WORKING PAPER
2016-01

REPA

Resource Economics
& Policy Analysis
Research Group

Department of Economics
University of Victoria

A Panel Data Analysis of Interior Log Supply in British Columbia

Jordan Clapper

May 2016

REPA Research Group
Department of Economics
University of Victoria PO Box 1700 STN CSC Victoria, BC V8W 2Y2 CANADA
repa@uvic.ca
Fax: 250.721.6214
http://web.uvic.ca/~repa/

A Panel Data Analysis of Interior Log Supply in British Columbia

by

Jordan Clapper

Abstract

In British Columbia, the primary forest sector is a leading contributor to the provincial economy, so understanding the determinants of log supply in BC is important for policy. In their analysis, Sun et al. 2015 estimated log supply elasticities using panel data across eight forest districts in the BC Coastal forest region from 2003 to 2013. This paper extends that analysis across 18 forest districts for the BC Interior forest region that harvest primarily Spruce-Pine-Fir (SPF), Douglas Fir-Larch (Df-Larch), Hemlock-Balsam (HemBal), and Cedar (CE). The analysis suggests that the elasticity of BC Interior log supply is inelastic. For the Interior forest region as a whole, using data for select species, the short run elasticity ranges from 0.26-0.41, and the long run log supply elasticities are estimated to be approximately 0.39. Insignificant determinants of log supply for the BC Interior include the interest rate, while significant determinants are the stumpage rate, the price of fuel, and the wage rate. Further, the research finds that the elasticity of BC interior log supply varies across species. The dominant species for the BC Interior are SPF and Df-Larch. Results indicate that Df-Larch is more sensitive to log prices in the short-run compared to SPF. Specifically, SPF is found to have an elasticity ranging from 0.61 to 0.95 in the short to long run, while the log price elasticity of Df-Larch ranges from 0.61 to 1.09 for the short to long run.

Table of Contents

INTRODUCTION

For generations the lumber industry in Canada has been a large contributor to the domestic and global economies. With over 348 million hectares of forest, Canada has the world's third largest forest area (next to Russia and Brazil), and is home to 43% of the world's certified forests. Given this vast forest supply—and the fact that deforestation rates are closely monitored and maintained—Canada has secured itself as a reliable source of timber with many countries including the United States, China, Japan and South Korea (NRCan, 2015).

Out of all the provinces in Canada, British Columbia (BC) stands out as the main contributor to the forest industry because of its large endowment of accessible forest resources. For instance, according to Statistics Canada, BC is home to 19% of Canada's total forest area, and has the second largest endowment of forest area next to Quebec which has 24% of Canada's forests. The BC Interior was responsible for 42% of total Canadian softwood and hardwood production in 2015 (Statistics Canada, 2015). In addition, the forest industry is the largest manufacturing sector in BC. In 2013, revenue from the forest industry in BC was $15.7 billion which translates to approximately 2.5% of provincial GDP (MNP, 2015).

The forest industry is also a significant contributor to employment in the province. In 2013, the industry employed 145, 800 full-time indirect and direct employees which translates to about 6.3% percent of jobs in BC. The BC Ministry of Forests, Lands and Natural Resource Operations (FLNRO) has worked closely with First Nations since 2002. Tenure agreements have been signed with 175 of the 203 First Nations. These agreements provide "$334 million in revenue sharing and access to 63.2 million cubic meters of timber as of 2013" (MNP, 2015).

The forest regions are split geographically into one Coast and two Interior regions (Northern Interior and Southern Interior). Overall, the Interior regions accounted for approximately 73% of the total BC harvest in 2015 (HBS). The forest regions are further split in to regional forest Districts. Currently there are 8 and 18 regional forest districts for the Coast and Interior, respectively.

In general, the regions and districts in BC differ considerably with respect to species composition as well as access to timber. Where the dominant species on the Coast are Hemlock, Douglas Fir and Cedar the Interior region is largely dependent on Lodge Pole Pine, Balsam Fir, Spruce, Interior Douglas Fir and Larch. In 2015 Spruce-Pine-Fir (SPF) accounted for 81% of the total harvest for the Interior region in BC. Generally, it is considered more difficult to access timber on the Coast because the terrain has steeper slopes and the supply is more remote.

Given the forgoing overview of the BC forestry industry and the fact that BC is a significant contributor to Canada's output of forest products, understanding the determinants of log supply for the BC Interior is valuable with regards to academic research and public policy. Included in these factors are environmental conditions, global trade policy, provincial policy, general market conditions and production costs. The Mountain Pine Beetle (MPB) attack in the BC interior peaked in 2005 and is expected to have a considerable effect on timber supply. FLNRO estimates that 18.3 million hectares of forest have been affected. In addition, as average temperatures across the province have increased in recent years, there have been a growing number of forests damaged by fire in the BC Interior. Moreover, market conditions such as the 2008 global financial crisis led to a considerable decrease in the demand for forest products from the BC interior. This was largely a result of decreased softwood consumption in the US associated with the housing crisis.

Likewise, costs of production are expected to limit a logging company's ability to harvest. Specifically, the stumpage rate is the cost of a tree as it stands; the wage rate is the cost of labor; the cost of capital represented by the interest rate; and the transportation cost given by the price of fuel. Since the scale of the BC forest industry is of global significance, understanding the sensitivity of BC's log supply with regards to a logging company's costs of production is a necessary.

Surprisingly, at this point there has been little analysis performed to model BC's log supply. The analysis put forward in this paper in part extends the method used in Sun et al. (2015) to the BC Interior regions for the period of January 2004 to December 2015, and also contributes to the existing literature by estimating supply elasticities on a species specific basis. In particular, elasticities are estimated for Df-Larch and SPF. For the species specific analysis, monthly data are used across 12 forest districts which harvested primarily the species of interest.

During recent years the need for log supply analysis has grown in the public policy realm (Fooks et al. 2013, van Kooten and Johnston 2014, Bogdanski et al. 2011, Abbott et al. 2009, Stennes et al. 2010). As a case in point, the 2006 Softwood Lumber Agreement (SLA) between the USA and Canada expired in October 2015. As of the writing of this paper, the two countries are currently engaged in a one year agreed upon free-trade stand-still. Based on past experience from Lumber I through Lumber IV, following the stand-still the US may apply a tariff on imported Canadian forest products. The economic effects of the tariff can partly be determined by analysis involving log supply. In fact, van Kooten and Johnston (2014) used log supply elasticity in a spatial equilibrium trade model to estimate the welfare impacts associated with certain scenarios concerning the global trade of logs and lumber. In their analysis, they estimate the impacts of removing export restrictions on Canadian lumber exports to the US. For accurate results, any spatial equilibrium analysis involving trade in logs and lumber will rely heavily on accurate estimates of the elasticities of supply and demand. Models such as the REPA-PFC forest trade model can be further used in public policy to assess the impacts of changes in trade policy across countries.

For the BC Interior, log prices are reported per species by FLNRO in the Interior Log Market (ILM) monthly reports that are available on FLNRO's website. The research presented here will focus on the log species that account for the greatest share of harvest in the BC Interior. In particular, SPF, Df-Larch, HemBal and CE are the most harvested species in the Interior region. As a result, the monthly log price data are readily available for these species, and for 18 forest districts.

