Prices of Raw-wood Assortments in Selected Markets of Central Europe and their Development in the Future

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The aim of the paper is to evaluate the price development of timber assortments in selected countries in Central Europe, to compare the prices and identify the factors influencing the prices, and to quantify the extent of their impact on the prices. A further aim is to predict the price development based on comparing various models for predicting time series of prices. The analyses of the price development was carried out for the assortments of spruce, fir, and beech sawlogs in Slovakia, Czech Republic, and selected Austrian provinces. The analyzed period covered the years from 2001 to 2017 per individual months. Following the selected factors, the study was focused on the timber price development, and subsequently the prediction up to the end of 2019 was calculated. The most significant factor having a negative impact on the price development was the global economic crisis. Following all the prediction methods, the next two years can expect an increase in the prices of sawlogs, except the beech sawlogs in Austria. Analysis of the price developments in the selected countries confirmed that all global factors reflected the price level trends approximately equally in all countries.

Keywords: Timber prices; Wood market; Price modeling; Timber assortments; Incidental felling

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INTRODUCTION

Strategic decision making and planning in the forestry management is based on the expected results, as well as on a certain extent of risk or uncertainty (Leskinen and Kangas 2001). Timber prices, as the main medium of the realizable value, belong, in the long term, to the most important variables influencing the optimization of forestry management. They are, however, influenced by various factors, which need to be identified and quantified if possible. These factors and their influence result in a certain extent of risk or uncertainty in managing the forest land, arising from a huge variability of forest ecosystems and natural conditions and global climate change (Holécy and Hanewinkel 2006; Brunette and Couture 2013; Hanewinkel *et al.* 2013; Brunette *et al.* 2015; Johnston and Withey 2017). Predicting the extent of these factors and their effect is possible only by following the information on their previous development and using a mathematical model based on such development.

Information on the timber price development represents valuable knowledge for strategic marketing planning in forestry management and the wood-processing industry. (Suchomel *et al.* 2012). Besides the economic and social factors, natural and ecological conditions, which can influence the volume of timber and its quality, are also important for determining the price (Mutanen and Toppinen 2007; Malinen *et al.* 2015; Merganič *et al.* 2016). The essential factors significantly influencing the timber prices in the long term are the same in most countries. Incidents such as windthrows, earthquakes, or global economic crises are almost impossible to predict. In some cases, it can be said that such incidents are likely to occur more often than in the past. Several authors (Holécy and Hanewinkel 2006; Hanewinkel *et al.* 2013; Kouba 2013; Kostadinov *et al.* 2014; Brunette *et al.* 2015; Gejdoš and Potkány 2017) focus on estimating the extent of risk caused mainly by natural factors *via* analyzing the development of incidental fellings in selected areas. Following the models based on the past development and modified with the estimated risk extent, it is possible to predict the development of such factors (Holécy and Hanewinkel 2006; Brunette *et al.* 2015; Gejdoš and Potkány 2017). The prices in individual states are naturally influenced also by the wood species composition of forests, costs of services associated with the forestry production, the structure of subsequent wood-processing industry, and the quality of produced assortments.

Many studies deal with predicting the development of prices in the market. An overview of basic procedures and methods are discussed *e.g.* in (Elliot and Timmermann 2013) and prices of commodities are dealt with separately. The following sources focus on the agriculture sector (Bailey and Chan 1993; Fama and French 2016; Kirchner *et al.* 2016). When making predictions in the forestry management, it is important to consider certain specifics associated with the nature of production and long production cycle. Most prediction models known so far are based on the statistical stochastic models, which can be combined with estimates made by experts from the respective field (forestry, wood processing). They mainly use the procedures and principles of econometric modeling (Forboseh *et al.* 1996; Gong 1999). Existing studies have already dealt with predicting the timber prices in various alternatives for forest managements and cost optimization (Pukkala and Kangas 1996; Leskinen and Kangas 1998; Leskinen and Kangas 2001). Comparison of the prices in individual countries is complicated due to various quality requirements of sawlog quality classes, as well as quoting the prices on various trade parities (Malinen and Kilpeläinen 2013). Prices are very often different depending on the thickness of the specific assortment in the quality class. An exact comparison of prices of individual assortments in various countries is therefore not possible. The most important assortment classes (sawlogs, pulpwood, fuelwood) differ from each other only minimally regarding the quality requirements, and therefore their comparison can provide valuable and reliable information for strategic planning.

The pressure on the renewable resources is increasing due to the growth of world population in the past decades (Timah *et al.* 2008). The next few years will hardly see a decrease in these statistics. In the future, a huge potential for the economic contribution to the forestry management will be represented by the timber sale, its energy potential, as well as by the carbon sequestration provided by the forest stands and paying for priced non-production forest functions (mainly the function of securing the water sources) (Buma and Livneh 2015; Kozuch and Adamowicz 2016; Vettorazzi and Valente 2016; De Vries *et al.* 2017; Vass 2017; Quintero-Mendez and Jerez-Rico 2017).

