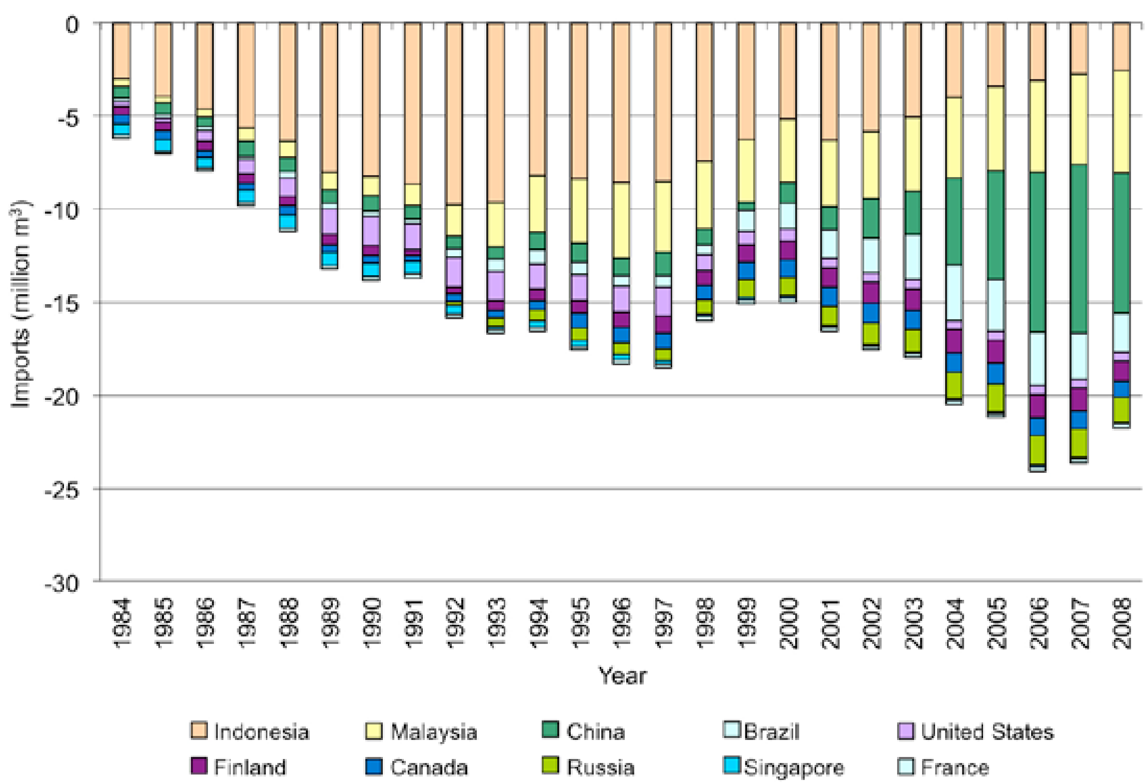


Figure 21. Top exporters of plywood, 1984–2008. (Source: FAOSTAT n.d.)

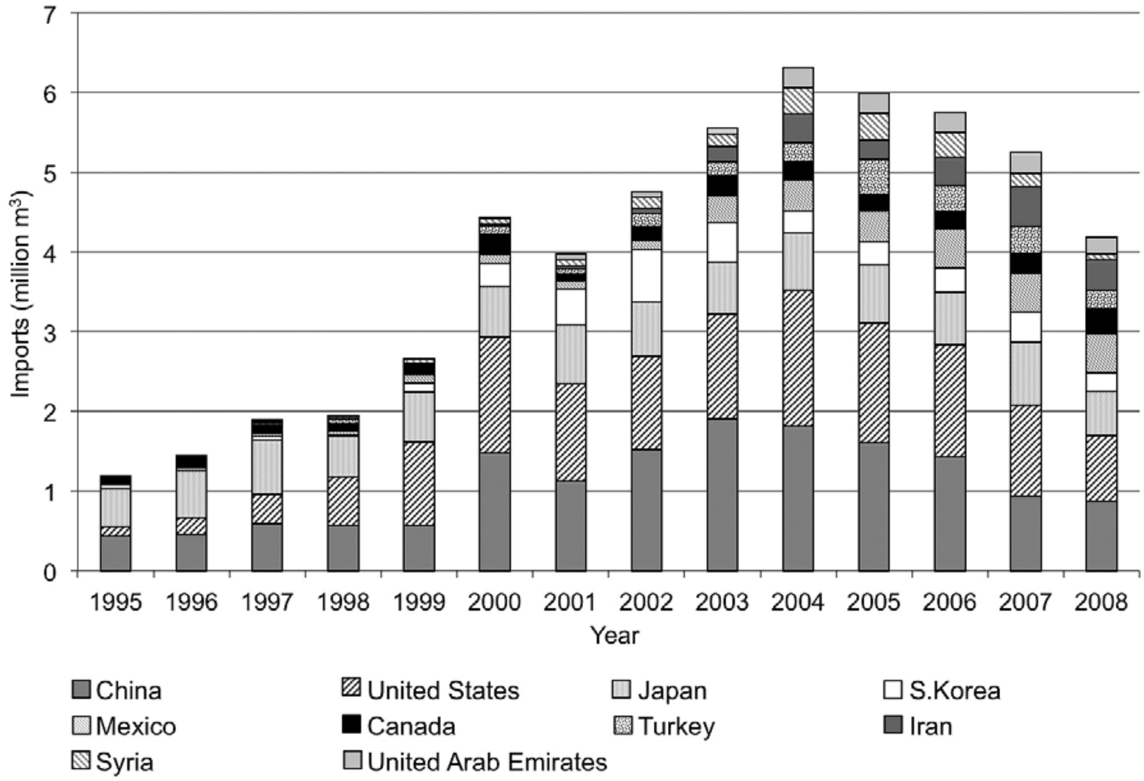


Figure 22. Regions with net import of medium-density fibreboard, 1995–2008. (Source: FAOSTAT n.d.)

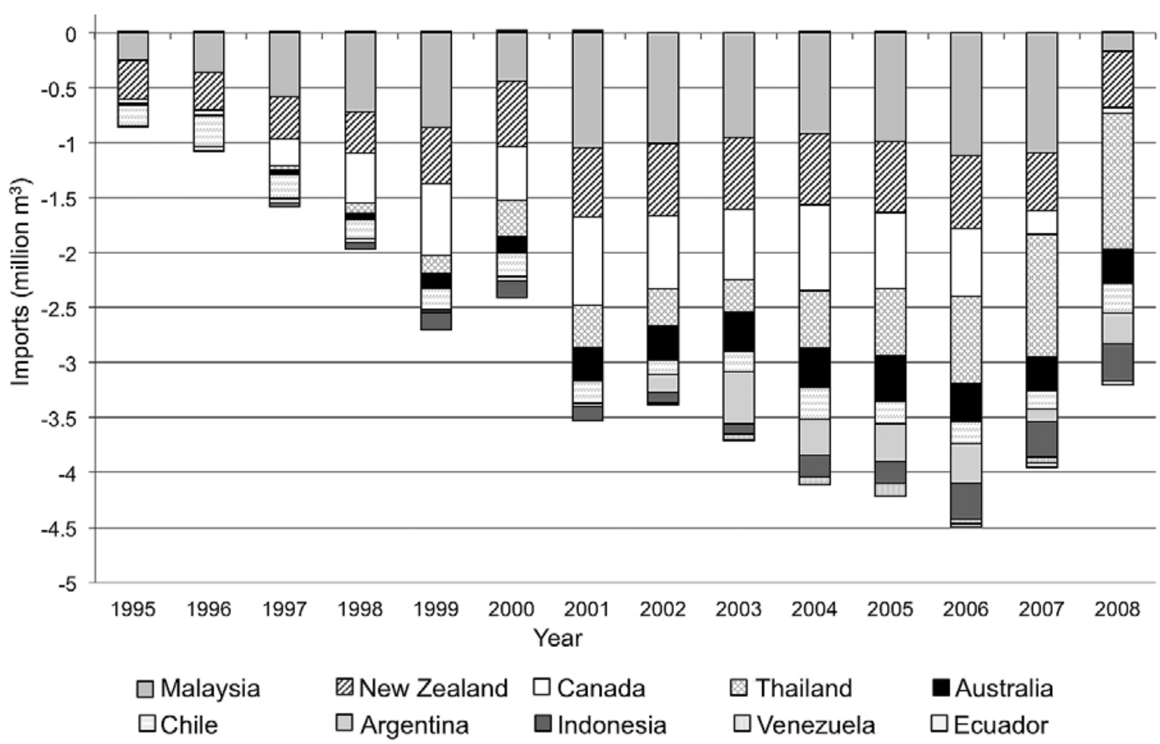


Figure 23. Regions that are net exporters of medium-density fibreboard, 1995–2008. (Source: FAOSTAT n.d.)

In summary, the United States still remains the best market opportunity for western Canadian producers. China's market has seen rapid growth and is now an important market for lumber, but is modest in comparison to historic sales to US markets. Opportunities to diversify our markets for sawnwood (lumber) and panel products are limited. The constraints include stagnant or even declining wood markets, physical location (e.g. northern Africa and the Middle East), and increased competition from Chile, Brazil, the Russian Federation, and China (although mostly in panels). As a result, if more lodgepole pine is to be consumed, it will likely be in markets where western Canada has a natural competitive advantage due to geography, as well as in domestic sales and in the US.

5.3 Trends in the United States

The US market is BC's, and Canada's, largest export market for wood products (Figure 24). BC's prospects for using more MPB-killed timber rest largely on competing effectively within the US market *vis-à-vis* the rest of Canada and other competitors for this market. Changes in demand in this market greatly impact the demand for BC-produced wood products, and thus how much lodgepole pine timber can effectively be used for wood products.

Figure 25 shows how the US import market for lumber and panel/plywood increased between 1990 and 2005 before declining abruptly from 2006 to 2009. Throughout this period Canada has been a significant lumber and wood panel supplier to the US, but the relative importance of Canadian supply has been steadily diminishing since about 1996. Appendix Table A2 provides a detailed breakdown of US import demand from 2000 to 2009.

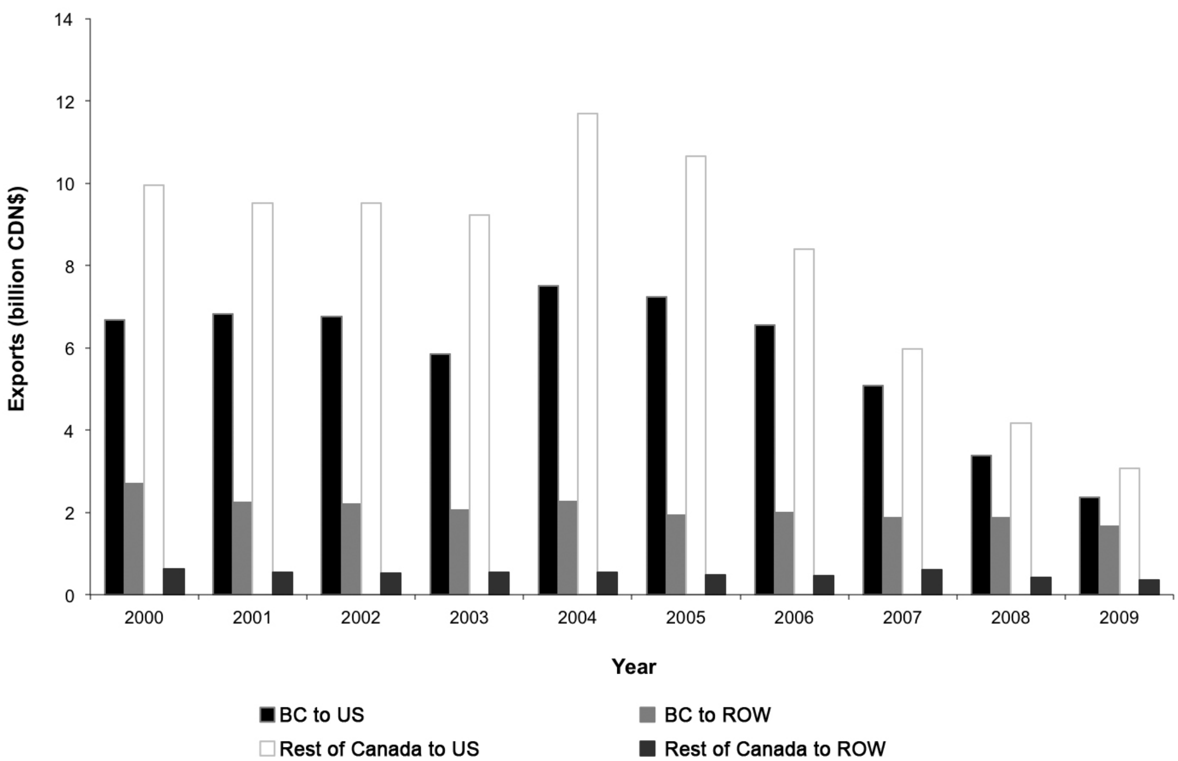


Figure 24. Value of BC's and the rest of Canada's wood product exports by region (billion CDN$), 2000–2009 (product code HS44 – wood and articles made of wood). (Source: Statistics Canada n.d.[b]. Note: "ROW" indicates rest of world (excluding Canada and US).)

