Sustainable Wood Products as Substitutes in Building Construction: Evidence Based on Price Elasticity of Demand in Canada

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Abstract

Engineered and reconstituted wood products play an important role in building design and construction, and have positive environmental impacts. In order to promote the use of wood and wood-based products, there is a need to understand the economic factors that influence the choice of construction material. We estimated the own and cross price elasticities of demand of construction material in Canada using standard log-linear regression models with consumption and price data from 1990 to 2017. Our study shows that engineered and reconstituted wood products are substitutes for cement and steel, and hence there is a need to focus on the development of these value-added forest products, to create sustainable local economies that are economically viable, environmentally sound and socially responsible.

Keywords: Building construction industry, construction material, engineered wood products, price elasticity, sustainability, wood-based products.

1. Introduction

The building construction industry in Canada has always been an important driver of the overall national economy, and has been widely recognized as one of the world's largest market for commercial, residential and infrastructure development. The residential construction sector alone contributed Canadian $52.58 billion in 2016, which is an increase of 2.5% of the real GDP of Canada from the previous year (Leclair and Audet, 2017). The building construction industry is highly labour intensive, employing nearly three times as many workers per dollar of output as the average for the entire goods sector (Leclair and Audet, 2017). Also the building construction industry provided an employment of 686,000 in 2016 (Leclair and Audet, 2017). However, the Canadian building construction industry is dependent on the mortgage rates, which are directly impacted by the Bank of Canada interest rates. Rising interest rates and high indebtedness leads to a contraction in the demand for building construction and renovation industry (Allen et al., 2009). Building renovation spending, which is often an overlooked part of the industry, has also been a major growth segment for the construction industry and contributes to nearly 60% of the industry revenues (Leclair and Audet, 2017). Although, the choice of construction material for buildings in Canada is driven by various factors, such as, (i) economic factors, (ii) technological factors, and (iii) environmental factors (Allen and Iano, 2014), the demand for new building construction and renovations largely depends on the price of construction material (wood, concrete, steel, and others).

Wood and wood-based products play an important role in sustainable building design and construction, and have positive environmental impacts (climate change mitigation, reduction in waste and emissions) (Kibert, 2016). Few building materials possess the environmental benefits of wood. Wood is not only the most widely used building construction material, but also has characteristics that make it suitable for a wide range of applications for both residential and non-residential construction sectors (Kibert, 2016). In order to generate information on factors influencing the use of wood in the building construction industry in Canada, it is important to understand the price elasticities of demand. The estimated own and cross price elasticities of demand help in deciding whether the products are substitutes, whether products respond to price elasticity changes or whether there are differences in construction material (wood, concrete, steel, and others) regarding price effects (Jochem et al., 2016). However, there are no studies to our knowledge that estimate the own and cross price elasticities of demand for wood-based products and their substitutes in the Canadian building construction industry.

The efficient and durable wood products obtained from trees can range from a minimally processed log to a highly processed composite engineered wood product produced (glue-laminated beams or cross-laminated timber panels) at a large production facility (Kibert, 2016). In the recent past, the general population is becoming more aware of the concept of wooden buildings and their potential environmental benefits. Wooden buildings help in increasing the efficiency with which buildings use resources, while reducing building impacts on human health and the environment. This is because wood requires minimal amount of energy-based processing and has low levels of embodied energy relative to many other building construction materials (such as concrete and steel) (Kibert, 2016). In addition, more efficient engineered and reconstituted wood products are becoming popular compared to the sawn lumber (for example manufactured I-joists for floors as compared to standard milled wood) in building construction industry, as these are simple to install and have several engineering and architectural advantages, such as longer spans and smaller sizes (Kibert, 2016). Engineered wood products are materials that have been manufactured by bonding together wood fibres, and are being increasingly used in the building construction industry. The engineered wood products also have longer design life, as the products are not subject to rot or other similar atmospheric effects to the same extent as natural wood (Scharai-Rad and Welling, 2002). Reconstituted wood products made of wooden particles, including particleboards, oriented strand boards, wafer-boards, medium-density fibreboards, are also commonly used in the building construction industry (Scharai-Rad and Welling, 2002). Therefore, the market participants as well as policy makers need to understand the interactions between prices of wood or wood-based products, and the prices of the associated substitutes.

