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Time Series Analysis for Short-Term Forest Sector Market Forecasting

Die Zeitreihenanalyse als Instrument für kurzfristige Prognosen von Marktentwicklungen im wald-basierten Sektor

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Keywords: Time Series Analysis, Forest Sector, VAR, VECM, Cointegration, Nonstationarity, Forecasting

Schlüsselbegriffe: Zeitreihenanalyse, Forst- und Holzwirtschaft, Kointegration, Nichtstationarität, Prognose

Summary

Among the various functions of the forest its special significance as a source of raw materials for the timber industry can be emphasized. Wood is an environmentally friendly and a renewable resource. By the growing and simultaneously competing use of the natural resource wood, its commercial role becomes increasingly important. To bring economic potentials into conformity with social and environmental requirements for the performance of the ecosystem forest, wise management of the use of the natural product wood is necessary, also with respect to a successful, sustainable-oriented and bio-based economy. Reliable predictions about possible

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short-term changes in the timber market are scarce although they play a key role in supporting decision making. Forecasts help to recognize and minimize risks in the supply chain management e.g. initiating the adjustment of timber harvesting to fast changing market conditions. In this context, the relevance of the statistical technique of time series methods in forest sector research is highlighted in this paper. The main purpose of this research method is to extract important information out of the time series itself as well as possible causal relationships between the time series and to use this information to identify future economic developments. The fact that time series methods provide strong results combined with only modest data requirements underlines their unique usefulness for the analysis of forest economic issues. To some extent, they can serve as an alternative for the often very complex models of the forest sector. Therefore, this work aims at sensitizing to the advantages of time series for forest sector short-term modelling. Based on this, a breeding ground is provided for progressive research in the forest sector through the application of time series analysis.

Zusammenfassung

Unter den zahlreichen Funktionen des Waldes ist seine besondere Bedeutung als Rohstofflieferant für die Holzindustrie hervorzuheben. Als eine umweltfreundliche und nachwachsende Ressource findet Holz eine breite Verwendung. Durch die in den letzten Jahren gewachsenen und gleichzeitig miteinander konkurrierenden Nutzungsansprüche gewinnt die kommerzielle Rolle von Holz immer stärker an Bedeutung. Um wirtschaftliche Potenziale nutzen und parallel dazu den gesellschaftlichen und ökologischen Anforderungen an die Leistungsfähigkeit des Ökosystems Wald Rechnung tragen zu können, ist ein umsichtiger Umgang mit der Naturressource Holz geboten, auch hinsichtlich einer erfolgreichen, nachhaltig orientierten und bio-basierten Wirtschaft. Zuverlässige Prognosen über mögliche kurzfristige Veränderungen auf dem Holzmarkt sind rar, wären jedoch für die Entscheidungsfindung von Bedeutung. Vorhersagen helfen, Risiken im Supply-Chain-Management zu erkennen und zu minimieren z.B. durch Anpassung der Holzernte an sich schnell ändernde Marktverhältnisse. In diesem Zusammenhang wird in dieser Arbeit die Relevanz der statistischen Techniken der Zeitreihenanalyse für die Forschung im Forstsektor hervorgehoben. Der Hauptzweck dieser Methode ist, wichtige Informationen über zeitliche Zusammenhänge aus der Zeitreihe selbst sowie mögliche kausale Zusammenhänge zwischen den einzelnen Zeitreihen zu gewinnen und diese anschließend für die Prognose künftiger wirtschaftlicher Entwicklungen weiter zu nutzen. Die Tatsache, dass Zeitreihenverfahren zu sehr guten Ergebnissen trotz nur geringer Datenanforderungen führen, unterstreicht ihr enormes Potential für die Analyse von waldwirtschaftlichen Fragestellungen. Damit wird auch den im Forstsektor oft sehr komplexen Modellen Rechnung getragen. Das Ziel der vorliegenden Arbeit ist es daher, für die Vorteile von Zeitreihen bei kurzfristigen Modellierungen des Forstsektors

zu sensibilisieren. Darauf aufbauend wird, basierend auf der Anwendung von Zeitreihenmodellen, der Nährboden für weitere Forschung im Bereich des Forstsektors bereitet.

1. Introduction

To bring economic potentials into conformity with social and environmental requirements for the performance of the ecosystem forest, wise management of the use of the natural product wood is necessary. In this respect, an optimal institutional framework is fundamental for a successful, sustainable-oriented and bio-based economy, which not only Germany but the European Union as a whole has committed itself (BMBF and BMEL (2014), European Commission (2012)).

Therefore, reliable predictions about possible changes in the timber market play a key role in supporting decision making. Especially predictions about future developments of quantities and prices are crucial for the management in forest industry as well as for traditional forest management such as timber production. Forecasts help to recognize and minimize risks in the supply chain management e.g. by adjusting timber harvesting to changing market conditions.

For this purpose, the statistical technique of time series analysis is presented and its relevance for forestry economics is examined. Time series analysis has been widely used in different fields of science for many years. Time series models are basically used to disclose the underlying relationship in a sequence of observed (past) values of a variable as well as the possible causal relationship between time series. After fitting a model they help to predict the future values of the variable of interest. The main purpose of this method is to extract important forecasting information out of the time series and to use this information to identify future (economic) developments.