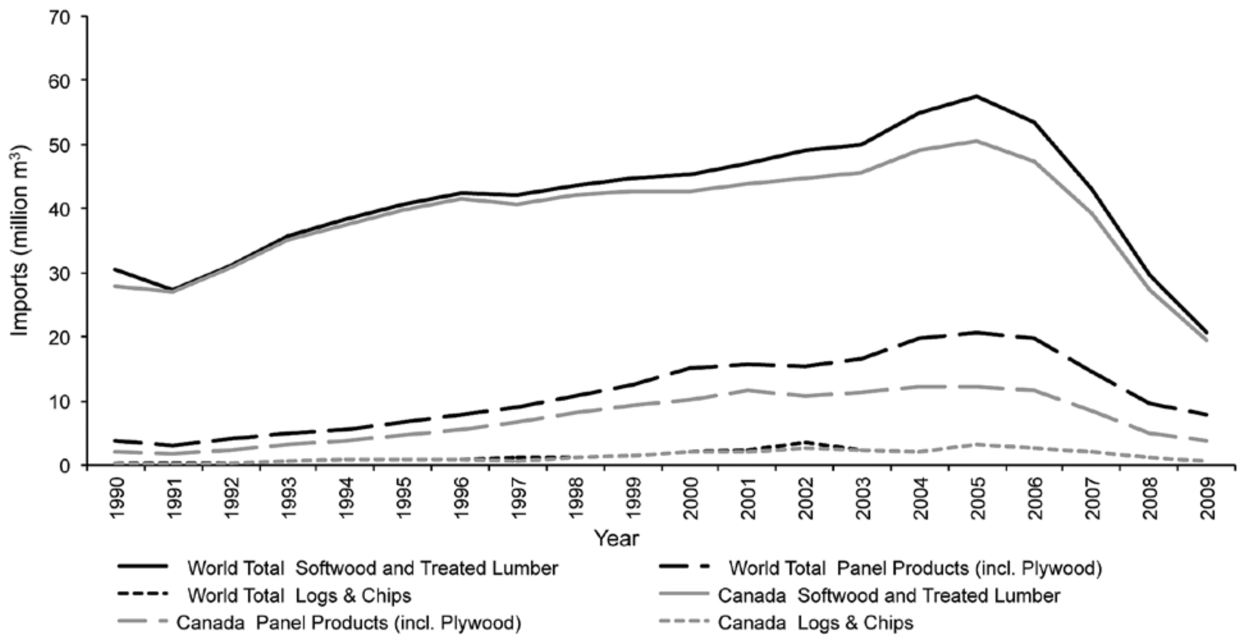


Figure 25. Trends in US imports of major wood aggregates from Canada and the World, 1990–2009. (Source: USDA n.d.)

Generally speaking, the change in US imports for various wood products is reflective of changes in total US demand and US domestic supply. The changes in imports from Canada specifically reflect these two determinants in addition to changes in Canadian domestic demand for wood products and, to a lesser extent, demand in (non-US) overseas markets. Much of the demand for solid wood products is associated with the construction and repair/remodelling of residential buildings. In the United States in 2003, 38% of lumber was consumed in new single- and multi-family houses, 27% in repair and remodelling of residential buildings, 2% in non-residential buildings construction, and 33% in non-building uses such as in manufacturing and industrial uses, packaging, and shipping (Spelter et al. 2007). As a consequence of a very strong US housing market during the majority of the last decade, demand was also very strong for Canadian and BC wood products (Figures 24–25, Appendix Table A2).

Figure 26 shows changes in the volume of US imports relative to changes in US housing starts. As Figure 26 shows, US imports from Canada correspond closely with changes in new housing construction (lumber and OSB/waferboard), while other products such as treated lumber and moldings (shaped wood) are not as closely related. This reflects the different end-use demand for wood products, such as renovations versus repairs and maintenance in residential buildings and industrial uses. It also reflects changes in Canadian competitiveness within the US market compared to other supply regions due to things like production costs, exchange rates, bilateral tariffs, and shifts in consumer preferences. For example, Canadian suppliers of MDF, plywood, softwood flooring, prefabricated buildings, and builder's carpentry have lost considerable market share in the US market over the 2000–2009 period (Appendix Table A2).

From a western Canadian perspective, different regions of the US market have varying importance across different product markets. For most product markets, the Pacific Northwest market is BC's most important market, especially for lower-value or bulky products such as chips, logs, sawdust, energy products, mouldings, dowelling and posts. There are a few notable exceptions. The US South is a growing market for BC's treated lumber and siding, even though the siding market as a whole is decreasing. The Midwest and Northeast US markets are strong markets for all non-OSB panel products.

In 2011, demand for all wood products in the United States is expected to increase marginally from the lows of 2009 and 2010, taking into account a continued weak housing market and a relatively slow recovery from the recession. Demand is expected to increase further in 2012. These expectations rest on higher US housing forecasts and higher levels of housing renovations and repair expenditures. The National Association of Home Builders is forecasting housing starts of 688 000 units in 2011 and just over 1 million in 2012, up from starts of 586 000 in 2010 (NAHB 2011). This forecast is slightly more optimistic than that of the Mortgage Bankers Association, who are forecasting starts of 616 000 units in 2011 and 860 000 units in 2012 (MBAA 2011). Harvard University's Joint Center for Housing Studies expects that remodelling and renovation activity (residential investment) will steadily increase by about 3% per year over the next 5 years (JCHS 2011a).

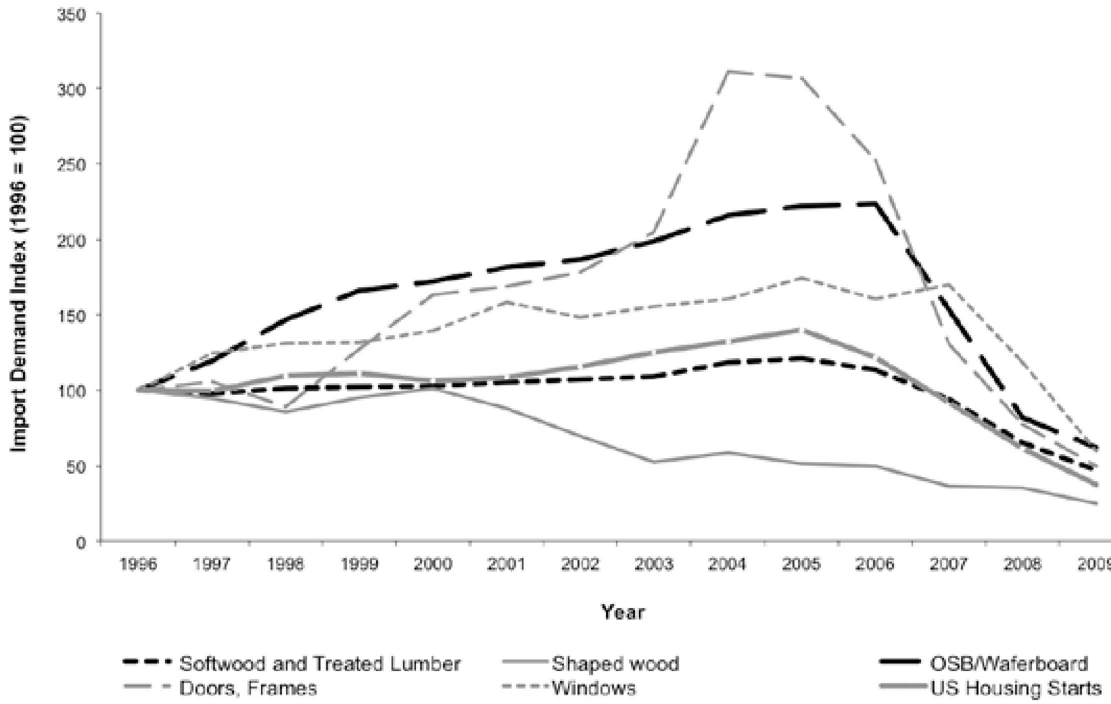


Figure 26. Changes in US import demand for Canadian wood products relative to US housing starts, 1996 to 2009. Index: 1996 = 100. (Sources: USDA n.d. and US Department of Commerce n.d.)

The outlook beyond 2012 is difficult to predict. Major regional and world events can have significant impacts on markets, as witnessed over the past three years in North America and around the world. Longer-term wood demand is largely driven by major demographic and income trends. For the US housing market, some of the most important drivers of long-term demand are immigration and natural population changes. These demographic factors are carefully studied by researchers and analysts, and forecasts are integrated into housing and wood demand projections.

Forecasts that look far into the future are few. One recent forecast by the USDA Forest Service projects that softwood lumber demand in the US will be about 58 and 61 billion board feet (or 137 and 144 million m^3) in 2020 and 2030 respectively (Haynes et al. 2007). This level of consumption corresponds to import demand of 23.5 and 25.2 million board feet (or 55.5 and 59.5 million m^3) in 2020 and 2030 respectively. The 2020 forecast is less than the peak demand levels reached in 2004–2005 (58 million m^3) during the US housing bubble (see Table 2A in Appendix 1).

As noted above, much of the demand for lumber is derived from the need to build and repair residential buildings; primarily, single family homes. This source of demand makes up about 60% of the total demand expected in the USDA Forest Service projections (Haynes et al. 2007). These expectations are derived from studies such as The State of the Nation's Housing reports conducted by Harvard University's Joint Center for Housing Studies (JCHS), which project the number of new households based on demographic trends. Housing starts in the US are expected to remain weak relative to pre-recession levels, and forecasts also anticipate that a large proportion of new households will be characterized by lower incomes than in the recent past (JCHS 2009). This may create a trend toward smaller houses that consume less wood per new housing unit. Household projections from JCHS before and after the global recession decreased from 1.46 million households per year to 1.25 million households per year respectively (JCHS 2007, 2009). The most recent JCHS projection anticipates household formation of 1.25 to 1.46 million households per year over the next 10 years, which will support annual demand for new housing completions of 1.7 to 1.9 million units per year (JCHS 2011b). Despite the expected need for more housing units, the type of housing chosen by new households (new house versus old, house versus apartment, large versus small) will depend on the price of housing alternatives and people's ability and willingness to pay. A significant change in the variety of housing demanded in the US market could have a dramatic impact on the amount of wood products demanded and the robustness of long-term forecasts such as those by Haynes et al. (2007). Given the state of the US and global economies, it is unclear whether past housing trends, such as more and larger single-family homes (see Howard 2007), will continue into the future. This casts uncertainty on long-term forecasts of lumber and wood panel demand that were conducted before the current economic crisis.

5.4 Discussion: Market Opportunities

There is no single measure or indicator of the potential for greater volumes of salvage pine to be absorbed into global wood product markets. One measure is to look at total global imports of softwood products. This ignores existing market competition and assumes products from salvaged pine are perfect substitutes for other existing softwood products. As such, this approach overestimates the potential demand for expanded supply from salvaged pine. An alternative measure is to take past growth, assume it will continue into the future, and use it as a basis for the potential of western Canada's pine products to find a market. This side-steps the issue of incumbent suppliers, it assumes these pine products can fulfill growth in demand over the coming years, and involves basing expectations on a forecast of future conditions.

It is difficult to forecast demand, and forecasted results are uncertain. Forecasts involve many assumptions that may not be tenable. First, forecasting involves the assumption that roundwood production in other regions of the world remains constant. This is unlikely to be the case because The Russian Federation, Australia, and the southern cone countries of Chile, Argentina, and Uruguay are expected to increase production of softwood products. Second, it assumes that salvaged pine produces products with similar characteristics demanded by the market. For some wood products this may be a reasonable assumption, but not for others. Third, it assumes that salvaged pine products are cost competitive with products from other supply regions, though this is unlikely given the many factors that affect trade such as transportation costs, currency values, and language. Finally, it assumes future growth will continue as it has in the past. However, the current global recession and severe downturn in the US market underscores the pitfalls associated with such assumptions, especially with short-term projections (1–3 years).

