ACTA FACULTATIS XYLOLOGIAE ZVOLEN, 66(1): 151−159, 2024
Zvolen, Technická univerzita vo Zvolene
DOI: 10.17423/afx.2024.66.1.12

AN ECONOMETRIC MODEL OF TIMBER DEMAND IN THE SLOVAK REPUBLIC

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ABSTRACT

Generally, the timber market is affected by several factors that are reflected in the structure of the supplied and demanded quantities of timber assortments. Econometric modelling is widely used to identify and analyse such factors. This paper deals with the development and evaluation of an econometric model of timber demand on the domestic market of the Slovak Republic in the monitored period of the years 2000 – 2021. The timber demand is determined by two factors: the timber price and GDP. The analysis shows that the raw timber market can be characterized as a regular market with a declining demand curve and a relatively inelastic response concerning price changes. The influence of the GDP factor is more significant, which confirms the theory of the derived demand for wood from the demand for wood products. The results of econometric modelling make it possible to elaborate alternative ex-ante forecasts of timber market development and, as such, they may form the basis for the effective application of different economic and political tools in the forestry and forest-based industry.

Keywords: econometric modelling; timber demand; derived demand; quantitative market analysis.

INTRODUCTION

The complex of forestry and forest-based industry is one of the important branches of the Slovak economy. Even though the share of forestry in the country's GDP is at the level of 0.7% (Ministry of Agriculture and Rural Development of the Slovak Republic, 2022), forestry forms an important raw material base for the forest-based industry. Based on data from the Green Reports of the Ministry of Agriculture and Rural Development of the Slovak Republic, an average of 8.4 mil. m^3 of wood per year was harvested in the years 2020 – 2021, which is 1.54 m^3 per capita per year. During this period, the average annual export of wood accounted for approximately 25% of wood production, the import of wood accounted for almost 10% of wood production, and the average consumption of wood by forest-based industry represented a volume of almost 7 mil. m^3 per year. According to the analysis of wood balance in Slovakia (Parobek *et al.,* 2014), almost 83 % of all resources used in Slovakia originated in forest biomass, 16.1 % were from industry waste, and only 1 % came from used paper. On the other hand, over 84 % of resources were used industrially, while nearly 16 % were used for energy purposes.

Considering the strategies of the forestry and forest-based industries, it is a crucial aspect to know how the timber market would behave depending on the action of numerous

factors and also to harmonize the structure, quantity and quality of the supplied and demanded quantities of timber assortments. To analyse the market and its development as well as to identify and quantify factors influencing such a market, economic and mathematical methods are used. The output of data processing and market analyses are econometric models that provide information for the planning and management process of enterprises running their business within the forestry and forest-based industry.

Modelling timber market in the countries of Western Europe (Koch *et al.,* 2013; Bergen, 2012), of Scandinavia (Brännlund *et al.,* 1983; Toppinen and Kuuluvainen, 2010; Sjølie *et al.,* 2011) and of North America(Adams and Haynes, 1980; Song *et al.,* 2011; Susaeta *et al.,* 2012) is of long-lasting tradition. The econometric models of timber demand, compiled using FAO databases on a cumulative basis with subsequent long-term prognoses, are available in the countries of Central and Eastern Europe (e.g., Kangas and Baudin, 2003; Jonsson, 2010). Based on the data of the period of years 1990 – 1995, the timber market equilibrium was analysed for the conditions of the Slovak Republic, while timber supply was determined by the planned volume of timber harvesting and the timber demand was determined by the timber prices and the level of GDP (Smrtník, 1997). Econometric models of the total timber supply and demand constructed following the data from the period of the years 1990 – 2003 did not confirm the theoretical hypotheses about the effect of timber prices – such results being related to the non-standard nature of the market in this period affected by the transformation of the economy, the reliability of the analysed data and the turbulent economic and legislative environment (Trenčiansky, 2005). Models are dominated by non-price factors that affect demand for timber assortments (Trenčiansky, 2005). Lower impact of price, or even the absence of its impact together with the dominance of non-price factors was also confirmed in the case of models of demand on the wood products market (Hlodák, 2023). Taking into account the econometric models of wood products demand, the theory of derived demand was confirmed (Paluš, 2002), while e.g., the sawn wood demand reflects activity in the construction industry and the economic situation in the country (Paluš *et al.,* 2018). In the broader sense, timber demand is derived from the production parameters of the entire economy Hurmekoski *et al.,* 2015; Borzykowski, 2017). In addition to economic factors, timber demand (resp. timber market) is affected by the (i) tools of forest and other related policies(Hurmekoski and Hetemäki, 2013; Onoja and Idoko, 2012) (ii) demographic changes (O'neill *et al.,* 2010), (iii) customer preferences in the use of wood products, (iv) prices of substitute products (Kangas and Baudin, 2003), and (v) changes in exchange rates (Hurmekoski *et al.,* 2015). The effect of price on demand is determined by calculating price elasticities (Jonsson, 2013). In many cases, price inelasticity of demand on wood and wood products market was confirmed (Trenčiansky, 2005; Simangunsong and Buongiorno, 2011; Michinaka *et al.,* 2011; Hlodák, 2023). The objective of the paper is to build up and evaluate an econometric model of timber demand on the domestic market of the Slovak Republic in the monitored period of the years 2000 – 2021.