Empirical literature on forest industry and timber markets focuses primarily on the study of long-term scenarios. Less attention has been paid to the short-run behaviour of forest products and timber markets, and there are even fewer studies that are explicitly concerned with the short-term forecasting issues, as stated by Hetemäki et al. (2004). Due to globalization and internationalization, forest product markets have become more interrelated. They are urged to respond quickly to fast changing market conditions. Therefore, short-term forecasts play an essential role.

Hänninen (2004) takes a swipe at consultants, analysts and private organizations publishing short-term forecasts for the forest sector as they are based on ad hoc assumptions and often not even well documented. He emphasizes the advantage of economic forecasting based on econometric and time series models, where existing knowledge of how the economy works is presented. These models provide forecasts and policy advices, and produce frameworks for progressive research strategies.

With this in mind, and in order to encounter the scarcity of short-term forecasting models for the forest sector, a selection of existing scientific literature in forest sector modelling is presented and analysed. Special attention is attached to the issue of short-term forecasting of quantities and prices in the forest sector based on times series analysis. The statistical improvements of the forecasting techniques over time are highlighted and the selection of the explaining variables is examined. The results of different studies are compared and the underlying methodology is assessed in order to find a useful approach allowing for a simple short-term modelling where at the same time providing meaningful predictions of future developments in the forest sector.

This work aims at sensitizing to the advantages of time series and along with this at preparing the ground for further research in the field of forest sector short-term modelling. The basic techniques of time series analysis and their historical improvement over time are presented in the beginning. Selected important error measures are then given, often applied in forecasting to help assess the goodness of a forecasting model. Hereinafter, a structured historical overview of forest research literature based on time series analysis is provided. Finally, some closing remarks and conclusions for future analysis are discussed.

2. Material and Method

The application of time series analysis has a long history in different fields of science. The pioneering work of Box and Jenkins (1970) with the underlying model class of autoregressive integrated moving average (ARIMA) processes constitutes a milestone in the history of time series analysis. Starting with the predominant class of univariate ARIMA processes, Box and Jenkins (1970) developed a first multivariate time series method, which accounted for the statistical character of time series. Hamilton (1994) provides background knowledge about the most popular method of time series analysis, the Box-Jenkins method. Starting with scalar time series models introduced by Kalman (1960) and Box and Jenkins (1970), the ARIMA models build the predominant class of time series models. These go back to Wold (1938) who stated that any purely non-deterministic stationary time series can be expressed as an infinite moving average (Wold decomposition theorem), which can be described by the infinite sum of the past errors with decaying weights (Pfaff 2008).

Judge et al. (1988) define stationarity as a property that ensures constancy of the means, variances and autocovariances through time. This implies that stationary time series must not have trends, fixed seasonal parameters or time-varying variances. For convenience reasons, these underlying implications might be very useful as they help to understand the basic inherent explanatory power of time series. In reality, however, these friendly stationarity properties of economic data are often violated, so that this assumption appears to be very restrictive and to not correctly reflect economic reality.

Thus, a lot of research has been done since then particularly concerning the properties of time series which on their part directly influence the significance and consistency of research outcomes. In many cases, the fact that time series analysis focuses on available data is often considered as both a restriction and a challenge. And yet, besides the tacit simplicity arising from the employment of already available data, in the course of this work the advantage of vector models more precisely will be highlighted where there is no necessity for distinction between exogenous and endogenous variables. Based on this, a breeding ground is provided for progressive research in the forest sector through the application of time series analysis.

Harvey and Shepard (1992) interpret that the principal univariate structural time series models are therefore nothing more than regression models in which the explanatory variables are functions of time and the parameters are time-varying. Following this, adding observable explanatory variables to structural time series models is seen as some kind of a natural extension as alike is seen the construction of multivariate models.

The most common class of multivariate time series is the class of vector autoregressive (VAR) models which were originally designed for stationary processes. Usually though, economic time series are of a dynamic nature. This is the reason why they are characterized by non-stationarity (see Figure 1). A non-stationary process is featured by a non-constant mean level, a non-constant average size of fluctuations and a varying type of dependence.

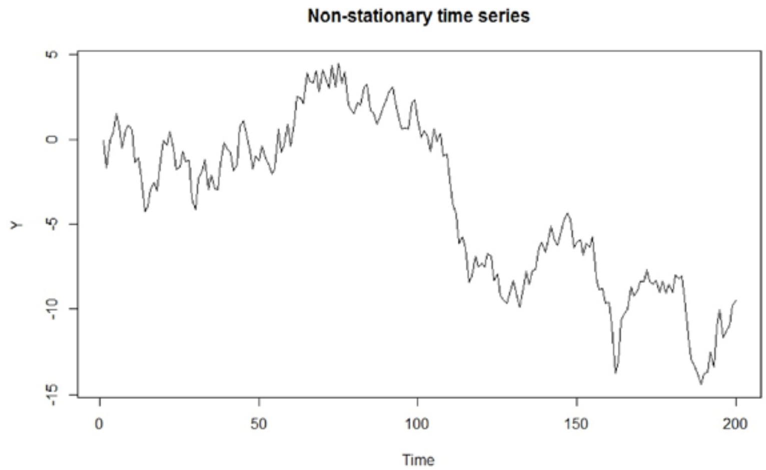

Figure 1: Example for a non-stationary time series

Abbildung 1: Beispiel einer nicht-stationären Zeitreihe

Engle and Granger (1987) have shown that when time series are characterized by non-stationarity, cointegration is a particularly appropriate statistical technique to deal with spurious regression resulting from non-stationarity. In the presence of a cointegration relationship between time series the use of a vector error correction model (VECM) appears to provide better results in terms of forecasting quality.

