Determinants of Sawnwood Consumption in Slovakia

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This paper aimed to determine coniferous and non-coniferous sawnwood demand drivers and used historical data on their development as independent variables in the sawnwood demand models. The study presented a general form of *ad hoc* model that explained sawnwood consumption per capita as a function of a range of socio-economic factors. Based on the theory of demand, the most important factors were identified to enter the regression model including significant price and income variables. In the case of the non-coniferous sawnwood model, time lag variables were applied. The results of the estimated econometric models confirmed the presence of different explanatory variables for both types of sawnwood. While consumption per capita of both coniferous and non-coniferous sawnwood was determined by the activities of the construction sector, and demand appeared to be very elastic in relation to the number of completed dwellings, the price and substitution for other wood materials had a significant impact only on non-coniferous sawnwood.

Keywords: Sawnwood consumption; Demand factors; Substitution effect; Econometric model

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INTRODUCTION

The wood processing industry holds a significant position within the industrial sector in Slovakia. The sawnwood industry plays an important role in Slovakia's domestic and international forest product markets. Due to the nature of coniferous sawnwood products (limited number of tree species and generally lower products differentiation), there are only a few large, several middle, and a large number of small sawmills in the market. In contrast, the non-coniferous sawmilling sector is more diversified (in the number of tree species used and product specialisation) with a more homogenous structure in terms of company size in Slovakia (Paluš 2013). Coniferous and non-coniferous sawnwood has been traditionally and widely used in different applications, mainly in construction, furniture production, and manufacturing such as pallets, cross ties or sleepers, scaffolding, and dunnage. Innovations in the non-coniferous sawnwood sector aim to extend the uses into new structural applications and the use of temperate sawnwood in external environments through thermal and chemical modification (UN 2015a). According to the Food and Agricultural Organisation (FAO 2017), Slovak sawmills produced over 1.15 mil. m^3 of coniferous and 0.55 mil. m^3 of non-coniferous sawnwood in 2015. The total exports of coniferous sawnwood accounted for almost 0.63 mil. m^3 and of non-coniferous sawnwood over 0.15 mil. m^3, while volumes of imports were negligible. The side products and waste generated in the production process enter as industrial material to other related sectors of the wood processing industry, namely the production of wood-based panels and pulp and paper. The importance of the sawmilling sector as a whole has increased during the last year with the increasing demand for renewable energy. This was promoted by the

European Union (EU) energy strategy 2020 and 2030 goals aiming at the meeting of 2050 greenhouse gas reduction targets (European Commision 2014). Based on calculations by Parobek and Paluš (2016), the total volume of waste (sawdust and residues) flow from sawnwood production is over 1.5 mil. m^3. Therefore, Engelbrecht argues that sawmills should benefit from the development of wood-based bioenergy markets due to higher prices for waste products demanded by bioenergy markets (Engelbrecht 2006).

There have been a number of studies developed to identify and quantify the influence of the underlying factors affecting sawnwood demand, most of them arising over the last decades of the last century. Econometric methods are widely used for demand modelling. Consumption of sawnwood is determined by a set of factors. In general, sawnwood demand is largely influenced by the economic development of a country and mostly linked to the trajectory of gross domestic products (GDP). This concept considering GDP to be the explanatory income variable was used in some earlier and later studies (Buongiorno 1977, 1996; Michinaka *et al*. 2011; Jonsson 2013). Alternatively, other studies incorporated variables linked to construction and housing activities, different sector economic indicators (*e.g.* input cost, wages), or population (McKillop 1967; Adams and Blackwell 1973; Buongiorno *et al*. 1984; Singh and Nautiyal 1986). With the aim to take into account information from a variety of end-use sectors and to reduce the problem of multicollinearity, some studies used a constructed end-user index combining the activity of different end-use sectors (Baudin and Lundberg 1984; Brooks *et al*. 1995; Kangas and Baudin 2003). The influence of price on demand is estimated through the calculation of direct (Buongiorno 1977; Kangas and Baudin 2003; Jonsson 2013) or cross-price elasticities, thus giving the possibility to determine substitution relations either between the wood products and their substitutes or between the markets (Baudin and Solberg 1989; Hetemäki *et al*. 2004). Based on the extensive literature review of factors influencing and reliably explaining consumption for sawnwood, Hurmekoski and researchers identified a general form of *ad hoc* model that explains consumption per capita as a function of a set of economic variables (Hurmekoski *et al*. 2015). Compared to the former numerous studies, there have been only some aimed at the modelling of the sawnwood market during the 21st century (Kangas and Baudin 2003; Hetemäki *et al.* 2004; Buongiorno 2009; Jonsson 2013; Hurmekoski *et al*. 2015). Factors that affected coniferous sawnwood market development in Slovakia were investigated (Šupín and Paluš 1999; Paluš and Parobek 2008; Parobek and Paluš 2008; Parobek *et al*. 2014).