The aim of the paper is to evaluate the development of raw wood assortment prices in the selected countries of Central Europe, compare them, and subsequently identify the factors influencing the prices. A further goal is to predict the price development based on comparing various models for predicting time series of prices. Subsequently, the results will provide a background for business predictions for the timber market in order to create scenarios for future management in forests taking into account the forest sustainability. Revenues from the timber sale will compose the main part of financing the forestry entities in the future. Since all individual timber markets in Europe are interconnected, monitoring the markets and price development is important due to several reasons. Analysis of the price development regarding the changing conditions in forest management in the context of global climate change will comprise an inevitable component of understanding the current frontier of forest economics.

EXPERIMENTAL

Materials and Methods

The analysis of the price development was carried out for the assortments of spruce, fir, and beech sawlogs in Slovakia, Czech Republic and selected Austrian provinces (Burgenland, Low Austria, Eastern Styria, Salzburg). The assortment of the sawlogs was selected for the analysis due to its position in individual assortments supply structure (the second most common assortment after pulpwood and industrial wood), as well as due to the fact that it can be placed and sold relatively well in local markets. Pricing of this assortment is further influenced by the price development of assortments in lower quality classes (*e.g*. fuelwood and energy wood). The analysis was focused on individual months (monthly) in the period of 2001 to 2017 according to nominal prices of wood. The price data were obtained from the magazine Holzkurier (Austria) (2017), the Czech Statistical Office (Czech Republic) (2017), and the Forestry Market Information System (Slovakia) (2017). Methods of analysis, synthesis, and comparison were used for evaluating the time series of assortment prices. The impact of inflation on the price development was disregarded intentionally in order to point out the influence of the specific time period. Since inflation is influenced by many factors, which are not associated with the trade of raw wood assortments, it would distort the impact of the specific period on the prices. Therefore, the inflation was not taken into account when calculating the prices. Slovak prices prior to 2009 were converted from the Slovak Crowns to Euro using the average monthly exchange rates according to the currency tables of the Národná banka Slovenska (Slovak national bank) (2017). Prices of wood in the Czech Republic were converted to Euro using the average monthly exchange rates according to the currency tables of the Czech National Bank (2017). All prices are listed without VAT. The prices in the Czech Republic and Slovakia are at the trade parity Free Carrier (FCA) according to Incoterms (2010), and the prices in Austria are at the parity free forest road (forest storage of wood). Database of price development created this way represents a unified solution that cannot be found in any literature sources dealing with this field.

For the sake of modelling the future development of prices of selected assortments, it was inevitable to identify the factors affecting the timber market. Following the ex-post analysis results, the subsequent factors were selected: incidental fellings (resulting from global climate change); global economic crisis (as an impact of the macroeconomic environment); and specific impacts of the market environment in the EU, as well as in individual countries (events that can be time identified and affected the timber trade directly or indirectly). Subsequently, the price development during one year affected by the analyzed factors was monitored. The assortment price in the particular month, when the selected factor occurred, was considered the initial value. Price development of this assortment in the following 12 months was taken into account as the arithmetic mean expressed by the percentage deviation from the initial value (Table 3). In the case of incidental fellings, a decline in the influence of windthrow wood can be anticipated within one year after the windthrow; regarding other factors, time sequences corresponding to their occurrence were selected. This experimental procedure was selected in order to find out whether individual events and factors influenced the timber prices significantly within one year after their occurrence. A period of 12 months was chosen due to the possibility of mirroring all impacts of the selected factor on the timber market (*e.g.* time passed from the complete removal of incidental felling, closing the wood processing contracts, filling the stock capacities in wood processing industries).

For the statistical analyses of price development dependencies and the influence magnitude of individual factors, the software packages STATISTICA 12 and MS Excel were used. As prediction models for price development, the following methods were used: linear trend estimation, multivariate exponential smoothing and prediction, and Box-Jenkins Method: ARIMA statistical model with autocorrelation coefficient, which are described generally in (Cipra 1986; Leskinen and Kangas 1998; Carmona 2014), for the conditions in forestry in (Abildtrup *et al.* 2012). Linear models are often called causal or factor models due to the presence of explanatory time series. Their use including various estimation methods being modifications of the basic method of the least square from linear regression analysis are described in various econometrics books (Cipra 1986; Hatrák 2007; Baltagi 2011). These works mention the linear model to be a suitable model for predicting further development of time series in econometrics.

Multivariate exponential smoothing is another method often used for smoothing and predicting the time series values. This method provides an adaptive approach to the trend element, which is very often used in practice (Holt 1957; Brown and Mayer 1961).