The fact that time series methods provide strong results combined with only modest data requirements underlines their unique usefulness for the analysis of forest economic problems, given the often very complex models which forest sector research is confronted with. Thus, the methodology of time series analysis along with their improvements over time is introduced in this part. It presents, further, important error measures often applied in forecasting models to evaluate the goodness of the forecasting model.

2.1. The econometrics of unit-root processes

One important feature of time series data as opposed to e.g. cross-section data is that different observations are likely to be correlated. Another one is the possible dynamic relationship between variables so that the change in a variable today may affect the same and/or another variable today as well as in future time periods. This is why it is important to know for how long in the future this relationship holds and how strong is its impact quantitatively to better assess the consequences of economic decisions.

To illustrate the dynamic relationship of time series, a brief look is taken at a simple first-order autoregressive process (AR(1) process):

$$y_t = \varphi y_{t-1} + \epsilon_t \qquad (1)$$

The current period's value of y_t is explained by its previous one and an error process ε_t, where ε_t is a white noise (uncorrelated, with a mean of zero and a constant variance). When forecasting is the objective, a representation of this kind enables to use the knowledge accumulated in the past from the observation to predict future values of the variable of interest (Judge et al. 1988). The path of this process depends on the value of φ. If $|\varphi| \geq 1$, then shocks accumulate over time and hence the process is non-stationary. If $|\varphi| > 1$, the process grows without bounds, and if $|\varphi| = 1$ is true, the process has a unit root (Pfaff 2008).

Usually the generating process of a time series is more complicated than a simple AR-process and may depend on further past values of y_t additionally as e.g. $y_{(t-2)}$, $y_{(t-3)}$ and so on. So that it can be generalized to an autoregressive process of order p (AR(p) process) of the form:

$$y_t = \varphi_1 y_{t-1} + \varphi_2 y_{t-2} + \cdots \ \varphi_p y_{t-p} + \epsilon_t \qquad (2)$$

For reasons of simplicity the lag operator notation is used to describe the lagging of a variable, where e.g. $Ly_t = y_{t-1}$ when the lag operator L is applied once, and $L^2 y_t = L(Ly_t) = Ly_{t-1} = y_{t-2}$ when L is applied twice. In terms of lag operator L the AR(p) process in (2) can be rewritten then as

$$y_t = \varphi_1 L y_t + \varphi_2 L^2 y_t + \cdots \ \varphi_p L^p y_t + \epsilon_t \qquad (3)$$

$$\varphi_p(L) y_t = (1 - \varphi_1 L - \varphi_2 L^2 - \cdots \ \varphi_p L^p) y_t = \epsilon_t \qquad (4)$$

Setting $\varphi_p(L) = 0$ it can be rewritten as

$$\varphi_p(L) = (1 - \varphi_1 L - \varphi_2 L^2 - \cdots \ \varphi_p L^p)$$

$$= (1 - \varphi_1 L)(1 - \varphi_2 L) \ldots \left(1 - \varphi_p L\right) = 0 \qquad (5)$$

For an AR(p)-process to be stationary it is required that for all roots z of the polynomial

$$\varphi_p(z) = (1 - \varphi_1 z_1)(1 - \varphi_2 z_2) \dots (1 - \varphi_p z_p)$$

$$= (1 - \varphi_1 z - \varphi_2 z^2 - \cdots \varphi_p z^p) = 0, \quad \text{where } z = \sqrt{\varphi_p} \tag{6}$$

$|z_i| > 1$ is true. The modulus of a complex number $z = z_1 + iz_2$ is defined to be $|z| = \sqrt{(z_1^2 + z_2^2)}$. In view of this stationarity condition, when returning back to the case of an AR(1)-process, as the one in (1), $|\varphi| < 1$ is required because the only solution to $1 - \varphi z = 0$ is given for $z = 1/\varphi$, and the modulus $|z| = |1/\varphi| > 1$ is true only when $|\varphi| < 1$ (Judge et al. 1988). If $|z_i| = 1$ then a unit root exists implying non-stationarity which can be removed by detrending or by differencing as shown next.

2.2. Deterministic "detrending"

Having a deterministic trend δ in a time series makes it variant to displacements in time:

$$y_t = \delta + \gamma t + \epsilon_t \tag{7}$$

and

$$E(y_t) = \delta + \gamma t \tag{8}$$

By subtracting $E(y_t)$ from both sides of the former equation (7)

$$y_t - E(y_t) = \delta + \gamma t + \epsilon_t - \delta - \gamma t = \epsilon_t \tag{9}$$

the deterministic trend is filtered out of the time series and one ends up with a stationary white noise process which is called trend stationary.

2.3. Difference stationarity

Even after deterministic "detrending" economic time series often show stochastic properties that are inconsistent with the assumptions of stationarity. This is met by the approach of Box and Jenkins (1970) where time series are differenced until stationarity is achieved. Such a time series is called integrated defined by Engle and Granger (1987) as follows.

Definition: A series with no deterministic component that has a stationary, invertible ARMA representation after differencing *d* times is said to be integrated of order *d*, which is denoted as $x_t \sim I(d)$.

A series is then an integrated process of order *d (I(d))* when d differences are required to make the series stationary. Such a stationary time series is illustrated in Figure 2.