A method for estimating the interactions between prices of wood or wood-based products and the prices of the associated substitutes is the calculation of own and cross price elasticities of demand. The own price elasticity of demand measures the relative change in demand of a product as a consequence of a relative price change of the same product (Buongiorno, 1979). In contrast, the cross-price elasticity of demand measures the relative change in demand of a product as a consequence of a relative price change of another product (Buongiorno, 1979). In case prices affect the wood consumption and its substitutes in the building construction industry, there is a need to focus on engineered and reconstituted wood products as substitutes. In case, prices do not affect wood consumption in the building construction industry, there is a need to develop new technically improved wood-based products that can reduce technical (for example building strength, fire and moisture protection) and subjective (for example consumer information) barriers in the market (Buongiorno, 1979). Moreover, the analysis of own and cross price elasticities will help the policy makers to design policy measures towards climate change mitigation strategies, and towards a more sustainable economy.

Therefore, the general purpose of this study is to provide further information on price influencing the choice of construction materials in Canada. For this purpose, the own and cross price elasticities of demand for wood-based buildings and their associated substitutes in Canada are estimated. We examine the demand of two product categories: (i) buildings as a whole which are generally an aggregate of various construction materials, and (ii) construction materials such as lumber, cement and steel independently. Finally, we include the prices of engineered and reconstituted wood products in the analysis of own and cross price elasticities to analyze the impact of their prices on the consumption of construction material in Canada. The estimated own and cross price elasticities of demand help in deciding whether the existing engineered and reconstituted wood products are substitutes, and whether there is a need to develop improved wood-based products as per market demand.

The rest of the paper is organized as follows. Section 2 provides a brief overview of the use of wood-based products in the building construction in Canada. Section 3 provides a comprehensive literature review of the factors influencing demand and usage of the construction material in general and wood-products in particular, in the building construction industry. Section 4 presents the details of the methodology, describing the model specifications and data employed for the analysis. The empirical findings are presented and discussed in Section 5. Section 6 provides the concluding remarks.

2. Use of wood-based products in building construction in Canada

Wood-based products are important building construction materials in Canada, as they use less energy and emit fewer greenhouse gases (GHG) and pollutants over their life cycle than traditional, energy-intensive construction materials (Elling, 2015). Therefore, using wood in building construction can help Canada achieve its climate change goals and increase competitiveness of its forest products industry (Elling, 2015). In addition to the cost-effectiveness and environmental friendly characteristics of wood, there are other advantages of using wood in building construction, which include ease of assembly, and reduced noise and waste (Kibert, 2016). Moreover, the new generation of engineered wood products (for example glue-laminated beams or cross-laminated timber panels), provide strength and safety norms at par with traditional construction materials (Scharai-Rad and Welling, 2002). The National Building Code of Canada approved wood frame construction up to six storeys in 2015. As a result, British Columbia, Quebec, Ontario, Alberta and Nova Scotia have amended their building codes to allow for mid-rise wood frame construction. Residential construction is the major consumer of lumber, structural panels and engineered wood products in Canada. For example, new single-family units built in 2013 used 1.3 billion board feet of lumber, 226 million board feet equivalent of engineered wood products, and 1.1 billion square feet (3/8-inch basis) of structural panels, whereas multifamily unit buildings used 522 million board feet of lumber, 113 million board feet equivalent of engineered wood products and 292 million square feet (3/8-inch basis) of structural panels for framing and sheathing (Elling, 2015). The demand for engineered wood products has also been increasing due to the need for efficient and sustainable use of natural resources (Opacic et al., 2018).

Softwood lumber contributes 80% to 85% of the wood usage in residential building construction, and is mainly used in the construction of floor, wall, and roof systems (O'Connor et al., 2004). The rest of the wood usage is hardwood, engineered wood products, plywood, and oriented strand board (O'Connor et al., 2004). For example, in single-family construction in 2013 in Canada, the total usage of wood included 1086 billion board feet of softwood lumber, 226 billion board feet equivalent of engineered wood products, 526 million square feet (3/8-inch basis) of plywood, and 602 million square feet (3/8-inch basis) of oriented strand board. The prices of softwood lumber as well as other wood-products have been steadily rising over the past several years (Elling, 2015). Moreover, the cost of construction materials account for more than 50% of the total cost of building construction (Elling, 2015). Therefore, the analysis of price changes of the construction material will provide an insight into the demand for new building construction and renovation spending.

