KONCEPT STACIONARITY JEDNOROZMĚRNÝCH ČASOVÝCH ŘAD – NA PŘÍKLADU CZV ŘEPKY OLEJNÉ

CONCEPT OF STATIONARITY OF UNIVARIATE TIME SERIES – ON EXAMPLE OF FARMER PRICE OF OILSEED RAPE

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Anotace:
Koncept stacionarity je významný pro analýzu jednorozměrných časových řad. Na jeho základě je možné sestavit odpovídající model pro analýzu časové řady a její předpověď. Příspěvek, na příkladu cen zemědělských výrobců řepkových semen, ukazuje vybrané postupy zjištění stacionarity, resp. nestacionarity jednorozměrné časové řady. Časová řada cen zemědělských výrobců řepkových semen v České republice obsahuje měsíční data za období červenec 1993 – prosinec 2004.

Klíčová slova:
Jednorozměrná časová řada, stacionární - nestacionární, autokorelační funkce, autoregresní model.

Summary:
Concept of stationarity is important for univariate time series analysis. On its basis it is possible to form correct models for time series description and its forecast. The paper shows some of the possible approaches of detection stationarity or nonstationarity of univariate time series on the example of the farmer price of oilseed rape. The time series of farmer price of oilseed rape in the Czech Republic contains month data within the period since July 1993 till December 2004.

Key Words:
Univariate time series, stationary - nonstationary, autocorrelation function, autoregressive model.

INTRODUCTION

A time series is a sequence of numerical data in which each item is associated with a particular instant in time. A time series analysis can be univariate or multivariate. An analysis of a single sequence of data is called univariate time series analysis while an analysis of several sets of data for the same sequences of time periods is called multivariate time series analysis. The purpose of time series analysis is to study the dynamics or temporal structure of the data. This approach can be applied for forecasting as well.[4]

To make results about time series and also for forecasting it is useful to know about a time series stationarity. Generally, the concept of stationarity is important for model making. In case of univariate time series it is possible to form two types of models – ARMA models for stationary time series and ARIMA models for nonstationary time series. For correct application it is necessary to know if a time series is stationary or nonstationary.

OBJECTIVE AND METHODS

The aim of this paper is to test the *null hypothesis* H_0: The time series of farmer price of oilseed rape in the Czech Republic is stationary. The aim of the is verified of some quantitative methods. Three different types of examination were applied, as it is described below.

1. An examination of a time series graph

This procedure can be used only for first cursory projection about the stationarity of the time series. But it is useful because we can make first assumption about a time series.

2. An examination of an autocorrelation function (ACF)

The autocorrelation function (ACF) is a useful tool for summarizing the properties of a time series[3]. The sample autocorrelation function may alternatively be called correlogram. In this graph the sample autocorrelation coefficients r_k are plotted against the lag k for $k = 1, 2, \ldots, M$ where M is usually much less than N.[2] The values of ACF can be calculated on the basis of the next formula:

$$ACF(k) = \frac{\sum_{t=1}^{N}(X_t - \overline{X})(X_{t-k} - \overline{X})}{\sum_{t=1}^{N}(X_t - \overline{X})^2}$$ [5].

3. An examination of an autoregressive model AR(1)

On the basis of AR(1) model, the assumption about stationarity or nonstationarity of a time series can be confirm, as well. The autoregressive model is a regression model where the explanatory variables are lags of the dependent variables. The autoregressive model with the explanatory variable being the dependent variable lagged one period is called AR(1). It can be derived from the next formula:

$$Y_t = \alpha + \phi Y_{t-1} + e_t$$ [3].

On the basis of the ϕ values can be set a formal definition of stationarity and nonstationarity. For the AR(1) model, it is possible to say that Y is stationary if $|\phi| \prec 1$ and is nonstationary if $\phi = 1$. The other possibility, $|\phi| \succ 1$, is rarely considered in economics.[3]

This is the most popular method of stationarity examination, which is established on Dickey-Fuller test. This approach examines the hypothesis that the variable in question has a unit root.[5]

As an example for the analysis of univariate time series was chosen the time series containing month data of farmer price of oilseed rape in the Czech Republic within the period since July 1993 till December 2004.