Based on the economic theories and the results of the studies from other countries together with the results of previous research in the Slovak Republic, the following hypotheses were defined for the timber market in the Slovak Republic:

H1: The timber demand is a derived demand for wood products,

H2: The timber price is a coordinator in the timber market, thus the timber market in the analysed period is considered to be the standard one,

H3: The timber demand reacts inelastically to changes of the market price and

H4: The effect of non-price factors on the timber demand is more significant than the timber price.

MATERIALS AND METHODS

Each model reflects an abstraction of a real system characterized by its objectives, components, and correlation (Schwarzbauer, 1993). The essence of this paper lies in the estimation of demanded quantities of wood assortments within the analysed time series (2000 – 2021) using linear regression equations. Then, a statistically verified and economically interpretable econometric model of timber demand in the Slovak Republic shall serve as a result of this research.

The constructed econometric model clarified the causal relationships between the variables and, at the same time, the effects of factors on the timber demand in the Slovak Republic were identified and quantified.

Based on the theoretical formulation of the relevant relations, market identification and choice of independent variables together with potential dependent variables, the general notation of the linear equation of the model of timber demand was as follows:

$$Q_t = a + b_1.f_{1(t)} + b_2.f_{2(t)} + ... + b_k.f_{k(t)} + u_t (t = 1, 2, ..., n) \quad (1)$$

where: Q_t - demanded volume of timber within the t-year,
$f_{1\text{-}k(t)}$ - factors affecting timber demand within the t-year,
a - absolute parameter of the model,
b - estimated parameters of independent variables,
u_t - random element of the model within the t-year,
k - number of factors affecting timber demand,
n - number of observations.

Quantification of the model enabled the calculation of the values of the dependent variables (demanded volume of timber) pursuant to the independent (factors of the demand). To estimate the model parameters, the least-square method was used (Šmelko and Wolf, 1977).

Considering the economic interpretation of the timber demand model, the factors affecting timber demand were evaluated. Moreover, the average relative elasticities of demand were calculated, and the actual and estimated quantities of demanded timber were compared. Finally, the state of timber marked during the analysed period was evaluated.

The domestic market volume of demanded timber serves as the econometric model's dependent variable. Considering models of timber demand, the final volume of demanded timber shall be expressed as the domestic timber consumption Q within the t-year (Jonsson, 2010; Paluš *et al.*, 2018).

To identify potential factors that may affect timber demand, the theory of derived demand is taken into account and the following factors are analysed: Gross domestic product (GDP), the value of construction production (VCP), the index of the production of wood and paper products (PWPP), the average domestic price of wood assortments (PD) and export timber prices (PER) as well as the fixed base index of timber prices (ITP). In order to eliminate the effect of inflation, the factors GDP, VCP, ITP were expressed in constant prices. Data on potential factors influencing the timber demand in the Slovak Republic are presented in Tab. 1. When compiling the model, the potential effect of the factors of derived timber demand (GDP, VCP, PWPP) and price factors (PD, PER, ITP) was especially considered. The demand factors were included into the model step-by-step so that the maximum coefficient of determination (and thus the best statistically significant combination of factors) is to be reached, and, at the same time, the conditions of

multicollinearity and autocorrelation of residuals are met. The statistical significance of the estimated equation parameters was tested using the t-test, the coefficient of determination was tested using the F-test, the autocorrelation of the residuals was tested using the Durbin-Watson test (DW), and the multicollinearity was tested using the variance inflation factor (VIF). After the quantification and verification of the model of timber demand, the average relative elasticities were calculated in the case of significant factors. The average elasticity of a specific factor was calculated as a relative change in the demanded volume of timber if this factor increases by 1 % within the year t. If such change is higher than 1, reaction is the elastic one. On the contrary, if such change is lower than 1, the impact of such factor is inelastic.

