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Krzysztof ADAMOWICZ, Aleksandra GÓRNA

THE APPLICATION OF TREND ESTIMATION MODEL IN PREDICTING THE AVERAGE SELLING PRICE OF TIMBER

The article analyzes the possibility of adopting trend estimation model to predict the average selling price of timber (CGUS). The study used information about the average selling prices of timber in chosen periods (2006-2017). The data concerning the actual CGUS was used to create a trend estimation model. The models and CGUS predictions were conducted based on three different time series encompassing 5-year periods. The predicted (CGUS) trend estimation in particular years was requested based on extrapolation, which exceeded the accepted set of information used in the study to create a trend estimation model. On the basis of the conducted study it was ascertained that the method of modeling linear trend estimation should be adopted in the price prediction process. The error assessment with which the linear function formulas are burdened, it was noticed that the value of the coefficient of residual variation was between 4.40% and 7.82%. It was also noticed that the linear modeling of CGUS trend estimation, despite unfavorable values of coefficient of determination and convergence, to some extent, can be viewed as an assistance tool in the decision-making process in the scope of predicting the height of the analyzed price. This view was supported by the achieved predictions which were verified with the actual prices of timber. The price difference between the actual and the predicted one was between -1.59 PLN to 2.27 PLN, and in relative terms the predictive error was between 0.83 to 1.15%. In our opinion the presented research process can constitute a reference point as a comparative element to verify the results for other, new price prediction models. The process of modeling timber prices should be extended by other predicators which are connected with forest market chain.

Keywords: wood economics, forest economics, price forecast, prediction methods, trend estimation model

Introduction

A sustainable development of multifunctional forestry practices requires cooperation of numerous sectors as it takes places on three areas i.e. ecology, economics, and social [Zajac 2001; Płotkowski 2004; Gołos and Zając 2008; Paschalis-Jakubowicz 2011; Adamowicz and Kaciunka 2014; Kaliszewski and Młynarski 2014; Szramka et al. 2016]. All these areas penetrate and permeate,

Krzysztof ADAMOWICZ✉ (*krzysztof.adamowicz@up.poznan.pl*), Aleksandra GÓRNA (*aleksandra.gorna@up.poznan.pl*), Poznan University of Life Sciences, Poznan, Poland

but the economic dimension is the one which is the mutual dimension. Naturally, this is connected, among other things, with the necessity of decision- -making as far as forest marketing is concerned, and the price constitutes its significant part. Both prices as well as the quality of timber on the market are subject to change, hence monitoring and predicting these changes is a vital element of the process [Wysocka-Fijorek and Lachowicz 2018]

Paschalis-Jakubowicz indicate that the factors which shape the relations of supply and demand for timber and wood products are demographic changes, economic growth, local environmental conditions and energy policy (or policies) [Paschalis-Jakubowicz 2012]. The market mechanisms are also influenced by the legal and organizational solutions of managing forest resources adopted in particular countries. This influence on the examples of the Czech Republic and Slovakia was discussed by, among others: [Grladinović et al. 2007; Suchomel and Gejdos 2007; Teplická et al. 2015]. The Polish conditions in this scope were analyzed by: [Szyndler 2007; Ratajczak 2011; Zubkowicz 2013; Adamowicz and Noga 2014; Grzegorzewska and Stasiak-Betlejewska 2014; Szramka et al. 2016; Szramka and Adamowicz 2017]

Regardless of the adopted forest farm management system in particular countries, the synthetic indicators which characterize the economic condition of a forest farm are the relations between the labor costs and the prices of timber, and clean earnings [Ripken 2000]. That is why, it is necessary to search for academic methods of supporting the forest farm management systems in this particular scope.

One of the elements of the first management function, i.e. planning, is predicting future situations and economic phenomena. Here, predicting the prices of timber, from forest marketing viewpoint, is particularly significant. The development of the studied phenomenon is the basis for economic and market analyses, and for a proper market orientation and to realize marketing strategies it is vital to monitor the price changes on the local and global scale [Suchomel and Gejdos 2007]. Furthermore, the prices of timber and wood products are shaped by market regulations and the wood market, in numerous countries, including Poland. Despite some restrictions resulting from the adopted forest industry paradigm, the prices are shaped by the free market. That is why, the knowledge concerning the future fluctuations and price trends constitute the basis for understanding the system mechanisms and trend estimations to take place on the wood market [Chai et al. 2019].

