Time scale regression analysis of oil and interest rate on the exchange rate: a case study for the Czech Republic

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Abstract

This paper studies the impact of the Pribor and Oil return rate on the CZK/USD exchange rate return in the different time scale. The time scales were got from the Maximum Overlap Discrete Wavelet Transformation. Thanks to this method we were able to analyse the data generation process in different time horizons. We applied the regression on the wavelet series coefficients which represents the different time scale. The most important results were found for the series from the low-pass filter, which represents the slow movement in the time series. Both regression parameters were significant with a negative sign on this time scale, in comparison with non-transformed data when Pribor did not have a significant impact on CZK/EUR. This conclusion confirms the usefulness of the wavelet transformation for the macroeconomics analysis.

Keywords: *wavelet, oil price, time scale regression, multiresolution analysis.*
JEL Classification:*C22, C46, C51*

Introduction

The main object of Czech national bank is price stability. For this purpose, CNB uses inflation targeting. One of the most important factors in price determination and macroeconomics condition is oil price. Because the settlement currency in theoil market is US dollar, the main channel of oil shock transmission is through the Exchange rates. So we can decompose the oil price in Czech crown into the two component:

$$p_{CZK} = e_{USD} + p_{USD} \qquad (1)$$

wherep_{czk} is the logarithmic oil price in foreign currency, e_{USD} is logarithmic foreign currency per unit of USD and p_{USD} is the logarithmic price of oil in USD. Following Krugman (1983) the rice in the oil price has negative impact on the balance of payment for oil importing countries such a Czech republic. Zhou in 1995 found that oil price fluctuation is one of the most important shock in exchange rate movement. The similar conclusion bring Camarero and Tamarit (2002) Huang and Guo (2007) and Lizardo and Mollick (2010).

The correlation between exchange rate returns and oil return analysed Cifarelli and Paladino (2010) and Reboredo (2012). Cifarelli and Paladino (2010) utilized multivariate generalized autoregressive conditional heteroskedasticity model when they found along-term negative correlation between these time series. On the other hand,Reboredo (2012) utilize copula function and found aweak correlation with some substantially rises. The possible puzzle in these conclusions could rise from the strong assumption about homogenous market participants. On the markets operate different agents with different utility functions. This heterogeneity is connected with different investment time horizons. For example,Reboredo and Rivera-Castro (2013) analyzed thecorrelation between oil return and seven currency returns through wavelet correlation. They found that for thepre-crisis period doesn´t exist significant correlation on any scales. However,

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after global crisis period, they found negative correlation value for all scales. The similar pattern found Fryd (2017) when utilize wavelet coherency methodology on the Czech crown and oil return series. So it´s obvious that it is crucial to distinguished the investment horizons. However, the question is if it is sufficient to estimateonlythecorrelation between exchange rate returns and oil return. For example, MacDonald (1998) divide the real exchange rate determinants into the two groups. One of them is created by real interest rate and the second one contains fundamental factors when one of them is oil price. From this purpose, we will analyze the impact of interest rate return (Pribor) and oil return (Oil) on the CZE/USD return on the different time scales. Ramsey (2011) used the same methodology for the estimation of Phillips curve in the US for different time scales.

In this article, we utilize the wavelet transformation for analyzing the following data generation process:

$$\Delta CZK/EUR_t = \alpha_0 + \alpha_1 \Delta Pribor_t + \alpha_2 \Delta WTI_t + \epsilon_t \qquad (2)$$

We show that the significance of $\alpha_{0,1,2}$is changing with time scales. Following Ramsey (2011) we use only basic equation with contemporaneous variables, in order tofocus on the usefulness of the wavelet transformation for the analysis of economic relationships.

The paper is organized as follows. We begin with methodology description presenting wavelet analysis. A data description and an empirical analysis of oil return, CZK/USD dependency and Czech money market rate Pribor follow. The last part is devoted to the discussion and conclusion.

Methodology

The principle of wavelet transformation is in the filtration of the original time series with awavelet function. The wavelet transform uses a basis function that is dilated or compressed and shifted along the time series. The transformation´s outputprovides a time-frequency representation where the informationisassociatedwithspecifictime scales and locations in time. There are two basic wavelet functions, mother wavelet ψ and father wavelet ϕ.The mother wavelet is defined as:

$$\psi_{j,s} = 2^{-\frac{j}{2}} \psi\left(\frac{t - 2^j k}{2^j}\right) \qquad (3)$$

Moreover, father wavelet is defined as:

$$\phi_{J,k} = 2^{-\frac{J}{2}} \phi\left(\frac{t - 2^J k}{2^J}\right) \qquad (4)$$

Where$j = 1, \dots, J$is the scaling parameter and k is the translation (or shift) parameter.