Forecasting issues aside, the prospects for using more salvaged lodgepole pine timber to produce products for non-North American markets are challenging. Reflection on recent inter-regional trade flows reveals that most market opportunities for increased BC exports are for traditional products such as lumber, roundwood, panels, and chips.

The biggest opportunity in terms of volume is in the export of logs to China, especially if the Russian Federation implements significant additional export taxes on logs. The Russian government was scheduled to impose an 80% log export tax on softwood logs (not less than EUR 50 per m^3 of wood) on January 1, 2010; however this has been delayed. The current tax rate is 25% (or not less than EUR 15 per m^3 of wood). But this may not occur, at least not in the context of log exports between the EU and the Russian Federation: an agreement was recently announced between the Russian Federation and the EU that will see the existing tax eliminated for the EU if the Russian Federation successfully becomes a WTO member (Reuters 2010). It is still unclear whether this agreement would extend to other WTO members such as China. If it did, the elimination of the tax will certainly reduce BC's log export opportunity. Even if the 80% tax is fully implemented, export opportunities are limited given the low value and bulkiness of logs. There are also other challenges: for example, even if export to these regions was economical, there may be issues surrounding phytosanitary concerns and provincial policy encouraging domestic manufacturing of timber (*BC Forest Act,* sections 127–129 [Province of BC 2011]) that need to be addressed before this opportunity could be realized.

The Asian, African, and Mexican lumber markets may be reasonable opportunities for exports from western Canadian producers, since Canadian producers are already strategically oriented toward lumber. The markets with the largest increases in consumption have been China and Mexico. But, again, western Canadian exporters must compete with other supply regions such as the Russian Federation, the US Pacific Northwest (and the US South in terms of the Mexican market), Chile, and New Zealand, all of which have geographical advantages over the BC Interior and Alberta (see ITTO [2009] for a breakdown of Chinese lumber imports). Canadian exporters also compete with Chinese sawmills that source logs from within China and around the world, especially from the Russian Federation and New Zealand. The imposition of the Russian log export tax certainly increased the competiveness of BC lumber in the Chinese market. An increase in the Russian log tax from 25 to 80% would improve the prospects of growth in BC exports to China. But an extension of the proposed elimination of the tax between the Russian Federation and EU to China would certainly dampen demand for BC lumber. Another outstanding issue with the Chinese market is its price sensitivity, which could become problematic if lumber prices begin to rise significantly. While BC exports to China have increased markedly over the past few years, this has occurred while prices decreased due to depressed market demand in North America and Japan (see Table 8). Therefore, it is unclear whether the recent upward trend of Chinese demand will continue when prices begin to increase. Other growing lumber markets are located in North Africa and the Mediterranean region. Specifically demand

Table 8. BC lumber exports to China and Japan, 2000 to 2009 (m^3 and CDN$). (Source: Statistics Canada n.d. [b])

			2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
China	Quantity (m^3)	Spruce-pine-fir lumber	17 254	18 616	26 710	45 755	59 291	38 065	83 272	343 347	832 669	1 942 977
		Cedar lumber	3828	8650	15 542	33 722	50 285	52 753	80 442	80 703	68 858	56 504
		Other softwood lumber	31 154	63 314	109 018	125 745	145 915	159 313	165 918	212 900	255 630	519 438
	Value (1000 CDN$)	Spruce-pine-fir lumber	4064	3874	5493	8631	8227	6674	9549	32 209	105 745	212 388
		Cedar lumber	1197	3563	7832	13 343	20 583	18 534	26 293	27 953	26 005	19 937
		Other softwood lumber	6012	11 720	18 784	23 512	27 272	28 770	28 776	37 812	45 456	85 159
	Average Price (CDN$/$m^3$)	Spruce-pine-fir lumber	223	207	201	182	139	203	119	96	127	118
		Cedar lumber	345	403	556	470	461	351	327	326	343	344
		Other softwood lumber	307	325	317	302	292	299	246	257	246	189
	Quantity (m^3)	All lumber types	52 236	90 580	151 270	205 222	255 491	250 131	329 632	636 950	1 157 157	2 518 919
	Value (1000 CDN$)		11 272	19 157	32 109	45 486	56 082	53 978	64 618	97 974	177 206	317 483
	Average Price (CDN$/$m^3$)		303	328	359	326	312	301	250	255	252	216
Japan	Quantity (m^3)	Spruce-pine-fir lumber	1 445 639	1 479 455	1 539 553	1 547 643	1 747 567	1 555 576	1 891 452	1 774 686	1 793 461	1 332 895
		Cedar lumber	308 600	259 342	239 271	252 671	249 743	210 389	235 380	166 488	163 312	109 090
		Other softwood lumber	2 618 052	2 121 055	1 832 606	1 609 957	1 916 728	1 432 222	1 310 135	838 024	747 794	536 576
	Value (1000 CDN$)	Spruce-pine-fir lumber	454 779	428 184	388 789	366 029	457 148	389 733	462 297	394 599	397 231	275 235
		Cedar lumber	207 279	174 705	156 590	153 461	140 466	111 234	98 718	76 270	71 778	55 885
		Other softwood lumber	1 019 367	801 463	692 712	577 422	665 395	465 561	419 452	260 987	248 678	198 000
	Average Price (CDN$/$m^3$)	Spruce-pine-fir lumber	331	289	359	289	263	254	247	224	220	218
		Cedar lumber	676	676	634	554	634	547	471	519	536	602
		Other softwood lumber	463	470	482	498	483	431	450	353	360	397
	Quantity (m^3)	All lumber types	4 372 291	3 859 852	3 611 430	3 410 271	3 914 038	3 198 187	3 436 967	2 779 198	2 704 567	1 978 561
	Value (1000 CDN$)		1 681 425	1 404 351	1 238 092	1 096 913	1 263 008	966 529	980 466	731 856	717 687	529 120
	Average Price (CDN$/$m^3$)		485	494	500	486	494	437	434	375	374	423
Total Quantity (m^3)			4 424 527	3 950 432	3 762 700	3 615 493	4 169 529	3 448 318	3 766 599	3 416 148	3 861 724	4 497 480
Total Value (1000 CDN$)			1 692 697	1 423 509	1 270 201	1 142 399	1 319 090	1 020 507	1 045 084	829 830	894 893	846 604
Total Average Price (CDN$/$m^3$)			424	429	439	421	407	371	345	316	314	317

has been rising in the oil-producing states of Saudi Arabia, Iran, and Algeria (USDA FAS 2006). However, these markets are small, are far from BC, and are currently supplied by many regions (Europe, Latin America, and Oceania).

Opportunities for non-primary products are, again, very limited. Asia and Africa are net importers of many board and panel products, but again these markets are small and challenging in terms of volume. One of the challenges relates to global furniture production and consumption trends (Kaplinsky et al. 2003). Recent trends in the globalization of this industry and, in particular, its spread to countries that pay workers relatively low wages (Ince et al. 2007) has resulted in many of these countries expanding production and/or importation of MDF and hardboard, both of which are used in furniture construction. The growing global demand for furniture and the increased globalization of the furniture industry pose both a challenge and an opportunity for western-Canadian producers. There is an opportunity to direct more solid wood products derived from lodgepole pine into the global furniture supply chain system. The challenge is to be cost competitive. Therefore, BC and Alberta likely have two options. One is to supply inexpensive (low-margin and mass-produced) products to existing furniture supply chains producing furniture for the low- to middle-cost segment of the furniture market. The other is to produce high-quality wood products (specialty products that are not mass produced) or complete articles of furniture for higher-cost furniture markets, in order to compensate for high labour costs and a longer distance to final market. In either case, the amount of wood volume that could be consumed through these product channels is likely minor, and it is unclear whether salvaged pine timber is the best source of wood for such opportunities.

Given the challenges of selling in markets outside of North America, some of the biggest opportunities for western Canadian products remain in the US market. But the ability of markets (other than lumber and panel markets) to absorb a large increase of products sourced from BC's Interior pine forests are unclear due the relatively small size of these markets. For lumber and panel opportunities, any significant increase in BC production and exports into the North American market may lead to significant impacts on market prices and market shares in the absence of contemporaneous growth in market demand. Such impacts could result in increased trade tensions and reduced net benefits from increased lumber and panel production. Thus the opportunity to use increased volumes of salvaged pine may exist, but is dependent on the future growth of lumber and panel demand. Looking forward, it is not clear if or when the US demand for imported wood products will reach the levels observed from 2004 through 2006 again (when the US market hit 20-year record highs in single-family construction, median house size, and spending on renovations and repairs) (Table 9).

In summary, producers in BC and Alberta face severe challenges when attempting to find market demand for products derived from salvaged lodgepole pine. Even if the wood product sector is successful in expanding market shares in traditional and non-traditional markets, the market opportunities are limited in terms of volume of wood and are not likely to absorb all of the available wood supply. Any significant expansion into non-traditional markets will likely involve taking market share away from existing suppliers, and will require offering comparable products for reduced prices or offering differentiated products for similar prices. Either way there are considerable challenges for western Canadian wood product exporters who want to expand into these markets, due to cost and location disadvantage in comparison to other supply regions.

Table 9. Historical US housing statistics, 1990–2009. (Sources: US Census n.d. and *US Department of Commerce n.d)

	Total housing starts (thousands)	Single family starts (thousands)	Median size of completed single family houses (ft^2)	Average size of completed single family houses (ft^2)	Residential investment* (Billion US$[2005])
1990	1192.7	894.8	1905	2080	349.0
1991	1013.9	840.4	1890	2075	397.3
1992	1199.7	1029.9	1920	2095	429.7
1993	1287.6	1125.7	1945	2095	471.5
1994	1457.0	1198.4	1940	2100	456.1
1995	1354.1	1076.2	1920	2095	492.5
1996	1476.8	1160.9	1950	2120	501.8
1997	1474.0	1133.7	1975	2150	540.4
1998	1616.9	1271.4	2000	2190	574.2
1999	1640.9	1302.4	2028	2223	580.0
2000	1568.7	1230.9	2057	2266	583.3
2001	1602.7	1273.3	2103	2324	613.8
2002	1704.9	1358.6	2114	2320	664.3
2003	1847.7	1499.0	2137	2330	729.5
2004	1955.8	1610.5	2140	2349	775.0
2005	2068.3	1715.8	2227	2434	718.2
2006	1800.9	1465.4	2248	2469	585.0
2007	1355.0	1046.0	2227	2521	451.1
2008	905.5	622.0	2215	2519	444.2
2009	554.0	445.1	2135	2438	342.7
2010	586.8	471.1	2168	2391	332.4

6. Conclusions

The immense scale of the mountain pine beetle outbreak in western Canada has created a web of interrelated forest management and economic challenges for the region. For the landowner, the natural response to such an outbreak is to salvage as much of the value of the dead pine as possible in light of market and forest stewardship objectives. However, the salvage-harvesting scale is such that its impacts are incredibly far reaching. How much so is a difficult question to answer.

A comprehensive understanding of the ramifications of current and future responses to the MPB outbreak, while likely elusive, is an important goal for the research community, policymakers, industry, and other stakeholders. The MPB epidemic is now declining in much of BC; however, its more recent spread into northeast BC and Alberta is raising similar questions in new jurisdictions. In addition to the ongoing challenges presented by the MPB outbreak, the issues we have discussed here will be relevant to future large-scale forest disturbances within and outside of the current area of MPB infestation.

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Appendix 1. Annual Allowable Cut in British Columbia, 2000 to 2009.