The analysis of time series is particularly important in the prediction process. The analysis of time series can encompass observations collected in different time periods [Bowerman et al. 2005]. For example, time series are usually constructed as yearly, quarterly or monthly observations. Suchodolski and Idzik's [2018] opinion was taken into account while constructing the research methodology; they claimed that based on the research conducted in Płock forest district the timber prices are characterized by a visible changeability which was systematic in nature, which means that it is possible to isolate trends and cyclicity. They also indicated that the decisive factors influencing changeability of timber prices in Płock forest district were long-term changes, which include trend estimation as well as cyclical fluctuations. At the same time, the seasonal changes impact the short-term price fluctuations per annum [Suchodolski and Idzik 2018].

Taking into consideration the above observations, it has been decided to test the possibility of creating year-long predictions of timber prices based on the trend estimation model. The presented research process is a pilot study, hence it was decided to use information of wood prices as a subject of prediction study. The information of wood prices on the basis of article 4 (4) of the Act from 30th October 2002 on forest tax [Dz. U. from 2017 poz.1821 and from 2018 poz. 1588 and 1669] that are released by the Central Statistical Office of Poland.

Research methodology

The source information about the average timber prices (C_{GUS}) in particular periods (2006-2017) was collected from Monitor Polski[1] published in Dziennik Ustaw [Journal of Laws][2]. The data dealt with the actual C_{GUS} which were used to create trend estimation model. The models and C_{GUS} predictions were conducted based on three time series encompassing 5-year periods. The predicted in particular years (C_{GUS}) trend estimation was requested based on extrapolation, which exceeded the accepted set of information used in the study to create C_{GUS} trend estimation model (prolonging the trend line in linear function).

Prediction accuracy is determined by the means of ex post errors [Kocel 2010]. Creating predictions should be monitored, i.e. their accuracy should be checked and, if necessary, adjustments should be made. Bearing this in mind, the accuracy verification process of the C_{GUS} predictions, created by means of particular trend estimation models in the research, ex post analysis was conducted, which was based on C_{GUS} predictions for 2015, 2016, and 2017 and compared the achieved results with the actual (empirical) C_{GUS} for these particular years. The accuracy of the predictions was estimated by calculating the absolute error (EI) out of the actual difference and the predicted C_{GUS}, from the classical cross proportions the approximation error (EII) was determined for the two types of prices.

In order to create the C_{GUS} trend estimation model, the parameter estimation of the linear function was conducted ($y_t = at + b$). The parameter estimation for C_{GUS} function was done by solving the classical set of formulas:

[1]Monitor Polski is an official gazette of the Republic of Poland published by the Prime Minister of Poland, in which legal acts (not laws) and public decisions are published.

[2]Dziennik Ustaw is a Journal of Laws of the Republic of Poland in which legal acts are published.

$$\begin{bmatrix} \sum_{t=1}^{n} y_t = n \times b + a \times \sum_{t=1}^{n} t \\ \sum_{t=1}^{n} y_t \times t = b \times \sum_{t=1}^{n} t + a \times \sum_{t=1}^{n} t^2 \end{bmatrix} \quad [1]$$

y_t – the price of timber in period t;
t – period (1 year);
n – the number of observations;
a – coefficient of C_{GUS} trend estimation;
b – constant term of C_{GUS} trend estimation (theoretical C_{GUS} in period $t = 0$).