This paper is broken up in to six sections. A brief literature review is presented in the next section followed by an outline of the general theoretical framework. After that, sources and methods of data analysis are discussed prior to a review of econometric methods and summary statistics. Presented in the final sections are the empirical results and a summary of findings.

LITERATURE REVIEW

At this point, there is a growing literature involving the determinants of global as well as domestic log supply. Most recently, Mojahednia (2015) estimated log supply elasticities with respect to various grades of logs for the Interior and Coastal regions of BC using Two Stage Least Squares (2SLS) with monthly time-series from January 2000 to December 2013. The results suggest that the log supply for high grade logs is elastic on the Coast and inelastic for the Interior. More specifically, she estimates long-run elasticities of 0.74 and -0.44 respectively, for high-grade and low-grade logs in the Interior. Although the elasticity for the low grade logs is not significant, the analysis suggests that high-grade logs are more sensitive to price changes compared to low-grade logs in the BC Interior.

Fooks et al. (2013) use a vector error correction model to estimate supply and demand elasticities for British Columbia as a whole. In particular, they use data from January 1995 to September 2008 and find an elasticity of supply for BC of 1.03—suggesting that the log supply is moderately elastic. The stumpage rate turns out to be statistically significant in determining log supply, but the cost of fuel is not a significant factor. Unexpectedly, they find that the stumpage rate has a positive effect on log supply in BC. This is opposite of expectations since the stumpage rate is a cost to tenure holders. Furthermore, they use their elasticity estimates to explore the issue of log export bans in forest rich countries.

In an analysis outside of BC, Zhang and Buongiorno (2012) use panel data from 25 provinces over a 10-year period from 1999 to 2009 to explore the determinants of log supply in China. Specifically, they use a least squares with dummy variables (LSDV) model as well as a random effects GLS model to estimate log supply elasticities. The main purpose of their analysis is to determine impacts of market fluctuations and policy changes regarding forest products in China. Overall, their results indicate that "the timber supply was inelastic, between 0.3 and 0.4 depending on the method" (p. 602). They conclude that the LSDV method is preferred over the GLS random effects method. In their analysis significant determinants of log supply include the log price, stock level, quota and a policy dummy variable. In general, they determine that the wage and interest rate are not significant determinants of log supply in China.

Another example outside of Canada is by Bolkesjo et al. (2010) who estimated timber supply equations for sawlogs and pulpwood using panel data across 102 Norwegian municipalities from 1980 to 2000. In particular, they use static and dynamic equations to estimate effects in the short run as well as the long run. Furthermore, they explore multiple methods of estimation including fixed effects, random effects, pooled OLS and a first difference method. Associated prices are included as variables in the respective equations along with the interest rate and the growing stock. The analysis concludes that "...elasticities based on pure cross-section analysis could be very biased and misleading" (p. 679). They acknowledge that in part their conclusion stems from the large variance of the harvest volume and the growing stock across municipalities. Overall, they determine that the best method to use is the first differencing procedure.

Bolkesjo and Solberg (2003) use a pooled Tobit model and a fixed-effects Tobit model to estimate short as well as long-term effects of selected variables that affect short-term round wood supply by Norwegian nonindustrial private forest owners. Specifically, they use panel data for the time period of 1989 to 1997. Variables included in their analysis are the current round wood price, the expected round wood price, exogenous income, sustainable harvesting level, forestland (ha), the age of the owner, wealth of owner and the interest rate. In general, for the pooled Tobit model all variables are statistically significant with the exception of the exogenous income of the owner. In comparison, significant variables in the fixed-effects Tobit model include the stumpage price, the expected stumpage price, the owners age and the interest rate. They conclude that both models vary in results and that the fixed-effects model is better suited for short-run round wood supply analysis.

Finally, Zhang (1996) estimated two equations that describe supply and demand in logs for the BC Coast and the US Pacific Northwest. Using OLS methods and quarterly time-series data 1990 to 1994, they find that supply is inelastic on the BC Coast. In particular, they estimate a 0.11 elasticity of supply using a simple equation including the log price, lumber price and quarterly dummies as predictor variables. Similar to Fooks et al. (2013), Zhang (1996) uses the determinants of supply to examine the effect of log export restrictions on employment. Consistent with other analyses, they conclude that log export restrictions lead to a considerable dead weight loss for the BC economy. In contrast, van Kooten (2014) shows that the log export restrictions benefit the forest industry in BC and are preferred over free trade.

THEORETICAL FRAMEWORK

As previously mentioned, this research extends the log supply analysis as outlined in Sun et al. (2015). In their analysis they use Hotelling's lemma to determine the profit function for a logging company in BC. This requires the assumption of perfectly competitive markets. According to the 2014 report on major primary processing facilities in BC, there were a total of 94 lumber mills in the Interior BC as of 2014 (FLNRO, 2014). In other words, the industry is significantly large in the BC interior. Therefore, it is safe to assume that all prices are determined in a competitive market. Thus a logging firm's input supply function is given by equation (1).

$$\frac{\partial \pi(P,P_S,P_L,P_E,I,O)}{\partial P} = S_L(P,P_S,P_L,P_E,I,O) \tag{1}$$

Specifically, equation one states a logging firm's net supply function S_L is equal to the profit function of a firm with regards to price. In this case, P is the log price, P_S is the stumpage rate, P_L is the wage rate (or cost of labour), P_E is the transportation cost (i.e., cost of diesel), I is the interest rate, and O is other factors affecting log supply. Dummy variables for the recession

2007 to 2009 are included, as well as monthly dummies to estimate seasonal influences. Assuming that equation (1) is in Cobb-Douglas form, upon applying the natural logarithm on both sides of the equation the short-term supply function is given by equation (2). With the log-log regression model the coefficients become the elasticities with regards to the respective independent variables. In this case, β_1 represents the short-run elasticity with respect to log price.

$$\ln Q_{it} = \beta_1 lnP_{it} + \beta_2 lnP_{S_{it}} + \beta_3 lnP_{L_{it}} + \beta_4 lnP_{E_{it}} + \beta_5 lnI_{it} + \beta_6 Jan_{it} + \beta_7 Feb_{it} + \beta_8 Mar_{it} + \beta_9 Apr_{it} + \beta_{10} May_{it} + \beta_{11} June_{it} + \beta_{12} July_{it} + \beta_{13} Aug_{it} + \beta_{14} Sep_{it} + \beta_{15} Oct_{it} + \beta_{16} Nov_{it} + \beta_{17} Recession_{it} \quad (2)$$

Further, the cross sectional unit i represents forest districts. The forest districts for the Coast and Interior are displayed in Fig. 1. In particular, the BC Interior regional analysis includes all 18 forest districts. Likewise, t represents the monthly time variables for the period January 2004 to December 2015. It is important to note that log price is assumed to be an exogenous variable. This assumption stems from the fact that "supply and demand shocks in a forest district are assumed to have little impact on the broader [Interior] log market" (Sun et al. 2015, p. 732). Dynamic effects are estimated by lagging the dependent variable as displayed in equation (3) with $Q_{i,t-1}$ as lagged harvest.