RESULTS AND DISCUSSION[3]

Concept of stationarity and nonstationarity is a broad topic and can be examined and evaluated with many kinds of tools, especially, using statisticalical instruments. A stationary time series is one whose basic properties don't change over time. In contrast, a nonstationary variable has some sort of upward or downward trend.[5]

[3] The calculations were made in SPSS package.

Economists usually focus on the one particular type of nonstationarity that seems to be present in many macroeconomic time series: the *unit root nonstationarity*. Following are different ways of thinking about whether a time series variable is stationary or has a unit root, which means that is nonstationary.

In the AR(1) model, if $\phi = 1$, then *Y* has a unit root. If $|\phi| \prec 1$ then *Y* is stationary.

If *Y* has a unit root then its autocorrelations will be near one and will not drop much as lag length increases.
If *Y* has a unit root, then it will have a long memory. Stationary time series do not have long memory.
If *Y* has a unit root then the series will exhibit trend behaviour, especially if α is non-zero.
If *Y* has a unit root, then ΔY will be stationary. For this reason, series with unit roots are often referred to as difference stationary series.[3]

The null hypothesis *(H_0)*, that should be accepted or rejected by three different procedures - the examination of the time series graph, the examination of the autocorrelation function and the examination of the autoregressive model, is following:

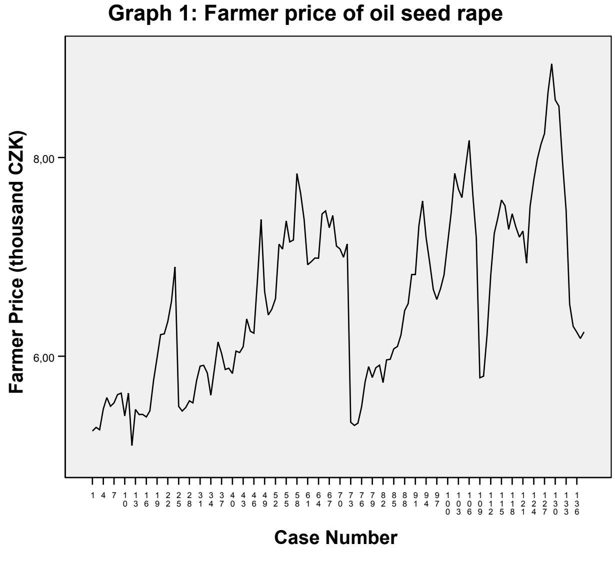
H_0: The time series of farmer price of oilseed rape in the Czech Republic is stationary.
In the opposition to the null hypothesis, the alternative hypothesis *(A)* stands:

A: The time series of farmer price of oilseed rape in the Czech Republic is nonstationary.

Examination of time series graph

In general, from a graph of time series it is possible to find first visual orientation of time series - if it stationary or not. For being sure it is necessary to do another, more qualified, analysis. The examination of time series graph dealing with stationarity and nonstationarity can be really make only for cursory notion about the time series. It can't be the main point in the decision-making process.
In the case of farmer price of oilseed rape, it is possible to assume that the time series has any trend behaviour during analysed period (see Graph 1), basic long-term tendency seems to be increasing. The visual examination shows that the time series is probably nonstationary.