3. Literature Review

We did not find any peer-reviewed published studies regarding the factors influencing demand and usage of construction material in general (or wood-products in particular) in the building construction industry in Canada. However, a comprehensive literature review of similar studies in other countries revealed that price of construction material plays a significant role in the decision for at least residential construction, and the studies on price elasticity of demand is a common practice to examine the impact of price changes on the demand and usage of construction material (Jochem et al., 2015, 2016). McKillop et al. (1980) were the first to study the interaction between the demand of the wood-based products (coniferous lumber and plywood) and substitute structural materials (steel, aluminum, and concrete) used for construction in the US based on timber prices. Eastin et al. (1999, 2001)) used surveys in Germany to examine the influencing factors on the choice of construction material. Gold and Rubik (2009) used consumer opinions to study the choice of construction material, and found that the decisive factors in the consumer opinions were quality, security and durability of the construction material. Another study found that the buying decision is influenced by price and quality of the construction material (Burrows and Sanness, 1999). Uusivuori and Kuuluvainen, (2001) further noted that factors that influence the choice of construction materials vary between residential and non- residential buildings. They also found that the major factors influencing the choice of non-residential buildings include price of construction material and typical regional methods of construction (Uusivuori and Kuuluvainen, 2001). In the estimation of own and cross price elasticities of demand for wood-based products and its associated substitutes in the German construction sector, Jochem et al. (2015) found non-significant results for the residential building construction industry. However, they also found that the demand for wood-based products and its associated products were substitutes for the non-residential building construction industry, and recommended that more attention was needed to develop and promote these engineered and reconstituted wood products (Jochem et al., 2015).

The study conducted by the APA-The Engineered Wood Association, the Canadian Wood Council, FPInnovations and others, to estimate the actual wood product usage and potential for more wood products to be substituted for other building materials, compared the amount of lumber, engineered wood products and competing products (concrete and steel) used for building construction in Canada (Elling, 2015). The study found that the usage of competing products has been steadily increasing in the recent past in the Canadian building construction industry. For example a comparison of the structural framing material usage in single-family construction in Canada from 2006 to 2013 found that the usage of softwood lumber and engineered wood products has decreased from 266 million board feet to 198 million board feet, and from 402 million board feet equivalent to 196 million board feet equivalent, respectively. Whereas in the same period, the usage of concrete and steel has increased from 13 million board feet equivalent to 46 million board feet equivalent, and from 1 million board feet equivalent to 8 million board feet equivalent, respectively. Similar in the framing applications, the volume of concrete used in floor and wall applications has also risen, despite a decline in single-family starts.

In the past, most non-residential and multi-family residential buildings in Canada over four storeys tall were built using primarily concrete and steel. But recent changes to building codes, along with the development of engineered wood products, have led wood-based products to be considered as more environmentally-friendly and a cost-effective alternative for tall buildings (Kibert, 2016). The stability, durability and renewability of wood-based products, as well as the targets for a greener, sustainable and low-carbon industry, provides a big potential for increasing the use of wood in building construction (Huang et al., 2009). Moreover, wood as a building material is seen from the perspective of low water and air pollution, low solid waste compared to concrete and steel (Liu et al., 2005). Another advantage of using wood-based products in building construction is the provision of flexibility of structures and composition of the walls that can be designed as low cost and less energy intensive (Roos et al., 2008). Therefore, there is a need for constant expansion of wood-based construction in architecture along with the development of new engineered and reconstituted wood products, and new building systems (Sun 2014, 2017). In this study, we only focus on the residential construction in Canada, as separate data for non-residential building construction in Canada in not readily available. It is quite possible that the results of analysis for demand and usage of wood and wood-based products for residential and non-residential construction may be different (Ramage et al., 2017).

4. Methodology

4.1 Model Used

The prices of products and their substitutes are the main economic factors that affect their demand. The own and cross-price elasticities of demand of any products can be estimated empirically based on the relationship between the demand and the prices of the product and its substitutes. Generally, independent variables are never known in total, and the dependent variable cannot be fully explained. This is accounted for by an error term in the equation.
The log-linear regression model (equation 1) helps estimate the price elasticities, as the logarithmic transformation of the dependent and independent variables allows the coefficients to be interpreted as elasticities (Jochem et al., 2016).

$$ln(C_{1,t}) = \beta_0 + \beta_1 \times ln(P_{1,t}) + \beta_2 \times ln(P_{2,t}) + \cdots + \beta_n \times ln(P_{n,t}) + \beta_{n+1} \times ln(C_{1,t-1}) + \varepsilon \quad [1]$$

Where, $C_{1,t}$ = dependent variable, consumption of construction material (lumber, cement, steel) in period t

$P_{1,t}$ to $P_{n,t}$ = independent variables (prices of lumber, cement, steel, engineered wood products (EWP), reconstituted wood products (RWP), and veneers and plywood) in period t

β_i to β_{n+1} = coefficients of independent variables that are interpreted as price elasticities