The autoregressive integrated moving average model ARIMA(1,0,1) model was used in Nochai and Nochai (2006) and Leskinen and Kangas (1998; 2001). The model for non-seasonal series is called the autoregressive integrated moving average model, denoted by ARIMA (p, d, q). Here p indicates the order of the autoregressive part, d indicates the amount of differencing, and q indicates the order of the moving average part. If the original series is stationary, d = 0 and the ARIMA models reduce to the ARMA models. The difference linear operator (Δ), defined by:

$$\Delta Y_t = Y_t - Y_{t-1} = Y_t - BY_t = (1 - B)Y_t \tag{1}$$

The stationary series W_t obtained as the dth difference (Δ^d) of Y_t,

$$W_t = \Delta^d Y_t = (1 - B)^d Y_t \tag{2}$$

ARIMA (p, d, q) has the general form:

$$\varphi_p (B)W_t = \mu + \Theta q(B)\varepsilon_t \tag{3}$$

where Y_t is the response (dependent) variable at time t; φ_0, φ_1, φ_2, · · · , φ_p are the coefficients to be estimated; ε_t is the error term at time t; and B is the backward linear operator defined by $BY_t = Y_{t-1}$. Prediction based on the method of multivariate exponential smoothing was calculated using the general model,

$$Forecast_t = S_t \,.\, I_{t-p} \quad (4)$$

where S_t stands for the (simple) exponentially smoothed value of the series at time t, and I_{t-p} stands for the smoothed seasonal factor at time t minus p (the length of the season). Thus, compared to simple exponential smoothing, the forecast is "enhanced" by adding or multiplying the simple smoothed value by the predicted seasonal component. This seasonal component is derived analogous to the S_t value from simple exponential smoothing as:

$$I_t=I_{t-p} + \delta \,.\, (1 - \alpha)\times e_t / S_t \quad (5)$$

Put into words, the predicted seasonal component at time t is computed as the respective seasonal component in the last seasonal cycle plus a portion of the error (e_t; the observed minus the forecast value at time t). Parameter δ can assume values between 0 and 1. If the δ parameter is equal to 1, then the seasonal component is modified "maximally" at every step by the respective forecast error. In most cases, when seasonality is present in the time series, the optimum δ parameter will fall somewhere between 0 and 1. The value entered in the alpha (α) box is the constant process smoothing parameter. The α parameter is necessary for all models. An α parameter equal to 1 means that each predicted value (forecast) is equal to the respective previous observation. The closer the α parameter it is to 1, the faster will the weights decrease (and the greater will be the effect of immediately preceding or "younger" observations). In plots of the series, small values of a produce smooth fitted lines (forecasts) that only follow major trends or fluctuations spanning many observations; larger values of a (closer to 1) produce more jagged lines that are greatly influenced by even minor disturbances in the series.

The predicted period is until 2019. Predicted price values were compared with the values from the late 2017 and the average difference between those values in % was calculated (Table 4). For this statistical analysis, the software STATISTICA 12 and MS Excel were used, as well.

RESULTS

The first part of the results discusses the assessment of the development of spruce, fir, and beech sawlog prices in Slovakia, Czech Republic, and selected Austrian provinces.

Development of sawlog prices

Figure 1 illustrates the overview of the prices of spruce and fir sawlogs in individual quality classes. The prices in the Czech Republic are complemented with the quality class III.D, which is, regarding the price, the closest one to the class III.C in Slovakia. The influence of the crisis and the subsequent boom in the forestry and wood-processing industry moving into a gradual stagnation in 2017 is apparent. Therefore, it can be stated that the prices of coniferous sawlogs reached the top at the turn of the years 2014/2015.

Figure 2 shows an overview of the prices of beech sawlogs in individual quality classes. Austria is a specific country from the viewpoints of the wood species composition and state subsidies encouraging renewable energy sources. Especially in Salzburg, this situation is very noticeable; hence the sawlog prices are much higher than the prices in the Czech Republic or Slovakia. Another difference in Austria is that the price development cannot be recorded continually, since the beech sawlogs are traded solely during the dormancy period (from September to March). For creating a continuous time series for the periods when the wood assortment was not being sold and bough, the last know price from the previous month was used.