The recent development of global and regional sawnwood markets has varied substantially. According to Hurmekoski *et al*. (2015), the economic crisis that started in summer 2007 caused the European sawnwood markets to fall for several years, and historical trends and traditional major market indicators do not seem to support strong growth in sawnwood demand in the future. Though the climate change mitigation policies promoting the use of renewable construction materials could boost global demand for construction (Šálka *et al*. 2008; Jonsson 2013), there are changes projected in the number and structure of the population in European countries (UN 2015b). As an example, the population of Slovakia is expected to decline by almost 10% to 4.892 mil. by 2050. There are also visible trends in the urbanization of the population and major changes will occur in the population structure (Vokoun *et al*. 2006) that will affect the use of wood in construction. The economic growth in Europe is expected to be moderate, and there will be structural reforms needed to boost potential growth and mitigate the long-term effects of the lackluster external environment (Sarvašová *et al.* 2012) and aging populations (World Bank Group 2017).

All of these trends indicate that the sawnwood market sector is undergoing considerable changes, such as in its driving factors and consumption patterns, which may result in different linkages and new possible drivers for sawnwood consumption. Hurmekoski *et al.* (2015) suggested to link changes in the use of sawnwood to changes in consumption patterns and explain these changes in relation to the level of consumption per capita (CPC). They realised that sawnwood consumption per capita is generally related to construction activity, income, and prices; however, there are large regional differences in the drivers for sawnwood consumption in Europe. Buongiorno (2009) indicated that there was a divergence in sawnwood consumption per capita across countries during the last 20 years.

The main purpose of this research is to analyse the current coniferous and non-coniferous sawnwood consumption per capita in the Slovak Republic, with the focus on (i) identification of the key demand drivers; (ii) formulation and estimation of econometric models; and (iii) analysis of applied variables in the models. The estimation of parameters and quantification and verification of the applied econometric models are based on the theory of derived demand using a set of available economic indicators.

METHODS

The ultimate purpose of production is consumption. This applies to every production activity and to every kind of product. Therefore, product demand is in one way or another, consumer demand, and the theory of consumer demand is the core of all demand theories. To explain per capita consumption of sawnwood in Slovakia the level of population is used for converting absolute variables into per capita variables. Consumption per capita (CPC; m^3) was then calculated as:

$$CPC = \frac{Production + Import - Export}{Population} \quad (1)$$

In general, sawnwood is a kind of product that is not consumed directly but mostly used as an input in a number of production activities, *e.g.* residential and non-residential construction, furniture production, manufacturing, *etc.* The demand for sawnwood was derived from the demand for the final products such as houses, flats, and furniture. Demand for sawnwood will depend on the development of demand for the final products and reflect factors of economic activity, such as income, product price, output level, demographic factors, and the possible substitution of sawnwood for other materials (Baudin 2003; Paluš 2013).