ε = error term

t = month

$t-1$ = lagged month

The model helps in explaining the consumption of the construction materials (dependent variable) with respect to the prices of independent variables (construction materials including lumber, cement, steel, engineered wood products, reconstituted wood products, and veneer and plywood). The explanatory variables are selected on the basis of existing knowledge and the current literature. In addition, a lagged dependent variable is included as explanatory variable in the model, only if this variable is not strongly correlated with other explanatory variables. The lagged dependent variable also helps in accounting for trend effects in the endogenous dynamic regression model (Maddala and Lahiri, 1992). All the independent variables are tested for multicollinearity using the variance inflation factor (VIF) test, and only those variables are retained, which do not lead to multi-collinearity in the model specification (Stock and Watson 2014). The Durbin-Watson statistic is used to measure and to ensure that there is no autocorrelation of the residuals in the model specification (Stock and Watson, 2014). The models are also tested for normal distribution and homoscedasticity of the residuals (Stock and Watson, 2014), to ensure that there is no omitted variable bias in the model. When the cross price elasticities of demand have a positive sign, the products are substitutes, and when the price elasticities of demand have a negative sign, the products are complements. The coefficient of the independent variables indicate the percentage change in consumption of the construction material with 1% change in the price of the independent material (Stock and Watson 2014). The coefficient of the lagged term indicates that an increase of the wood construction share in the previous year causes a similar increase of the wood construction share in the following year with a high probability (Jochem et al., 2016). Changes in price cause the "wood" share to vary around this trend, and the absolute "wood" share can be compared to the "steel and reinforced concrete" share.

4.2 Model Specification

The general standard log-linear regression model specified in equation [1] is run as eleven different translog models. Each model has one dependent variable and many independent variables. First two models estimate the price elasticities of lumber, cement, steel, veneer and plywood, engineered and reconstituted wood products, and a lagged dependant variable for the aggregate demand of buildings in Canada. In the next nine models, we run independent translog models for each of the construction materials (lumber, cement and steel) with the same set of independent variables. Since softwood lumber constitutes 80% to 85% of the lumber used in the building construction industry in Canada, we replaced the variable lumber with softwood lumber in the last six models. All the eleven model specifications are shown in Table 1.

Table 1: Model Specification for log-linear regression models for estimating price elasticities

Model	Dependent variable (Y)	Independent variables (X's)
Model 1	Aggregate building demand	Price of Lumber Price of Cement Price of Steel Price of Veneer and Plywood Lagged Aggregate Demand
Model 2	Aggregate building demand	Price of Lumber Price of Cement Price of Steel Price of Veneer and Plywood Price of Engineered Wood Products (EWP) Price of Reconstituted Wood Products (RWP) Lagged Aggregate Demand
Model 3 Model 4 Model 5	Consumption of Lumber Consumption of Cement Consumption of Steel	Price of Lumber Price of Cement Price of Steel Price of Veneer and Plywood Lagged Aggregate Demand
Model 6 Model 7 Model 8	Consumption of Softwood Consumption of Cement Consumption of Steel	Price of Softwood Price of Cement Price of Steel Price of Veneer and Plywood Lagged Aggregate Demand
Model 9 Model 10 Model 11	Consumption of Softwood Consumption of Cement Consumption of Steel	Price of Softwood Price of Cement Price of Steel

	Price of Engineered Wood Products (EWP)
	Price of Reconstituted Wood Products (RWP)
	Price of Veneer and Plywood
	Lagged Aggregate Demand

4.3 Data

The monthly data (Mar 1990 to Jul 2017) for aggregate demand of building were obtained from *Statistics Canada Table 026-0001 (Building permits, residential values and number of units, by type of dwelling)*. The building permits survey covers all Canadian municipalities that issue permits. The number of Canadian municipalities surveyed exceeds 2,350, representing all the provinces and territories, and accounting for 95% of the Canadian population. The data corresponds only to the value associated to the units built between 1990 to 2017 (Figure 1). It is evident that the number of residential units in Canada decreased slightly from 1990 to 1995, increased from 1995 to 2003, decreased from 2003 to 2009, and finally has shown a recovery from 2009 onwards. This change in number of residential units from 1990 to 2017 corresponds to the economic cycle in Canada. The trend effects are accounted for by lagged dependent variable in the regression model (Maddala and Lahiri, 1992).