At first, following the above formula (1), the value of trend coefficient (a) was estimated:

$$a = \frac{\overline{y \cdot t} - \overline{y} \cdot \overline{t}}{\overline{t^2} - (\overline{t})^2} \quad [2]$$

Symbols as in formula no.1

On this basis, the coefficient the average C_{GUS} increase and decrease between the particular periods (t) were determined. The value of free parameter of the analyzed function (b) was estimated by using the value of C_{GUS} trend estimation (a), arithmetical average of the number of period used in the simulation $(\bar{t})$ and arithmetical average of C_{GUS} $(\overline{y_t})$:

$$b = \overline{y_t} - a \times \bar{t} \quad [3]$$

The efficiency of suiting the C_{GUS} trend function to the actual prices was conducted by determining the parameters of a stochastic structure, i.e.: residual standard deviation, coefficient of standard variation, coefficient of convergence, coefficient of determination and the standard errors in structural parameters of trend equation.

Residual standard deviationwas ($S(e_t)$) calculated by following the formula:

$$S(e_t) = \sqrt{\frac{\sum_{i=1}^{n} (y_t - \hat{y}_t)^2}{n-k}} \quad [4]$$

$\overline{y_t}$, n – like in formula 1;
$\hat{y}_t$ – theoretical value in the present time;
k – the number of estimated parameters (in the case of trend linear function the k symbol is 2).

The coefficient of standard variation $(V_{S(e_t)})$ was calculated according to the formula:

$$V_{S(e_t)} = \frac{S(e_t)}{y_t} \cdot 100\% \qquad [5]$$

$S(e_t)$ – like in formula 4;
y_t – like in formula 1.

The coefficient of residual variation explains to what extent the dependent variable is influenced by the random factor. It means that the obtained percentage of the average level of the wood raw material price is random fluctuations. It was assumed that the model is useful for predictions when the coefficient of residual variation assumes value smaller than 20% $(V_{S(e_t)} < 20\%)$.

The coefficient of convergence (φ^2) was calculated following the formula:

$$\varphi^2 = \frac{\sum_{i=1}^{n} (y_t - \hat{y}_t)^2}{\sum_{i=1}^{n} (y_t - \overline{y}_t)^2} \qquad [6$$

$\overline{y}_t$ – like in formula 1;
$\widehat{y}_t$ – like in formula 4 ;
y_t – weighted average value of actual prices of timber in *t*-period.

The coefficient of determination (R^2) was calculated following the formula:

$$R^2 = 1 - \varphi^2 \qquad [7]$$

φ^2 – like in formula 6.

By using the coefficient of determination (R^2) it was possible to determine which part of data can be explained by the model. The following classification of results was adopted: R^2 = 0.0-0.5 – insufficient match; R^2 = 0.5-0.6 – weak match; R^2 = 0.6-0.8 – satisfactory match; R^2 = 0.8-0.9 – good match; R^2 = 0.9-1.0 – very good match. The standard errors for structural parameters of the trend equation ($S_{(a)}$) and ($S_{(b)}$) were calculated by the formulas:

$$S_{(a)} = \frac{S(e_t)}{\sqrt{\sum_{i=1}^{n} t^2 - n\bar{t}^2}} \qquad S_{(b)} = \sqrt{\frac{S^2(e_t)\sum_{i=1}^{n} t^2}{n(\sum_{i=1}^{n} t^2 - n\bar{t}^2)}} \qquad [8, 9]$$

$S(e_t)$ – like in formula 5;
t, n –like in formula 1.
The relative and absolute error was calculated using the formula:

$$\Delta x = |x - x_0|$$

$$\sigma = \frac{\Delta x}{x} \cdot 100\,\%$$

Δx – relative error,
x – real value,
x_0 – calculated value,
σ – absolute error.

These errors are referred to as ex post errors.

Results by issues

According to the adopted methodology, time series smoothing was conducted which meant estimating linear function of C_{GUS} trend (Table 1). The model presented a 5-year-long C_{GUS} trend estimation for the period 2012-2016, and for it the empirical form of the extrapolation formula was achieved $y_{t1\_5} = 2.99\ t + 176.85$, for 2011-2015 period $y_{t2\_5} = 1.26\ t + 181.17$ and for the model depicting 2010-2014 period the formula was $y_{t3\_5} = 5.277\ t + 161.70$.