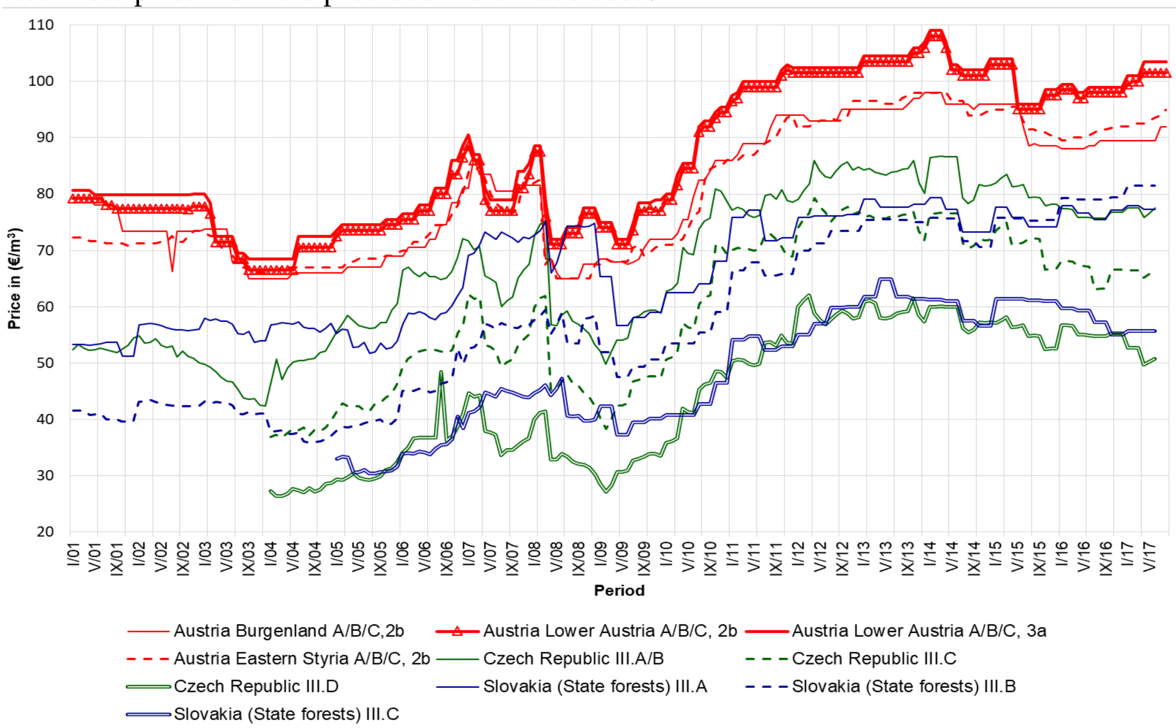

Fig. 1. Development of spruce/fir sawlogs in Slovakia, Czech Republic and selected provinces of Austria for the period 2001 to 2017

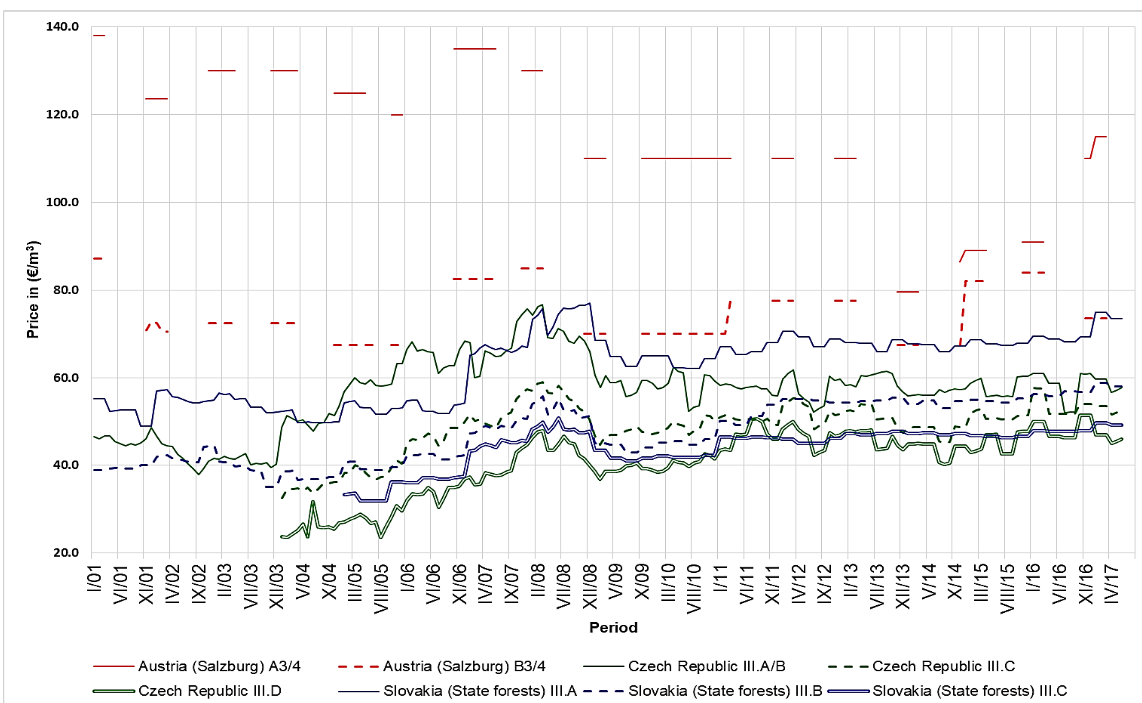

Fig. 2. Development of beech sawlogs in Slovakia, Czech Republic and Austria (Salzburg) for the period 2001 to 2017

The price development of beech sawlogs mirrors the overall long-term stagnation in the European market with this assortment. It is caused by the long-term decrease in the demand for beech lumber. In some countries, local authorities or governments have introduced programs encouraging the use of beech wood. The wood processing plants also have introduced modern tomography-based technologies for more efficient and optimal valuation of these assortments (Stangle *et al.* 2015). The dynamic development of the energy sector causes an increase in the prices of beech wood of lower quality classes. Therefore, it is only a matter of time until the beech sawlog prices will start to increase gradually. The prices of beech sawlogs reached their maxima in the period prior to the crisis (in the late 2008).