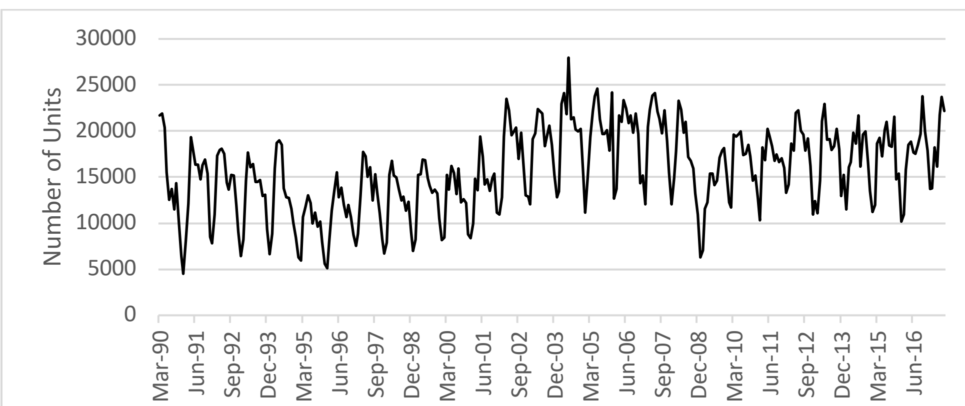

Figure 1: Number of residential units built in Canada from 1990 to 2017

The monthly data for price of cement (Mar 1990 to Jul 2017) and steel (Jan 2004 to May 2013) prices were obtained from *Statistics Canada Table 329-0075 (Industrial product price index – 2318, by North American Product Classification System (NAPCS 2012), index 2010=100)*. The monthly price data for lumber, softwood and veneer and plywood (Mar 1990 to Jul 2017), engineered wood products, and reconstituted wood products (Jan 2010 to Jul 2017) were obtained from *Statistics Canada Table 329-0075 (Industrial product price index – 2318, by*

NAPCS-2012, index, 2010=100). The NAPCS 2012 uses 2010-based Industrial Product Price Index (IPPI) series. The historical series of all data for the months prior to January 2010 were obtained by linking together indexes from the 2010-based IPPI series and the corresponding 2002-based IPPI series. There has been a steady increase in the prices of cement and steel from 1990 to 2017 (Figure 2). However, the prices of wood-based products (lumber, softwood, engineered and reconstituted wood products, and veneer and plywood) follow similar trends to the number of buildings built (Figures 1 and 2).