Table A1. Annual Allowable Cut (AAC) by district and region, 2000 to 2009. (Sources: BCMFR 2010a and 2010b)

Region	District	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Coast	Cambell River	4 351 010	4 284 150	4 258 500	4 267 620	4 251 660	4 222 255	3 987 203	3 963 098	3 960 818	3 946 058
	Chilliwak	1 328 755	1 328 755	1 328 755	1 328 965	1 328 965	1 328 965	1 328 965	1 328 965	1 328 965	1 328 965
	N. Island Central Coast	5 855 744	5 839 270	5 724 270	5 724 330	5 724 330	5 717 235	5 239 527	5 117 417	5 117 417	5 096 177
	North Coast	1 082 980	1 056 604	972 904	1 002 664	950 584	909 354	829 730	730 460	723 020	723 020
	Queen Charlotte	1 568 650	1 544 600	1 544 600	1 544 600	1 544 600	1 530 625	1 464 618	1 464 618	1 464 618	1 464 618
	South Island	2 872 700	2 872 700	2 820 050	2 410 463	2 425 466	2 412 831	2 41 2831	2 411 189	2 429 479	2 545 391
	Squamish	756 500	756 501	756 502	756 503	753 504	753 505	753 506	753 507	753 508	753 509
	Sunshine Coast	1 781 365	1 772 485	1 772 485	1 772 815	1 772 815	1 767 655	1 718 215	1 721 215	1 721 215	1 721 215
Coast Total		19 597 704	19 455 065	19 178 066	18 807 960	18 751 924	18 642 425	17 734 595	17 490 469	17 499 040	17 578 953
North	Fort Nelson	1 500 000	1 500 000	1 500 000	1 500 000	1 500 000	1 500 000	1 625 000	1 625 000	1 625 000	1 625 000
	Kalum	2 625 000	2 625 000	2 300 000	2 272 884	2 272 884	2 132 884	2 132 884	2 132 884	2 201 884	2 201 884
	Mackenzie	3 050 000	3 050 000	3 050 000	3 050 000	3 050 000	3 050 000	3 050 000	3 050 000	3 050 000	3 050 000
	Nadina	3 485 815	4 947 815	4 923 117	4 923 117	5 123 117	5 123 117	5 123 117	5 123 117	5 327 000	5 327 000
	Peace	4 262 033	4 328 033	4 328 033	4 555 000	4 555 000	4 555 000	4 555 000	4 875 000	4 875 000	4 875 000
	Prince George	9 953 661	9 953 661	12 834 000	12 814 000	15 511 000	16 154 000	16 154 000	16 154 000	15 493 000	15 493 000
	Skeena Stikine	2 497 611	2 497 611	2 389 611	2 274 000	2 274 000	2 274 000	2 274 000	2 274 000	2 274 000	2 274 000
North Total		27 374 120	28 902 120	31 324 761	31 389 001	34 286 001	34 789 001	34 914 001	35 234 001	34 845 884	34 845 884
South	Arrow Boundary	2 155 000	2 155 000	2 185 000	2 185 000	2 185 000	2 185 000	2 185 000	2 185 000	2 185 000	2 196 000
	Cascades	2 647 770	2 151 570	2 143 950	2 474 650	2 474 650	3 450 071	3 450 071	3 450 071	3 448 071	3 384 171
	Central Cariboo	3 807 000	3 807 000	3 807 000	3 768 000	3 768 000	3 768 000	3 768 000	5 770 000	5 770 000	5 770 000
	Columbia	950 000	950 000	950 000	950 000	905 000	905 000	905 000	905 000	905 000	905 000
	Headwaters	602 377	602 377	602 377	602 377	602 377	602 377	536 000	536 000	536 000	536 000
	Kamloops	2 986 830	2 982 430	2 982 430	2 986 020	4 856 020	4 856 020	4 968 370	4 968 370	4 681 600	4 681 600
	Kootenay Lake	700 000	700 000	681 300	681 300	681 300	681 300	681 300	681 300	681 300	681 300
	Okanagan Shuswap	3 016 000	3 056 000	3 056 000	3 056 000	3 056 000	3 256 000	3 976 000	3 976 000	3 976 000	3 976 000
	Quesnel	3 239 000	4 161 000	4 161 000	4 161 000	6 193 000	6 220 000	6 220 000	6 220 000	6 150 000	6 280 000
	Rocky Mountains	1 601 500	1 612 570	1 612 570	1 612 570	1 682 570	1 732 570	1 732 570	1 732 570	1 682 570	1 682 570
	100 Mile House	1 362 000	1 362 000	1 334 000	1 334 000	1 334 000	1 334 000	2 000 000	2 000 000	2 000 000	2 000 000
South Total		23 067 477	23 539 947	23 515 627	23 810 917	27 737 917	28 990 338	30 422 311	32 424 311	32 015 541	32 092 641
Grand Total		70 039 301	71 897 132	74 018 454	74 007 878	80 775 842	82 421 764	83 070 907	85 148 781	84 360 465	84 517 478

Table A2. Volume of US imports of wood products, 2000 to 2009. (Source: USDA FAS n.d.)

Product	Source	Units	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Builders Carpentry	World	No.	12 343 306	13 011 678	14 052 572	15 385 872	21 939 559	24 580 486	22 736 169	21 893 690	14 873 369	7 913 686
	Canada		5 789 431	6 005 758	6 312 312	7 231 497	10 842 411	10 720 092	8 849 512	4 733 051	2 836 813	1 794 564
Softwood Logs	World	m^3	1 736 200	1 785 858	2 103 193	1 936 885	1 720 836	2 760 731	2 315 039	1 725 201	846 594	405 636
	Canada		1 643 170	1 739 385	2 064 467	1 915 357	1 711 539	2 740 634	2 243 252	1 719 471	841 654	402 550
Softwood Lumber	World	m^3	45 296 123	46 825 556	49 044 796	49 801 561	54 857 090	57 303 068	53 440 391	42 955 333	29 541 433	20 587 779
	Canada		42 727 253	43 667 044	44 655 327	45 403 105	49 139 215	50 367 707	47 241 082	39 109 012	27 171 425	19 370 480
Hardboard	World	m^3	521 112	672 459	791 378	908 853	1 237 777	1 417 573	1 445 305	1 182 919	710 094	453 529
	Canada		140 126	184 523	200 900	252 743	372 242	405 606	393 755	502 765	350 035	127 599
Medium Density	World	m^3	3 365 992	3 108 176	2 439 692	2 682 596	3 306 813	3 460 320	3 364 443	2 767 649	2 235 393	2 000 132
Fiberboard	Canada		1 143 828	1 399 458	1 336 007	1 345 266	1 525 266	1 401 055	1 304 976	1 108 729	785 674	631 561
OSB/waferboard	World	m^3	6 753 520	7 167 679	7 499 181	8 044 403	8 723 891	9 341 730	8 973 487	5 999 193	3 190 510	2 412 901
	Canada		6 723 554	7 095 903	7 289 644	7 776 666	8 429 334	8 684 550	8 748 171	5 998 117	3 188 918	2 411 965
Other Panel	World	m^3	1 654 843	1 414 700	1 048 147	959 847	964 359	1 321 124	1 310 772	819 193	562 889	412 298
Products	Canada		323 933	430 629	453 622	345 992	364 449	399 951	391 877	282 649	212 309	166 529
Particleboard	World	m^3	1 979 191	2 357 208	1 365 041	1 472 459	1 411 813	1 284 653	1 050 541	900 350	708 162	597 914
	Canada		1 496 221	2 226 253	1 192 589	1 280 448	1 187 996	1 049 539	761 062	744 575	621 505	545 292
Prefabricated	World	No.	74 951	52 171	60 204	153 714	78 172	104 474	188 051	119 536	102 785	57 213
Buildings	Canada		56 623	24 059	35 210	26 681	30 203	29 815	30 060	24 944	10 325	7 691
Pulpwood	World	m^3	64 612	28 471	52 790	126 285	145 641	259 528	121 573	93 854	153 490	156 531
	Canada		64 612	28 471	51 772	119 603	142 262	259 312	108 271	84 589	136 217	156 529
Railroad Ties	World	m^3	56 997	38 671	117 862	97 708	51 600	86 212	59 336	42 400	40 397	23 167
	Canada		56 206	36 661	113 841	94 457	47 956	82 020	55 569	40 052	38 239	20 939
Softwood Chips	World	t*	209 359	85 837	47 165	179 814	64 823	89 857	53 476	14 121	27 598	20 921
	Canada		209 308	85 218	44 290	164 708	64 751	89 856	52 246	13 387	17 051	20 444
Softwood Flooring	World	m^2	300 020	380 338	513 143	819 233	1 989 867	2 537 726	1 530 511	1 380 823	635 624	259 351
	Canada		66 871	9 294	22 810	9 180	25 073	9 811	11 554	5 664	3 974	5 217
Softwood Plywood	World	m^3	373 835	612 135	820 965	1 172 308	1 822 854	2 164 658	1 650 781	958 739	674 921	552 077
	Canada		253 045	383 063	431 890	458 341	461 202	463 642	371 621	290 139	161 387	99 857
Softwood Siding	World	m^3	202 500	164 750	138 038	124 301	127 235	124 600	99 176	81 543	76 005	51 340
	Canada		200 167	163 808	136 155	117 460	120 940	107 212	97 079	75 190	71 034	48 061
Softwood Veneers	World	m^2	172 716 153	194 838 691	221 568 982	224 323 494	295 512 893	326 304 257	292 289 077	162 805 998	119 054 292	97 503 570
	Canada		160 144 872	186 813 987	203 397 118	200 520 842	263 486 799	283 498 774	251 127 510	160 092 523	117 215 608	96 709 071
Treated Lumber	World	m^3	95 285	102 903	97 942	59 986	60 047	71 460	44 924	39 550	63 783	95 532
	Canada		88 444	90 351	82 114	53 735	55 032	60 577	35 230	22 033	59 016	85 281
Wood Packing	World	No.	54 553 789	45 324 100	43 625 432	45 450 371	42 557 359	49 518 078	41 547 922	41 946 146	31 496 157	24 832 592
Material	Canada		39 918 752	29 938 649	33 750 035	34 314 204	34 697 016	35 199 192	30 920 338	30 939 438	22 480 831	17 068 875

* 't' refers to metric tonnes (1000 kg).

Appendix 2. Summary of Empirical Market Studies

The information presented here is derived from an extensive review of the recent literature (1990–2010) on demand and supply of wood products. From this review we have sought to identify the magnitude of the relevant elasticity measures and to highlight the range of values that are found across studies. Clearly, a wide variation exists among these estimates due to the difference in the problems addressed, theoretical and empirical methodologies, time periods, and types of data.

Empirical market demand and supply studies are founded on economic theory, where relationships derived from equilibrium conditions predict how changes in supply or demand in one market will affect equilibrium prices in both the output and input markets. The direction and magnitude of changes are summarized by elasticity measures. Elasticity measures are either a principal output of empirical forest product markets studies or an essential input for analytical or simulation market studies.

A.2.1 Price Elasticity of Total Demand for Wood Products

Table A3 indicates the price elasticity of total demand (including both domestic and imported demand) for certain wood products in the US, Canada, EU, and other international markets. The elasticity values are principally estimated for all softwood species and all regions in a country, but in some cases they have been focused on specific regions, species, and end-uses. The estimates for the US price elasticity of aggregate demand for softwood lumber are highly inelastic, falling between -0.08 and -0.38 for the long run and -0.07 and -0.14 for the short run. Estimates at the disaggregate level are more elastic: Nagubadi et al. (2004) and Lewandrowski et al. (1994) report that the price elasticity of demand estimates for different species falls between -0.137 and -1.795. Adams et al. (1992) report price elasticity of demand estimates for different end-uses falling between -0.13 and -1.15. Seldon and Boyd (1991) report price elasticity of demand estimates for different regions falling between -0.2 and -0.36. Nagubadi et al. (2004) also report price elasticity of demand for wood structural panel of -1.161, which is higher than Adams and Haynes's (1996) estimate of -0.59 for OSB.

Gellner et al. (1991) report that the estimate for Canada's long-run price elasticity of demand for lumber is -0.54. In Bernard et al. (1997), the estimates given for Quebec and Ontario are -0.35 and -10.83 respectively. Their estimates for Canada's price elasticity of demand for roundwood fall between -0.12 and -0.7.

For structural panel products, Simangunsong and Buongiorno (2001) report that the value estimates for the price elasticity of total demand for 64 countries fall between -0.18 and -0.39, and -0.07 and -0.14, for the long run and short run respectively. The value estimates for the price elasticity of total demand for unprocessed wood fall between -0.29 and -0.49 in the long run and -0.09 and -0.14 in the short run. Finally, value estimates for the price elasticity of total demand for pulp and paper products range from -0.1 to -0.4 in the long run and -0.09 to -0.18 in the short run, which are relatively higher than McCarthy and Lei's (2010) estimates for pulp and paper.