Tab. 1 Potential factors affecting the timber demand in the Slovak Republic (2000 – 2021).

Factor	Abbreviation	Unit	Max.	Min.	Average	Assumed effect
Average domestic prices	PD	€.m^{-3}	58	29	41	-
Average export prices	PER	€.m^{-3}	63	28	46	-
Index of timber prices (2005 = 100)	ITP		155	93	114	-
GDP (prices of 2015)	GDP	bil. €	90 892	43 397	69 217	+
Value of construction production (prices of 2011)	VCP	mil. €	10 178	4 683	7 349	+
Index of production of wood and paper products (2015 = 100)	PWPP		108.3	88.7	98.43	+

The following sources of input data were used: the Green Reports of the Ministry of Agriculture and Rural Development of the Slovak Republic (Ministry of Agriculture and Rural Development of the Slovak Republic, 2022), the FAOSTAT database (FAOSTAT, 2023) and the Statistical Yearbooks of the Slovak Republic from the years of 2001 – 2022 (Statistical Office of the Slovak Republic, 2023). The final model is the result of an optimal mutual combination of potential factors. When developing the model, also potential independent factors lagged by one analysed period (t-1) were considered. Statistical analyses were conducted using the STATISTICA software (Statsoft Inc.).

RESULTS AND DISCUSSION

The development of total production, exported as well as imported volume of timber with the domestic timber consumption during the analysed time (2000 – 2021) is shown in Fig. 1. Total timber production during the analysed period varies between 5.7 and 9.6 mil. m^3. The total timber supply is determined by the planned volume of harvesting, while it is affected by the accidental felling, especially in the case of coniferous timber assortments. The timber export during the analysed period varies between 1.1 and 3.4 mil. m^3. The volume of imported timber has been increasing and in recent years it has reached the level of the volume of timber exports. Domestic wood consumption represents the quantity of demanded timber on the domestic market. The volume of this timber varies during the analysed time series from 4.3 to 8.9 mil. m^3. Between the years of 2000 and 2005, a significant growth in domestic consumption can be observed. During the period of years 2005 – 2010, the volume of domestic consumption reached amount between 7 and 7.7 mil. m^3. As a result of the recession in the economy in 2008, the domestic timber consumption decreased to the level

of 5.7 mil. m^3 by the year of 2013. After this fall, the consumption has started to increase again, and it reached the maximum value at the level of almost 9 mil. m^3 during the years of 2018 and 2019. In 2020, drop to the level of 7.1 mil. m^3 was recorded, while in 2021, the timber consumption increased once more to the level of 8 mil. m^3.

The econometric model of timber demand identifies and quantifies the factors causing variations in the Slovak Republic domestic timber consumption during the period.