$$\ln Q_{it} = \beta_1 lnQ_{i,t-1} + \beta_2 lnP_{it} + \beta_3 lnP_{S_{it}} + \beta_4 lnP_{L_{it}} + \beta_5 lnP_{E_{it}} + \beta_6 lnI_{it} + \beta_7 Jan_{it} + \beta_8 Feb_{it} + \beta_9 Mar_{it} + \beta_{10} Apr_{it} + \beta_{11} May_{it} + \beta_{12} June_{it} + \beta_{13} July_{it} + \beta_{14} Aug_{it} + \beta_{15} Sep_{it} + \beta_{16} Oct_{it} + \beta_{17} Nov_{it} + \beta_{18} Recession_{it}\, t \quad (3)$$

Fig 1: BC Coast and Interior Forest Districts

Assuming that the value of P_{it} is fixed beyond time t and that the process continues, $Q_{i,t-1}$ will approach a long run equilibrium of Q_{it}. Solving for the equilibrium Q_{it} and taking the derivative with respect to P_{it} will estimate the long run multiplier. Since the inputs are logs, the multiplier is the long run elasticity. In other words, the long run elasticity is the estimated impact on the equilibrium lnQ_{it} of a change in lnP_{it}. In this case, long-run elasticities are calculated from equation (4) using the coefficients from the dynamic equation (Greene 2012, p. 423). Specifically, the calculated long run elasticity η_S is derived by dividing the short run elasticity by one minus the coefficient on the lagged dependent variable. In general, the coefficient on the lagged dependent variable is expected to be statistically significant. This expectation reflects the fact that logging companies take time to prepare for harvest.

$$\eta_S = \beta_2/(1 - \beta 1) \quad (4)$$

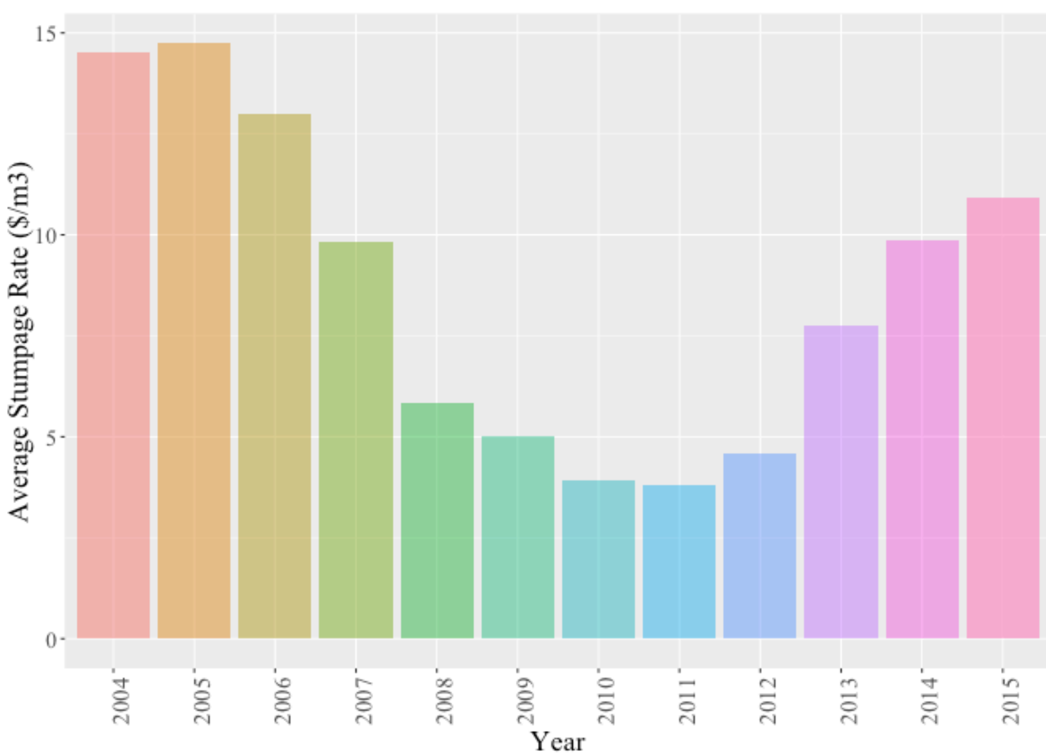
Moreover, the fixed effects method in this analysis incorporates a constant term. Nonetheless, according to Greene (2012), the FE estimator cannot accommodate time invariant variables (pp.359-360). Since the constant term is invariant within panels, the interpretation of its value does not contribute to the results of this analysis.

According to the law of supply and demand, the log price is expected to have a positive impact on the log supply. As the price of logs increases (ceteris paribus) producers should have more resources and incentives to increase harvest. In the BC interior, harvest tends to decrease in the spring and increase in the winter months; hence, it is expected that the monthly dummy variables capture this effect. In addition, the US recession had a considerable impact on the harvest levels in the Interior from 2007 to 2009. Thus, it is expected that the recession dummy will have a negative and significant impact in both models. The stumpage rate is a cost to the logging companies and is expected to have a negative sign. Moreover, the wage rate and transportation costs are expected to have a negative effect on harvest. In general, as input costs increase for a firm, there are less resources dedicated to production. Finally, the effect of the interest rate on harvest is ambiguous. If the interest rate has a positive effect on harvest, the variable is representative of the opportunity cost of holding trees. Conversely, if the effect is negative, the interest rate variable is representative of the cost of capital (Sun et al. 2015, p.732).

DATA

The data are from various sources. Harvest volume and value scaled per forest district is from FLNRO's Harvest Billing System (FLNRO, 2015). The stumpage rate is calculated by dividing the sum of value by the sum of volume per month per district and species for each model respectively. Stumpage rate units are $\$/m^3$. Fig 2 displays average stumpage across 18 districts and 4 species groups from 2004 to 2015.

Fig 2: BC Interior average stumpage rate



In general, stumpage varied considerably since 2004 from a high of $\$14.74/m^3$ in 2004 to a low of $\$3.82/m^3$ in 2011. Since the majority of the forests are owned by the provincial government in BC, stumpage rates are priced through a transaction evidence appraisal system that is based on competitive auctions through BC Timber Sales. The fluctuations in stumpage can be largely explained by the decrease in demand during the recession 2007-2010, and by the decrease in quality of harvest resulting from the Mountain Pine Beetle infestation that peaked in the BC Interior in 2005.