A.2.2 Price Elasticity of Domestic Demand for Wood Products

Five studies presented in Table A4 provide price elasticity estimates of domestic demand for Canada, China, Japan, EU countries, and the international market.

Kinnucan and Zhang (2004) employ a trade model for Canadian softwood lumber including Canadian domestic demand, US import demand, and import demand for the rest of the world. They report an estimate of Canadian domestic demand elasticity of -0.17. Li et al. (2006) report that the estimate for the price elasticity of domestic demand for paper and paperboard in China is -0.69. Yoshimoto et al. (1999) consider three types of lumber in modeling the Japanese forest sector: Japanese domestic lumber, lumber processed in Japan from logs imported from the US, and imported lumber. They model these types of lumber to investigate possibilities of increasing lumber production in Japan. They report price elasticity of total domestic lumber demand estimates for eight Japanese regions with an un-weighted mean estimate of -0.53.

Kangas and Baudin (2003) report the price elasticity of domestic demand for various wood products in EU countries. Uusivuori and Kuuluvainen (2001) study the substitution between the main categories of imported wood and between imported and domestic wood using a cost–function approach and panel data for the world's 36 most important wood-importing countries. They report an estimate of -0.16 for the price elasticity of domestic demand for wood.

A.2.3 Price Elasticity of Import Ddemand for Wood Products

Eleven studies are summarized in Table A5. For the studies in our review, the estimated long-run price elasticity of the US import demand for Canadian softwood lumber ranges from -0.62 to -1.98, while the short-run estimate is -0.815. Hseu and Buongiorno (1993) further report the elasticity by species. The demand for imports of all species (except for fir) is elastic, and the most price-elastic species are pine (-6.33), hemlock (-3.83), and spruce (-2.76).

Li et al. (2006) estimate the price elasticity of China's demand for imported paper and paperboard to be -0.6. Vincent et al. (1991) estimate the price elasticity of Japanese import demand for North American logs to be -2.46. Mutanen (2006) report the price elasticity of import demand for coniferous sawnwood in Germany. Kangas and Baudin (2003) report the price elasticity of import demand for various wood products in EU countries.

Turner and Buongiorno (2004) estimate the price elasticity of the world import demand for structural panels, and report values that fall between -0.7 and -1.53 for long-run elasticity. For pulp and paper products the estimates fall within the range of -0.48 to -1.2. Finally, world import demand elasticity for roundwood was estimated to be -0.74. Uusivuori and Kuuluvainen (2001) estimate the price elasticity of five categories of industrial roundwood. The elasticity of softwood and wood chips are close to 1 in the short run. The elasticity of wood chips has a positive sign in the long run, which could be attributed to the dominance of Japan and the presence of supply-side effects, according to Uusivuori and Kuuluvainen (2001).

A.2.4 Price Elasticity of Total Supply for Wood Products

Studies that estimated price elasticity of total supply are summarized in Table A6. Price elasticity of total supply for wood products indicates how responsive different supply regions are to change in prices. The literature provides estimates for the Canadian supply elasticity for softwood lumber ranging from 0.09 to 2.41. More specific to British Columbia, estimates of 0.84 for the BC Coast supply elasticity and 0.38 for the BC Interior supply elasticity are reported by Latta and Adams (2000). Values for the United States supply elasticity for softwood lumber range from 0.26 to 0.7. Williamson et al. (2004) estimate the price elasticity of supply for chip in BC to be close to 1.

Brown and Zhang (2005) estimate the supply elasticity for disaggregated paper products in the US. Their estimates range from 0.41 to 2.75 and 0.24 to 1.77 for the long run and short run respectively. Hseu and Buongiorno (1997) report elastic supply for the pulp and paper industry in both the US and Canada. Finally, Bolkesjø et al. (2010) report price elasticity of supply for sawlogs and pulpwood in Norway.

A.2.5 Price Elasticity of Domestic Supply for Wood Products

Studies of domestic supply are summarized in Table A7. Price elasticity of domestic supply for wood products indicates how responsive domestic supply is to change in prices. Imports are controlled for in the calculation. Seven studies are found under this heading. Song et al. (2011), Baek and Yin (2006), and Myneni et al. (1994) report highly inelastic price elasticity estimates for US softwood lumber supply in the range from 0.13 to 0.27. Estimates reported are higher at the disaggregate level both geographically (Adams and Haynes 1996) and by species (Lewandrowski et al. 1994).

Lewandrowski et al. (1994) estimate supply elasticity to be above 1. They explain that the much higher estimates are due to speculative behaviour.

Yoshimoto et al. (1999) report estimates for Japanese domestic lumber between -0.163 and 0.174, and a range of values from 0.095 to 0.757 for Japanese domestic lumber processed using logs imported from the US.

A.2.6 Price Elasticity of Export Supply for Wood Products

Eight studies estimate and report the price elasticity of export supply for softwood lumber. These are summarized in Table A8. The elasticity of export supply from Canada to the US falls between 0.18 and 1.063. The price elasticity for imported lumber supply from the US to Japan is 0.478, with respect to Japanese imported lumber prices. The estimated elasticity of export supply from non-Canadian countries to the US is reported to be 1.5. Kangas and Baudin (2003) report the price elasticity of export supply for various wood products in EU countries; some of them have unexpected signs.

A.2.7 Cross-price Elasticity

Table A9 summarizes a number of cross-price elasticity estimates of demand or supply for wood products found in the literature. The cross-price elasticity of demand measures the rate of response of quantity demanded of one product due to a price change of another product. Similarly, the cross-price elasticity of supply is defined as the responsiveness of the supply of one product to a change in the price of another product. The only exception is Latta and Adams (2000), who estimate the input demand responsiveness to the output price.

Nagubadi et al. (2004) and Lewandrowski et al. (1994) examine substitution between Canadian imports and domestically produced species in the United States. Nagubadi et al. (2004) report that Canadian spruce-pine-fir (SPF) imports substitute for untreated southern yellow pine (cross-price elasticity equal to 0.40) and engineered wood products (cross-price elasticity equal to 0.35).

The softwood lumber that Canada exports to the US is a mix of spruce, fir, redcedar, pine, hemlock, and other species. Hseu and Buongiorno (1993) examine the price elasticity of substitution between these species in the US import market. Only cross-price elasticity between different species with respect to pine is reported in Table A9.

Williamson et al.'s (2004) positive cross-price elasticity between lumber supply and chip price indicates that lumber and chips are complements in production, while Bernard et al.'s (1997) negative cross-price elasticity suggests kiln-dried SPF and air-dried SPF are substitutes in production. Latta and Adams (2000) report that roundwood demand responds positively to softwood lumber price, with elasticity ranging from 0.26 to 0.78.

Gellner et al. (1991) estimate a factor demand dynamic model for the Canadian and US construction industries using quarterly data from 1979 through 1986. One of the interesting findings from this study is that the cross-price elasticity estimate suggests plywood and lumber are complementary products in both Canada and the US. Thus, if North American market structure has remained similar to how it was in the 1980s, the increase in lumber supply from BC could increase the demand for plywood in the two countries.

The rest of the studies in Table A9 report cross-price elasticity estimates of demand for certain wood products in Japan, China, Germany, and other international markets.

A.2.8 Income Elasticity of Demand

Income elasticity of demand estimates for wood products in the US and world markets found in the literature are summarized in Table A10. The income elasticity of demand estimates for Canadian lumber in the US range from a long-run value of 0.63 to 3.85 and a short-run value of 1.107 to 2.81. The income elasticity of demand estimates for lumber in the US by Baek and Yin (2006) is 0.46 or 0.47. Lewandrowski et al. (1994) report the estimates by species, with elasticities ranging from 0.686 to 2.702.

McCarthy and Lei (2010) report the income elasticity of demand for pulp and paper in different regions. Short-run demands are generally income inelastic. Long-run demands are relatively more elastic. South American demand is more income elastic, while North America is the least elastic among all regions.

Li et al. (2006) estimate the income elasticity of demand for paper and paperboard in China to be close to 1. Chas-Amil and Buongiorno (2000) estimate the income elasticity of demand for paper and paperboard in Europe is 0.26 in the short run and 0.60 in the long run.

The income elasticity of demand estimates for a variety of wood products for 64 countries are reported in Simangunsong and Buongiorno (2001) and Turner and Buongiorno (2004).

A.2.9 Supply Elasticity with Respect to Input Prices

Table A11 summarizes the results of supply elasticity with respect to input prices. We focus on a few studies that looked at softwood lumber supply elasticity with respect to the price of log inputs. Baek and Yin (2006) estimate the elasticity of softwood lumber supply, with respect to the price of log inputs, to be -0.15 in the US. The estimates for Canada are in the wide range of -0.09 to -5.07 (Williamson et al. 2004; Latta and Adams 2000; Bernard et al. 1997).

Table A3. Price elasticities of total demand. (*indicates significance at 10% level or better)

Author	Problem Addressed	Product	Country/ Region	Elasticity	Time-frame	Range and Type of Data	Theoretical Method	Empirical Method
Song et al. (2010)	Modeling US softwood lumber sector by uisng cointegration in dynamic equation	Softwood lumber	US	-0.181* -0.141*	Long run Short run	Monthly, 1/1990–8/2006	Simultanesous equation of dynamic demand, supply, and import	2SLS
Baek and Yin (2006)	Access the impacts of the MOU and SLA	Softwood lumber	US	-0.15* -0.08*	Long run	Quarterly, 1980–2001	Simultanesous equation of US demand, US supply, and Canadian export	3SLS
Nagubadi et al. (2004)	Examine substitutability among imported and domestically produced species	Untreated southern yellow pine Treated southern yellow pine Douglas fir lumber Wood structural panel Other softwood	US	-0.719* -1.795* -1.623* -1.106* -0.428*	Short run	Monthly, 1/1989–7/2001	Derive cost share equations from minimizing restricted translog subcost function of softwood-utilizing industry	MLE for SURE
Adams (2003)	Access market and resource impacts of a Canadian lumber tariff	Softwood lumber	US	-0.1	Short run		Production function	3SLS, 2SLS
Adams and Haynes (1996)	Timber assessment model	Softwood lumber softwood plywood OSB	US	-0.07 -0.09 -0.59	Short run	1980–1989 1980–1989 1980–1989	Production function	3SLS, 2SLS
Myneni et al. (1994)	Examine the welfare impacts of the Canada-US softwood lumber trade dispute	Softwood lumber	US	-0.1	Long run	1961–1990	Simultanesous equation of demand, supply, and export	Full information maximum likeli hood
Lewandrowski et al. (1994)	Modeling US softwood lumber sector by considering present inventories and price expectations	Southern pine Douglas-fir Western pine	US	-0.667* -0.149* -0.137	Short run	Monthly, 1/1977–12/1987	Simultanesous equation of demand, supply, expected price, and production S	NL3SL
Spelter (1992)		Softwood lumber	US	-0.174			Technology diffusion model	
Adams et al. (1992)	Estimates of the elasticity of demand for softwood lumber by end-using secotr	Softwood lumber	US residential US non-residential US other	-0.13 -0.55 -1.15 -0.6345	Short run Long run Long run Long run	1950–1987	Stochastic parameter approach	Kalman filter

Table A3 (continued). Price elasticities of total demand. (*indicates significance at 10% level or better)

Author	Problem Addressed	Product	Country/ Region	Elasticity	Time-frame	Range and Type of Data	Theoretical Method	Empirical Method
Seldon and Boyd (1991)	Estimate demand for four regions and test the hypothesis that regional lumber demand parameters are stochastic	Lumber	US (Northeast)	-0.2017*	Short run	1950–1985	Derived lumber demand from the profit maximization of construction companies and resale establishments in three regions	OLS
			US (North Central)	-0.234*				OLS
			US (West)	0.035*				OLS
			US (Southeast)	-0.3622*				OLS
			US (Northeast)	-0.2404				Kalman filter
			US (North Central)	-0.234				Kalman filter
			US (West)	0.0349				Kalman filter
			US (Southeast)	-0.0708				Kalman filter
Gellner et al. (1991)	Develop factor demands in the U.S. and Canadian construction industries integrating a model of long-run factor demand with a model of short-run adjustments	Lumber	US	-0.38	Long run	Quarterly, 3/1979–4/1986	Factor demand dynamic model derived from cost-minimizing behavior of the construction industry	MLE
		Plywood		-0.1				
		Particleboard		-0.09				
		Nonveneered panels		-0.1				
		Lumber	Canada	-0.54				
		Plywood		-5.32				
		Particleboard		-2.38				
		Nonveneered panels		-1.28				
Williamson et al. (2004)	Access potential impacts of US countervail and kyoto ratification on the Canadian lumber and chip industry.	Roundwood	BC	-0.703*	Short run	1963–1999	A multi-output restricted Leontief profit function model Varialbes	2SLS, Instrumental
			Ontario	-0.159				
			Quebec	-0.606*				
Latta and Adams (2000)	Estimate lumber supply and Marshallian factor demand elasticity for three Canadian regions.	Roundwood	Canada/BC coast	-0.55	Short run	1962–1995	Normalized, restricted quadratic profit function	INL3SLS
			Canada/BC interior and Alberta	-0.12				
			Canada/East	-0.42				
Bernard et al. (1997)	Analyze integrated model of Quebec-Ontario-US Northeast	SPF softwood lumber	Canada/Quebect	-0.35*	Short run	1965–1990	Simultanesous equation of demand and supply	INL3SLS
			Canada/Ontario	-10.83				
			US/Northeast	-2.06*				
Chas-Amil and Buongiorno (2000)	Examine EU paper and d paperboar demand	Paper and paperboard	Europe	-0.23	Short run	panel data, 1969–1995	Derived demand from cost function; Least squares with dummy (LSDV)	GLS
				-0.53	Long run			