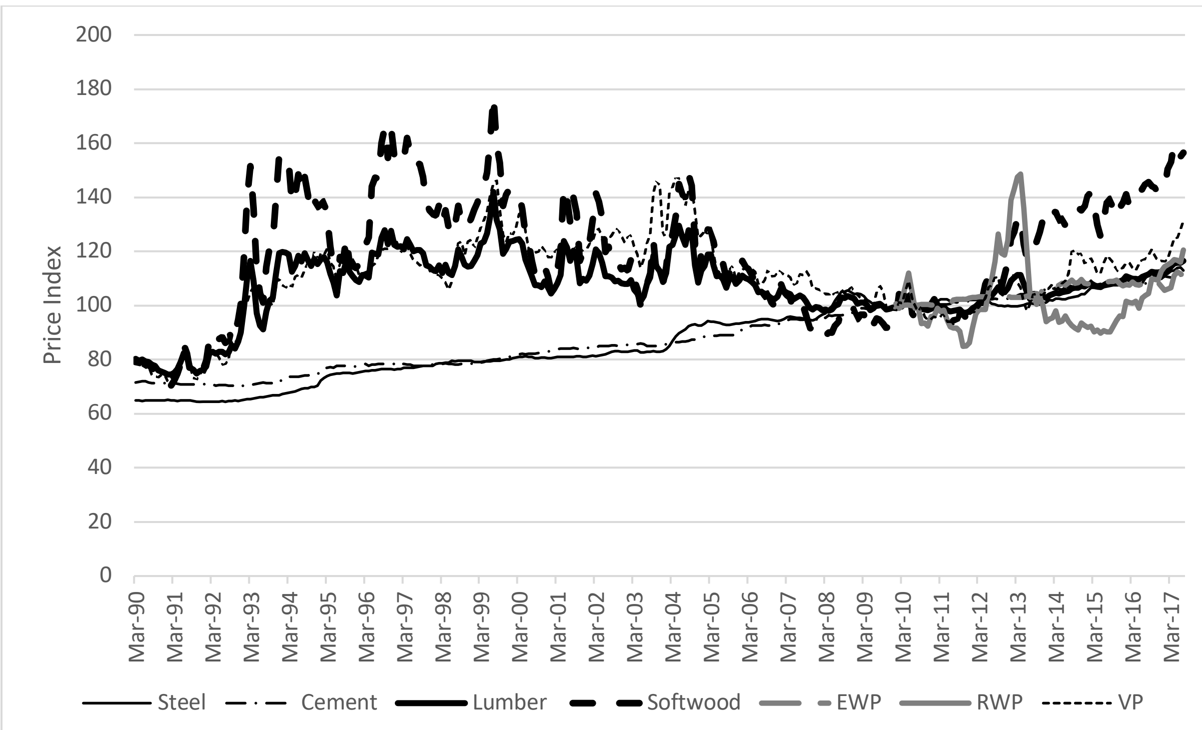

Figure 2: Price of building construction material in Canada from 1990 to 2017

5. Results and Discussion

The results of demand for buildings as a whole (aggregate consumption of construction material) are shown in Table 2. Model 1, which uses the aggregate demand for building units as the dependent variable, and price of construction material (lumber, cement, steel, veneer and plywood) as independent variables. Only the price of lumber (*p-value = 0.0002*) and veneer and plywood (*p-value = 0.0017*) have a significant impact on the aggregate demand of buildings. In addition, the lagged aggregate demand is highly significant (*p-value = 0.0000*), indicating the aggregate demand of buildings is significantly dependent on the demand for last year, and the demand for aggregate buildings follows a clear trend, subject to the prices of construction material remaining constant. While the price elasticity of lumber has a negative sign (meaning the demand increases with a reduction in price of lumber), the price elasticity of veneer and plywood has a positive sign (meaning the demand increases with an increase in price of veneer and plywood). The coefficients indicate the percentage change in demand with 1% change in price. With the introduction of the engineered wood products and reconstituted wood products in the model (see results of Model 2 in Table 2), it was noticed that the prices of both these products have a significant impact on the demand of building construction in Canada. The price elasticities for both products were negative, indicating that the aggregate demand of buildings increases with a decrease in price of engineered wood products and reconstituted wood products. Therefore, we further focused our attention on the role of price of engineered wood products and reconstituted wood products on the demand of building construction material rather than aggregate building demand in Canada. Both models show very good explanatory power (see R^2 in Table 2), and do not suffer from the problem of auto-correlation as indicated by the Durbin-Watson test.

Table 2: Estimated price elasticities of construction material with respect to aggregate demand of buildings in the Canadian construction sector

	Aggregate Demand Model 1	P-value	Aggregate Demand Model 2	P-value
Price of Lumber	-1.3284	0.0002 ***	-7.5809	0.0419 *
Price of Cement	-0.1512	0.8078	-2.0285	0.4837
Price of Steel	0.8822	0.1017	3.3359	0.0075 **
Price of Veneer and Plywood	0.9682	0.0017 **	1.2986	0.1898
Price of EWP			-5.9717	0.0087 **
Price of RWP			-1.4939	0.0172 *
Lagged Aggregate Demand	0.72552	0.0000 ***	0.49761	0.0000 ***
Intercept	8.0052	0.0000 ***	-1.62477	0.7380
Model Fit	Year	R^2	P-value	Durbin-Watson
Aggregate Demand Model 1	1990-2017	0.6189	0.0000 ***	1.5688
Aggregate Demand Model 2	2010-2017	0.6525	0.0000 ***	1.8863

Significance: '*' 0.05, '**' 0.01, '***' 0.001

Table 3 shows the estimated own and cross price elasticities with respect to individual product consumption (including lumber in Model 3, cement in Model 4, and steel in Model 5) in the Canadian construction sector. The own price elasticities of demand show the expected negative sign, with their significance levels displayed in Table 2. The cross-price elasticities of cement (*p-value = 0.0107*) and veneer and plywood (*p-value = 0.0000*) are significant in the lumber consumption model, whereas the cross-price elasticity of steel (*p-value = 0.0000*) is significant in the steel consumption model. The negative sign of the coefficient of price of cement in the lumber consumption model indicates that cement is a complement of lumber, and the positive sign of the coefficient of price of veneer and plywood in the lumber consumption model indicates that veneer and plywood are substitutes for lumber in building construction. Similarly, the negative sign of the coefficient of price of cement in the steel consumption model indicates that cement is a complement of steel. Once again all the lagged consumption variables (lumber, cement and steel) in each model are highly significant indicating that the consumption of construction materials) is significantly dependent on the demand for last year consumption of the same materials, and the demand for construction materials follows a clear trend, subject to the prices of other construction materials remaining constant. The model shows very good explanatory power (see R^2 in Table 3), and does not suffer from the problem of auto-correlation as indicated by the Durbin-Watson test.