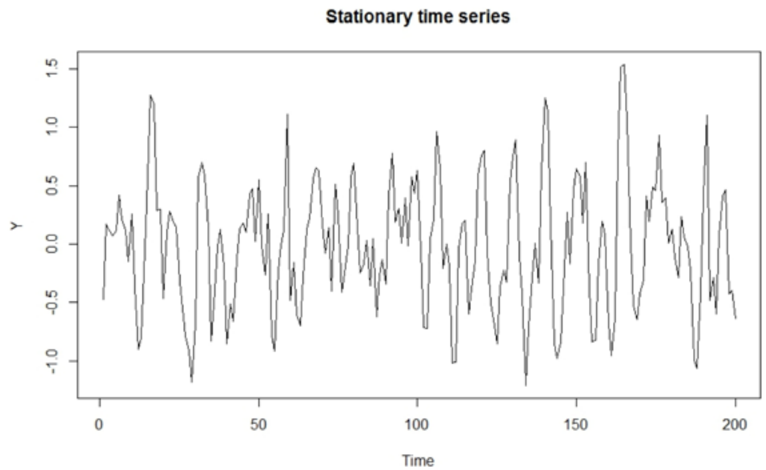

Figure 2: Example of a stationary time series

Abbildung 2: Beispiel einer stationären Zeitreihe

Difference stationary time series is often said to have unit roots (i.e., roots of the autoregressive polynomial that lie on the unit circle (Pfaff 2008)).

2.4. Spurious regression

The application of the method of ordinary least squares (OLS) in the presence of integrated time series appears to be problematic. The residuals (errors) may be serially correlated (or autocorrelated) and have a growing variance over time. Especially in the case of difference stationary data the error term often seems to be highly correlated. Hence, the result is the so called spurious regression (or nonsense regression) given by very high coefficient of determination R^2 of the regressions and high significance of explanatory variables where there may not be any significance at all. The phenomenon of spurious regression can be traced back to Yule (1926) and Hooker (1901). In Hendry (2004) and Hendry (1986) a historic background of nonsense regressions is provided (Pfaff 2008). This phenomenon is very often connected to and especially typical for the fact, that economic time series simply have trends. When the original (non-detrended or non-differenced) data are used for regression, they correlate without any causal relationship. This problem is less present when cross-sectional data are used. To cope with spurious regression, difference stationarity is applied by testing for unit roots as well as the techniques of cointegration.

2.5. The existence of cointegration

Using differenced data in time series analysis is often considered problematic as the information filtered out by differencing may be very important with regard to a possible existence of long-run equilibrium relationship between level-data (undifferenced) which economic theory usually relates to (Davidson et al. 1978).

Granger (1981) introduced the concept of cointegration which accounts for the existence of a stable long-term relationship between several non-stationary time series. It was further formalised by Engle and Granger (1987) where for following definition of cointegration is found:

Definition: The components of the vector x_t are said to be *cointegrated of order d,b*, denoted $x_t \sim CI(d,b)$, if (i) all components of x_t are $I(d)$; (ii) there exists a vector $\alpha \neq 0$ so that $z_t = \alpha' x_t \sim I(d-b)$, $b>0$. The vector α is called the *cointegrating vector*.

Although the individual series are non-stationary, they are tied to each other by the cointegrating vector. Deviations from a long-run equilibrium path are possible, but these errors are characterized by a mean reversion to its stable long-run equilibrium. And this fact is what made the concept of cointegration so valuable to economists, namely the possibility to detect a stable long-run relationships among non-stationary variables (Pfaff 2008).

In Sims (1980) the possibility was presented to developed models for many time series and the vector autoregressive model (VAR) was born. An approach to apply this method for multivariate time series was designed by Johansen (1988) and Johansen and Jusélius (1990). They state further that in the presence of cointegration, a multivariate system can be defined in a general error correction representation which would relate the change in one variable to past equilibrium errors, as well as to past changes in both variables (Engle and Granger 1987, Johansen 1988). A reduced form error correction model (ECM) is given by:

$$\Delta X_t = \sum_{i=1}^{p-1} \Gamma_i \Delta X_{t-i} + \Pi X_{t-1} + \Phi D_t + \mu + \varepsilon_t \qquad (10)$$

Where $\varepsilon_t \sim i.i.d.N(0,\sigma^2)$ is a vector of independent, identical, normally distributed errors, D_t is a matrix of saisonal dummy variables, μ is a vector of constants and X_t is a vector of used variables. The left-hand side of the ECM is stationary. To balance the model, the right-hand side has to be stationary as well. To achieve stationarity on both sides, the term ΠX_{t-1} must be stationary.

The number r of cointegration relations (vectors) is to be determined, which means for the rank of the $p \times p$ *matrix* $\Pi = \alpha\beta'$ is to be tested. Each column of matrix β corresponds to one long term equilibrium and α describes the weights, also interpreted as the speed of adjustment, with which the system returns to the equilibrium after a disturbance. The term ΠX_{t-1} is stationary if the matrix Π has full rank. If the rank is zero, it is the null matrix (r = 0), then the term is no longer of interest. If it is of reduced rank (r < p), than there is cointegration. Then there exist r matrices $\Pi = \alpha\beta'$ for which ΠX_{t-1} is stationary.

2.6. Performance of forecasting models

After fitting the in-sample model with data and verifying it with out-of-sample data, the accuracy of the predicted values is to be assessed. This is done by comparing the forecasting performance of the estimated model with the out-of-sample data. To do this, there are different measures available some of which are presented below.