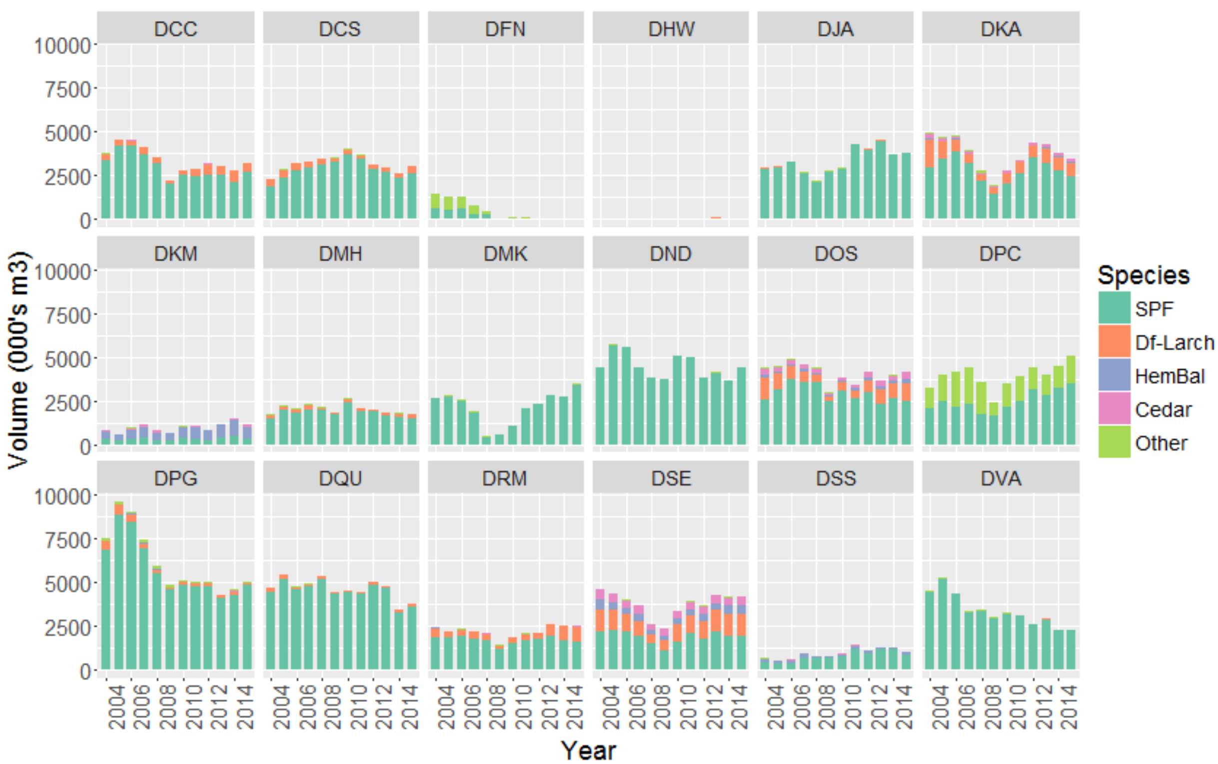
Table 1: BC Interior District Names and Average Harvest

	District Name	Acronym	Average Harvest (000s m3)
Northern Interior			
	Coast Mountain	DKM	79.03
	Skeena Stikine	DSS	63.72
	Nadina	DND	377.90
	Fort Nelson	DFN	28.28
	Peace	DPC	205.17
	MacKenzie	DMK	177.03
	Fort St. James	DJA	284.81
	Vanderhoof	DVA	282.01
	Prince George	DPG	497.16
	Average Harvest (000s m3)		221.68
Southern Interior			
	Headwaters	DHW	3.47
	Thompson Rivers	DKA	308.95
	Cascades	DCS	261.51
	Okanagan Shuswap	DOS	333.78
	Quesnel	DQU	392.59
	Cariboo Chilcotin	DCC	282.75
	100 Mile House	DMH	170.50
	Selkirk	DSE	305.70
	Rocky Mountain	DRM	177.37
	Average Harvest (000s m3)		250.51

Total harvest volumes per district by species from January 2004 to December 2015 are displayed in Fig 3 and the district names, acronyms and average monthly harvests are in Table 1. Overall, the districts of Prince George (DPG), Quesnel (DQU), and Nadina (DND) produced the most timber, whereas, the districts of Headwaters (DHW), Fort Nelson (DFN), and Skeena Stikine (DSS) produced the least. As expected, it is clear that SPF is the dominant species group across all districts.

It is important to note that in 2013 FLNRO reclassified many of the small producing forest districts. For instance, some of the harvest from DHW was reallocated to DPG and the Kalum forest district (DKA). Not surprisingly, the highest producing districts are concentrated in the Southern Interior regions that are in closer proximity to foreign markets.

Fig 3: Harvest per forest district

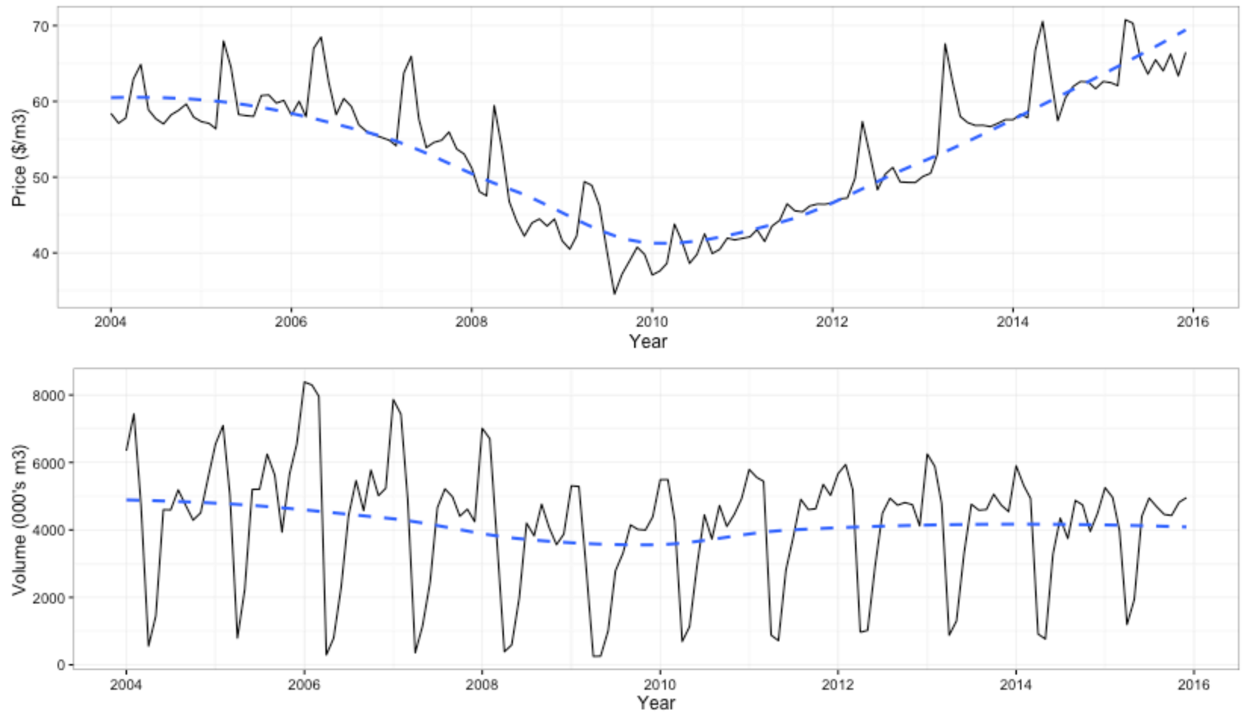


Since 2004, harvest volumes have varied considerably in most districts in the BC Interior. This is assumed to be a result of the housing crisis in the US that has not yet shown full recovery. The most dramatic decline in harvest is observed in DPG, where harvests fell by 65% from 2004 to 2013. In addition to market fluctuations, environmental factors have also played a role in diminishing log supply across districts. More specifically, the MPB outbreak that began in the early 1990s had a considerable impact on the forest supply in BC. For instance, FLNRO estimates that, by 2021, 58% of the pine volume in the BC Interior regions may be affected.