Basically, sawnwood consumption per capita is influenced by the price of the product and income; however, there is a range of other specific factors determining consumption. Hurmekoski and his team of researchers identified differences in countries across Europe applying the *ad hoc* model explaining sawnwood consumption per capita as a function of the domestic price of sawnwood, the price of a substitute product, the price of a complement product, GDP per capita, renovation activity, residential construction activity, unemployment, and economic openness (Hurmekoski *et al*. 2015). For the purposes of modelling sawnwood CPC in Slovakia, a set of explanatory variables during the period of 1995 to 2015 was selected, taking into account the availability of data. A set of the following factors were examined – price of coniferous and non-coniferous sawnwood, price of particle boards, price of wood-based panels, price of construction

materials, price of furniture, GDP, GDP per capita, number of completed dwellings, new construction including modernisation and renovation, repairs and maintenance, population, economically active population, recorded unemployment rate, and gross income and expenditures per household. The authors performed a set of initial tests to exclude variables with weak explanatory power, overlap, or multicollinearity. The final general form of *ad hoc* model was defined as follows,

$$CPC = f(p_d, p_s, p_c, GDPC, DWC, NCM\&R, R\&M, EAPOP, UE, EH) \quad (2)$$

where y is sawnwood consumption per capita and X is a vector of explanatory variables. To estimate parameters of the given model, ordinary least squares estimation method was used. The Durbin-Watson test was used to test the autocorrelation of residues and variance inflation factors (VIF) to test multicollinearity in a Statistical Package for the Social Sciences (SPSS Inc., version 18, Chicago, USA). In an effort to reduce autocorrelation of residues and increase the explanatory power of variables lagged, dependent and explanatory variables were included in the model. To be able to interpret directly the estimated model parameters as elasticities, all data were transformed to logarithms. The following general forms of log function were used,

$$\ln CPC_t = \beta_0 + \beta \ln X + \gamma \ln CPC_{t-1} + \varepsilon_t \quad (3)$$

$$\ln CPC_t = \beta_0 + \beta \ln X + \gamma \ln X_{t-1} + \varepsilon_t \quad (4)$$

where $ß_0$ is a constant, X is a vector of explanatory variables, CPC_{t-1} is a one year lag of the dependent variable, X_{t-1} is a vector of a one year lag of explanatory variables, and ε_t is the error term.

Table 1 summarizes the set of variables used for the models. It provides the variable identifier, name, unit, source, and expected influence of a given variable on sawnwood consumption.

Table 1. Set of Variables Used in the Models

ID	Variable	Unit	Source	H0
CPC	Sawnwood consumption per capita	m^3	FAO	+
p_d	Domestic price of sawnwood	€/m^3 (1995 = 100)	FAO	-
p_s	Domestic price of particle boards	€/m^3 (1995 = 100)	FAO	+
p_c	Price index of construction materials	Price index % (1995 = 100)	SOSR	-
DWC	Completed dwellings	Number	SOSR	+
NCM&R	New constructions and modernisation	€ (1995 = 100)	SOSR	+
R&M	Repairs and maintenance	€ (1995 = 100)	SOSR	+
EAPOP	Economically active population	Numbers	SOSR	+
UE	Unemployment rate	% of total	SOSR	-
EH	Expenditures per household	€ (1995 = 100)	SOSR	-

p_d = domestic price of sawnwood, p_s = domestic price of a substitute (particle board), p_c = domestic price of a complement (construction materials), GDPC = GDP per capita, DWC = number of completed dwellings, NCM&R = new construction including modernisation and renovation, R&M = repairs and maintenance, EAPOP = economically active population, UE = recorded unemployment rate, and EH = expenditures per household; FAO- Food and Agriculture Organization, and SOSR- Statistical Office of the Slovak Republic

Due to the differences in the nature of demand shifters for coniferous and non-coniferous sawnwood, individual models of sawnwood CPC were developed and tested for each commodity separately. In this study, the authors considered several variables. Export or import price was used as an approximation to domestic price of coniferous and non-coniferous sawnwood and particleboard, depending on prevailing export or import volume of a commodity, respectively.