The mean absolute percentage error (MAPE) measures the average differences between predicted y_t and actual $\hat{y}_t$ values. Only absolute deviations are considered irrespective of whether the differences are positive or negative. This avoids offsetting of over- and underestimates.

$$\frac{1}{T}\sum_{t=1}^{T}\left|\frac{y_t - \hat{y}_t}{y_t}\right| \qquad (MAPE) \tag{11}$$

The root mean square error (%RMSE) is another measure for forecasting quality. Basically, it is the root of the mean of all squared forecast errors. RMSE avoids the use of absolute values. It is more sensitive to outliers then MAPE because it amplifies and punishes large errors more severely. Chai and Draxler (2014) conclude that any single metric emphasizes only a certain aspect of the error characteristics. Therefore, a combination of metrics is often required to assess model performance.

$$\sqrt{\frac{1}{T}\sum_{t=1}^{T}\left|\frac{y_t - \hat{y}_t}{y_t}\right|} \qquad (RMSE) \tag{12}$$

In view of this statement, Theil's inequality coefficient, also known as Theil's U-statistic (Winker 2010), is shortly discussed as a more accurate metric of the forecasting performance of a model, since the importance of large errors is emphasised here by weighing large errors more strongly than smaller ones. Theil's inequality coefficient originally developed by Theil (1966) compares errors of the forecast model with errors of the so called naïve model (when the predicted value is the same as one period before: y_t =) y_{t-1}, i.e. the status quo is assumed for the future). The coefficient verifies that actual changes in the endogenous variable are predicted. Here, y_0 in the denominator is the final value of the in-sample time series and T the number of forecasting points in time. In the case of Theil's U-statistic equalling one, the status quo is precisely projected into the future. It is one or greater when the naïve model describes the data as good as or even better than the model respectively. It means the forecasting model does not succeed in providing better results than the naïve model and it should be dropped then. The smaller Theil's inequality coefficient is the more accurate forecasts are obtained using the proposed model. It equals zero when the model perfectly meets the realized values of the analysis period.

$$U = \sqrt{\frac{\sum_{t=1}^{T} u_t^2}{\sum_{t=1}^{T} (y_t - y_{t-1})^2}} \qquad (Theil's\ U) \tag{13}$$

3. Application of time series forecasting models in forest research literature

In this section, an overview of the application of time series methodology in forest sector modelling is given while at the same time investigating their forecasting performance and their practicability. A comprehensive synthesis of existing research conducted worldwide on modelling the forest sector is offered below. To remedy the scarcity, or rather absence of short-term forecasting in the forest sector, the focal issue of this synthesis lies on the attempts done by now to predict demand and supply, as well as prices for forest products.

3.1. ARIMA – the Box-Jenkins approach in the forest literature

As aforementioned, an early major contribution in time series methods for short-term forecasting modelling refers to the univariate Box-Jenkins method. The method provides forecasts using exclusively past values of the variable of interest, or in other words the historical behaviour of a series (Hoff, 1983). This most popular method, also called ARIMA analysis, seemed to provide accurate short- to medium-term forecasts. The pioneering studies by Buongiorno et al. (1979), Buongiorno et al. (1984) and Buongiorno et al. (1988) followed, shifting the focus from univariate to multivariate time series analysis. Below, a structured overview of forest research literature based on time series analysis is provided (see Table 1). The focus here lies primarily on short-term forecasting models for quantities and prices in the forest sector using the technique of times series analysis. In addition though, based on selected studies the improvements of this technique over time are extracted. At the same time, the attention is focused also on the considered variables helping to predict forest quantities and prices.

Table 1: Overview of forest research literature based on time series

Tabelle 1: Übersicht über forstwissenschaftliche Untersuchungen die auf Zeitreihenanalysen aufbauen

Author		ARIMA	Multivariate Regression	Cointegration	VAR	VEC	Short-run Forecasting
Buongiorno et al. (1979)			x				
Buongiorno et al. (1984)		x	x (bivariat)		x		
Buongiorno et al. (1988)			x				
Lewandrowski et al. (1994)		x					x
Buongiorno and Uusivuori (1992)	law of one price			x			
Alavalapati et al. (1997)	law of one price			x			
Hänninen (1998)	law of one price			x			
Nanang (2000)	law of one price			x			
Yin et al. (2002)	law of one price			x	x		
Yin and Baek (2005)	law of one price			x			
Jennings et al. (1991)					x		
Hetemäki and Kuuluvainen (1992)				x			x
Toppinen and Kuuluvainen (1997)				x			x
Toppinen (1998)			x	x			x
Heikkinen (2002)				x	x	x	x
Brännlund et al. (1999)		x	x				
Kim et al. (2003)			x		x		
Limaei et al. (2011)			x				
Hetemäki et al. (2004)		x	x	x	x	x	x
Hetemaki and Mikkola (2005)		x	x	x	x	x	x
Baek (2012)				x			
Nanang (2010)			x	x		x	
Hietala et al. (2013)				x	x		
Nagubadi and Zhang (2013)				x		x	x
Bolkesjo and Buongiorno (2006)					x		x
Song et al. (2011)				x		x	
List et al. (2016)							x
Total	*27*	*5*	*10*	*17*	*9*	*5*	*10*

Buongiorno et al. (1979) analyzed monthly imports of Canadian softwood lumber to the United States explained by the variables import price, domestic wood price, overall price level, housing starts in the United States and one-period-lagged import quantity. Domestic wood price was found to have the largest effect on import quantity followed by housing starts and import price. In all five alternative models considered here import price influenced import quantity negatively. Despite good statistical characteristics and accurate postsample forecasts of the model at first glance, it did not employ unit roots test to check for non-stationarity.

