FOREIGN TRADE CZECH AND THE SLOVAK REPUBLIC - TIME SERIES ANALYSIS

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Abstract

In our paper, we will analyze the time series of export from Czech to Slovak Republics. The paper is focused on applications; its goal is to identify models suitable for the time series of Czech Republic exports and utilization of such models for predictions. Data of the Czech Republic foreign trade are published monthly by the Czech Statistical Office. However, the published data is not up to date – at the first stage, only estimates are published, which are subsequently made more accurate (in several steps). Moreover, even these estimates are published with a time delay of two to three months. On the other hand, values of certain series (such as the exchange rates of CZK with respect to other currencies) are published more or less immediately and are exact. Hence, if we are able to identify a model describing the dependence between the above-mentioned time series, such a model can, at least, considerably speed up construction of preliminary estimates, thus significantly reducing the waiting time for one of the most important and most closely watched macroeconomic time series in the Czech Republic.

Key words: time series analysis, transfer function model, export, exchange rate

JEL Code: C53, F47

1 Introduction

This paper deals with analysis of the monthly time series of exports from the Czech Republic to Slovakia and predictions in this time series with the aid of the SARIMA Model and the Transfer Function Model. The authors' original intention was to analyze both exports and imports, and the relevant analyses have in fact been carried out; however, we will restrict ourselves to exports in this paper. The reason is the large scope of such analyses and the size of the paper, which would go beyond the restrictions specified by the organizers of this Conference. The goal of our work is to find a model suitable for the exports time series and make use of this model for predictions. We will show dependence between the exports time series and the CZKEUR exchange rate. This dependence is then used for building the Transfer Function Model. The Czech Republic foreign trade data is published by the Czech Statistical Office (www.czso.cz) at several stages. At the first stage it is just in the form of estimates, which are subsequently made more accurate. For example, at the time this paper is being written (April 2015), first estimates for the Czech Republic foreign trade are known up to February 2015. On the other hand, the CZK exchange rate values (namely, their monthly averages) with respect to other currencies are exact and published by the Czech National Bank (www.cnb.cz) immediately after the respective month's end. The analysis of foreign trade and exchange rate is engaged in Heczková (2014), in Arize (2000) or in Brčák (2013).

In this paper, the dependence of the exports time series is described with the aid of a suitable model, and then it is used for predictions. We have used different models: ARIMA, SARIMA – cf. Anderson (1976); Box, Jenkins, Reinsel (1994); Granger, Newbold (1986); Wei (1990), and Transfer Function Models (TFM) – cf. Pankratz (1991); Liu (1991). As a result we have obtained a suitable model and predicted the time series for exports to Slovakia for several months ahead. The sources of our data are the Czech Statistical Office (monthly exports time series in millions CZK, fixed prices) and the Czech National Bank (exchange rate time series – monthly averages). These series were observed in the following periods: the exports from January 1999 to February 2015 (194 observations), and the CZK/EUR exchange rates from January 1999 to April 2015 (196 observations). The analysis was carried out in SCA and eViews software.

2 Methodology

The general form of stochastic models for time series is used in this paper:

$$\phi_p(B)\Phi_P(B^L)(1-B)^d(1-B)^D Z_t = \theta_q(B)\Theta_Q(B^L)\varepsilon_t \qquad (1)$$

where the symbols used have their standard meanings usually used in the literature – e.g., Box, Jenkins, Reinsel 1994.

Identification of the model was mainly based on the values of autocorrelation and partial autocorrelation functions (ACF, PACF), as well as those of extended and inverse autocorrelation functions (EACF, IACF) in addition to other methods, such as SCAN and Corner Table. The output is very extensive; hence just the most important parts are cited here, together with parameter estimates. The analyzed time series are non-stationary and had to be transformed to achieve stationarity (using current and seasonal differentiating). The stationarity was verified with the aid of several methods – test of unit roots, homoscedasticity tests, and Dickey-Fuller tests.

We calculated the values of the cross-correlation function (CCF) in order to prove linear dependence between the analyzed (already transformed, and therefore stationary) time series. The CCF values confirmed the mutual linear dependence between the transformed time series of the Czech Republic exports, and the transformed exchange rate time series. After that we applied the Transfer Function Model in its general form:

$$Y_t = c + v_0 X_t + v_1 X_{t-1} + v_2 X_{t-2} + \ldots + v_K X_{t-K} + \frac{1}{(1-\phi_1(B))(1-\Phi_1(B^L))}\varepsilon_t \qquad (2)$$

where Y_t is the output series of the exports (after the relevant transformations), and X_t is the input series of the CZK/EUR exchange rates (again after the relevant transformations); the last term is the noise series, usually denoted by N_t in the literature. The parameters were estimated with the aid of the LTF method – cf. Pankratz (1991) and Liu (1991). The resulting model was used for predictions.