In their Coast analysis, Sun et al. (2015) used log species as a cross section to estimate log supply elasticities per forest district. The log price data used for their analysis were obtained from the Vancouver log market (VLM). The monthly VLM prices are transaction based and are detailed with regards to individual log species. In comparison, the log price data used in this analysis is obtained from the monthly ILM reports. The ILM data differs from those of the VLM because the data are based on a mill specific sample. In addition, the ILM reports are not species specific; rather, prices are reported for species groups such as the ones used in this analysis (SPF, Df-Larch, HemBal, CE). Since ILM log prices are not expressed by forest district, volume weights per district were used to express a district weighted average log price for the BC Interior regional model. Furthermore, harvest volume fluctuates ambiguously across districts in the Interior. To repeat the analysis for the Interior—as it was done for the Coast—it would be necessary to have a district specific log price per species. Since these prices are not available, the model for this analysis was adjusted to determine species specific log supply elasticities for SPF and Df-Larch. The district weighted average log price is plotted alongside the total harvest for the BC Interior in Figure 4.

As expected, log prices are observed to adjust seasonally. In general, peaks in the log price occur during the spring break-up months when harvesting conditions do not accommodate logging operations in the Interior regions. An inventory build-up occurs in the months leading up to the expected seasonal decrease in harvest supply; as the supply diminishes, available logs are worth more. This is consistent with the observation that harvest volumes fluctuate considerably throughout the year with the lowest harvests occurring in the spring months.

Fig 4: Average log price and total harvest BC interior



Moreover, log prices were generally lower during the US recession from 2007-2009, but have since recovered. Similarly, total harvest in the BC Interior declined during the recession; unlike log prices, however, harvest has not yet shown full recovery from pre-2007 levels. This observation is expected to be a result of sustained lower US demand following the recession.

Data for the other variables are from Statistics Canada (StatsCan, 2015). Specifically, the average rates for forestry, mining, fishing, quarrying, and oil and gas extraction for BC are used for the labor cost (i.e., wage rate). Transportation costs are represented by the price of diesel fuel at self-service filling stations in Vancouver BC. The consumer price index (CPI) base year 2002 is used to deflate all the log price and input cost data. Finally, the Bank of Canada bank rate is used for the interest rate. Table 2 summarizes these variables as well as their expected signs.

Table 2: Summary statistics and expected signs for input variables

Variables	Mean	Max	Min	SD	Expected Sign
Harvest ($10^6 m^3$)	245.28	1,579.13	0	194.61	
Log price (C$/$m^3$)	53.81	77.77	7.82	11.36	+
Stumpage (C$/$m^3$)	8.60	20.00	0	6.25	-
Wage (C$/hour)	28.43	34.89	23.04	2.93	-
Diesel (C$/liter)	117.26	151.5	69.44	21.09	-
Interest rate	2.04	4.75	0.5	1.35	+ or -

EMPIRICAL METHOD

The Southern Interior forest region makes up approximately 60% of the productive forest land in BC, and holds 40% of the provincial Allowable Annual Cut (AAC). Moreover, there are eight forest districts in the South, which generated about 54% of total provincial revenue (https://www.for.gov.bc.ca/rsi/). In comparison, the Northern Interior forest region comprises nine forest districts that administer 58% of BC's forest land. This analysis combines the two Interior forest regions to create a BC interior regional model with districts as the cross section. As pointed out, since log price data were not available on a monthly basis for the BC Interior across all species, this analysis incorporates a sample of the total harvest. Nonetheless, the species included here represent a large majority of the harvest in the Interior.

Similar to previous analyses for BC, a stochastic term is added to equations (2) and (3) to create the empirical model. Initially both fixed-effects (FE) and random-effects methods (RE) were employed to estimate log supply elasticities for both the regional and the species specific equations. Overall preference for RE versus FE is determined by the Hausman test. In particular, the Hausman test compares each model's coefficients and determines the most efficient and consistent estimator. Specifically, the null hypothesis that both FE and RE estimators are consistent is tested against the alternative hypothesis that only one is consistent.

Whereas the omitted effects in the FE model are assumed to have a positive correlation with the included variables, the RE method will be preferred if this is not the case. More specifically, if the omitted effects are not correlated with the included variables then it might be beneficial to use the RE method (Greene 2012, p.371).

To satisfy the stationarity assumption, a series of unit root tests were performed. The Levin-Lin-Chu (2002) test, the Im-Pesaran-Shine (2003) test, and the Breitung (2000) test. In addition, Hadri's (2000) Legrange Multiplier statistic is used to test the stationarity of all panels (Greene 2012, p.971; Sun et al. 2015, p.733). Overall, the variables for the BC Interior all turn out to be stationary. Moreover, the Hausman test results were consistent with expectations, so that the FE model is preferred in all cases.

RESULTS AND DISCUSSION

The estimation results for the BC Interior regional model using FE regression are displayed in Table 3. The static as well as the dynamic model results are given, with the restricted models estimated by eliminating statistically insignificant non-dummy variables in the general model. As anticipated, the log price coefficient is positive and significant in all cases.

In the general static model the log price, stumpage rate, diesel price and interest rate are all statistically significant and the signs are as expected. In particular, the coefficients on the stumpage rate and diesel price are negative, and the sign on the interest rate is positive. Moreover, the wage does not contribute to log supply; however, the wage rate coefficient is negative which is consistent with expectations. In the spring months, the Interior harvesting conditions are not favorable in part due to unfit road conditions resulting from the winter run-off. This period is often referred to as the spring break-up. During this time, many logging companies are forced to suspend operations temporarily leading to a decline in overall log supply. Prior to the break-up there is often a buildup of inventory that occurs in the mills. Consistent with the observation of the spring break-up, the seasonal dummy variables indicate that the months with the highest harvest volumes are January and February. In comparison, the months with the lowest harvest volumes are April, May and June. Also consistent with expectations, the coefficient on the recession dummy variable is negative and significant in all cases. Furthermore, the adjusted R-squared of 0.72—suggests that the model fit is reasonably good. Overall, the short-run elasticity for the static model is estimated to be 0.41 indicating that the log supply is inelastic in the BC interior forest region.

In comparison, the lagged dependent variable is positive and statistically significant in the dynamic model. This result represents the fact that procedures require additional time for capital accumulation and harvest planning. Consequently, the estimate for the long-run elasticity is expected to differ when compared with the short-run estimate. In line with the static model, the coefficient on the stumpage rate is negative and significant in the long-run. For instance, in the restricted dynamic model when the stumpage rate increases by 1%, the log supply is estimated to decrease by 0.47% and 0.43% for the short and long-run models respectively. Similar to the static model, the wage rate is statistically insignificant and exhibits a negative sign. The monthly dummy variables are consistent with expectations in that they suggest that the lowest harvest

Table 3: Timber supply equation for BC Interior forest region estimated by fixed effects methods using panel monthly data from January 2004-December 2015.