Buongiorno et al. (1984) compared an econometric model based on housing starts, prices, and past imports, with a univariate time series model using past imports only, and a bivariate time series model of imports and housing starts to forecast United States softwood lumber imports. While the econometric model appeared to remain superior for policy analysis, the bivariate time series model showed the best forecasting quality whereas at the same time it required much less information. They foreshadowed that theoretical synthesis of multivariate and econometric approaches would possibly lead to future advances.

Four years later, Buongiorno et al. (1988) developed a multivariate time series model equivalent to the reduced form of a dynamic structural model to reveal the reasons for the duplication of Canadian softwood lumber imports into the United States, using monthly data for the domestic lumber price and the exchange rate. For the exchange rate, no significant influence on imports could be found. On the contrary, the price was found to have a significant impact on import quantities and vice versa. This effect seemed to hold in the short as well as in the long run.

Using quantitative analysis of univariate time series Lewandrowski et al. (1994) developed an ARIMA model using monthly data to forecast the short-run behaviour of lumber markets for three regions of the United States and Canada. Own prices, expected future prices and finished-product inventories were the key factors affecting the short run. They found that lumber markets respond quickly but only to regional market disturbances. No cross-price effects between the U.S. regions could be found which implies that local policy decisions cannot negatively influence producers in other areas. Significant cross-price effects were though found between Canada and areas of the United States. Notwithstanding the fact that the ARIMA model used here managed to forecast short-run (monthly) behaviour of lumber markets, a big downside can be seen in the neglecting of the non-stationarity problem of time series.

3.2. VAR and VEC models (The superiority of the cointegration method)

A common feature and major shortcoming of the above mentioned studies was that none of them considered the problem of non-stationarity. It was not until after the development of the cointegration methodology by Granger (1981) and Engle and Granger (1987) and the maximum likelihood estimation for ECM by Johansen (1988) and Johansen and Jusélius (1990) that a more effective way was found to cope with non-stationarity and spurious regression. New time series econometric models have been developed since then, which can be used to provide reasonable and more accurate short-term forecasts, such as vector and cointegration models.

The seminal work of Johansen and Jusélius (1990) paved the way for further research in the forest sector based on this newly developed approach. A series of papers using cointegration followed, to study the theory of the "law of one price" (e.g. Buongiorno and Uusivuori (1992), Yin et al. (2002) and Yin and Baek (2005) for the United States, Alavalapati et al. (1997) and Nanang (2000) for Canada, Hänninen (1998) for the United Kingdom). Depending on the region or product group of interest, they came to contradicting outcomes. For instance, Yin et al. (2002) could not find evidence for the "law of one price" with regard to saw timber and pulp wood in the United States, whereas Yin and Baek (2005) could support this theory for softwood lumber markets.

A three-lag VAR model with ten macroeconomic variables by Jennings et al. (1991) examined the Canadian lumber industry, aiming at demonstrating the usefulness of the VAR method. The results confirmed those of Buongiorno et al. (1988) that exchange rate had no significant influence on lumber production and export quantity of lumber from Canada to the United States. No evidence was found that any variable describing the Canadian wood market influenced the GDP, except for the variable inventory of lumber held by lumber manufacturers. Housing starts in the United States seemed to be the only variable having a significant influence on export quantity.

Cointegration theory based on Johansen's multivariate cointegration method and the "general to specific" modelling approach as proposed by Hendry et al. (1988) and Spanos (1990) was used by Toppinen (1998) to estimate a dynamic error correction model. Employing recent developments in time series econometrics, she reformulated the short-run demand and supply models of the Finnish sawlog market. The method used monthly data for a relatively short period of less than 12 years and resulted in two cointegrating vectors (rank equaled two) theoretically consistent with the demand and supply equations. In previous studies by Hetemäki and Kuuluvainen (1992) and Toppinen and Kuuluvainen (1997), where no price effect was present on either supply of or demand for sawlogs, the models estimated were, thus, regarded as incapable of performing short-term forecasting. As opposed to these investigations, in Toppinen (1998) both in the short and long run, sawlog supply was effected positively by stumpage price, whereas the price effect in sawlog demand did not hold in the short run. Moreover, Toppinen (1998) highlighted the use of the cointegration approach in modelling price and quantity of forest product markets as beneficial and as well transferable to forest markets in other countries.

A modelling technique for short-run (yearly) decision making was proposed by Heikkinen (2002). He examined the applicability of cointegration to study the correlation between expected asset returns in the Finnish forestry and an optimal investment portfolio. VAR and VEC models were estimated and their impact on the optimal portfolio was then compared. Six major Finnish timber assortments and three major investment alternatives (stocks, government bonds, and deposits) were included in the asset set. Forestry returns seemed to be correlated with the other types of assets in the long-run while not much relevant for the short-run performance prediction of the investment portfolio in terms of asset returns.

Brännlund et al. (1999) applied a multivariate technique to forecast prices of Swedish forest products, which was based on the idea that time series of prices and quantities from different forest sectors typically co-vary over time. Unfortunately, the applied maximum autocorrelation factor approach could not significantly improve the forecasting performance of the naïve-ARIMA models.