Considering the basic demand theory, it is expected that domestic price of sawnwood will have a negative impact on consumption (Varian 2010). To estimate the cross-price elasticities of substitute and complement products, the authors included the prices of particleboards (a substitute with an expected positive impact on consumption) and prices of construction material (a complement with an expected negative impact on consumption). The reason for excluding the price of wood-based panels and furniture production price index was because of their weak explanatory power. Coniferous sawnwood is mainly consumed in the construction sector, and the number of completed dwellings was considered as an approximation of construction activity. Since 1995, the number of completed dwellings has been increasing in Slovakia (SOSR 2016) and it can be expected that this factor will have a positive impact on sawnwood consumption per capita.

New construction, including modernisation and renovation, and repairs and maintenance, was used as other derived demand shifters with an expected positive influence on sawnwood consumption. Consumption also greatly depends on the purchasing power of consumers. For this reason, the authors included a variable "registered unemployment rate" that reflected indirectly income possibilities and purchasing power of the population.

As stated by Estelami *et al.* (2001), unemployment not only represents economic problems but also increases the sensitivity of individuals to pricing policy. Fisher (1973) described the negative correlation between prices and unemployment and therefore the authors expected the negative sign of this variable on sawnwood CPC. The purchasing power of the population was also considered as a proxy to "economically active population" represented by people ages 15 and over who are either employed or unemployed. Coniferous and non-coniferous sawnwood data for production and trade, as well as sawnwood and particleboard price data, were used from FAO forestry databases (FAO 2017) and population and other economic data was compiled from the Statistical Office of the Slovak Republic (SOSR 2016).

RESULTS AND DISCUSSION

Based on the above-mentioned methodology, the research experimented with different variables that can greatly influence sawnwood consumption per capita. To determine the most important variables, the regression model included logical price and income variables and, in the case of non-coniferous sawnwood model, also a time lag variable (1 year lag of domestic sawnwood price).

Table 2 shows the estimated parameters of coniferous and non-coniferous sawnwood consumption per capita models supplemented by other statistical characteristics. Parameters in both nonlinear models represent the direct elasticity indicating the influence of changes in the explanatory variable on sawnwood CPC.

Table 2. Coniferous and Non-coniferous CPC Model Results

Model (OLS)	Short-term Elasticities				
	Constant	DWC	UE	P_d Lag	p_s
CPC_{CSNWD}	-22.696 **	2.486**	-1.441**		
CPC_{NCSNWD}	1.14 E^{-16} **	3.002**		-0.510*	1.587**
	Statistical Characteristics				
	R^2	S_e	DW	F	
CPC_{CSNWD}	0.951	0.344	1.395	79.683**	
CPC_{NCSNWD}	0.750	0.568	1.844	16.028**	

**, * - statistical significance of coefficient at the significant level 1% and 5%, CPC_{CSNWD} and CPC_{NCSNWD} is coniferous and non-coniferous sawnwood consumption per capita, DWC – dwellings completed, UE – unemployment rate, P_d Lag – 1 year lag of domestic sawnwood price, p_s – domestic price of particle board (substitute), R^2 – coefficient of determination, S_e – standard error, DW – Durbin Watson, and F – F test

Discussion and Analysis of the Model Variables

To better explain the influence of the determined factors on sawnwood consumption, one can analyze the development of all model variables. Generally, based on official available data provided by FAO (FAO 2017), during the period of 1995 to 2015, the sawnwood consumption in Slovakia has been increasing with fluctuations specific mostly for coniferous sawnwood during the years of the economic crisis.

The maximum total sawnwood consumption over 2.5 mil. m^3 was recorded in 2008. In this year the total sawnwood consumption increased by more than 13 times compared to 1995. On average, a share of coniferous sawnwood consumption on total sawnwood consumption was 61%.