Table 1. Descriptive Statistics for the Prices of Selected Raw-wood Assortments

Spruce and Fir	Aver.	Median	Modus	Variance	Standard deviation	Variation Coeff.	Skewness	Kurtosis
Burgenland A/B/C, 2b	80.6	80.5	multiple	123.6	11.1	13.8	0.1	-1.5
Lower Austria A/B/C, 2b	86.3	81.0	101.5	166.2	12.9	14.9	0.1	-1.6
Lower Austria A/B/C, 3a	87.7	83.8	79.9	160.5	12.7	14.5	0.1	-1.6
Eastern Styria A/B,C, 2b	80.3	77.3	67.0	131.3	11.5	14.3	0.2	-1.6
Czech republic III.A/B	66.9	66.4	77.5	173.7	13.2	19.7	-0.1	-1.5
Czech republic III.C	59.9	62.7	multiple	178.4	13.4	22.3	-0.3	-1.4
Czech republic III.D	45.0	47.9	52.7	140.0	11.8	26.3	-0.1	-1.6
Slovakia III.A	66.6	69.3	multiple	91.7	9.6	14.4	-0.2	-1.7
Slovakia III.B	57.5	55.4	53.5	223.6	15.0	26.0	0.2	-1.5
Slovakia III.C	49.3	52.6	61.4	109.3	10.5	21.2	-0.3	-1.3
Beech								
Salzburg A 3/4	113.9	110.0	110.0	201.5	14.2	12.5	-0.4	0.0
Salzburg B 3/4	74.1	72.5	70.0	31.3	5.6	7.5	0.8	-0.5
CR III.A/B	56.9	58.3	59.7	60.1	7.7	13.6	-0.4	0.4
CR III.C	49.7	50.6	51.7	34.7	5.9	11.9	-1.2	0.9
CR III.D	41.8	44.1	47.0	51.9	7.2	17.3	-1.1	0.2
SR III.A	64.2	66.8	multiple	72.5	8.5	13.2	-0.3	-1.1
SR III.B	49.1	50.7	54.4	57.0	7.6	15.4	-0.2	-1.4
SR III.C	45.3	46.7	multiple	23.5	4.8	10.7	-1.2	0.8

Basic descriptive statistics of the price development are illustrated in Table 1. When studying the development of coniferous and non-coniferous sawlog prices, it is apparent that despite a number of factors influencing the state and regional market, the prices of these individual assortments correlate in individual states. The level of such correlation is illustrated by the Pearson correlation coefficient in Table 2. The average prices of sawlogs were calculated and their level of dependence was assessed statistically. The prices of coniferous sawlogs correlate strongly in all three countries; only Slovak prices show slightly lower values of correlation. The reason is the specific market environment in the Slovak Republic and long-term contracts of the dominant forestry entity (Lesy SR, š.p. – State Enterprise Forests of the Slovak Republic).

Low level of correlation is shown by the Slovak and Czech prices of beech sawlogs when compared to the Austrian prices. It is due to the already mentioned conditions of trade and subsidy policy in Austria. A similar situation is found with the prices of coniferous sawlogs in the Czech Republic and Slovakia, which also show a weak correlation (r = 0.579). It is partially caused by different wood species composition in these countries (Table 2).

Table 2. Correlation Between the Assortment Prices in Selected Countries

Spruce [*r*]			
	Austria	**Czech Republic**	**Slovakia**
Austria	1.000	0.956	0.860
Czech Republic	0.956	1.000	0.840
Slovakia	0.860	0.840	1.000
Beech [*r*]			
	Austria	**Czech Republic**	**Slovakia**
Austria	1.000	0.250	-0.013
Czech Republic	0.250	1.000	0.579
Slovakia	-0.013	0.579	1.000

Influence of Selected Factors on Timber Prices

Table 3 illustrates the influence of selected factors (identified in time) on the sawlog price development in Austria, Slovakia, and the Czech Republic. A one-year period, since the occurrence of the factor, was assessed. The factor represented by the decrease in oil prices at the turn of 2014 and 2015 was the only exception (assessed period from November 2014 to May 2015).