A VAR model was calculated by Kim et al. (2003) to estimate the impacts and to evaluate the dynamics of the currency value change on the forest products import quantities in Korea. Depending on exchange rate and import price, they examined import quantities of different wood products to Korea and found a significantly negative effect of exchange rate on import quantity. However, the model fitted the data only moderately. Granger causality of exchange rate on import quantity was found only for hardwood roundwood but not on softwood roundwood import quantity.

A basic multivariable regression analysis was done by Limaei et al. (2011). They investigated the effect of GDP, population size and domestic wood production on export and import of wooden products in Iran. The augmented Dickey Fuller (ADF) test for a unit root in a time series data by Dickey and Fuller (1979) was used to show the stationary process of the predicted autoregressive model for export of wood. They demonstrated the possibility to predict the wood export via a first order autocorrelation function. As a result, GDP seemed to have the largest impact on export quantity, but not a significant impact on import.

Hetemäki et al. (2004) partly agree with these findings. They compared the short-term predictive ability of four different models referring to lumber import demand of Germany, Finnish lumber export to Germany as well as Finnish sawlog demand. The categories considered here were ARIMA models (referred to as the naïve models), single-equation multivariate models (denoted as partial models), as well as VAR and VEC models as system models. The results indicated that one could clearly improve on the ARIMA forecasts by moving to the partial single-equation or systems approaches (VAR and VEC models). Only for the lumber import demand, the partial model fitted best both in-sample as well as out-of-sample. Although it fitted best in-sample also in the case of Finnish lumber exports to Germany, the VEC model turned out to be the best forecasting model in both cases, of the Finnish lumber exports as well as of the Finnish sawlog demand.

To contribute to the scarce literature on short-term forecasting, similar models and a structural time series model were estimated by Hetemaki and Mikkola (2005) to analyze the import demand for coated printing and writing paper in Germany, using quarterly data. Results indicated that forecasting quality increases when moving from single-equation to multivariate VAR models. By optimally combining different models, Hetemäki and Mikkola (2005) assumed a possibility of improvement in terms of forecasting accuracy.

Baek (2012) applied the Phillips-Hansen fully-modified cointegration (FM-OLS) framework, developed by Phillips and Hansen (1990), to study the import quantity of Canadian lumber to the United States, since the FM-OLS method seems to be less sensitive to changes in lag structure and to perform better for finite sample size than the cointegration techniques by Engle and Granger (1987) or Johansen (1988). Using a cointegration procedure for monthly data he came to the conclusion, that a long-run equilibrium relationship exists and that the exchange rate plays no significant role in explaining the import quantity.

These findings substantiate the results of Nanang (2010). Using Johansen's multivariate cointegration approach, he revealed a significant positive long-term effect of exchange rate and income on exported timber products. He employed the augmented Dickey Fuller unit root tests to check for non-stationarity of time series.

Hietala et al. (2013) estimated an unrestricted VAR model with six equations for Finland and Sweden for the period from 1995 to 2008. Following the methodology of Johansen (1992) and the specification of Pantula (1989), they used a cointegration framework to study the exchange rate pass-through in Finnish and Swedish sawnwood exports to the United Kingdom. Although the size of the impact seemed to be country specific, they found a significantly positive effect of the exchange rate on export quantity for both countries. This empirical result is contrary to the general assumption, that in a small open economy exporters are price takers and thus, the relative competitors' prices determine the quantities exported from each country of origin. Finnish exports appeared to have been affected to a great extent by currency fluctuations, while in contrasts, the pricing strategy exploited by Swedish exporters appeared to have been somewhat less affected by currency movements. The authors argued that the lower total costs of transportation from Sweden to the United Kingdom might have been one reason for the more stable export demand faced by Swedish exporters and the more stable Swedish sawnwood price.

The impact of import price, influenced by various trade restriction measures, on the import quantity of Canadian softwood lumber into the United States is part of the investigation by Nagubadi and Zhang (2013). Following Buongiorno et al. (1979), they added some additional variables to the model, like U.S. softwood lumber imports from the rest of the world, interest rate, seasonal factors, and policy dummy variables representing various dispute phases. Monthly data on Canadian softwood lumber imports for more than 32 years were employed. Comparing OLS regressions with a multivariate cointegration framework (Johansen 1988, 1995), ADF unit root and Granger causality tests, they found housing/construction activity and the U.S. domestic lumber prices having a positive impact in the long run, while Canadian lumber import prices having a negative long-run impact on U.S. lumber import quantity from the Canadian provinces covered by their investigation. Estimating a VECM they showed that in the short run, trade dispute and resulting trade restrictive phases negatively impacted the U.S. softwood lumber imports from the covered Canadian provinces.

To test the short- and long-run impacts of exchange rates on the trade of various forest products, Bolkesjo and Buongiorno (2006) estimated a reduced form bivariate dynamic model using monthly observations of U.S. exports to various countries, and U.S. imports from Canada. In the short run, exchange rate was found to have a quite significant negative impact on export quantity, while in the long run the elasticity decreased but remained still significant. Short- and long-run elasticities of import quantity with respect to the exchange rate were positive, but insignificant in the short run. Due to the fact that only few of the export and import series were non-stationary, VAR models were used here instead of cointegration, to obtain results suggesting that exchange rates do matter in international forest products trade, both in the short and in the long run.

An error correction model was derived by Song et al. (2011) estimating a system of dynamic demand and supply equations to analyze the U.S. softwood lumber market using monthly data. Demand and supply of U.S. softwood lumber seemed to be relatively price inelastic in the short run, and not much more elastic in the long run. Similar to this, Canadian supplies were also not price elastic in both, the short and long run. Canadian imports though, as softwood lumber supply to the U.S., seemed to be slightly more price elastic than the domestic lumber supply, in the short and long run. Along with other variables, they used the exchange rate as independent variable and came to the conclusion that exchange rate had significantly positive effect on import quantity, so that import quantity rises when exchange rate rises and the dollar grows stronger.