	Static model		Dynamic model	
Explanatory variables	General	Restricted	General	Restricted
ln harvest(-1)			0.31(0.02)***	0.31(0.02)***
ln logprice	0.41(0.14)***	0.41(0.16)***	0.26(0.13)**	0.27(0.13)**
ln stumpage	-0.47(0.03)***	-0.47(0.03)***	-0.43(0.03)***	-0.43(0.03)***
ln wage	-0.05(0.46)		0.10(0.42)	
ln diesel	-0.34(0.15)**	-0.34(0.14)**	-0.33(0.14)**	-0.33(0.13)***
interest rate	0.12(0.02)***	0.12(0.02)***	0.11(0.02)***	0.11(0.02)***
Jan	0.28(0.09)***	0.28(0.09)***	0.28(0.09)***	0.28(0.09)***
Feb	0.27(0.09)***	0.27(0.09)***	0.16(0.09)*	0.15(0.08)*
March	-0.08(0.09)	-0.08(0.09)	-0.18(0.08)**	-0.18(0.08)**
April	-2.54(0.10)***	-2.54(0.10)***	-2.55(0.09)***	-2.56(0.09)***
May	-1.89(0.10)***	-1.89(0.10)***	-1.06(0.10)***	-1.07(0.10)***
June	-0.73(0.10)***	-0.73(0.10)***	-0.09(0.10)	-0.10(0.09)
July	-0.18(0.10)	-0.18(0.09)*	0.02(0.09)	0.01(0.09)
August	-0.10(0.10)	-0.09(0.09)	-0.02(0.09)	-0.03(0.09)
September	-0.09(0.10)	-0.09(0.09)	-0.07(0.09)	-0.07(0.08)
October	-0.20(0.09)	-0.20(0.09)	-0.18(0.09)	-0.18(0.09)
November	-0.06(0.09)	-0.06(0.09)	-0.04(0.09)**	-0.04(0.08)**
Recession	-0.60(0.05)***	-0.60(0.05)	-0.47(0.05)***	-0.46(0.05)***
Constant	13.11(1.5)***	12.98(0.6)***	9.38(1.41)***	9.65(0.81)***
Calculated long run elasticity			0.38	0.39
Number of observations	2,289	2,289	2,244	2,244
Adjusted R^2	0.72	0.72	0.75	0.75

Numbers in parenthesis are the Standard Errors in the static models
*** Indicates statistical significance to 1% or better
** Indicates statistical significance to 5% or better
* Indicates statistical significance to 10% or better

volumes are experienced in the spring months of April, May and June. Overall, the long-run elasticity for the dynamic model is estimated to range from 0.38 to 0.39. Moreover, the short-run elasticity in the dynamic model is estimated to range between 0.26 to 0.27 indicating that log supply is more elastic in the long-run as expected. In general, since all inputs in the model can be varied in the long-run, it is expected that the harvest would be more sensitive to changes in price when compared to the short-run where all variables are fixed.

As mentioned, the results for the species-specific models use panel data across districts for the period January 2004 to December 2015. In contrast to the BC Interior regional model, which uses a species-volume weighted district average price, the species-specific models use prices directly from the Interior Log Market monthly reports.

The static and dynamic SPF models across 12 BC Interior forest districts are reported in Table 4. In line with expectations, the sign of the log price variable is positive in all cases of the SPF model. With the exception of the stumpage rate, all of the other explanatory variables are not significant when looking at SPF in particular. As expected, the stumpage rate exhibits a negative sign in all cases. Moreover, the seasonal dummy variables are similar to the regional model in that the months with the highest and lowest harvest occur in the winter and spring respectively. Finally, the recession variable is as expected in that it predicts that the recession had a negative and significant impact on the BC Interior SPF harvest. Overall, the adjusted R-squared ranges from 0.79 to 0.82 in different models. In comparison to the regional model in Table 2, the log price is more elastic as estimated by the SPF specific equation. For instance, elasticities for SPF in the interior range from 0.61 in the short-run to 0.95 in the log-run. In particular, as the log price increases for SPF by 1% it is expected that the log supply will increase by 0.95% in the long-run and 0.61% in the short-run.

Table 4: Timber supply equation for BC Interior forest region SPF estimated by fixed effects methods using panel monthly data from January 2004-December 2015.

	Static model		Dynamic model	
Explanatory variables	General	Restricted	General	Restricted
ln harvest(-1)			0.36(0.02)***	0.36(0.02)***
ln logprice	0.91(0.18)***	0.99(0.59)***	0.61(0.16)***	0.61(0.16)***
ln stumpage	-0.20(0.04)***	-0.18(0.03)***	-0.17(0.03)***	-0.16(0.03)***
ln wage	0.29(0.41)		0.21(0.36)	
ln diesel	-0.21(0.13)		-0.13(0.12)	
interest rate	0.03(0.02)		0.03(0.02)*	0.03(0.02)*
Jan	0.31(0.08)***	0.32(0.08)***	0.32(0.07)***	0.32(0.07)***
Feb	0.29(0.08)***	0.29(0.08)***	0.19(0.07)***	0.18(0.07)***
March	-0.08(0.08)	-0.08(0.08)	-0.18(0.07)**	-0.15(0.07)**
April	-2.30(0.10)***	-2.32(0.10)***	-2.27(0.08)***	-2.28(0.08)***
May	-1.93(0.09)***	-1.94(0.09)***	-0.94(0.10)***	-0.94(0.10)***
June	-0.65(0.09)***	-0.66(0.08)***	0.18(0.09)*	0.16(0.09)*
July	-0.12(0.08)	-0.14(0.08)	0.14(0.08)*	0.12(0.07)*
August	-0.01(0.08)	-0.02(0.08)	0.03(0.07)	0.01(0.07)
September	-0.04(0.08)	-0.05(0.08)	-0.03(0.07)	-0.04(0.07)
October	-0.08(0.08)	-0.09(0.08)	-0.09(0.07)	-0.10(0.07)
November	-0.03(0.08)	-0.04(0.08)	-0.01(0.07)	-0.02(0.07)
Recession	-0.27(0.06)***	-0.22(0.05)***	-0.16(0.05)***	-0.15(0.05)
Constant	9.27(0.06)***	8.95(0.59)***	5.88(1.23)***	5.91(0.60)***
Calculated long run elasticity			0.95	0.95
Number of observations	1,526	1,526	1,492	1,492
Adjusted R^2	0.79	0.79	0.82	0.82

Numbers in parenthesis are the Standard Errors in the static models
*** Indicates statistical significance to 1% or better
** Indicates statistical significance to 5% or better
* Indicates statistical significance to 10% or better

Results for the Df-Larch model are provided in Table 5. As with the previous two cases, all variables exhibit the expected signs, except that the log price is only significant for Df-Larch in the static model. In the dynamic model, stumpage is positive and statistically significant which is opposite of what is expected and observed in the previous models. Again April-June are the months in which the lowest harvests occur, and the recession dummy variables are negative and significant. In contrast to the regional model, the interest rate is negative and significant in the short-run; this suggests that it is representative of the cost of capital rather than the opportunity cost of holding trees. The adjusted R-squared varies from 0.81 to 0.86 in different models.

According to estimation results from the static model, the Df-Larch log supply is more sensitive to changes in log price when compared to SPF. In particular, the short-run elasticity in the static model for Df-Larch ranges from 1.16 to 1.40. This suggests that the log supply of Df-Larch across the 12 sampled districts in the BC Interior is price elastic. As mentioned, the log price variable is not significant in the dynamic model for Df-Larch. Consequentially, the long-run estimated supply elasticity in Table 5 is not representative of the sensitivity of log supply with regards to price. In general, the log prices of Df-Larch are considerably higher than that of SPF. Perhaps its higher comparative value contributes to an increased sensitivity with regards to log price. This observation is consistent with the results by Mojahednia (2015) in that higher grade logs tend to be more elastic than low grade logs in the BC Interior.