Table 3: Estimated own and cross price elasticities with respect to individual product consumption (including Lumber, Cement, and Steel) in the Canadian construction sector

	Model 3		Model 4		Model 5	
	C_{Lumber}	P-value	C_{Cement}	P-value	C_{Steel}	P-value
Price of Lumber	-0.8644	0.0000 ***	-2.0321	0.0792	-3.8537	0.1348
Price of Cement	-1.1231	0.0107 *	-1.5337	0.1117	-6.3117	0.0000 ***
Price of Steel	0.6604	0.0522	0.5613	0.6452	-1.9059	0.2364
Price of Veneer and Plywood	1.5132	0.0000 ***	1.4586	0.0546	1.1807	0.1941
$C_{(Product,\ t-1)}$	0.7164	0.0000 ***	0.7879	0.0000 ***	0.2287	0.0225 *
Intercept	1.7499	0.0046 **	3.5708	0.1590	27.4523	0.0086 **
Model Fit	Year	R^2	P-value	Durbin-Watson		
C_{Lumber}	1990-2011	0.7890	0.0000 ***	2.1728		
C_{Cement}	2004-2017	0.6592	0.0000 ***	1.8963		
C_{Steel}	2004-2013	0.4897	0.0000 ***	1.9535		

Significance: '*' 0.05, '**' 0.01, '***' 0.001
C_{Lumber}: Consumption of Lumber
C_{Cement}: Consumption of Cement
C_{Steel}: Consumption of Steel
$C_{(Product,\ t-1)}$: Lagged product consumption

We re-ran all the models by replacing the data of lumber with available data of softwood. Table 4 shows the estimated own and cross price elasticities with respect to individual product consumption (including softwood in Model 6, Cement in Model 7, and Steel in Model 8) in the Canadian construction sector. The results of own and cross price elasticities of demand using softwood instead of lumber show almost identical results for this relationship.

Table 4: Estimated own and cross price elasticities with respect to individual product consumption (including Softwood, Cement and Steel) in the Canadian construction sector

	Model 6		Model 7		Model 8	
	$C_{Softwood}$	P-value	C_{Cement}	P-value	C_{Steel}	P-value
Price of Softwood	-0.33060	0.0000 ***	0.1630	0.7026	-0.4779	0.2193
Price of Cement	-1.0971	0.0134 *	-2.8303	0.0724	-5.5980	0.0000 ***
Price of Steel	0.5249	0.1212	1.4375	0.3831	-1.6267	0.3114
Price of Veneer and Plywood	1.21097	0.0000 ***	-0.1175	0.8775	0.2639	0.6953
$C_{(Product, t-1)}$	0.72123	0.0000 ***	0.7867	0.0000 ***	0. 2493	0.0114 *
Intercept	21.3906	0.3890	0.8886	0.8720	20.2599	0.0089 **

Model Fit	Year	R^2	P-value	Durbin-Watson
$C_{Softwood}$	2010-2011	0.7333	0.0928 **	2.1790
C_{Cement}	2004-2013	0.6595	0.0000 ***	1.9355
C_{Steel}	2004-2013	0.4841	0.0000 ***	1.9688

Significance: '*' 0.05, '**' 0.01, '***' 0.001
$C_{Softwood}$: Consumption of Softwood
C_{Cement}: Consumption of Cement
C_{Steel}: Consumption of Steel
$C_{(Product, t-1)}$: Lagged product consumption

The most interesting results were obtained by including the prices of engineered wood products and reconstituted wood products in the log-linear model. Table 5 shows the estimated own and cross price elasticities with respect to individual product consumption (including softwood in Model 9, Cement in Model 10, and Steel in Model 11), including the prices of engineered wood products and reconstituted wood products in the log-linear model, in the Canadian construction sector. The cross-price elasticities of engineered wood products is significant in cement (*p-value = 0.0087*) and steel consumption models (*p-value = 0.0085*), and the cross price elasticities of reconstituted wood products is significant in cement (*p-value = 0.0419*) and steel consumption models (*p-value = 0.0316*). The positive sign of the coefficient of price of engineered wood products in softwood, cement, and steel consumption models indicates that engineered wood products are substitutes for these products in building construction. The magnitude of the coefficients for cement and steel consumption models indicates that with every 1% decrease in price of engineered wood products, the consumption of cement and steel in building construction industry will decrease by 12.45% and 1.88%, respectively. Similarly the positive sign of the coefficient of price of reconstituted wood products in the cement and steel consumption models indicates that reconstituted wood products are substitutes for these products in building construction, whereas the negative sign of the coefficient of price of reconstituted wood products in the softwood consumption model indicates that reconstituted wood products are complements for softwood products in the building construction industry. The magnitude of the coefficients for cement and steel consumption models indicates that with every 1% decrease in the price of reconstituted wood products, the consumption of cement and steel in building construction industry will decrease by 2.23% and 7.89%, respectively. All the models show very good explanatory power (see R^2 in Table 5), and do not suffer from the problem of auto-correlation as indicated by the Durbin-Watson test.