The next step of the research was determining the parameters of stochastic structure. The value of the angular coefficient for the C_{GUS} prediction model, based on the function $y_{t1_5}$was 2.99; however, the absolute value of linear function of the trend was 176.85. It was estimated that the average error of the prediction ($S(e_t)$)in this case was 8.18 PLN. On this basis it was assumed that the empirical C_{GUS} differed from the theoretical values formulated on the basis of the trend equation by (+)8.18 PLN on average. The coefficient of residual variation ($VS(e_t)$) of the analyzed model was 4.40%, hence it was decided that the estimated model of the linear function can be used in the C_{GUS} prediction process. The coefficient of convergence was 0.7 whereas the coefficient of determination for this model was 0.3. If our task is only to understand the relationships between the variables then lower values of the determination coefficient are acceptable however it should be remembered that they will not explain anything to our explore. It is also useful information that allows to continue research with the use of different econometric models for example ARIMA or SARIMA and compare the obtained results.

It was calculated that the standard errors of structural parameters of trend function are respectively $S_{(a)} = 2.59$ and $S_{(b)} = 8.58$. Based on these results it was ascertained that the angular coefficient of the analyzed linear function of the trend was accurate in the range +/- 2.59, and the estimated absolute value of the linear function of the trend was in the range +/- 8.58 (Table 2).

The value of the angular coefficient based on the C_{GUS} prediction model based on the function y_{t2_5} was 1.26; however, the absolute value of the linear

Table. 1 The price of wood in Poland in the years 2006-2017

Period	Price (PLN)
2006	133,37
2007	147,28
2008	152,53
2009	136,54
2010	154,65
2011	186,68
2012	186,42
2013	171,05
2014	188,85
2015	191,77
2016	191,01
2017	197,06

Source: Own study based on data from Monitor Polski.

function of the trend was 181.17. It was estimated that the average error of the prediction ($S(e_t)$) in this case was 9.02 PLN. On this basis it was concluded that the empirical C_{GUS} differed from the theoretical values calculated by means of the trend equation by (+)9.02 PLN on average. The coefficient of residual variation ($VS(e_t)$) of the analyzed model was 4.88, hence it was decided that the estimated model of the linear function can be used in the C_{GUS} prediction process. The coefficient of convergence was 0.9 whereas the coefficient of determination for the model of y_{t2_5} function was 0.1. It was also calculated that the standard errors of structural parameters of the trend function are respectively $S_{(a)} = 2.85$ and $S_{(b)} = 9.46$. As a result, it was decided that the estimated angular coefficient of the analyzed linear function of the trend was accurate in the range +/- 2.85, and the estimated absolute value of the linear function of the trend was in the range +/-9.46 (Table 2).

The value of the angular coefficient of the C_{GUS} prediction model based on the y_{t3_5} function was 5.28, and the absolute value of the linear function of the trend was 161.70. It was estimated that the average error of the prediction ($S(e_t)$)was, in this case, 13.88 PLN. As a result, it was decided that the estimated model of the linear function can be used in the C_{GUS} prediction process. The coefficient of convergence was 0.7 whereas the coefficient of determination for this model was 0.3. The standard errors of the structural parameters of the trend function were respectively $S_{(a)} = 2.59$ and $S_{(b)} = 8.58$. Based on this, it was estimated that the angular coefficient of the analyzed trend linear function was accurate in the range +/-2.59, and the estimated absolute value of the linear function of the trend was +/-8.58 (Table 2).

Table 2. Linear function formula and stochastic structure parameters for 5-year C_{GUS} prediction models

Period	Index		Formula of the linear function	Parameters of the stochastic structure					
	a	b		$S(e_t)$	$VS(e_t)$	(φ^2)	(R^2)	$S_{(a)}$	$S_{(b)}$
2012-2016	2.990	176.850	$Y_{t1\_5} = 2.99\,t + 176.85$	8.18	4.40	0.69	0.31	2.59	8.58
2011-2015	1.261	181.170	$Y_{t2\_5} = 1.26\,t + 181.17$	9.02	4.88	0.94	0.06	2.85	9.46
2010-2014	5.277	161.700	$Y_{t3\_5} = 5.28\,t + 161.70$	13.88	7.82	0.67	0.33	4.39	14.56