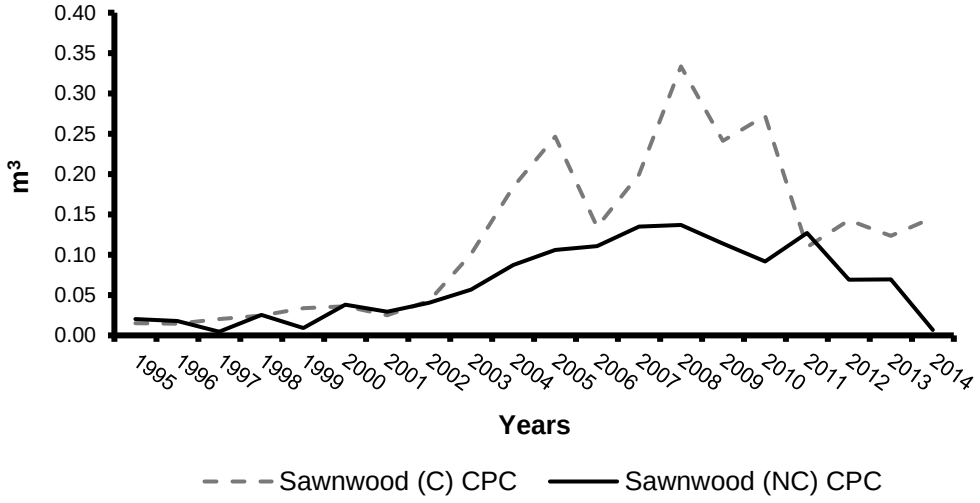

Fig. 1. Consumption per capita of sawnwood (C, NC) in Slovakia

In general, consumption per capita followed the trend of total sawnwood consumption. However, there were visible differences between the coniferous and non-coniferous consumption per capita figures (Fig. 1). On average, during the observed time period, the non-coniferous sawnwood CPC was almost two times lower than that of the coniferous; nevertheless, its development was more stable and showed lower fluctuations over time.

The largest end-use sector for sawnwood was the residential construction, and the development in this sector directly influenced sawnwood consumption. In particular, demand for wooden dwellings is favoured by attributes of wood, such as its ecological aspects, energy saving, thermal insulation, speed of construction, *etc.* and affected by factors related to *e.g.* loan amount, available subsidies, price of wooden dwellings, and other geographical factors. The models indicated that the number of completed dwellings had the strongest influence on coniferous, as well as the non-coniferous sawnwood consumption per capita in Slovakia. This variable involves all dwellings acquired by new construction, improvements, and other construction repairs (SOSR 2016). Figure 2 shows the growth of completed dwellings in Slovakia during the observed period. The most positive development trend was recorded before 2009 when the number of competed dwellings was almost 20 thousand units. After that point, due to the financial and economic crisis, the number dropped until it fell below 15,000 in 2011. This development trend reflects the overall level of the socio-economic situation and is largely connected to the trend of other macroeconomic indicators, such as GDP growth, unemployment rate, population growth, *etc.* (National Bank of Slovakia 2015a,b).