The coefficients from wavelet transformation are obtained by projecting the wavelet $\psi(.)\phi(.)$ onto time series *x(t)*. We distinguished three wavelet transformation, the Discrete Wavelet Transformation, Continuous Wavelet Transformation and Maximum Overlap Discrete Wavelet Transform (MODWT). Following Ramsey (2011) we use MODWT which allow us to compute the wavelet series coefficients at all scales given by:

$$W_{j,k} \equiv \sum_{k}^{N} \psi_{j,k} x(t) \tag{5}$$

$$V_{J,k} \equiv \sum_{k}^{N} \phi_{J,k} x(t) \tag{6}$$

Where $W_{j,k}$ represent the wavelet coefficient at level *j*. and $V_{J,k}$ represent scaling coefficient at level *J*. Sometimes we call the mother wavelet as high-pass filter because capture the high movement in the time series.

For example,*j=1*is connected with the passband$\frac{1}{4} < f < \frac{1}{2}$, for *j=2* $\frac{1}{8} < f < \frac{1}{4}$ etc. On the other hand the father wavelet is low-pass filter and captures the slow movement in the time series such a long trend. The passband for father wavelet is $0 < f < \frac{1}{2^{J+1}}$.

Thanks to the wavelet transformation we can decompose the original time series*x(t)* to the component which captures the different time scales:

$$x(t) \approx V_J + W_J + W_{J-1} + \cdots + W_j + \cdots + W_1 \tag{7}$$

We use this multiresolution decomposition and separate the information from each time series at each scale. Then we apply the following regressions:

$$\Delta CZK/EUR[W_j]_t = \beta_{j0} + \beta_{j1} \Delta Pribor[W_j]_t + \beta_{j2} \Delta WTI[W_j]_t + \epsilon_t \tag{8}$$

$$\Delta CZK/EUR[V_J]_t = \alpha_{J0} + \alpha_{J1} \Delta Pribor[V_J]_t + \alpha_{J2} \Delta WTI[V_J]_t + \epsilon_t \tag{9}$$

Data

For our analysis, we use WTI daily price, CZK/USD daily price and Pribor rate. The sample period spans from 06/01/1993 until 30/09/2009. From the reason of data nonstationary we computed crude oil price exchange rate returns and Pribor (Prague InterBank Offered Rate) change on a continuous compounding basis as the difference between the log of the current price and that of the one-period lagged price. The return series are stationary processes. In the following analysis, the variables will be in the log-difference.Following Ramsey (2011) we use theDaubechies least asymmetric (LA8) wavelet of length**L = 8** (Daubechies, 1992) with *J=4*.

Empirical part

In the first, we estimate the equation (2). The results are in the table (1). From the reason of significant autocorrelation, we used HAC estimator for standard errors. We can see that Pribor variable doesn´t have asignificant influence on the exchange rate. On the other hand, the WTI return has asignificant impact on the Exchange rate return. This estimation will bethe benchmark for the next outputs.

The next estimation is from the equation (8) where j=1. The W_1represents the frequency range bandpass1/4<f<1/2. This range corresponds to the fastest movement in the time series.

Again, we used HAC with results in Table (2). For this model, we cannot see the statistically significant impact on both variables. The p-value for a robust version of Wald test is 0.41.

Table 1: Results from estimation model from equation (2)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-6.46E-05	3.44E-05	-1.874719	0.0609
PRIBOR	0.002321	0.004518	0.513661	0.6075
WTI	-0.015010	0.005677	-2.643798	0.0082

R-squared	0.004999	Mean dependent var	-6.95E-05
Adjusted R-squared	0.004306	S.D. dependent var	0.002242
S.E. of regression	0.002237	Akaike info criterion	-9.366222
Sum squared resid	0.014368	Schwarz criterion	-9.359997
Log likelihood	13462.26	Hannan-Quinn criter.	-9.363978
F-statistic	7.212237	Durbin-Watson stat	2.324270
Prob(F-statistic)	0.000751	Wald F-statistic	3.694493
Prob(Wald F-statistic)	0.024978		

Table 2: Results from estimation model from equation 8 for scale j=1

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.47E-21	7.82E-06	-1.88E-16	1.0000
PRIBOR	-0.003726	0.007669	-0.485830	0.6271
WTI	-0.010315	0.008277	-1.246204	0.2128

R-squared	0.002208	Mean dependent var	4.38E-21
Adjusted R-squared	0.001513	S.D. dependent var	0.001628
S.E. of regression	0.001626	Akaike info criterion	-10.00382
Sum squared resid	0.007595	Schwarz criterion	-9.997593
Log likelihood	14378.49	Hannan-Quinn criter.	-10.00157
F-statistic	3.176414	Durbin-Watson stat	3.430482
Prob(F-statistic)	0.041882	Wald F-statistic	0.881667
Prob(Wald F-statistic)	0.414204		

The next model represents the frequency bandpass$\frac{1}{8} < f < \frac{1}{4}$. The estimation output with HAC standart errors is in the table (3). We can see similar conclusions as in the table (1). WTI return has significant impact on the exchange rate return. The $\beta_{2,2}$ from equation (8) is significant for $\alpha = 0.05$.