Six extensive windthrows, significantly affecting one of the countries in question, were assessed. Two of these windthrows (Alžbeta and Žofia) affected only Slovakia. Even if a windthrow affects only one country, it has an impact on the timber market in the whole region (neighboring countries). Therefore, also in the case of this windthrow, its impact on prices in other countries was calculated as well. Correlation between the prices development in selected countries is proven (Table 2). Another factor was assessed specifically for Slovakia, when in 2010 the state entity Lesy SR, š.p. (managing 50% of all forests in the country) changed their trade policy and signed individual 10-year contracts with four companies guaranteeing an exclusive supply of the whole available volume of the coniferous sawlog assortments for fixed prices.

Table 3. Impact of the Factors on Sawlog Prices in Austria, the Czech Republic, and Slovakia

Cause/Windstorm	Spruce, Fir			Beech		
	Slovakia	Czech Republic	Austria	Slovakia	Czech Republic	Austria
Alžbeta (19. 11. 2004)	- 1.8 %	+ 10.1 %	+ 4.5 %	+ 5.6 %	+ 14.4 %	- 4 %
Kyrill (19.1.2007)	+ 5.8 %	-2.8 %	- 1.4 %	+ 10.3 %	+ 10.1 %	- 0.9 %
Klaus (27.1.2009)	- 1.3 %	+ 18.2 %	+ 6.3 %	-2.2 %	-1.3	0
Xynthia (7.3.2010)	+ 21.1 %	+ 21.1 %	+ 22.4 %	+ 5.7 %	+ 3.6 %	+ 6.8 %
Žofia (15.5.2014)	- 0.45 %	- 5.4 %	- 3.9 %	- 0.3 %	+ 2.3 %	+ 9.8 %
Niklas (3.4.2015)	+ 0.92 %	- 4.4 %	- 6.6 %	+ 1.6 %	+ 2.3 %	+ 2.24 %
Global crisis (2008-2009)	- 8.4 %	- 21.4 %	- 15.5 %	- 11.3 %	- 14.3 %	- 13.5 %
Specific contracts in Slovakia (I/2010)	+ 21.1 %	-	-	+ 5,7 %	-	-
Sanctions against Russia (III/2014)	- 0.6 %	-2.7 %	- 3.9 %	+ 0.74 %	+ 3.9 %	+ 15 %
Drop in oil prices (2014/15)	+ 4.6 %	- 5.8 %	- 4.4 %	+ 0.3 %	+ 4.9 %	+ 9.8 %

The largest volume of damaged wood, mainly in coniferous stands, was caused by the windstorms "Klaus" and "Kyrill". Nevertheless, they did not lead to a significant decrease in the sawlog prices in the following year. On the contrary, one year after the windstorm Klaus, the prices of coniferous sawlogs increased significantly. This can be explained by the economic boom and growth in the construction activities in the period after the crisis. Interesting is the fact that in the aftermath of the windstorm "Kyrill", the prices of non-coniferous sawlogs increased. Therefore it can be said that more extensive windthrows influence the sawlog markets only in a short term, and their negative impacts decrease during the year. Yet, they significantly influence the quality of the timber supply after the event. In general, timber from windthrows has lower value than timber obtained from standard felling. This is also another reason why the negative impact on the prices of assortments of higher quality classes is not so significant. The most serious decrease was recorded in the case of coniferous sawlogs after the windthrow "Niklas". Nonetheless, from the long term point of view, an indirect impact of the windthrows on the timber prices in the form of reducing the planned fellings, changing assortment structure *etc.* can be anticipated. This simple analysis has also shown that the windthrows can have different impact on the timber trade depending on the extent of the windthrow and the period when it occurred. Therefore, it is important to consider other factors affecting the timber market. The basic statistical analysis of this factor (windthrows), therefore, would not show significant results.

The global economic crisis can be labeled as the most significant factor that has influenced the timber prices negatively. At its peak in 2008 and 2009, the prices of the coniferous and non-coniferous sawlogs dropped by 15% and 13%, respectively, on average per the three countries. The crisis has thus influenced the entities in the forestry and wood-processing system (as well as other spheres of economy). The prices of sawlogs are directly connected with the construction sector. When the crisis strangled the construction activities, the demand for construction lumber dropped dramatically, having a direct impact on the decreasing prices of sawlogs. The sanctions against Russia and the decrease in oil prices in 2014-2015 influenced the prices of only non-coniferous sawlogs in Austria significantly. The sanctions influenced mainly the timber import to the Western European countries and the investments into sawmills of Austrian and German groups in Russia. It led to a decrease in the prices of mainly coniferous sawlogs being the main imported assortment from Russia.

The prices of coniferous sawlogs in Slovakia were significantly affected by signing the 10-year contracts between the entity Lesy SR, š.p. and four selected companies. It meant that in 2010, the whole available volume of coniferous sawlogs from one half of Slovak forests was sold to four companies, which led to a 20%-increase in prices of this assortment in Slovakia being a liquidation for several smaller wood-processing companies.

The analysis of the price development of selected assortments shows that mainly the market with beech sawlogs stagnates, and the price fluctuations are rather of seasonal nature. The economic and financial crisis in 2008 and 2009 was identified as the most significant factor influencing negatively the prices of timber, having long-term effects. A strong impact was identified also in the case of incidental fellings caused by windthrows. Nevertheless, their effects are only of short- or medium-term nature and were eliminated within one year after the windthrow occurred.