A convenient and simple way how to use time series for forecasts is presented by List et al. (2016). Based on List (2015) they compare 30 different so-called "naïve forecasts" of monthly supply quantities of timber in two case-study regions with different marketing conditions. Using relatively simple data naïve forecasts provide a rough estimation of the timber supply in the different forest owner associations considered in the study. It turns out that for each of the regions in Styria and Burgenland, the accuracy of the generated forecasts is significantly different and hence, a different model type seems to be superior in each of the regions.

A final glance at Table 1 discloses the general prevalence of cointegration analysis in the empirical modelling of supply, as well as demand and prices for forest products. 17 out of 27 cited studies have used the cointegration approach for investigation. In recent years, an increasing tendency can be observed towards the application of VEC models for short-term forecasting, despite the fact that only few research is as yet done in this field, and even less when it comes to forecasting timber prices. Hence, it can be deduced that further research is required to better assess the potentials of these models for short-term forecasts in the forest sector.

4. Conclusions

Due to economic developments like European integration, globalization, emergence of new information and communication technologies, fluctuations in economic variables are conveyed at a faster speed than ever before (Hetemäki et al. 2004). Globalization and internationalization have accelerated the interdependencies of forest sector markets worldwide. Thus, the need for accurate short-term forecasts of forest products is increasingly moving into the spotlight.

As yet, available short-term forecasts in the forest discipline, mainly conducted by private consulting organizations, are very often based on ad hoc and not well documented assumptions, as pointed out at the beginning. The lack of transparency and of discerning scientific foundation questions the reliability of the information content of assertions based on such forecasting analysis. To provide authoritative statements for future developments of the forest sector, more sophisticated analysis based on reliable and scientifically proven outcomes are necessary.

Economic forecasts based on econometric and time series models benefit from existing knowledge of how the economy works. In the forest research literature, there are few forecasting models and they are primarily limited to long-term scenarios. This paper reveals existing gaps in this field of research. Further, it sensitizes for the advantages of time series models' employment for forest sector short-term modelling while based on this preparing the ground for further research analysis.

Forecasting models in the forest sector are often characterised by a high degree of complexity requiring an extensive knowledge of data to different subjects (such as economic, forest growth, environmental protection etc.), which hampers the practical feasibility and the general applicability of the models. Data sets used are often large and complex and appear to be impractical in terms of compatibility of various objectives considered all rolled into one. The limited availability of appropriate and precise data with respect to all subjects taken into account even further aggravates the feasibility and along with this the usefulness of forecasting models. In many cases data can be obtained only as quarterly or only as annually data, or are often collected not in a uniform manner or not time-consistently. This fact can considerably weaken the validity of the models, additionally.

In this sense, time series methods have the advantage that they produce solid results while working with modest data. The most well-known method for analysis of time series data, the Box-Jenkins method with the class of the ARIMA processes by Box and Jenkins (1970), marked the unique movement away from the widespread perception of stationarity of time series.

Since then, a lot of research on econometric tests such as unit roots test has been done to make methods based on time series more efficient. More particularly, the development of the cointegration approach by Engle and Granger (1987) broke new ground allowing for the consideration of time series having a long-run relationship, irrespective of whether they are non-stationary but moving together rather than away from each other over time.

In the presence of cointegration, error correction models have proven to be far superior to traditional methods in econometric time series theory like e.g. the OLS method, especially when it comes to effectiveness in terms of forecasting quality. With development of the maximum likelihood method by Johansen and Jusélius (1990) the estimation of an error correction formulation was enabled, to handle the problem with non-stationarity and spurious regression.

Important aspects, contributing to a better understanding of economic forecasting and the prevalence of forecast failure, are depicted by Hendry and Clements (2003). They crown the technique of cointegration as the most useful modelling device when it comes to forecast accuracy, in the presence of non-stationarity due to stochastic trends or unit roots.

The usefulness of this particular technique generally originating from the development of time series methods over time, and their applicability for predictions in the forest sector have been highlighted in this study. A great deal of commitment to the technique of cointegration has likewise been shown in Abildtrup (1999). The book contains papers covering different fields of the forest sector where the ability of the technique of cointegration is examined, specifically geared towards the analysis of forest economics problems. Here again, little research is dedicated to the study of short-run dynamics.

Consulting organizations have recognized the shortage of and the increasing need for short-term forest sector forecasts leading to the fact that, unfortunately, often unreliable forecasts are delivered, not based on firm theoretical framework and regardless the high cost of forecasting errors with regard to the decision making process. In that respect, to say it with Buongiorno (1996), regardless of methodological shortcomings and data quality, a formal model that lays out all assumptions unambiguously, is a better way to study the forest sector than no model at all.

Given the problem of the accuracy and the high degree of complexity of existing forest sector models, this paper aimed at sensitizing to the advantages of time series analysis by analyzing the development of short-term forest sector forecasting models. As the technique of time series analysis provides a comparably simple approach for short-term modelling using already available data while at the same time performing quite well in terms of useful results, the increasing need for accurate short-term forecasts of forest products seems to be partly met by the application of time series and more precisely by the application of VEC models to which an increasing attention has been paid in recent years.

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