Table 3: Results from estimation model from equation 8 for scale j=2

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.61E-20	7.70E-06	-2.10E-15	1.0000
PRIBOR	0.014040	0.015192	0.924223	0.3554
WTI	-0.019441	0.007816	-2.487336	0.0129

R-squared	0.011411	Mean dependent var	-3.26E-20
Adjusted R-squared	0.010722	S.D. dependent var	0.000867
S.E. of regression	0.000862	Akaike info criterion	-11.27334
Sum squared resid	0.002134	Schwarz criterion	-11.26711
Log likelihood	16202.79	Hannan-Quinn criter.	-11.27109
F-statistic	16.56933	Durbin-Watson stat	1.295281
Prob(F-statistic)	0.000000	Wald F-statistic	3.513159
Prob(Wald F-statistic)	0.029931		

For frequency bandpass $\frac{1}{16} < f < \frac{1}{8}$ or equivalently *j=3* we have estimation output in table (4). For this time scale we can see significant parameter $\beta_{3,1}$ for $\alpha = 0.01$. On the other hand the WTI return does not have significant impact on the exchange rate return.

Table 4: Results from estimation model from equation 8 for scale j=3

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2.57E-21	8.56E-06	3.01E-16	1.0000
PRIBOR	0.028873	0.010916	2.644997	0.0082
WTI	-0.007419	0.007798	-0.951402	0.3415

R-squared	0.019080	Mean dependent var	1.89E-21
Adjusted R-squared	0.018397	S.D. dependent var	0.000529
S.E. of regression	0.000524	Akaike info criterion	-12.27008
Sum squared resid	0.000788	Schwarz criterion	-12.26386
Log likelihood	17635.10	Hannan-Quinn criter.	-12.26784
F-statistic	27.92212	Durbin-Watson stat	0.355361
Prob(F-statistic)	0.000000	Wald F-statistic	4.062918
Prob(Wald F-statistic)	0.017298		

The last coefficient series from the mother wavelet filter represents the bandpass $\frac{1}{32} < f < \frac{1}{16}$. The estimation output is displayed in table (5). In this situation we can not reject the null hypothesis for t-test. The p-value from robust Wald test is 0.098. This value is too close to the 0.1 and so we do not reject the joint hypothesis.

Table 5: Results from estimation model from equation 8 for scale j=4

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2.85E-21	1.47E-05	1.94E-16	1.0000
PRIBOR	-0.010966	0.010202	-1.074911	0.2825
WTI	-0.011528	0.007038	-1.637954	0.1015

R-squared	0.007399	Mean dependent var	5.70E-21
Adjusted R-squared	0.006708	S.D. dependent var	0.000364
S.E. of regression	0.000363	Akaike info criterion	-13.00539
Sum squared resid	0.000378	Schwarz criterion	-12.99916
Log likelihood	18691.74	Hannan-Quinn criter.	-13.00314
F-statistic	10.70083	Durbin-Watson stat	0.094478
Prob(F-statistic)	0.000023	Wald F-statistic	2.321921
Prob(Wald F-statistic)	0.098269		

The last transformation with the father filter represents the long-term behaviour of the time series for bandpass $0 < f < \frac{1}{32}$. The estimation results are shown in the table (6). This result is very interesting because we can see significant $\alpha_{4,1}$ from the equation (9) for $\alpha = 0.05$ and $\alpha_{4,2}$ for $\alpha = 0.01$.

Table 6: Results from estimation model from equation 9 for scale J=4

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-6.15E-05	2.18E-05	-2.824740	0.0048
PRIBOR	-0.021582	0.010894	-1.981050	0.0477
WTI	-0.039664	0.011805	-3.360004	0.0008

R-squared	0.056811	Mean dependent var	-6.95E-05
Adjusted R-squared	0.056154	S.D. dependent var	0.000411
S.E. of regression	0.000399	Akaike info criterion	-12.81314
Sum squared resid	0.000458	Schwarz criterion	-12.80691
Log likelihood	18415.48	Hannan-Quinn criter.	-12.81089
F-statistic	86.46463	Durbin-Watson stat	0.012560
Prob(F-statistic)	0.000000	Wald F-statistic	6.891651
Prob(Wald F-statistic)	0.001033		

Conclusion

In this article, we analysed the dependency of the CZK/USD exchange rate on the Pribor and oil price respectively returns. We used wavelet methodology for the time series decomposition to the different time scale. Concretely the Daubechies least asymmetric (LA8) wavelet of length**L = 8** was used with multi-resolution level J=4. We found a significant impact of WTI on the CZK/USD for bandpass $\frac{1}{8} < f < \frac{1}{4}$ and $0 < f < \frac{1}{32}$. The Pribor has a significant impact on the exchange rate for bandpass $\frac{1}{16} < f < \frac{1}{8}$ and $0 < f < \frac{1}{32}$. The both variables were significant only for bandpass $0 < f < \frac{1}{32}$ with negative signs. This conclusion is very interesting because it suggests that the Pribor and Oil influence the CZK/USD in the longer time horizon. If we compare this result with classical estimation for non-transformed data, we get a better view on the data generation process. This result could be important for monetary policy.

Acknowledgements

The work on this paper was supported by the grant IGS F4/73/2016 of the University of Economics, Prague.

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