3 Analysis of the Time Series for the Czech Republic Exports

3.1 SARIMA Models

First of all we found a suitable SARIMA model for the time series of the exports. After a thorough analysis and study of ACF, PACF, EACF, IACF, test of unit roots, homoscedasticity tests, and Dickey-Fuller tests – cf. Pankratz (1991), we identified this model in the following form (cf. the output from SCA):

$$(1 - 0.3131B^3 - 0.257B^4 + 0.2422B^{10})Y_t = (1 - 0.3074B)(1 - 0.6302^{12})\varepsilon_t$$

where $Y_t = (1-B)(1-B^{12})\,Export_t$, ε_t is the white noise, and B is the classical backward-shift operator ($B^k\, Y_t = Y_{t-k}$). This model successfully passed all stages of verification and was shown to be fully adequate. This fact is also seen from the value of the index of determination, amounting to 0.982.

We can therefore observe that the value of the time series of the exports (after the current and seasonal differentiating) at time t depends on its own past values (with the values of the time shift at 3, 4, and 10), and on the random component's value with the current and seasonal parameters.

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SUMMARY FOR UNIVARIATE TIME SERIES MODEL --  VYVOZ
-----------------------------------------------------------------------
VARIABLE   TYPE OF    ORIGINAL     DIFFERENCING
          VARIABLE   OR CENTERED
                                        1      12
EXPORTN    RANDOM     ORIGINAL     (1-B)  (1-B  )
-----------------------------------------------------------------------
PARAMETER   VARIABLE  NUM./  FACTOR  ORDER   CONS-     VALUE      STD     T
   LABEL       NAME    DENOM.                TRAINT               ERROR  VALUE

  1    TH    EXPORTN    MA       1      1     NONE      .3074     .0737   4.17
  2   TH12   EXPORTN    MA       2     12     NONE      .6302     .0621  10.15
  3   PHI3   EXPORTN    AR       1      3     NONE      .3131     .0691   4.53
  4   PHI4   EXPORTN    AR       1      4     NONE     -.2570     .0675  -3.81
  5  PHI10   EXPORTN    AR       1     10     NONE     -.2422     .0696  -3.48

EFFECTIVE NUMBER OF OBSERVATIONS . .           171
R-SQUARE . . . . . . . . . . . . . .           .982
RESIDUAL STANDARD ERROR. . . . . . .   .363630E+05
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In a similar way we found a model suitable for the time series of the CZK/EUR exchange rates (the *Euro* series). This model is:

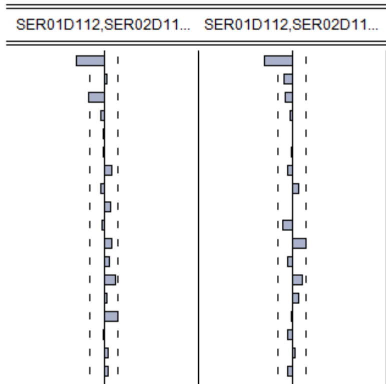
$$(1-B)(1-B^{12})X_t = (1+0,1901B)(1-0,6394B^{12})\varepsilon_t\,,$$

where $X_t = Euro_t$. The index of determination equals 0.985. The model shows that we again applied current and seasonal differentiating to achieve stationarity of the underlying series. This model also successfully passed all stages of verification and was shown to be fully adequate.

3.1 TFM Model

The following output (from the eViews software) shows the values of the cross-correlation function between (now already stationary) time series $(1-B)(1-B^{12})Y_t$ and $(1-B)(1-B^{12})X_t$. The cross-correlation function (CCF) expresses not only the intensity, but also the direction of the linear dependence between the differentiated series. This dependence will be used in building a dynamic linear model (i.e., Transfer Function Model). The eViews output clearly indicates the significant value of CCF (95% confidence interval) at time $t = 0$, equal to -0.3007. No dependence was proven at any other time values. In other words, we have identified a significant linear dependence between the transformed time series of the exports at time *t*, and the transformed time series for CZK/EUR exchange rates at time *t*. Now we will build the Transfer Function Model.

Fig. 1: Cross-correlation function



i	lag	lead
0	-0.3007	-0.3007
1	0.0303	-0.0911
2	-0.1666	-0.0781
3	-0.0300	-0.0207
4	-0.0010	0.0139
5	-0.0030	-0.0066
6	0.0861	-0.0432
7	-0.0267	0.0738
8	0.0773	0.0040
9	-0.0220	-0.1025
10	0.0852	0.1629
11	0.0585	-0.0515
12	0.1265	0.1172
13	0.0319	0.0708
14	0.1509	-0.0066
15	-0.0014	-0.0499
16	0.0413	0.0394
17	0.0418	-0.0495

Source: Output from Eviews software

After a thorough analysis of the data we have identified a suitable model as

$$(1-0.3065B^3+0.24B^4+0.2076B^{10})Y_t=-27346.9024\,X_t+(1-0.4048B)(1-0.6377B^{12})\varepsilon_t$$

where

$$Y_t=(1-B)(1-B^{12})\,Export_t \quad \text{and} \quad X_t=(1-B)(1-B^{12})\,Euro_t\,.$$