According to the methodological assumptions, after creating the trend linear function model the C_{GUS} theoretical (predicted) values were calculated for the years 2017, 2016, and 2015. By prolonging the 5-year line of the y_{t1_5} linear function of the trend, it was estimated that C_{GUS} reached 194.79 PLN/m^3. The achieved prediction was verified with the actual C_{GUS} in the analyzed year, which reached 197.06 PLN/m^3. Based on these results, it was assumed that the predicted C_{GUS} was by 2.27 PLN lower than the actual C_{GUS} achieved in 2017; however, the relative error (EII) for this prediction was 1.15% (Table 3). By prolonging the 5-year line of the y_{t2_5} linear function of the trend, it was estimated that C_{GUS} in the analyzed year reached 188.74 PLN/m^3. The prediction was verified with the actual C_{GUS} in the analyzed year, which reached 191.01 PLN/m^3. Based on these results it was assumed that the predicted C_{GUS} was by 2.27 PLN lower than the actual C_{GUS} achieved in 2016, however, the relative error (EII) for this prediction was 1.19% (Table 3). By prolonging the 5-year line of the y_{t3_5} linear function of the trend, it was estimated that C_{GUS} reached 193.36 PLN/m^3. The achieved prediction was verified with the actual

Table 3. Empirical and projected price in 2015-2017 as well as relative and absolute errors of obtained forecasts

Model	Year	Price (PLN)		EI (PLN)	EII (%)
		empirical	forecast		
$Y_{t1\_5} = 2.99\,t + 176.85$	2017	197.06	194.79	2.27	1.15
$Y_{t2\_5} = 1.26\,t + 181.17$	2016	191.01	188.74	2.27	1.19
$Y_{t3\_5} = 5.28\,t + 161.70$	2015	191.77	193.36	-1.59	0.83

C_{GUS} in the analyzed year, which reached 191.77 PLN/m^3. Based on these results it was assumed that the predicted C_{GUS} was by 1.59 PLN higher than the actual C_{GUS} achieved in 2015; however, the relative error (EII) for this prediction was 0.83% (Table 3).

Conclusions

In the contemporary and dynamically developing world, the ability of predicting the socio-industrial phenomena gains on its significance. The key ability of the managers nowadays is the skill to use the tools at hand in order to make predictions. Such knowledge is essential in the process of managing economic phenomena. The outcome of the decisions made today, to a great extent, depends on the manner in which the situation will develop in the future. Predictions lead to reducing risk and doubt but at the same time contribute to the increase of apt decisions, thus eliminating the loss in various areas of industry. As a result, in previous years, numerous scholars focused on prediction models including price prediction models. For example, Mondal et al. [2014] and Du [2018] conducted predictions of share price; McNally et al. [2018] studies the predictions concerning future Bitcoin prices; Duc Cao et al. [2015] as well as Kowalik and Herczakowska [2010] focused on the predictions of oil prices; Popławski [2006] presented short-term predictions of electricity prices at Polish Power Exchange (Towarowa Giełda Energii). In the subject literature, there are also research studies which compare various prediction models as far as their potential for predicting trend prices is concerned. The results of these studies were presented by, among others, Omar et al. [2016], Du [2018], McNally et al. [2018] Chou and Ngo [2016] , Shao and Dai [2018]. Only few of these works deal with the issues of predicting prices of such a specific material, as timber. Soares et al. [2010] attempted to create a price prediction model of eucalyptus (*Eucalyptus* spp). Kocel [2010] discussed the methodological basis for financial-industrial predictions for National Forests, and claims, among other things that predicting prices of wood can be conducted by means of: linear econometric models, exponential smoothing method (Holt's linear model and Winters' model) and ARIMA model. Bearing in mind the above facts, the study presented research results focusing on predicting timber prices by means of model created based on linear trends estimations of price change. The potential of using the trend estimation model for C_{GUS} predictions was presented. The analysis reveals that the model is an effective tool for short-term predictions of timber prices. The productivity of the estimated models reflects on the appropriately low value of ex post errors. C_{GUS} predictions achieved on the basis of the created trend estimation models differed from the actual prices, the range was from -1.59 PLN to 2.27 PLN, and in relative terms the prediction error was in the range from 0.83 to 1.15%. Taking into consideration opinions by Cieślak [2008]; Dittmann