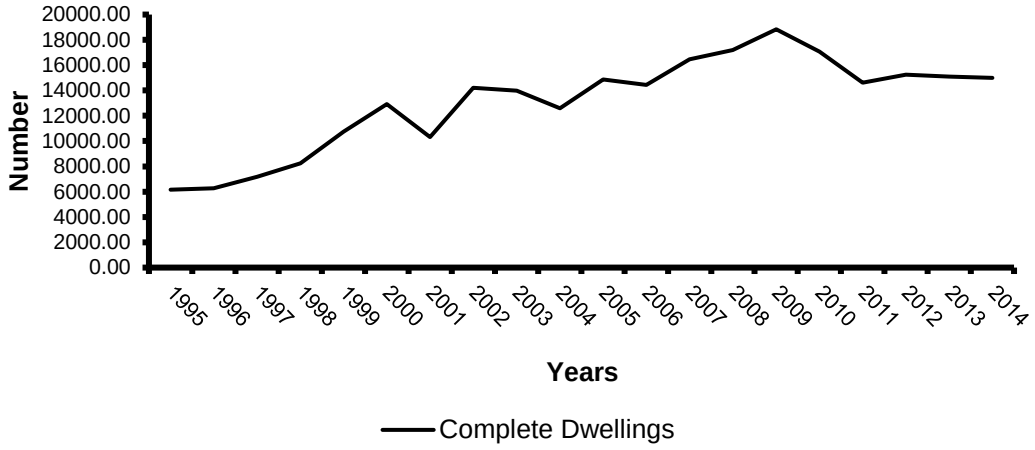

Fig. 2. Numbers of complete dwellings

The registered unemployment rate indirectly represented variables that reflected the purchasing power of the population. The development of unemployment has been opposite the development of sawnwood consumption per capita with the highest registered unemployment of 19% in 1999 (SOSR 2016). Consequently, the registered unemployment rate tended to decrease until 2008, and started to increase again after 2009, and eventually decreased in 2012 (Fig. 3).

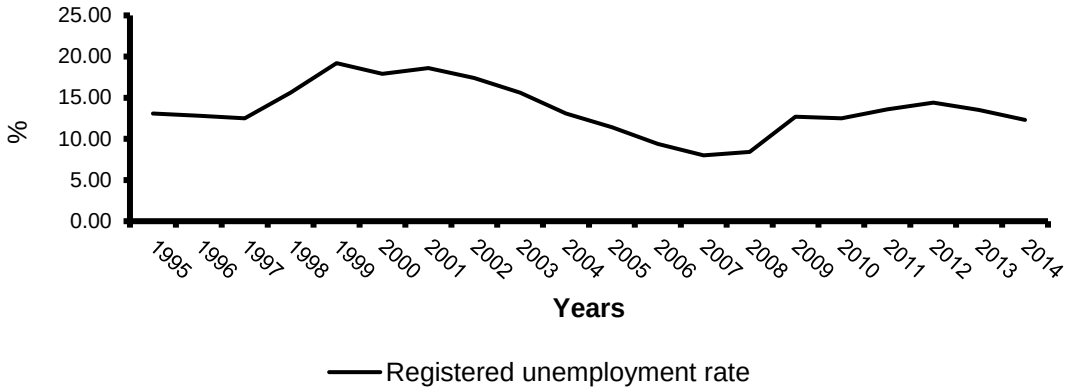

Fig. 3. The rate of registered unemployment in Slovakia

Available export and import prices were used as an approximation to domestic price of non-coniferous sawnwood and particleboard as in some of the previous studies (Michinaka *et al.* 2011; Hurmekoski *et al*. 2015). Sawnwood prices oscillated and reached their maximum in 2008 when the maximum sawnwood consumption was also recorded, and since then they decreased until 2011 (Fig. 4). The influence of own price on demand was reflected with a one-year time lag.