Table 5: Estimated own and cross price elasticities with respect to individual product consumption (including Engineered wood products and Reconstituted wood products) in the Canadian construction sector

	Model 9		Model 10		Model 11	
	$C_{Softwood}$	P-value	C_{Cement}	P-value	C_{Steel}	P-value
Price of Softwood	-0.0601	0.913	-12.9092	0.0722	-2.6130	0.0407 *
Price of Cement	-6.2997	0.436	-6.0854	0.2482	-1.4946	0.9122
Price of Steel	2.6178	0.269	4.3006	0.1234	-3.1807	0.0118 *
Price of EWP	0.5899	0.893	12.4456	0.0087 **	1.8762	0.0085 **
Price of RWP	-0.1895	0.719	2.2279	0.0419 *	7.8928	0.0316 *
Price of Veneer and Plywood	0.4567	0.486	2.9959	0.1059	3.8882	0.2183
$C_{(Product, t-1)}$	0.01059	0.9750	0.7551	0.0000 ***	-0.2010	0.2657
Intercept	21.3906	0.3890	-0.3771	0.9610	-26.2755	0.3258
Model Fit	Year	R^2	P-value	Durbin-Watson		
$C_{Softwood}$	2010-2011	0.6133	0.0427 **	1.7751		
C_{Cement}	2010-2017	0.6458	0.0000 ***	1.8190		
C_{Steel}	2010-2013	0.4921	0.0035 ***	2.2060		

Significance: ‘*’ 0.05, ‘**’ 0.01, ‘***’ 0.001
C_{Lumber}: Consumption of Lumber
C_{Cement}: Consumption of Cement
C_{Steel}: Consumption of Steel
$C_{(Product, t-1)}$: Lagged product consumption
EWP: Engineered wood products
RWP: Reconstituted wood products

The results of all these models indicate that wood-based products have a significant effect on demand in the building construction industry in Canada. Therefore, there is a need to focus on the price of engineered and reconstituted wood products in order to promote the use of these products in the building construction industry. The estimation of the price elasticities of engineered and reconstituted wood products further helped us in understanding their impacts on the aggregate demand of building construction in Canada. The results of our analysis, focusing on the factors influencing the demand of individual construction materials (lumber, cement and steel) in the building construction industry in Canada, helped us in differentiating between substitutes and complements for construction material based on price information, as well as the magnitude of the percentage change in demand for 1% change in price of each construction material. Since softwood is a major component of lumber consumption in the building construction industry, we replaced lumber with softwood in further analysis, but the results did not change significantly. Finally, we introduced the prices of engineered and reconstituted wood products in the analysis of demand of individual construction materials. Both these product categories were found to significantly impact the demand of construction materials in the building construction industry in Canada.

Although, many studies in the past have focused on the importance of wood-based products in the building construction industry, there are no studies to our knowledge, which focus on the economic factors (especially price elasticity) in influencing the demand for construction materials in Canada. Our study shows that the building construction industry plays an important role in the use of wood and wood-based products, and prices of different construction materials are one of the deciding factors in choosing the construction material. However, there are other environmental, technological and subjective factors that ultimately decide the choice of construction materials in the economy (Kibert, 2016). The knowledge and understanding about the factors affecting the choice of construction materials is essential for policy makers, the academic community and market participants in order to promote the use of wood and wood-based products in the construction industry in Canada. However, more research and comprehensive data are required to quantify factors influencing demand of construction materials in Canada. In addition, there is a need to directly and indirectly support wood and wood-based construction materials in buildings through government funding and appropriate supporting measures.

6. Conclusions

The purpose of this study was to provide further information on economic factors (price elasticities of wood-based products, cement and steel) influencing the choice of construction materials in Canada, in order to promote the use of wood-based products, especially engineered and reconstituted wood products in the building construction industry in Canada. In order to achieve these objectives, we estimated own and cross price elasticities of demand of construction materials using aggregate demand of buildings and independent demand of construction materials such as lumber, cement and steel. It was found that wood-based products, especially engineered and reconstituted wood products are substitutes for cement and steel in the building construction industry. The use of wood-based products in building construction will not only have positive environmental effects, but will also promote sustainable forest industry in Canada, which contributes to the national economy and supports many communities.

One of the limitations of our study is that there is no data for construction materials separately for residential and non-residential building construction in Canada. Another limitation is that the price may not be the only factor in making decisions about the use of construction materials. There are many other technological and subjective factors including the quality of construction material, consumer perceptions, incentives provided by government for the use of wood and wood-based products in building construction, and awareness of consumers about the environmental impacts of using wood and wood-based products. Moreover, information is lacking on the degree to which substitution will take place in response to change in other economic parameters such as relative energy costs, employment, and the state of national and regional economy. Additionally, the estimation process is complicated by the fact that price-induced substitution does not take place instantaneously but gradually over several years.

7. References

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