Graph 1: Farmer price of oil seed rape



Source: own calculation

If a time series is nonstationary, it is possible to use first difference of the variable. Usually a time series is nonstationary, while a first difference that means change in the variable, is stationary. With economic data, taking a first difference is usually enough to convert a nonstationary time series to a stationary one, but it's a good habit to test ΔY just to make sure. Unfortunately, there are major disadvantages of using first differences to correct nonstationarity. The two most important of these drawbacks are that using first differences:

changes the inherent theoretical meaning of the differenced variable, and

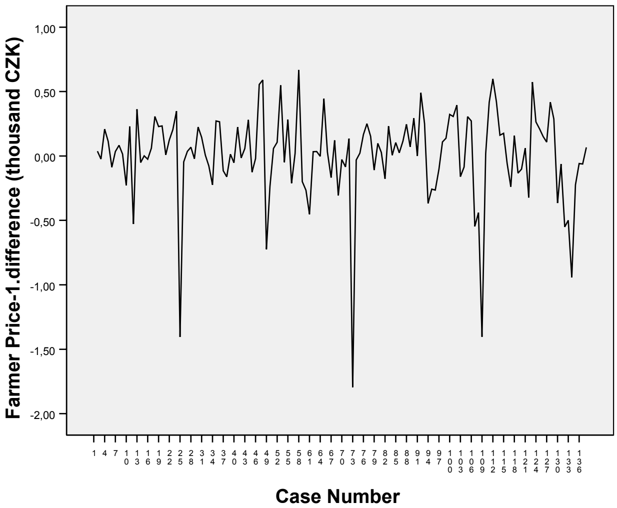
discards information about the long-run tend in that variable.

As a result, first difference should not be used without weighting the costs and benefits of that shift.[5]

In Graph 2, the first difference of farmer price of oilseed rape is depicted. The time series doesn't include any trend behaviour. The values oscillate around the zero with sometimes smaller and sometimes bigger amplitude. All these aspects indicate stationary time series.

After the modification of the time series it could be formed simpler model than in the case of nonstationary time series. But there are also some other problems to decide. If the past values of a time series are known, it is possible to make a very good estimate of its recent value. But the past values of changes and their development don't help to predict it very much. In the example, it may be more suitable to use original time series.

Graph 2: First difference of farmer price of oil seed rape



Source: own calculation

Examination of autocorrelation function

On the basis of a shape of an autocorrelation function, it is possible to recognise if a time series is stationary or nonstationary. But interpreting the meaning of a set of autocorrelation coefficients is not always easy. In general[2], it is possible to describe five kinds of time series behaviour as is described below.

Random series

A time series is said to be completely random if it consists of a series of independent observations having the same distribution. For large *N*, it is expected to find that $r_k \cong 0$ for all non-zero values of *k*.

Short-term correlation

Stationary series often exhibit short-term correlation characterized by a fairly large value of r_1 followed by one or further coefficients, which, while greater than zero, tend to get successively smaller. Values of r_k for longer lags tend to be approximately zero.

Alternating series

If a time series has a tendency to alternate, with successive observations on different sides of the overall mean, then the correlogram also tends to alternate. With successive values on opposite sides of the mean, the value of r_1 will naturally be negative, but the value of r_2 will be positive, as observations at lag 2 will tend to be on the same side of mean.

Nonstationary series

If a time series contains trend, then the values of r_k will not come down to zero except for very large values of lag. This is because an observation on one side of the overall mean tends to be followed by a large number of further observations on the same side of the mean because of the trend.