Unfortunately, since some of the results in the Df-Larch equation are not consistent with expectations, it is advised that they provide a basis for further research rather than an accurate estimate of price sensitivity. In particular, according to the results in Table 5, the price elasticity of Df-Larch log supply differs considerably in the short versus the long-run. For instance, in the static equation Df-Larch is price elastic and in the dynamic equation they are highly inelastic.

Table 5: Timber supply equation for BC Interior forest region Df-Larch estimated by fixed effects methods using panel monthly data from January 2004-December 2015.

	Static model		Dynamic model	
Explanatory variables	General	Restricted	General	Restricted
ln harvest(-1)			0.43(0.02)***	0.43(0.02)***
ln logprice	1.16(0.35)***	1.40(0.32)***	0.25(0.31)	0.29(0.16)
ln stumpage	0.07(0.05)		0.09(0.04)**	0.10(0.03)**
ln wage	-0.92(0.71)		-0.04(0.62)	
ln diesel	-0.40(0.24)		-0.26(0.22)	
interest rate	-0.08(0.04)*	-0.09(0.04)**	0.00(0.04)	
Jan	0.08(0.14)	0.05(0.15)	0.14(0.12)	0.14(0.12)
Feb	0.05(0.14)	0.03(0.15)	0.04(0.12)	0.05(0.12)
March	-0.15(0.14)	-0.15(0.15)	-0.24(0.12)**	-0.24(0.12)**
April	-2.00(0.17)***	-1.93(0.17)***	-1.84(0.14)***	-1.84(0.14)***
May	-1.25(0.17)***	-1.71(0.16)***	0.12(0.16)	0.12(0.16)
June	-0.42(0.15)***	-0.49(0.16)***	0.36(0.14)***	0.37(0.13)***
July	0.07(0.15)	0.08(0.16)	0.29(0.13)**	0.29(0.12)**
August	0.11(0.15)	0.09(0.15)	0.10(0.12)	0.09(0.12)
September	0.07(0.15)	0.07(0.16)	0.00(0.12)	-0.01(0.12)
October	0.00(0.14)	-0.02(0.15)	-0.06(0.12)	-0.07(0.12)
November	0.00(0.14)	-0.02(0.15)	0.08(0.12)	0.07(0.12)
Recession	-0.38(0.08)***	-0.29(0.08)***	-0.13(0.07)*	-0.11(0.06)*
Constant	8.86(2.69)***	2.95(1.26)**	5.28(2.33)**	3.71(0.90)***
Calculated long run elasticity			0.43	0.50
Number of observations	1,334	1,492	1,242	1,242
Adjusted R^2	0.82	0.81	0.86	0.86

Numbers in parenthesis are the Standard Errors in the static models
*** Indicates statistical significance to 1% or better
** Indicates statistical significance to 5% or better
* Indicates statistical significance to 10% or better

One difference between these two equations is the significance of the stumpage variable which is only significant in the dynamic model. If two or more predictor variables are highly correlated then the results often fail to be consistent with the assumptions of the model. In general, symptoms of multicollinearity include large swings in parameter estimates with small changes in the data, high standard errors associated with the estimated coefficients, magnitudes of coefficients that are opposite of expectations, and magnitudes of coefficients that are implausible (Greene 2012, p.89).

Since the stumpage rate was calculated as a sum of harvest value over the sum of harvest volume, it is a possible that stumpage is correlated with the lagged dependent variable in the Df-Larch restricted dynamic model. In fact, when the stumpage rate variable is removed from the restricted dynamic equation, the log price coefficient doubles in magnitude and becomes significant.

As a simple experiment with regards to the Df-Larch equation, we also ran the Df-Larch regression without the stumpage rate variable. The results are displayed in Table 6. For the general static model, the results differ from those in Table 5 only slightly. Excluding the stumpage rate variable from the general static equation increases the magnitude of the elasticity in the short-run from 1.16 to 1.26. In Comparison, the Df-Larch dynamic model is significantly different when the stumpage rate is not included as a regressor. In this case, the log price is significant in the long-run and the estimated elasticities are 0.61 and 1.09 for the short and long runs respectively. The adjusted R-squared declines slightly from 0.86 to 0.85. All of the other variables exhibit the expected signs, and the seasonal dummies suggest that the lowest harvests occur in March, April and May. The estimates in Tables 5 and 6 are meant to provide a base for further research regarding the Df-Larch specific log supply elasticities.

Table 6: Timber supply equation for BC Interior forest region Df-Larch estimated by fixed effects methods using panel monthly data from January 2004-December 2015, No Stumpage.

	Static model		Dynamic model	
Explanatory variables	General	Restricted	General	Restricted
ln harvest(-1)			0.44(0.02)***	0.44(0.02)***
ln logprice	1.26(0.34)***	1.40(0.32)***	0.62(0.30)**	0.61(0.19)***
ln wage	-0.73(0.77)		-0.27(0.67)	
ln diesel	-0.25(0.25)		-0.18(0.23)	
interest rate	-0.11(0.05)***	-0.09(0.04)**	-0.04(0.04)	
Jan	0.04(0.15)	0.05(0.15)	0.08(0.13)	0.08(0.13)
Feb	0.02(0.15)	0.03(0.15)	0.01(0.13)	0.01(0.13)
March	-0.16(0.17)	-0.15(0.15)	-0.24(0.13)*	-0.24(0.13)*
April	-1.93(0.17)***	-1.93(0.17)***	-1.87(0.15)***	-1.88(0.15)***
May	-1.73(0.16)***	-1.71(0.16)***	-0.39(0.16)**	-0.40(0.16)***
June	-0.53(0.16)***	-0.49(0.16)***	0.35(0.15)**	0.36(0.14)***
July	0.04(0.16)	0.08(0.16)	0.20(0.14)	0.20(0.13)
August	0.05(0.16)	0.09(0.15)	0.05(0.13)	0.06(0.13)
September	0.05(0.16)	0.07(0.16)	0.00(0.13)	0.00(0.13)
October	-0.02(0.15)	-0.02(0.15)	-0.06(0.13)	-0.07(0.13)
November	-0.02(0.15)	-0.02(0.15)	0.01(0.13)	0.01(0.13)
Recession	-0.31(0.09)***	-0.29(0.08)***	-0.08(0.08)***	-0.14(0.06)***
Constant	7.08(2.88)***	2.95(1.26)**	4.10(2.48)*	2.41(0.78)***
Calculated long run elasticity			1.11	1.09
Number of observations	1,492	1,492	1,356	1,356
Adjusted R^2	0.81	0.81	0.85	0.85

Numbers in parenthesis are the Standard Errors in the static models
*** Indicates statistical significance to 1% or better
** Indicates statistical significance to 5% or better
* Indicates statistical significance to 10% or better

Overall, the species specific models in Tables 4-6 suggest that log supply is more elastic for the two major species, SPF and Df-Larch, than for the BC Interior region as a whole. This result is puzzling since both the regional and the species specific models are estimated using districts as a cross section. Nonetheless, the log price variable was constructed differently for the regional model, where a species-volume weighted average log price variable was used.