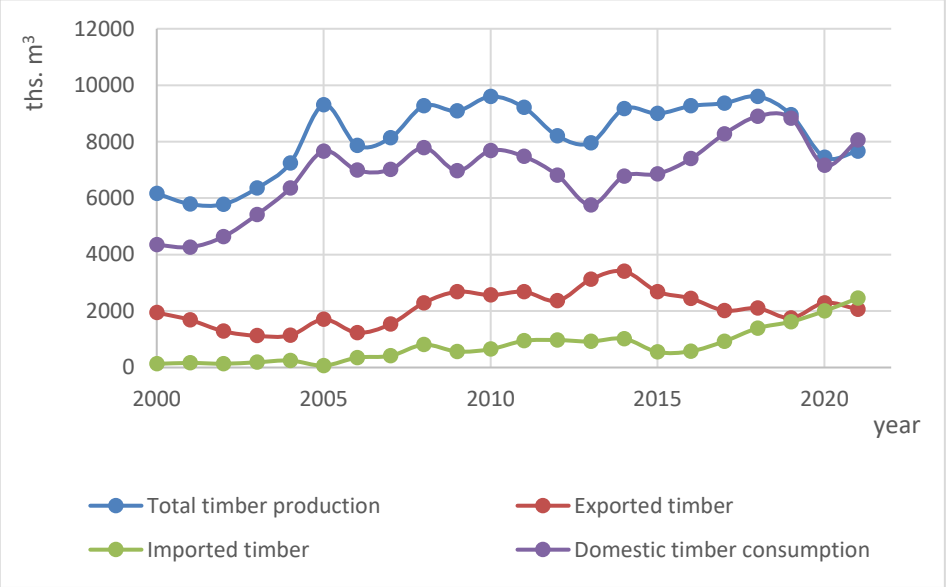

Fig. 1 Total timber production, exported and imported volume of timber and domestic consumption of timber in the Slovak Republic (calculation based on the data of the Ministry of Agriculture of the SR during the years 2001 – 2022).

Based on the econometric analysis of the time period of years 2000 – 2021, the equation of timber demand on the domestic market in the Slovak Republic was calculated. The resulting parameters of the regression model and the statistical characteristics of the timber demand model and the calculated elasticities of the timber demand model are presented in Tab. 2. The parameters of the econometric model are statistically significant, and they meet the conditions of random component correlation (DW = 1.6) and multicollinearity (VIF = 5.69). The VIF value is slightly over the limit of 5 and one might expect there is a certain level of collinearity. However, it should not negatively affect the accuracy of the model. As it is mentioned by Katz (2006), the values of VIF higher than 10 might significantly affect the model results. The coefficient of determination (R^2 = 0.73) proves a high dependence of the demanded amount of timber on the following factors: gross domestic product (GDP_t) and average timber prices on the domestic market (PD_t).

Tab. 2 Statistical characteristics of timber demand model.

N = 22	R = 0.857 R^2 = 0.734 F (2, 19) = 26,27 p<0.00000 DW=1,6						
	β- Coefficient	b	STD of b	T (1)4	p-value	VIF	Relative elasticity
Absolute parameter		2710.35	756.93	3.58	0.00199		
GDP_t	0.67	0.12	0.02	5.12	0.00006	5.69	+1.25
PD_t	0.33	-107.98	43.11	-2.51	0.02151	5.69	-0.64

As the GDP grows, the consumption of wooden products increases, which causes an increased demand for raw timber. The relatively high value of the β coefficient (0.67) points out the dominant effect of overall economic growth on the timber demand. The rather significant effect of total economic production on the timber demand as well as on the demand for wood products has been observed in several countries (Jonsson, 2010; Bergen, 2012; Hurmekoski *et al.*, 2015; Borzykowski, 2017). Based on the confirmed impact of the GDP, one may confirm the hypothesis H1, that the timber demand is derived from the demand for wood products. The theory of derived demand was confirmed by the studies of many authors (Kangas and Baudin, 2003; Michinaka *et al.*, 2011; Bergen, 2012; Paluš *et al.*, 2018; Hlodák *et al.*, 2022). Taking into account the developed econometric model, an alternative to the factor of GDP is the value of construction production (or production of wood and paper products). The higher construction production, the higher consumption of soft sawnwood particularly – simply, increased construction production causes an increased demand for soft sawnwood. Similarly, as the production of wood and paper products grows, the demand for timber assortments also grows. From a statistical point of view, there is a relatively high dependence between the factors of GDP on the one hand and VCP and PWPP, on the other hand. Based on the comparison of the coefficient of determination and fulfilment of the different conditions of the econometric model, the GDP factor was included in the econometric model of timber demand.

The growing average domestic timber prices affect the demanded quantity in a negative way. When the price increase by 1 %, the demanded quantity decreases by 0.64 %. Based on the mentioned, one may confirm the hypothesis H2 about the price being the coordinator on the timber market. Econometric models built upon the data originating from the 1990s did not confirm the effect of price on the demanded quantity (Trenčiansky, 2005). Most probably, it was caused by the non-standard market associated with the transition to a market economy, land restitution, high inflation and a turbulent economic and legislative environment.

The price factor participates in explaining the variance of the demanded quantity to a lower extent (β = 33%) than the GDP factor. A change in the average timber prices causes an inelastic reaction in the volume of demanded timber on the domestic market. On the contrary, changes of the GDP cause an elastic reaction in the volume of demanded timber (Tab. 2), thus, it seems that the GDP factor has a dominant impact on changes of demanded timber on the domestic market. The results of the analysis confirm the hypothesis H4 about the dominance of the impact of non-price factors (GDP) on the timber demand. At the same time, these results confirm the hypothesis H3 about the inelastic effect of the timber price on the demanded quantity. The actual volume of demanded timber on the domestic market as well as demanded volume calculated according to the econometric model are both presented in the Fig. 2.