Table A3 (continued). Price elasticities of total demand. (*indicates significance at 10% level or better)

Author	Problem Addressed	Product	Country/ Region	Elasticity	Time-frame	Range and Type of Data	Theoretical Method	Empirical Method
Simangunsong and Buongiorno (2001)	Estimating the demand equations of global forest sector	Sawnwood	World (64 countries)	-0.14*	Short run	1973–1997, panel	Cost minimization	OLS with country dummies
				-0.46*	Long run			
		Plywood & veneer		-0.14*	Short run			
				-0.39*	Long run			
		Fiberboard		-0.07	Short run			
				-0.18	Long run			
		Particleboard		0	Short run			
				0	Long run			
		Fuelwood & charcoal		-0.09*	Short run			
				-0.29*	Long run			
		Other industry roundwood		-0.14*	Short run			
				-0.49*	Long run			
		Newsprint		-0.13*	Short run			
				-0.29*	Long run			
		Printing & writing paper		-0.18*	Short run			
				-0.4*	Long run			
		Other paper & paperboard		-0.09*	Short run			
				-0.1*	Long run			
McCarthy and Lei (2010)	Examine regional demands for pulp and paper products	Total pulp and paper	Across all regions globally	-0.04*	Short run	Panel data, 1961–2000	Dynamic demand model	OLS
				-0.07*	Long run			
		Pulp		-0.05*	Short run			
				-0.11*	Long run			
		Paper/board		-0.04*	Short run			
				-0.05*	Long run			
		Newsprint		-0.03*	Short run			
				-0.07*	Long run			
		Printing/writing		-0.04	Short run			
				-0.08*	Long run			
		Household sanitary		-0.04*	Short run			
				-0.07*	Long run			
		Wrapping/packaging		0.01	Short run			
				0.02*	Long run			

Table A4. Price elasticities of domestic demand. (*indicates significance at 10% level or better)

Author	Problem Addressed	Product	Country/ Region	Elasticity	Time-frame	Range and Type of Data	Theoretical Method	Empirical Method
Kinnucan and Zhang (2004)	Examine economic impacts of the 1996 Canada–US softwood lumber agreement	Softwood lumber	Canada	-0.17	Long run	1996–2000	Structural trade model, simultaneous equation system	
Kangas and Baudin (2003)	Model and project forest products demand, supply, and trade in Europe	Coniferous sawn wood	Austria	-0.34*	Long run	1975–2000	Multiple equation approach	OLS
			Finland	-0.723				
			France	-0.542				
			Sweden	-0.187*				
		Non-coniferous sawn wood	Austria	-0.69*				
			France	-0.267				
		Plywood	Italy	-0.271				
		Particleboard	Austria	-0.14				
			Finland	-0.294				
			France	-0.346*				
			Germany	-1.171*				
			Italy	-0.299				
			Sweden	-0.625				
		Fibreboard	Austria	1.25*				
			Germany	-0.33				
		Newsprint	Austria	0.02				
			Finland	-0.163				
			Germany	-0.508				
			Norway	-0.659*				
			Spain	-0.176				
			Sweden	-0.677*				
		Printing and writing paper	Austria	0.29				
			Finland	-1.889*				
			France	-0.242				
			Italy	-0.341*				
			Sweden	-0.24				
		Other paper and board	Austria	-0.06				
			Finland	-0.0253				
			Italy	-0.501				
			Norway	-1.01				
			Sweden	-0.043				
			UK	-0.188				

Table A4 (continued). Price elasticities of domestic demand. (*indicates significance at 10% level or better)

Author	Problem Addressed	Product	Country/ Region	Elasticity	Time-frame	Range and Type of Data	Theoretical Method	Empirical Method
Li et al. (2006)	Examine the economic transition demand pattern of China's paper and paperboard industry	Paper and paperboard	China	-0.69*	Long run	1979–2001, after 1993 structural change	Derived demand from cost function/VECM	Instrumental variable, 2SLS/MLS
Yoshimoto et al. (1999)	Investigate possibilities of increasing lumber production in Japan	Lumber	Japan (Tohoku)	-0.552	Long run	1974–1995	Simple linear demand function	OLS
			Japan (Kanto)	-0.864				
			Japan (Hokuriku)	-0.529				
			Japan (Chubu)	-0.592				
			Japan (Kinki)	-0.343				
			Japan (Chugoku)	-0.839				
			Japan (Shikoku)	-0.476				
			Japan (Kyushu)	-0.003				
Uusivuori and Kuuluvainen (2001)	Examine substitution between the main categories of imported wood and between imported and domestic wood	Domestic wood	World (36 wood-importing countries)	0.16	Short run	1990–1997, panel data	Derive demand function from cost share equations using a translog restricted cost function	MLE for SURE system
				-0.35	Long run	1990–1997, panel data		

Table A5. Price elasticities of import demand. (*indicates significance at 10% level or better)

Author	Problem Addressed	Product	Country/ Region	Elasticity	Time-frame	Range and Type of Data	Theoretical Method	Empirical Method
Nagubadi et al. (2004)	Examine substitutability among imported and domestically produced species	SPF	US from Canada	-0.62*	Long run	Monthly, 1/1989–7/2001	Derive cost share equations from minimizing restricted translog subcost function of the softwood-utilizing industry	MLE for SURE
Kinnucan and Zhang (2004)	Examine economic impacts of the 1996 Canada–US softwood lumber agreement	Softwood lumber	US from Canada	-1.28	Long run	1996–2001	Structural trade model, simultaneous equation system	
			Rest of the World from Canada	-1.45				
Sarker (1996)	Examine Canadian softwood lumber export to the US	Softwood lumber US lumber price	US from Canada,	1.02* or 0.998*	Short run	Quarterly, 4/1973–3/1992	Two-country trade model	Error-correction model
				1.38* or 1.430*	Long run			
Lewandrowski et al. (1994)	Modeling U.S. softwood lumber sector by considering present inventories and price expectations	Softwood lumber	US from Canada	-0.815*	Short run	Monthly, 1/1977–12/1987	Simultanesous Equation of demand, supply, expected price and production	NL3SLS
Hseu and Buongiorno (1993)	Determine price elasticities of substitution between species in the demand of US softwood lumber imports from Canada	Softwood lumber	US from Canada	-1.98*	Long run	Monthly, 1/1974–12/1988	Cost minimization of aggregate US demand for imports and of share equations for each species	2SLS
				2.33* (to US Domestic price)	Long run			
		Spruce		-2.76*	Long run			
		Pine		-6.33*	Long run			
		Fir		-0.31	Long run			
		Hemlock		-3.83*	Long run			
		Redcedar		-1.03*	Long run			
		Others		-1.01*	Long run			
Li et al. (2006)	Examine the economic transition demand pattern of China's paper and paperboard industry	Paper and paperboard	China	-0.60*	Long run	1979–2001, after 1993 structural change	Derived demand from cost function/VECM	Instrumental variable, 2SLS/MLS
Vincent et al. (1991)	Examine the substitution between tropical and temperate sawlogs	Log from North America	Japan	-2.12*	Long run	1971–1978	Profit maximization of sawnwood industry	Three equation demand system using 3SLS
				-2.46*	Long run	1979–1987		
			Log from Soviet Union	-1.52*	Long run	1971–1978		
				-2.2*	Long run	1979–1987		
			Log from South Seas	-0.12*	Long run	1971–1978		
				-0.22*	Long run	1979–1987		

Table A5 (continued). Price elasticities of import demand. (*indicates significance at 10% level or better)

Author	Problem Addressed	Product	Country/ Region	Elasticity	Time-frame	Range and Type of Data	Theoretical Method	Empirical Method
Kangas and Baudin (2003)	Model and project forest products demand, supply and trade in Europe	Coniferous sawn wood	Austria	-0.53*	Long run	1975–2000	Multiple equation approach	OLS
			France	-0.356				
			Germany	-0.436*				
			Italy	-0.421*				
			Norway	-2.009				
			Spain	-0.609*				
			UK	-0.291				
		Non-coniferous sawn wood	Austria	-0.62*				
			France	-0.412*				
			Germany	-0.942*				
			Italy	-0.851				
			Spain	-0.684*				
			UK	-0.28				
		Plywood	France	-0.735				
			Germany	-0.904*				
			Italy	-2.522				
			UK	-0.177				
		Particleboard	Austria	-1.25				
			France	-0.174				
			Germany	-1.837				
			Italy	-0.461				
			Norway	-0.252*				
			Spain	-0.398				
			UK	-0.656*				
		Fibreboard	Austria	-0.73				
			France	-0.956*				
			Germany	-0.599*				
			Italy	-2.322*				
			Norway	-0.206				
			Sweden	-1.189				
			UK	-0.288*				
		Newsprint	Austria	1.18*				
			France	-0.64*				
			Germany	-0.372*				
			Italy	-0.416				
			UK	-0.379*				

Table A5 (continued). Price elasticities of import demand. (*indicates significance at 10% level or better)

Author	Problem Addressed	Product	Country/ Region	Elasticity	Time-frame	Range and Type of Data	Theoretical Method	Empirical Method
		Printing and writing paper	Austria	1.06				
			Germany	-0.323				
			Italy	-0.544				
			Norway	-1.725				
			UK	-0.444				
		Other paper and paperboard	Austria	0.11				
			Germany	-0.349*				
			Italy	-1.349*				
			Norway	-0.181				
Mutanen (2005)	Estimating substitution in coniferous sawnwood imports into Germany	Coniferous sawn wood	Germany from Russia	0.31*	Short run	Quarterly, 1/1991–1/2004	Cost share equation	MLE for SURE
			Germany from Finland	-0.01*				
			Germany from Sweden	-0.38*				
			Germany from other	-0.39				
Uusivuori and Kuuluvainen (2001)	Examine substitution between the main categories of imported wood and between imported and domestic wood	Softwood import	World (36 wood-importing countries)	-0.92	Short run	1990–1997, panel data	Derive demand function from cost share equations using a translog restricted cost function	MLE for SURE system
				-0.54	Long run			
		Wood chips import		-0.95	Short run			
				1.68	Long run			
		Nontropical hardwood		-0.69	Short run			
				-1.37	Long run			
		Tropical hardwood		-0.84	Short run			
				-1.68	Long run			
Turner and Buongiorno (2004)	Estimate price and income elasticities of demand for imports of forest products	Sawnwood import	World (64 countries)	-0.49*	Long run	1970–1987, panel data	Derive import demand by firms minimizing cost; demand is a function of price and income; Arellano–Bond approach	Generalized method of moments
		Plywood/veneer import		-0.81*				
		Particleboard import		-0.7*				
		Fibreboard import		-1.53*				
		Roundwood import		-0.74				
		Chemical pulp import		-0.48*				
		Recovered paper import		0.01				
		Newsprint import		-0.5*				
		Printing and writing paper import		-1.2*				
		Other paper and paperboard import		-0.74*				

Table A6. Price elasticities of total supply. (*indicates significance at 10% level or better)