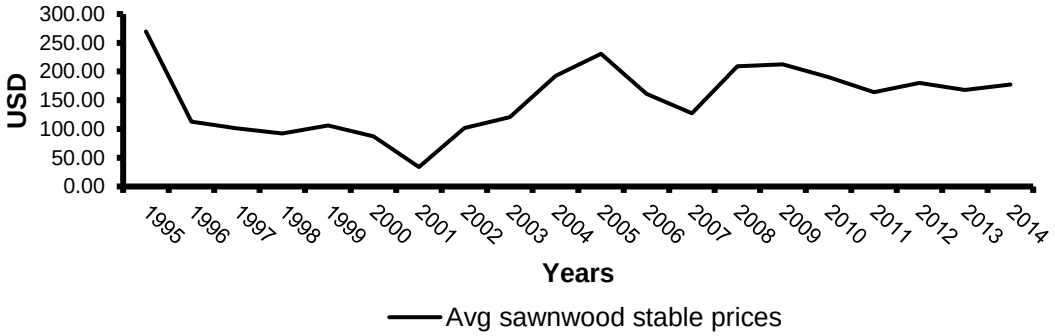

Fig. 4. Average sawnwood prices in Slovakia

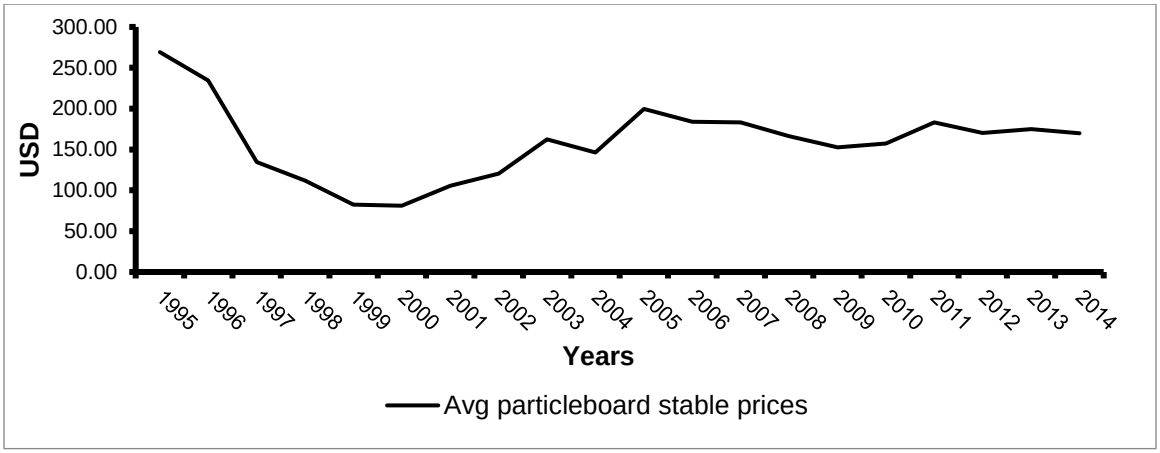

Fig. 5. Average particleboard prices in Slovakia

The trend in prices of particleboard showed more leveled development with an increase culminating in 2006 followed by a slight decline afterwards. As particleboard is considered to be the main substitute for non-coniferous sawnwood in furniture production, different construction applications, and building furnishing, its price development can cause changes in the demand for non-coniferous sawnwood and consumers may tend to substitute between these two wood products (Paluš 2013).

In general, the results of the study revealed several implications. When interpreting the estimates, it should be realised that this study produced country-specific results reflecting typical production and utilisation conditions of the domestic market. Firstly, the existence of different explanatory effects for both types of sawnwood suggested that their consumption per capita was partially linked to different drivers. Commonly, coniferous and non-coniferous sawnwood CPC were determined by their construction activity and it appeared very elastic in regards to the number of completed dwellings. Prices appeared to have an insignificant impact for coniferous and only a relatively small impact in non-coniferous sawnwood consumption. The estimate of the rate of unemployment, which was significant for coniferous consumption, suggested that its consumption per capita was elastic to the economic activity of population.

CONCLUSIONS

1. The demand for sawnwood in Slovakia reflected the activity in the construction sector and economic situation in the country. Consumption of coniferous sawnwood per capita was almost two times higher than that of non-coniferous sawnwood. This was in spite the fact that the growing stock of coniferous tree species represented only 41% from total growing stock in the Slovak forests.
2. The results showed that coniferous sawnwood consumption per capita was elastic to the number of completed dwellings (2.49) and also to the registered unemployment rate (-1.44). Non-coniferous sawnwood consumption per capita was also elastic to the number of completed dwellings (3.00) and inelastic to the prices of substitute products (1.59).
3. Independent variables, such as prices or completed dwellings, positively influenced development trend in sawnwood consumption. The development of unemployment had an opposite effect.
4. The estimated correlation between sawnwood CPC and the indicators related to wood resources utilization, as well as economic indicators, delineated specific features of the national market. Even if these relations may change continuously, they represent important background information for companies and policy makers to help make objective decisions.

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