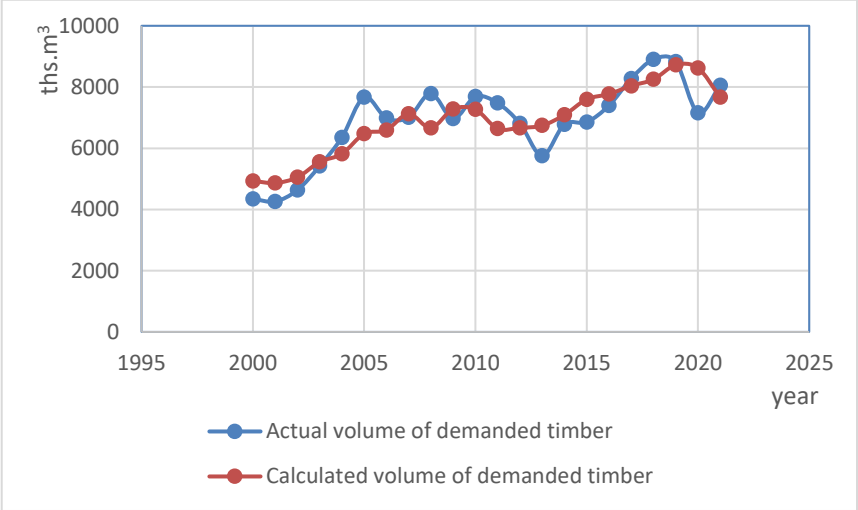

Fig. 2 Actual and calculated volume of demanded timber in the Slovak Republic.

The developed model corresponds to the results of the model built on the basis of the data from the years of 1990 – 1995 (Smrtník, 1997). At that time, the timber demand was a result of the effect of the price as well as the level of GDP. The value of construction production was considered to be an alternative to GDP.

The demand model confirms the hypothesis about the derived demand – the demand in the case of wood processing industries is derived from the total volume of income of economic entities, while, subsequently, the timber demand itself is derived from such demand. In partial markets, e.g. the demand for sawnwood in Slovakia reflected the activity in the construction sector and economic situation in the country (Paluš, 2012). Gross domestic product has an impact on plywood demand and demand for composite materials is dependent on the size of output in the construction industry, the size of housing construction, and output prices in the industry (Hlodák, 2023).

CONCLUSION

The total timber demand is the result of the complex action of a set of price and non-price factors.

Based on the econometric analysis of the data of time series of the years 2000 – 2021, the model of the overall timber demand on the domestic market in the Slovak Republic was constructed. The dependent variable is the volume of timber demanded in the domestic market. Considering the potential factors affecting the change in the demanded quantity, such price factors as the average domestic, export and overall timber prices together with the index of timber prices were analysed. Looking at the non-price factors, the following ones were analysed: gross domestic product and the value of construction production. Both are expressed in constant prices for the year of 2015.

Timber demand is derived from the demand for wood products. Considering the constructed econometric model, the demanded quantity depends on both, the level of GDP as well as the average timber prices. A change of average timber prices causes an inelastic response, while a change of GDP causes an elastic response of the demanded quantity. The amount of real GDP shall be perceived as the dominant factor. The demand models developed during the 1990s lack the price factor. Based on the results of the econometric analysis, one may conclude that the timber market has been standardized since then.

The compiled econometric model forms the basis for alternative forecasts of market development together with the potential simulation of the behaviour of timber producers and processors, taking into account the impact of the individual supply and demand factors. Based on the knowledge of market factors, market structure, behaviour of market subjects and considering the existence of forecasts of the development of individual economic variables, forestry and forest-based industries may coordinate their strategic goals.

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ACKNOWLEDGMENT

The authors would like to thank the Scientific Grand Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic and the Slovak Academy of Science. The paper was elaborated within the framework of Grant project VEGA 1/0376/23 “Economic and legal conditions of management of non-state forests in protected areas in Slovakia”, Grant project 1/0495/22 “Sustainability of Value Supply Chains and its Impact on the Competitiveness of Companies in the Forest and Forest-Based Sectors” and Grant project 1/0306/24 “The quantification and development of Payment for water protection ecosystem services from forest”.

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