Author	Problem Addressed	Product	Country/ Region	Elasticity	Time-frame	Range and Type of Data	Theoretical Method	Empirical Method
Williamson et al. (2004)	Access potential impacts of US countervail and kyoto ratification on the Canadian lumber and chip industry.	Lumber	BC	0.586*	Short run	1963–1999	A multi-output restricted Leontief profit function model	2SLS, Instrumental Varialbes
			Ontario	0.243*				
			Quebec	0.366*				
		Chip	BC	0.954*				
			Ontario	-0.148				
			Quebec	0.118				
Latta and Adams (2000)	Estimate lumber supply and Marshallian factor demand elasticity for three Canadian regions	Softwood lumber and chips	Canada/ BC coast	0.84	Short run	1962–1995	Normalized, restricted quadratic profit function	INL3SLS
			Canada/ BC interior and Alberta	0.38				
			Canada/East	0.65				
Bernard et al. (1997)	Analyze integrated model of Quebec–Ontario–US Northeast	Air-dried SPF	Canada/Quebec	1.03*	Short run	1965–1990	Simultanesous equation of demand and supply	INL3SLS
		Kiln-dried SPF		1.02*				
		Air-dried SPF	Canada/Ontario	2.12*				
		Kiln-dried SPF		2.41*				
		Kiln-dried SPF	US/Northeast	0.27*				
Brown and Zhang (2005)	Estimate supply elasticity for disaggregated paper products	Newsprint paper	US	2.75*	Long run	1981–2001	Derived supply from profit maximization; distributed lag model; price and output quantity are jointly determined	2SLS
				0.69*	Short run			
		Printing/writing paper		2.45*	Long run			
				1.07*	Short run			
		Tissue paper		1.77*	Long run			
				1.77*	Short run			
		Packaging paper		0.41*	Long run			
				0.24*	Short run			
Adams (2003)	Access market and resource impacts of a Canadian lumber tariff	Softwood lumber	US	0.7	Short run		Cost function	3SLS, 2SLS
Spelter (2001)		Lumber	Rest of Canada	0.09	Short run			
			BC	0.22				
			US South	0.26				
			US North	0.3				
			US West	0.36				
Hseu and Buongiorno (1997)	Examine output supply and input demand in the pulp and paper industry	Pulp	US	1.2	Long run	1959–1987	Nonparametric method exploiting the weak axiom of profit maximization	
		Newsprint		1.9				
		Paperboard		1				
		Other paper		1.2				
		Pulp	Canada	2				
		Newsprint		0.9				
		paperboard		1				
		Other paper		1.8				
Bolkesjø et al. (2010)	Estimate supply equations for sawlog and pulpwood	Sawlog	Norway	0.89*	Short run	Panel, 1980–2000	Derived supply from profit maximization, first difference	OLS
		Pulpwood		0.53*				

Table A7. Price elasticities of domestic supply. (*indicates significance at 10% level or better)

Author	Problem Addressed	Product	Country/ Region	Elasticity	Time-frame	Range and Type of Data	Theoretical Method	Empirical Method
Song et al. (2010)	Modeling US softwood lumber sector by using cointegration in dynamic equation	Softwood lumber	US	0.233* 0.159*	Long run Short run	Monthly, 1/1990–8/2006	Simultanesous equation of dynamic demand, supply, and import	2SLS
Baek and Yin (2006)	Access the impacts of the MOU and SLA	Softwood lumber	US	0.25* 0.13*	Long run	Quarterly, 1980–2001	Simultanesous equation of US demand, US supply, and Canadian export	3SLS
Myneni et al. (1994)	Examine the welfare impacts of the Canada-US softwood lumber trade dispute	Softwood lumber	US	0.27	Long run	1961–1990	Simultanesous equation of demand, supply, and export	Full information maximum likelihood
Lewandrowski et al. (1994)	Modeling U.S. softwood lumber sector by considering present inventories and price expectations	Southern pine Douglas-fir Western pine	US	1.494 1.283 1.497	Short run	Monthly, 1/1977–12/1987	Simultanesous equation of demand, supply, expected price, and production	NL3SLS
Adams and Haynes (1996)	Timber assessment market model	Softwood lumber	Pacific NW, West	0.335	Short run	1951–1989	Profit function	3SLS, 2SLS, OLS
			Pacific NW, East	0.586				
			Pacific Southwest	0.794				
			Northern Rockies	0.866				
			Southern Rockies	0.395				
			North Central	0.848				
			Northeast	0.188				
			South Central	0.937				
			Southeast	0.963				
			BC coast	0.935				
			Interior provinces	0.447				
			Eastern provinces	0.492				
		Softwood plywood	Pacific NW, West	0.748				
			Pacific NW, East	0.444				
			Pacific Southwest	1.12				
			Northern Rockies	0.6				
			South Central	0.395				
			Southeast	0.343				
		OSB	U.S.	0.512				
			Canada	0.433				
		Hardwood lumber	North Central	0.189				
			Northeast	0.244				
			South Central	0.813				
			Southeast	1.011				

Table A7 (continued). Price elasticities of domestic supply. (*indicates significance at 10% level or better)

Author	Problem Addressed	Product	Country/ Region	Elasticity	Time-frame	Range and Type of Data	Theoretical Method	Empirical Method
Kinnucan and Zhang (2004)	Examine economic impacts of the 1996 Canada–US softwood lumber agreement	Softwood Lumber	Canada	0.4	Long run	1996–2000	Structural trade model, SSE	
Yoshimoto et al. (1999)	Investigate possibilities of increasing lumber production in Japan	Domestic lumber	Japan (Tohoku)	0.097	Long run	1974–1995	Simple linear demand function	OLS
			Japan (Kanto)	0.042				
			Japan (Hokuriku)	0.043				
			Japan (Chubu)	0.058				
			Japan (Kinki)	0.102				
			Japan (Chugoku)	-0.163				
			Japan (Shikoku)	0.125				
			Japan (Kyushu)	0.174				
		Domestic processed lumber from logs imported from the US	Japan (Tohoku)	0.528				
			Japan (Kanto)	0.552				
			Japan (Hokuriku)	0.095				
			Japan (Chubu)	0.215				
			Japan (Kinki)	0.453				
			Japan (Chugoku)	0.757				
			Japan (Shikoku)	0.497				
			Japan (Kyushu)	0.146				

Table A8. Price elasticities of export supply. (*indicates significance at 10% level or better)

Author	Problem Addressed	Product	Country/ Region	Elasticity	Time-frame	Range and Type of Data	Theoretical Method	Empirical Method
Song et al. (2010)	Modeling US softwood lumber sector by using cointegration in dynamic equation	Softwood lumber	Canada to US	0.342* 0.271*	Long run Short run	Monthly, 1/1990–8/2006	Simultaneous equation of dynamic demand, supply, and import	2SLS
Baek and Yin (2006)	Access the impacts of the MOU and SLA	Softwood lumber	Canada to US	0.18* 0.19*	Long run	Quarterly, 1980–2001	Structural SSE: US demand, US supply, Canadian export	3SLS
Kinnucan and Zhang (2004)	Examine economic impacts of the 1996 Canada–US softwood lumber agreement	Softwood lumber	Canada to US	0.9	Long run	1996–2000	Structural trade model, simultaneous equation system	
Adams (2003)	Access market and resource impacts of a Canadian lumber tariff	Softwood lumber	Canada to US Non-Canadian to US	0.5-0.6 1.5	Short run	-	Cost function	3SLS, 2SLS
Lewandrowski et al. (1994)	Modeling US softwood lumber sector by considering present inventories and price expectations	Softwood lumber	Canada to US	1.063	Short run	Monthly, 1/1977–12/1987	Simultaneous equation of demand, supply, expected price and production	NL3SLS
Myneni et al. (1994)	Examine the welfare impacts of the Canada–US softwood lumber trade dispute	Softwood lumber	Canada to US	0.19	Long run	1961–1990	Simultaneous equation of demand, supply and export	Full information maximum likelihood
Yoshimoto et al. (1999)	Investigate possibilities of increasing lumber production in Japan	Lumber	US to Japan	0.478	Long run	1970–1996	Simple linear demand function	OLS
Kangas and Baudin (2003)	Model and project forest products demand, supply, and trade in Europe	Coniferous sawnwood	Austria	-1*	Long run	1975–2000	Multiple equation approach	OLS
			France	-0.909*				
			Germany	-0.855*				
		Non-coniferous sawnwood	Austria	-0.07				
			France	1.498*				
			Germany	0.733*				
		Particleboard	Austria	-0.47				
		Fibreboard	Austria	-0.24				
			Italy	0.124				
			Spain	0.242				
		Newsprint	Finland	1.517				
			Norway	1.517				
			Sweden	1.517				

Table A9. Cross-price elasticities. (*indicates significance at 10% level or better)

Author	Problem Addressed	Product	Country/ Region	Elasticity	Time-frame	Range and Type of Data	Theoretical Method	Empirical Method
Nagubadi et al. (2004)[a]	Examine substitutability among imported and domestically produced species	SYP-U to Canadian SPF	US and Canada	0.3985*	Long run	Monthly, 1/1989–7/2001	Derive cost share equations from minimizing restricted translog subcost function of softwood-utilizing industries	MLE for SURE
		SYP-R to Canadian SPF		0.0093				
		Douglas-fir to Canadian SPF		0.0661				
		Wood structual panel to Canadian SPF		0.346*				
Lewandrowski et al. (1994)	Modeling U.S. softwood lumber sector by considering present inventories and price expectations	Southern pine to Canadian lumber price	US	-0.589*	Short run	Monthly, 1/1977–12/1987	Simultanesous equation of demand, supply, expected price, and production	NL3SLS
		Southern pine to douglas fir		-0.057				
		Southern pine to western pine		-0.303*				
		Douglas fir to Canadian lumber		0.4*				
		Douglas fir to southern pine		-0.065				
		Douglas fir to western pine		-0.020				
		West pine to Canadian lumber		0.329*				
		West pine to douglas fir		-0.016				
		West pine to southern pine		-0.279*				
Hseu and Buongiorno (1993)[a]	Determine price elasticities of substitution between species in the demand of US softwood lumber imports from Canada	Spruce to pine lumber price	US and Canada	0.16	Long run	Monthly, 1/1974–12/1988	Cost minimization of aggregate US demand for imports and of share equations for each species	2SLS
		Fir to pine lumber price		-1.17*				
		Hemlock to pine lumber price		0.18				
		Redcedar to pine lumber price		-0.09				
		Others to pine lumber price		-0.1				
Williamson, Hauer and Luckert (2004)	Access potential impacts of US countervail and kyoto ratification on the Canadian lumber and chip industry.	Lumber supply to chip price	BC	0.074*	Short run	1963–1999	A multi-output restricted Leontief profit function model	2SLS, Instrumental Varialbes
		Chip supply to lumber price	BC	0.625*				
		Lumber supply to chip price	Ontario	0.058				
		Chip supply to lumber price	Ontario	0.165				
		Lumber supply to chip price	Quebec	0.331*				
		Chip supply to lumber price	Quebec	1.182*				

Table A9 (continued). Cross-price elasticities. (*indicates significance at 10% level or better)

Author	Problem Addressed	Product	Country/ Region	Elasticity	Time-frame	Range and Type of Data	Theoretical Method	Empirical Method
Latta and Adams (2000)	Estimate lumber supply and Marshallian factor demand elasticity for three Canadian regions	Roundwood demand to softwood lumber price	Canada/ BC Coast	0.78	Short run	1962–1995	Normalized, restricted quadratic profit function	INL3SLS
			Canada/BC Interior and Alberta	0.26				
			Canada/East	0.47				
Bernard et al. (1997)	Analyze integrated model of Quebec–Ontario–US Northeast	Kiln-dried SPF supply to air-dried SPF	Canada/ Quebec	-0.88	Short run	1965–1990	Simultanesous equation of demand and supply	INL3SLS
		Kiln-dried SPF supply to air-dried SPF	Canada/ Ontario	-2.09				
		Air-dried SPF supply to kiln-dried SPF	Canada/ Quebec	-0.72				
		Air-dried SPF supply to kiln-dried SPF	Canada/ Ontario	-1.58				
Gellner et al. (1991)	Develop factor demands in the US and Canadian construction industries integrating a model of long-run factor demand with a model of short-run adjustments	Nonveneered structural wood panels to lumber price	US	0.07	Long run	Quarterly, 3/1979–4/1986	Factor demand dynamic model derived from cost-minimizing behavior of the construction industry	MLE
		Paricleboard to lumber price		-0.82				
		Plywood to lumber price		-2.17				
		Labor and capital to lumber price		0.17				
		Nonveneered structural wood panels to lumber price	Canada	0				
		Paricleboard to lumber price		0				
		Plywood to lumber price		-0.02				
		Labor and capital to lumber price		-0.03				
Vincent, et al. (1991)[a]	Examine the substitution between tropical and temperate sawlogs	Log from Soviet Union to price of NA	Japan	1.88*	Long run	1971-78	Profit maximization of sawnwood industry	Three equation demand system using 3SLS
				2.65*		1979-87		
		Log from S. Seas to price of NA		0.29*		1971-78		
				0.53*		1979-87		