The model is also seen from the SCA output, and can, in an equivalent form, be re-written as

$$\begin{aligned}&Y_t=0.3065Y_{t-3}-0.24Y_{t-4}-0.2076Y_{t-10}=\\&=-27346.9024\,X_t+\varepsilon_t-0.4048\varepsilon_{t-1}-0.6377\varepsilon_{t-12}+0.2581\varepsilon_{t-13}\,.\end{aligned}$$

This means that the *Exports* time series (after the current and seasonal differentiating) depends on its own past values at times $t-3$, $t-4$ and $t-10$, on the value of the input time series of the CZK/EUR exchange rates (again after the current and seasonal differentiating) at time t, and the past values of the random component at times t, $t-1$, $t-12$ and $t-13$. This model successfully passed all stages of verification and was found to be fully adequate. The verification in particular included analysis of the series of the *Euro* input series' residuals with respect to the TFM models; zero linear dependence was identified for these residuals (which is in line with the theory). Quality of this model is also seen from the value of the index of determination, which equals 0.985.

Let us now have a look at the predictions, because of which both of the above-mentioned models were mainly derived. As of the time when this paper is being written, the values of the times series of the exports have been known up to February 2015, but the values of the time series of the exchange rates until April 2015. We are thus able to make use of the time shift between the series and put into the Transfer Function Model not the predicted values (as is usual) but the values that were actually observed in March and April. Of course, we expected that this step would improve accuracy of our predictions. We built our predictions in two ways, on the basis of both the SARIMA model and the TFM model, using the dependence between the series in question.

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SUMMARY FOR UNIVARIATE TIME SERIES MODEL --  VYVOZ2
-----------------------------------------------------------------------
VARIABLE   TYPE OF    ORIGINAL     DIFFERENCING
          VARIABLE   OR CENTERED
                                       1      12
EXPORTN    RANDOM     ORIGINAL     (1-B  ) (1-B  )
                                       1      12
  EURN     RANDOM     ORIGINAL     (1-B  ) (1-B  )
-----------------------------------------------------------------------
PARAMETER   VARIABLE  NUM./  FACTOR  ORDER   CONS-     VALUE      STD     T
   LABEL       NAME    DENOM.                TRAINT               ERROR  VALUE

  1    V0      EURN    NUM.      1      0     NONE-27346.9024 4993.1444  -5.48
  2   TH1    EXPORTN    MA       1      1     NONE       .4048     .0719   5.63
  3   TH12   EXPORTN    MA       2     12     NONE       .6377     .0623  10.24
  4   PHI3   EXPORTN    AR       1      3     NONE       .3065     .0638   4.80
  5   PHI4   EXPORTN    AR       1      4     NONE     -.2400     .0626  -3.84
  6  PHI10   EXPORTN    AR       1     10     NONE     -.2076     .0648  -3.20

EFFECTIVE NUMBER OF OBSERVATIONS . .           171
R-SQUARE . . . . . . . . . . . . . .          .985
RESIDUAL STANDARD ERROR. . . . . . .   .336685E+05
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Tab. 1: Predictions of exports to Slovakia

	Predictions	
Month	SARIMA	TFM
March	1,074,900 (39623)	1,067,900 (36455)
April	1,014,600 (48856)	1,011,100 (44694)
May	1,053,900 (57796)	1,050,400 (51635)

Source: Own calculation

The values shown in this Table are predictions three months ahead, with the standard deviation values in parentheses. In all three months the TFM predictions come out smaller. The smaller values of TFM standard deviation are in favor of TFM – they mean that the TFM predictions are more accurate. Hence we prefer the TFM model.

Conclusion

The goal of this paper is to find a model for the time series of the exports from the Czech Republic to Slovakia to be used for short-term predictions. We have successfully built a suitable model and made the predictions. During the analysis we have proven mutual linear dependence between the time series of the exports and the time series of the CZK/EUR exchange rates.

Within our analysis, suitable SARIMA models were built for all the time series under consideration, and for the exports series a TFM model was also built, in which the time series of the CZK/EUR exchange rates was used as the input series. Usually, predicted values of the input series are used when predicting within the TFM model; that is, predictions in the output series are calculated on the basis of such predicted values of the input one. However, thanks to the linear dependence between our series, which was proven within our analysis, and with regard to the time shift in publication of the time series values (i.e., the series of the exchange rates is published earlier than that of the foreign trade), we can use the actual values of the input series (in our case, the series of the exchange rates) instead of their predictions. This necessarily implies better quality of the predictions in the output series (in our case, the series of the exports). We can make use of these facts when making short-term predictions of the export in the Czech Republic for a relatively short period of two to three months. Nevertheless, let us note that – the more so in our economically turbulent times – predictions in economic times series are reasonable just for several periods ahead because external influences on evolution of such time series change very quickly and make impossible good-quality long-term predictions. Moreover we should realize that the foreign-trade data published on the Czech Statistical Office's website is just estimated and is made more accurate in several (two to three) subsequent steps. On the other hand, the models presented enable us put forth quite good estimates for the evolution of one of the most-closely watched economic time series, which substantially affects the creation of GDP.

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