[1996], Zeliaś [1997] and Kocel [2010], there are no predictions without any errors, hence the achieved results can be perceived as satisfactory. The authors believe that the presented proposal of methodological support of the planning system in forestry by using the trend estimation model can currently, to some extent, have a practical application. Due to the low value of coefficients of determination and high coefficient of convergence, the research should be continued in this scope. The search for a new wood price prediction model, which will consider all the independent variables deriving from related markets connected with wood, should be continued. It seems these markets should constitute a forest marketing chain based on wood.

Furthermore, the presented study explains the shaping process of prices in time series. This indicates the possibility of predicting prices based on the existing trends as far as price shaping is concerned, hence the achieved results can constitute a reference point in the search of the most efficient prediction models in this scope.

In accordance with the assumptions, this article presented a pilot study focusing on price predictions and their relationship to the so called C_{GUS}. In order to confirm the usefulness of the analyzed method of wood price predictions in particular forest districts, the presented process should be repeated but including the log-length system structure. However, it does not change the fact that the presented research focusing on C_{GUS} predictions possess academic and utilitarian validity. It should also be borne in mind that this price is being referred to by the appropriate regulations from 3rd February 1995 about the farm and woodland conservation act Dz. U. from 2017poz. 1161), local government revenue income act from 13th November 2003 (Dz. U. from 2018 poz. 1530, with later changes) and the decree of the Minister of Environment from 20th June 2002 about a one-off compensation for premature felling of a tree stand (Dz. U. poz. 905). Consequently, C_{GUS} predictions, apart from academic value, have also utilitarian application and can constitute a reference point for further scrutiny of price prediction in particular tree ranges.

Managing a forest farm under market conditions is connected with a constant decision-making process, which directly and indirectly influence the income obtained from this enterprise. In such a situation, the self-financing of forestry in Poland is a key factor in realizing statutory goals of forestry. The dynamic changes taking place in the areas surrounding forest farms as well as the changes in forest marketing result in making uncertain decisions with long-term outcomes. The necessity of being prepared for the future consequences of today's actions forces the decision-makers to prepare industry predictions and, on their basis, the action-plan. Hence, the main aim of predictions, in this case, is indicating the most plausible course of future phenomena and industrial processes as well as possible outcomes of the decisions. The knowledge about the shaping of future prices constitutes one of the foundations of the proper planning process focused on the income of wood selling, thus becomes a significant element of support system of the forestry decision-making process.

On the basis of the conducted research aiming at testing the possibility of creating annual C_{GUS} predictions by means of trend estimation model, it has been concluded that:

- Trend linear function modeling method should be used in predicting prices. By assessing the errors of linear functions it was expressed that the value of coefficient of residual variation was between 4.40% and 7.28%. This assumption constituted that the level of random fluctuations of C_{GUS} average in Poland allows the analyzed method to search for the more adequate price prediction model.
- The study should be continued as far as the more adequate wood price prediction model is concerned, especially when coefficient of convergence of the linear models was between 0.67 to 0.94, whereas the coefficient of determination was between 0.06 to 0.33. The presented research process should be repeated on a sample of chosen forest district taking into consideration the assortment prices.
- The linear modeling of C_{GUS} trend estimation, regardless of negative values of coefficients of determination and convergence, in a limited scope, can become a tool which supports the decision-making process in predicting the height of the analyzed price. It is indicated by the verification of the predicted and the actual prices of timber. The difference between the predicted and the actual price was between -1.59 PLN to 2.27 PLN, and in relative terms the prediction error was between 0.83% to 1.15%.
- The presented research process can constitute a reference point as a comparative element to verify the results of the predictions for other, new price prediction models. The timber price modeling process should expand over other predicators, which are connected with the forest marketing chain.

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