Table A9 (continued). Cross-price elasticities. (*indicates significance at 10% level or better)

Author	Problem Addressed	Product	Country/ Region	Elasticity	Time-frame	Range and Type of Data	Theoretical Method	Empirical Method
Li et al. (2006)	Examine the economic transition demand pattern of China's paper and paperboard industry	Domestic paper and paperboard demand to international price	China	0.59*	Long run	1979-2001, after 1993 structural change cost function	Derived demand from Instrumental variable,	2SLS
Mutanen (2005)	Estimating substitution in coniferous sawnwood imports into Germany	Russian to Finnish sawnwood	Germany	-0.52	Short run	Quarterly, 1/1991–1/2004	cost share equation	MLE for SURE
		Finnish to Russian sawnwood from Finland		-0.22				
		Russian to Swedish sawnwood		-0.31				
		Swedish to Russian sawnwood		-0.1				
		Finnish to Swedish sawnwood		-0.02				
		Swedish to Finnish sawnwood		-0.02				
		Russian to others		0.51				
		Others to Russian		0.08				
		Finnish to others		0.22				
		Others to Finnish		0.08				
		Swedish to others		0.44				
		Others to Swedish		0.22				
Uusivuori and Kuuluvainen (2001)[a]	Examine substitution between the main categories of imported wood and between imported and domestic wood	Softwood import to domestic wood price	World (36 wood-importing countries)	0.74	Short run	1990–1997, panel data	Derive demand function from cost share equations using a translog restricted cost function	MLE for SURE system
				1.1	Long run			
		Nontropical hardwood import to domestic wood price		0.48	Short run			
				1.91	Long run			
		Tropical hardwood import to domestic wood price		0.5	Short run			
				1.93	Long run			

[a] Indicates that we did not include all elasticity estimates from these studies.

Table A10. Income elasticities of demand. (*indicates significance at 10% level or better)

Author	Problem Addressed	Product	Country/ Region	Elasticity	Time-frame	Range and Type of Data	Theoretical Method	Empirical Method
Baek and Yin (2006)	Access the impacts of the MOU and SLA	Softwood lumber	US	0.47*/0.46*	Long run	Quarterly, 1989–2001	Structural SSE: US demand, US supply, Canadian export	3SLS
Sarker (1996)	Modeling Canadian softwood lumber export to the US	Canadian lumber	US	3.80* or 3.85* 2.81* or 2.68*	Long run Short run	Quarterly, 4/1973–3/1992	Two-country trade model	Error-correction model
Lewandrowski et al. (1994)	Modeling US softwood lumber sector by considering present inventories and price expectations	Southern pine lumber Douglas-fir lumber Western pine lumber Canadian lumber	US	2.702* 0.879* 0.686* 1.107*	Short run	Monthly, 1/77–12/87	Simultanesous equation of demand, supply, expected price, and production	Nonlinear 3SLS
Hseu and Buongiorno (1993)	Determine price elasticities of substitution between species of US softwood lumber imports from Canada	Canadian softwood lumber	US from Canada	0.63*	Long run	Monthly, 1/1974–12/1988	Derived demand from cost minimization of residential construction	2SLS
McCarthy and Lei (2010)	Examine regional demands for pulp and paper products	Total pulp and paper	NAFTA Asia Europe South America	0.44* 0.74* 0.53 0.89* 0.63* 1.05* 0.79* 1.32*	Short run Long run Short run Long run Short run Long run Short run Long run	Panel data, 1961–2000	Dynamic demand model	OLS
Li et al. (2006)	Examine the economic transition demand pattern of China's paper and paperboard industry	Paper and paperboard	China	1.01*	Long run	1979–2001	Derived demand from cost function/VECM	Instrumental variable, 2SLS/ MLS
Chas-Amil and Buongiorno (2000)	Examine EU paper and paperboard demand	Paper and paperboard	Europe	0.26 0.60	Short run Long run	Panel data, 1969–1995	Derived demand from cost function; Least squares with dummy (LSDV)	GLS

Table A10 (continued). Income elasticities of demand. (*indicates significance at 10% level or better)

Author	Problem Addressed	Product	Country/ Region	Elasticity	Time-frame	Range and Type of Data	Theoretical Method	Empirical Method
Turner and Buongiorno (2004)	Estimate price and income elasticities of demand for imports of forest products	Roundwood import	World (64 countries)	2.21*	Long run	1970–1987	Minimize cost subject to production function	Arellano–Bond
		Sawnwood import		2.71*				
		Plywood/veneer import		2.74*				
		Particleboard import		5.7*				
		Fibreboard import		1.76				
		Chemical pulp import		2.72*				
		Recovered paper import		2.5				
		Newsprint import		1.13*				
		Printing & writing paper import		1.47*				
		Other paper & paperboard import		1.14*				
Simangunsong and Buongiorno (2001)	Estimating the demand equations of global forest sector	Fuelwood and charcoal	World (64 countries)	0.16*	Short run	1973–1997, panel	Cost minimization	OLS with country dummies
				0.54*	Long run			
		Other industry roundwood		0	Short run			
				0	Long run			
		Sawnwood		0.12*	Short run			
				0.38*	Long run			
		Plywood and veneer		0.28*	Short run			
				0.75*	Long run			
		Fiberboard		0.41*	Short run			
				1.12*	Long run			
		Particleboard		0.27*	Short run			
				0.93*	Long run			
		Newsprint		0.5*	Short run			
				1.08*	Long run			
		Printing and writing paper		0.7*	Short run			
				1.52*	Long run			
		Other paper and paperboard		1.16*	Short run			
				1.3*	Long run			

Table A11. Supply elasticities with respect to input prices. (*indicates significance at 10% level or better)

Author	Problem Addressed	Product	Country/ Region	Input	Elasticity	Time-frame	Range and Type of Data	Theoretical Method	Empirical Method
Baek and Yin (2006)	Access the impacts of the MOU and SLA	Softwood lumber	US	Log	-0.15*	Long run	Quarterly, 1989–2001	Structural SSE: US demand, US supply, Canadian export	3SLS
Brown and Zhang (2005)	Estimate supply elasticity for disaggregated paper products	Newsprint paper	US	Fiber	-1	Long run	1981–2001	Derived supply from profit maximization; distributed lag model; price and output quantity are jointly determined	2SLS
					-0.3	Short run			
		Printing/writing paper			-0.7	Long run			
					-0.3	Short run			
		Tissue paper			-0.3	Long run			
					-0.3	Short run			
		Packaging paper			-0.6	Long run			
					-0.4	Short run			
Adams and Haynes (1996)	Timber accessment model	Hardwood lumber	US North Central	Stumpage	-0.042	Short run	1958–1988	Production function	
			US Northeast		-0.057				
			US South Central		-0.121				
			US Southeast		-0.127				
Hseu and Buongiorno (1997)	Examine output supply and input demand in the pulp and paper industry	Pulp	US	Capital	-0.3	Long run	1959–1987	Nonparametric method exploiting the weak axiom of profit maximization	
				Workers	-0.1				
				Energy	-0.2				
				Wood pulp	-0.3				
				Pulpwood	0				
		Newsprint		Capital	-0.2				
				Workers	-0.3				
				Energy	0.2				
				Wood pulp	-0.1				
				Pulpwood	-0.2				
		Other paper		Capital	-0.9				
				Workers	0.2				
				Energy	-0.3				
				Wood pulp	0.1				
				Pulpwood	0				

Table A11 (continued). Supply elasticities with respect to input prices. (*indicates significance at 10% level or better)

Author	Problem Addressed	Product	Country/ Region	Input	Elasticity	Time-frame	Range and Type of Data	Theoretical Method	Empirical Method
Williamson et al. (2004)	Access potential impacts of US countervail and kyoto ratification on the Canadian lumber and chip industry.	Lumber	BC	Wood	-5.07*	Short run	1963–1999	A multi-output restricted Leontief profit function model	2SLS, instrumental variables
				Labour	-0.139*				
				Energy	-0.014*				
			Ontario	Wood	-0.224*				
				Labour	-0.071				
				Energy	-0.006				
			Quebec	Wood	-0.351*				
				Labour	-0.293*				
				Energy	-0.052*				
		Chip	BC	Wood	-1.03*				
				Labour	-0.420*				
				Energy	-0.127*				
			Ontario	Wood	0.166				
				Labour	-0.160				
				Energy	-0.023				
			Quebec	Wood	-0.474*				
				Labour	-0.624*				
				Energy	-0.201*				
Latta and Adams (2000)	Estimate lumber supply and Marshallian factor demand elasticity for three Canadian regions	Softwood lumber and chips	Canada/ BC coast	Roundwood input	-0.46	Short run	1962–1995	Normalized, restricted quadratic profit function	INL3SLS
			Canada/BC Interior & Alberta		-0.13				
			Canada/East		-0.24				
Bernard et al.(1997)	Analyze integrated model of Quebec–Ontario–US	Air-dried SPF	Canada/Quebec	Aggregated logs, labor, and energy	-0.32	Long run	1965–1990	Simultanesous Equation of demand and supply	INL3SLS
		Kiln-dried SPF	Canada/Quebec		-0.09				
		Air-dried SPF	Canada/Ontario		-0.63				
		Kiln-dried SPF	Canada/Ontario		-0.15				
		Kiln-dried SPF	US/Northeast		-0.26				

Table A11 (continued). Supply elasticities with respect to input prices. (*indicates significance at 10% level or better)

Author	Problem Addressed	Product	Country/ Region	Input	Elasticity	Time-frame	Range and Type of Data	Theoretical Method	Empirical Method
Hseu and Buongiorno (1997)	Examine output sully and input demand in the pulp and paper industry	Pulp	Canada	Capital	-1.7	Long run	1959–1987	Nonparametric method exploiting the weak axiom of profit maximization	
				Workers	-0.2				
				Energy	0				
				Wood pulp	-0.1				
				Pulpwood	-0.4				
		Newsprint		Capital	-0.8				
				Workers	-0.1				
				Energy	0				
				Wood pulp	0				
				Pulpwood	-0.2				
		Other paper		Capital	-0.7				
				Workers	0.1				
				Energy	0.1				
				Wood pulp	0.1				
				Pulpwood	-1				

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cfs.nrcan.gc.ca

Canadian Forest Service Contacts

1 Atlantic Forestry Centre
P.O. Box 4000
Fredericton, NB E3B 5P7
Tel.: (506) 452-3500 Fax: (506) 452-3525
cfs.nrcan.gc.ca/regions/afc

Atlantic Forestry Centre – District Office
Sir Wilfred Grenfell College Forestry Centre
University Drive
Corner Brook, NF A2H 6P9
Tel.: (709) 637-4900 Fax: (709) 637-4910

2 Laurentian Forestry Centre
1055 rue du P.E.P.S., P.O. Box 3800
Sainte-Foy, PQ G1V 4C7
Tel.: (418) 648-5788 Fax: (418) 648-5849
cfs.nrcan.gc.ca/regions/lfc

3 Great Lakes Forestry Centre
P.O. Box 490 1219 Queen St. East
Sault Ste. Marie, ON P6A 5M7
Tel.: (705) 949-9461 Fax: (705) 759-5700
cfs.nrcan.gc.ca/regions/glfc

4 Northern Forestry Centre
5320-122nd Street
Edmonton, AB T6H 3S5
Tel.: (403) 435-7210 Fax: (403) 435-7359
cfs.nrcan.gc.ca/regions/nofc

5 Pacific Forestry Centre
506 West Burnside Road
Victoria, BC V8Z 1M5
Tel.: (250) 363-0600 Fax: (250) 363-0775
cfs.nrcan.gc.ca/regions/pfc

6 Headquarters
580 Booth St., 8th Fl.
Ottawa, ON K1A 0E4
Tel.: (613) 947-7341 Fax: (613) 947-7396
cfs.nrcan.gc.ca/regions/nrc

Canadian Wood Fibre Centre
A virtual research centre of
the Canadian Forest Service,
Natural Resources Canada
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