The price development is clearly affected also by the local market environment, which is influenced by the timber from countries with weaker economy, *e.g.* Belarus, Bosnia, and Herzegovina and imported to countries with stable economy (Austria, Italy). This fact can be affected also by the tariffs and taxes imposed on wood and wood products in countries which are not the EU members (Nemec *et al.* 2015).

Prediction of Timber Price Development

Table 4 shows the average results of predicting the price development of spruce, fir, and beech sawlogs in Austria, Slovakia, and Czech Republic in 2018 and 2019 based on the price development in 2001-2017. Three methods were used as prediction models.

Table 4. Average Results for Prediction Trend of Spruce, Fir, and Beech Sawlogs by the End of the Year 2019

	Spruce, Fir Sawlogs		
Country	**Linear model prediction**	**Box-Jenkins (ARIMA&autocorrel.coef.)**	**Multivariate exponential smoothing**
Austria	+ 12 %	+ 3 %	+ 9 %
Slovakia	+ 16 %	+ 6 %	+ 15 %
Czech Republic	+ 26 %	+ 6 %	+ 15 %
Beech Sawlogs			
Austria	- 11 %	- 6 %	- 13 %
Slovakia	+ 11 %	+ 6 %	+ 12 %
Czech Republic	+ 5 %	+ 5 %	+ 11 %

The coefficient of linear trend determination of coniferous sawlogs was the highest for Slovakia (0.81077) and the lowest for Austria (0.6615). The linear trend was even less accurate for the non-coniferous sawlogs with the values from 0.32104 for Austria to 0.6531 for Slovakia. From the viewpoint of accuracy, this prediction method can be considered the least accurate one, although it provides some kind of indication for the future development. This model predicts the highest increase for the spruce sawlogs in the Czech Republic (Table 4). The issue with the result reliability associated with this model is mainly caused by a shorter prediction period. The linear model is more suitable for longer time periods, where such negatives are minimized. However, in the case of timber prices in the current conditions of global climate change and timber market turbulences, predictions for longer time periods are not very useful. The residue test of ARIMA method showed that 90% of all observed prices meet the model predictions.

The nonstationary statistic model ARIMA is generally accepted as a satisfactory prediction model for processes where the level is changed, and these can be of unsystematic, accidental character, which is usual for most time series from practice. Besides random fluctuations, it also stochastically models the trend component (Cipra 1986; Leskinen and Kangas 2001). This model predicts that the price of coniferous sawlogs should increase by 3 to 6% in all states in the next two years. A similar increase is predicted for the beech sawlogs, except Austria, where a 6% decrease is anticipated. This analysis, however, is based on the ex post analysis results. Therefore, the model does not consider new factors influencing the timber price, such as the impact of increasing the ration of renewable energy sources in Austria, known for its attitude towards alternative energy sources.

The last applied model was multivariate exponential smoothing, which, in contrast to the method of moving averages, is based on all previously observed data. This method also predicts an increase in the spruce sawlogs price, while this increase should be the lowest in Austria as in previous results. It also predicts a decrease in the prices of beech sawlogs of up to 13% in Austria, representing the highest predicted decrease from all methods used.

Following all prediction methods, an increase in the prices of sawlogs, except the beech sawlogs in Austria, can be anticipated in the next two years. More efficient valuation of beech sawlogs has been a long-term problem (Fig. 2). The comparison with the real price development for the first six months since carrying out the analysis (from August 2018 to April 2018) has shown that all models systematically overestimate the model price development. Nevertheless, the model ARIMA was closest to the real values as it overestimated the prices by 2.5%. The linear model and multivariate exponential smoothing overestimated the real prices by almost 6%. Therefore, in regards to the decision making processes in management and carrying out the trade policies, the prediction model ARIMA is considered to be the most suitable.

DISCUSSION

The present results have established that the prices of coniferous sawlogs in individual states are correlated. The study by Stimm (2012) investigates the relationship between sawlog prices and non-sawlog prices for four main tree species, spruce, pine, beech, and sessile/pedunculate oak, based on data from the Bavarian state forests from 1978 to 2010. Using ordinary least square regressions, as well as maximum likelihood estimations for the sawlog price (dependent variable) and the non-sawlog price (independent variable), a significant positive relationship between these time series was only found for pine. The present results, as illustrated in Figs. 1 and 2, show that the prices of beech sawlogs do not correlate with the prices of spruce sawlogs. Windthrows do not influence the sawlog prices by more than 14% within one year from their occurrence. The decrease in the oil prices led to a general increase in the prices of beech sawlogs only. Nevertheless, the oil prices can significantly influence the costs required for logging and thus also the final timber price (Härtl and Knoke 2014). The authors of this study predict, considering various scenarios of oil price development, a more radical price increase until 2020 only for the following categories: assortments of spruce pulpwood and fuelwood; class III.C of beech sawlogs; and pulp- and fuelwood. This prediction is in line with the authors' results analyzing the decrease in oil prices at the turn of 2014/2015.