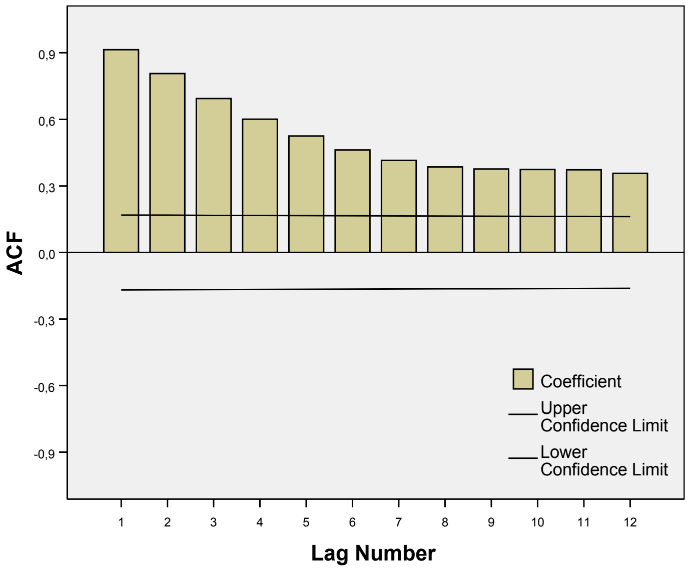
Seasonal series

If a time series contains seasonal variation, then the correlogram will also exhibit oscillation at the same frequency. For example if y_t follows a sinusoidal patter, then so does r_k.

Autocorrelation function of farmer price of oilseed rape in the Czech Republic in analysed period is shown in Graph 3. From the values of autocorrelation coefficients it is possible to see that values of farmer price of oilseed rape are highly correlated over the time. This time series is a prime example of autocorrelation function of nonstationary time series. The first autocorrelation coefficient is high, about 0.9. The rest of the autocorrelation coefficients descend for longer lags, however their diminution almost stop and don't tend to be zero.

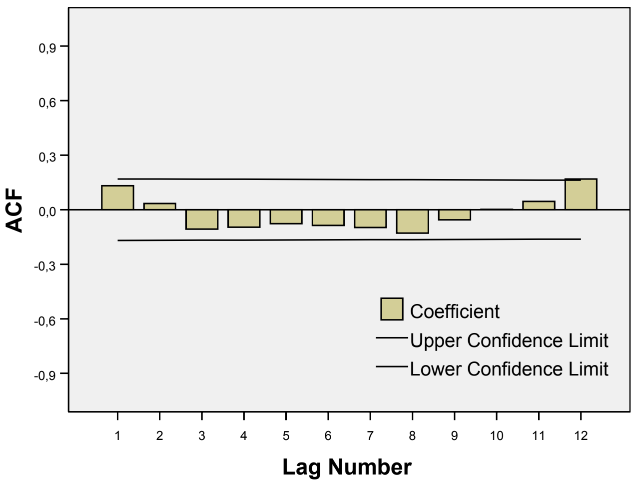
If a trend is not of the prime interest, then it should be removed from a time series before calculating r_k and changed it to stationary. But if a trend itself is of the prime interest, then it should be modelled, rather than removed. The time series in the example needs to cover each aspect of its development then the trend should retain.

Graph 3: Autocorrelation function



Source: own calculation

Graph 4: Autocorrelation function - first difference



Source: own calculation

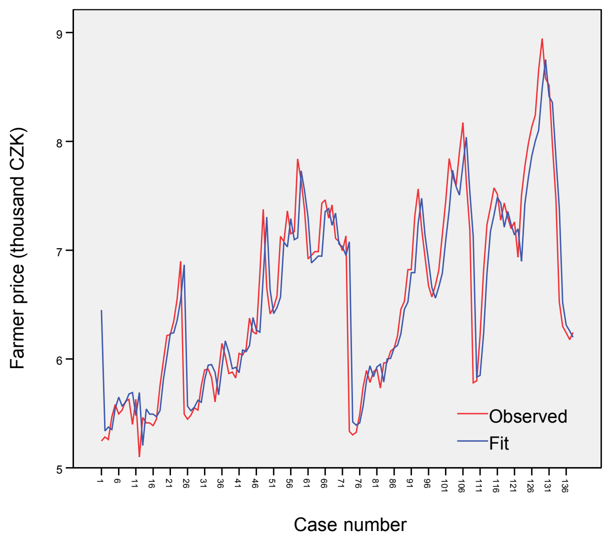
Autocorrelation function of first difference of farmer price of oilseed rape in the Czech republic is shown in Graph 4. The autocorrelation coefficients show that change in farmer price this month is essentially uncorrelated with the change in previous month. The values of all coefficients are near zero. The graph shows the stationary time series, however the autocorrelation coefficient for last lag used (*k=12)*, could be smaller. The autocorrelation functions, depicted in Graph 3 and Graph 4, confirm general assumption that an original time series is nonstationary, while a time series modified by first difference is stationary. But the selection and using of time series, for an analysis, must be well thought over, as it was already mentioned.