In contrast, the monthly ILM log price per species was used across districts for the species specific model. Since log prices are not available for all relevant species in the BC Interior, the regional analysis includes only those species that are harvested the most across all 18 districts. Consequentially, the results from the BC Interior regional model and the species specific models are considerably different. In general, it is estimated that the harvest of Df-Larch over the sampled 12 forest districts is more sensitive to changes in price than is the harvest of SPF for the BC Interior.

SUMMARY

This analysis suggests that log supply is inelastic in the short run as well as the long run for the BC Interior as a whole. For the BC Interior regional model, panel data across forest districts—from January 2004 to December 2015—was used to estimate a region specific price elasticity of supply. Overall, the elasticities ranged from 0.41 in the short run to 0.39 in the long run. In other words, a 1% increase in the log price increases harvest levels by 0.41% to 0.39%. This result is consistent with previous estimates of the price elasticity of supply for the BC Coast (Margolick and Uhler 1992, Zhuang 1996, Sun et al. 2015). Statistically significant variables include the stumpage rate, the diesel price and the interest rate. Seasonal dummies are consistent with the observation that the lowest harvests occur during the spring. Moreover, the great recession from 2007-2009 had a negative impact on log supply for the BC Interior.

Furthermore, species-specific models were estimated for Df-Larch and SPF across 12 forest districts that harvested primarily these species from 2004 to 2015. In both the short run and the long run elasticities vary depending on species. In particular, SPF log supply is estimated to be moderately inelastic in both the short run and the long run; whereas, Df-Larch log supply is elastic in both cases. The only other significant variable outside of the log price for SPF is the stumpage rate which is estimated to have a negative effect on SPF log supply. In comparison, the interest rate—as a cost of capital—is a significant determinate of the DF-Larch log supply in the short run. Although stumpage was initially estimated to be a significant determinant of DF-Larch log supply, it was later dropped from the model due to expected correlation with the other predictor variables.

The species specific analysis presented in this paper provides a basis for further research in modelling log supply for the BC Interior. As more detailed log price data become available, the methods employed can be used to explore the determinants of supply for other species in the BC Interior such as Cedar, Hemlock and Balsam.

WORKS CITED

Abbott, B., Stennes, B., & Cornelis van Kooten, G. 2009. Mountain pine beetle, global markets, and the British Columbia forest economy. Canadian Journal of Forest Research, 39(7), 1313-1321.

Amacher, G., Conway, C., and Sullivan, J. 2003. Econometric analyses of nonindustrial forest landowners: is there anything left to study?. Journal of Forest Economics. 9, 137-164.

Bogdanski, B., Sun, L., Peter, B. and Stennes, B. 2011. Markets for forest products following a large disturbance: Opportunities and challenges from the mountain pine beetle outbreak in western Canada. Pacific Forestry Centre, 2011.

Bolkesjø, T. F., and Solberg, B. 2003. A panel data analysis of nonindustrial private roundwood supply with emphasis on the price elasticity. Forest Science 49(4): 530-538.

Bolkesjø, T.F., Buongiorno, J. and Solberg, B. 2010. Joint production and substitution in timber supply: A panel data analysis. Applied Economics 42: 671–680.

Canadian Council of Forest Ministers, n.d. (no date), Canada's National Forest Inventory (CanFI), (accessed January 31, 2011).

Croissant, Y., and Millo, G., 2008. Panel data econometrics in R: the plm package. Journal of Statistical Software. 27(2)

Fooks, J. R., Dundas, S. J., and Awokuse, T. O. 2013. Are There Efficiency Gains from the Removal of Natural Resource Export Restrictions? Evidence from British Columbia. The World Economy, 36(8), 1098-1114.

Greene, W. H. 2000. Econometric Analysis: Seventh Edition , Pearson Education Inc. Upper Saddle River, NJ.

Hadri, K. 2000. Testing for stationarity in heterogeneous panel data. The Econometrics Journal, 3(2), 148-161.

Hoberg, G., Malkinson, L., and Kozak, L. 2016. Barriers to innovation in response to regulatory reform: performance-based forest practices regulation in British Columbia

Im, K. S., Pesaran, M. H., and Shin, Y. 2003. Testing for unit roots in heterogeneous panels. Journal of econometrics, 115(1), 53-74.

Levin, A., Lin, C. F., and James Chu, C. S. 2002. Unit root tests in panel data: asymptotic and finite-sample properties. Journal of econometrics, 108(1), 1-24.

Mathey, A., Nelson, H., and Gaston, C. 2009. The economics of timber supply: does it pay to reduce harvest levels. Forest Policy and Economics. 11, 491-497

Ministry of Forests, Lands and Natural Resources. 2014a. Harvest Billing System Reports. Retrieved from https://www15.for.gov.bc.ca/hbs/

Ministry of Forests, Lands and Natural Resources. 2014b. Interior Log Market Reports. Retrieved from https://www.for.gov.bc.ca/hva/logreports.htm

MNP. 2015. BC forest industry: economic impact study. Council of Forest Industries. Retrieved from: http://www.cofi.org/wp-content/uploads/2015/01/bc_industry_impact_01-2015.pdf

Mojahednia, M. Assessing the impact of policies and regulations on log supply: a British Columbia case study. 2015. Unpublished.

Niquidet, K., and Tang, J. Elasticity of demand for Canadian logs and lumber in China and Japan. Canadian Journal of Forest Research. 43, 1196-1202.

Niquidet, K., and Van Kooten, G. C. 2006. Transaction evidence appraisal: competition in British Columbia's stumpage markets. Forest Science. 52(4), 451-459

Statistics Canada. Table 303-0064 - Lumber production, shipments and stocks, by Canada and provinces, annual (cubic meters)

Stennes, B. K., Niquidet, K., and Van Kooten, G. C. 2010. Implications of expanding bioenergy production from wood in British Columbia: An application of a regional wood fiber allocation model. Forest Science, 56(4), 366-378.

Sun, L., Clapper, J., & Niquidet, K. 2015. A panel data analysis if Coastal log supply in British Columbia. Forest Science, 61(4), 731-736

The State of Canada's Forests. Annual Report 2015. 2015. Natural Resources Canada, Canadian Forest Service, Ottawa. 75 p. Retrieved from: http://cfs.nrcan.gc.ca/publications?id=36553

van Kooten, G. C., & Johnston, C. 2014. Global impacts of Russian log export restrictions and the Canada–US lumber dispute: Modeling trade in logs and lumber. Forest Policy and Economics, 39, 54-66.

van Kooten, G. C. 2014. Benefits and costs of impeding free trade: revisiting British Columbia's restrictions on log exports. Journal of Forest Economics, 20, 333-347.

Wear, D. N., & Parks, P. J. (1994). The economics of timber supply: An analytical synthesis of modeling approaches. Natural Resource Modeling, 8(3), 199-223.

Zhang, H. and Buongiorno, J. 2012. Markets, government policy, and China's timber supply. Silva Fennica, 46(4), 595-608.

Zhang, 1996. An economic analysis of log export restrictions in British Columbia. Presented at the A World of Forestry. Proceedings of the 25th annual southern forest economics workshop, New Orleans, LA, 168-181.