Time series modelling gives background to the information on past timber development and a framework for modelling the expert knowledge. For modelling the time series, models with integrated stochastic planning system that enable decision making in the risk and uncertainty conditions or that apply optimization calculations in forest management have been used successfully (Kangas *et al.* 2000). Leskinen and Kangas (2001) predicted the development of sawlog and pulpwood prices of spruce, pine, and birch until 2020 following the ARIMA model and questionnaire survey of forest owners and wood processors in Finland. Using the statistical model they predicted a 2% price increase of spruce sawlogs in Finland (in combination with the questionnaire the increase was of 2.7%). This model was based on the price development until the year 1950. The present similar prediction model predicts a 3% price increase of this assortment in Austria and a 6% increase in the Czech Republic and Slovakia. However, the present model also considers the current more turbulent market development of the last decade. From the viewpoint of the real development, this model can be labelled as real or slightly underestimating. In the study of Kostadinov *et al.* (2014), the authors simulated the development of sawlog prices in Switzerland for years 2018-19 based on their own model in four development scenarios. All four scenarios predict an increase in monthly timber prices in that period of 2.5 to 20%. This model also considered the social criteria and preferences of the individual entities in the sector. Our statistical prediction models are thus also compatible with these results.

Incomes from the sold timber represent the essential source of profits for forestry entities. In order to provide for the economic efficiency of their business activities, the timber sale earnings must cover all the costs associated with providing sustainable forest management and at the same time generate appropriate profit. Knowing the factors influencing the timber price development, as well as being able to implement them into the economic planning are becoming a necessary condition for survival of the business entities in the current turbulent environment.

Time series modelling gives background information on past timber price development and a framework for modelling expert knowledge. Timber price models for different timber assortments can be used in the optimization calculations of forest management planning (Leskinen and Kangas 2001).

In the future, it will be necessary to concentrate on the new sectors that are of interest to the forestry industry (carbon sequestration, carbon trade, renewable energy resources). For the wood processors it will be necessary to concentrate on developing the process of new products based on wood and investing in technology (Gejdoš and Potkány 2017). In the future, the timber prices can be affected by the planned introduction of indirect subsidies for forest ecosystem services. Forestry entities will no longer have to rely on logging at the utmost limits of logging possibilities. This situation can be, however, influenced significantly by global climate change and the increased intensity of incidental fellings.

An additional factor that can influence the situation is the possibility of a partial change in the wood species composition of forests and changes in the assortment structure.

These models have been shown to be suitable for short-term to medium-term predictions and are an integral part of planning and management in forestry. However, other tools should be investigated and tested for long-term planning.

CONCLUSIONS

1. Information on the timber prices represents a key management tool for forestry entities for optimal valuation of produced timber. The results have shown that the key factors influencing the timber market and timber prices essentially are of random nature and can occur at any time. The global economic crisis and some specific conditions of markets in individual countries (*e.g.* unfavorable long-term contracts) had the largest influence.
2. The stochastic model ARIMA with autocorrelation coefficient seems to be the most accurate for predicting the future development. Prediction of the future timber price development made by this model can be considered the most probable one. Nevertheless, the analysis of the past development of prices using the information on their development is inevitable for the future predictions. In addition, information on the local business relationships and forest logging potential in individual countries is important, too.
3. In Slovakia, many entities disregard these activities, causing them to lose a certain part of their competitiveness. Analysis of the price developments in the selected countries confirmed that all global factors reflected the price level trends approximately equally in all countries; however, the price levels for every country are different.
4. The results of predicting the timber prices from any prediction model will be influenced by incidental events, which can often reach disastrous parameters. In the near future, for instance, the timber market in the Central Europe will be influenced significantly by the outbreak of bark beetles in the Czech Republic or windthrows in Italy or Austria.

ACKNOWLEDGMENTS

The authors are grateful for the support of the Slovak Ministry of Education, Science, Research and Sport of the Slovak Republic; Slovak research and development agency, Grants: KEGA Nr. 013TU Z-4/2017 E-learning teaching modules focused on fast-growing tree plantations, KEGA Nr. 013TU Z-4/2018 Innovation methods in teaching of financial management, VEGA Nr. 1/0570/16 Mathematical modeling of specific risk management in forest land, VEGA Nr. 1/0031/18 Optimization of technological and work processes and risk assessment in the production of forest biomass for energy purposes; APVV-16-0297 Updating of anthropometric database of Slovak population.

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Article submitted: November 9, 2019; Peer review completed: January 13, 2019; Revised version received and accepted: February 18, 2019; Published: February 25, 2019.
DOI: 10.15376/biores.14.2.2995-3011