Examination of autoregressive model

First-order autoregressive model is a helpful instrument for detection if a time series is stationary or not. Estimated coefficients of function are the basic elements for it.

Graph 5 shows the shape of first-order autoregressive model of farmer price of oilseed rape in the Czech Republic. From the graph it is evident that fitted values are very similar to the observed. But it is not possible to use this model for the time series description or forecast due to conditions of using ARMA and ARIMA models, as a whole. In this case, the AR(1) model is primarily helpful as a tool for confirmation of the time series stationarity or nonstationarity.

Graph 5: AR(1) model



Source: own calculation

In Table 1, estimated parameters of autoregressive model of farmer price of oilseed rape in the Czech Republic, with their standard errors and t-values, are shown. The most important value in the table is the estimate of coefficient ϕ. As it was already mentioned, *Y* is stationary if $|\phi| \prec 1$ and is nonstationary if $\phi = 1$. On the basis of the estimation in the example, $\phi = 0.9225$, one could deducted that the time series of farmer price of oilseed rape is stationary. But making conclusions is not so easy. The value of ϕ is almost 1, which shows rather to nonstationary time series. It is necessary to be careful with values of ϕ near 1. These values usually indicate a nonstationary time series. The value of ϕ in the AR(1) model is closely related to the behaviour of the autocorrelation function and to the concept of nonstationarity.[3]

Table 1: Estimated parameters of AR(1) model of farmer price of oilseed rape in the Czech Republic

AR(1)	Coefficient	Standard error	t-value
α	6.4505	0.3512	18.365
ϕ	0.9225	0.0318	28.9595

Source: own calculation

CONCLUSIONS

The calculation and examination of farmer price of oilseed rape in the Czech Republic show that all ways used for stationarity detection may give the same result. All examinations rejected null hypothesis H_0 that the time series of farmer price of oilseed rape in the Czech Republic is stationary. The examinations also show possibility and pros and cons of using first difference of a time series. It is necessary to find optimal tools and model for next analysis and prediction of future development of farmer price of oilseed rape.

For next analysis of the time series it is necessary to consider the advantages and disadvantages of using time series and its first difference as well as using stationary and nonstationary model. The paper shows that it is possible to use different ways to detect if a time series is stationary or not. However, there are also another omitted possibilities. Moreover, every case, every example is specific and the analysis depends on what is of the researcher's prime interest. The prediction quality depends on the selection of suitable model.

References:

[1] BOX, G.E.P. – JENKINS, G.M. *Time Series Analysis: Forecasting and Control*. Revised Edition, 575 s. Holden Day, San Francisco (USA) 1976. ISBN 0-8162-1104-3.

[2] CHATFIELD, C. *The Analysis of Time Series: an Introduction*. Sixth Edition, 333 s. Chapman&Hall/CRC, Boca Raton (USA) 2004. ISBN 1-58488-317-0.

[3] KOOP, G. *Analysis of Economic Data*. 226 s. Wiley, Chichester (UK) 2000. ISBN 0-471-99915-6.

[4] MADDALA, G.S. *Introduction to Econometrics*. Third Edition, 636 s. Wiley, Chichester (UK) 2001. ISBN 0-471-49728-2.

[5] STUDENMUND, A.H. *Using Econometrics: a Practical Guide*. Fourth Edition, 639 s. Addison Wesley Longman, Boston (USA) 2001. ISBN 0-321-06481-X.

[6] *Situační a výhledová zpráva – Olejniny*. MZe, Praha 2004. ISBN 80-7084-258-X.

[7] http://www.mze.cz

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