https://doi.org/ 10.7251/EMC2101176N
UDK: 338.45(497.5):004.651.5.021

Datum prijema rada: 26. avgust 2020.
Submission Date: August 26, 2020
Datum prihvatanja rada: 14. jun 2021.
Acceptance Date: June 14, 2021

Časopis za ekonomiju i tržišne komunikacije
Economy and Market Communication Review

Godina/Vol. **XI** • Br./No. **I**
str./pp. 176-188

PREGLEDNI NAUČNI RAD / OVERVIEW SCIENTIFIC PAPER

CROBEX AND INDUSTRY PERFORMANCE IN THE CASE OF CROATIA: EVIDENCE FROM WAVELET COHERENCE

Ivan Novak | Assistant professor; University of Zagreb, Faculty of Economics and Business, Department of International Economics, Zagreb, Croatia; inovak@efzg.hr

Abstract: *Determinants of the stock market index movement have always been of interest to scholars and practitioners. Various time series techniques have already been applied to determine the relationship between the stock market prices and macroeconomic variables. Many of these techniques are unable to reveal the frequency and time dependent relationship often leading to incorrect specification. Furthermore, results may differ depending on the level of the economic development. This paper is using the Wavelet coherence as a rather novel approach compensating for some limitations of the conventional approach bringing further insight into the stock market price movement of the Croatian capital market. Wavelet transform enables observation of the connection between the CROBEX and the industry performance across time and frequency domain. This relationship is tested using monthly data for CROBEX and industrial production index volume in the period from January 1998 to September 2019. Significant positive relationship was confirmed in the period from 1998 to 2015 identifying CROBEX as the leading variable.*

Keywords: *correlation; wavelet coherence; stock market index; industry performance; Croatia*

JEL Classification: *E32, G14, F41.*

INTRODUCTION

Croatia is one of the post-transition economies that recently joined the European Union. In the last few decades Croatia has experienced transformation of the economy emphasizing promotion of the free market structures. This transformation was accompanied by privatization and development of the financial system. With rising efficiency of the financial intermediaries the stock market has experienced significant growth and relationship between the stock market and the fundamental economic variables has become an important issue for scholars and practitioners.

Rad je izložen na X međunarodnoj naučnoj konferenciji EDASOL 2020 / *The paper was presented at the X International Scientific Conference EDASOL 2020*

According to arbitrage pricing theory (APT) stock market prices movement could be explained by various macroeconomic variables (Ross, 1976). Some of the main macroeconomic indicators are industry performance, foreign direct investment (FDI), trade balance, exchange rate, interest rate and consumer prices (CPI) (Chang, Meo, Syed, & Abro, 2019). Nevertheless the relationship between the market index and the macroeconomic indicators is not necessarily straightforward. Even though stock markets are dependent on the microeconomics factors, general economic perspective and expectations (Durovic & Mutibaric, 2011) stock markets sometimes react without "clearly identifiable economic factors" (Peiro, 2016). Consequently to publicly available information capital markets may react even more quickly than macroeconomic variables (Benaković & Posedel, 2010). Therefore financial variables may be used to predict the level of the economic activity (Kim & In, 2003). Furthermore it is important to emphasize that Croatia is a small and open economy where the market sentiment may also be significantly influenced by the global trends therefore sentiment preceding the change of the economic activity. Nevertheless consequently to examining the connection between the industry performance and the capital markets depending on the methodology, data sample, level of the economic development, depth of the financial market and the prevailing monetary policy there are many interpretation of their causative relationship (Tomić & Sesar, 2015). Furthermore, previous studies deal primarily with developed capital markets and this relationship may not share the same properties in emerging countries. Therefore using a novel Wavelet coherence approach this paper aims to bring further insight regarding this relationship of the stock market prices and the industrial performance in Croatia.

Remaining of the paper is organized in five parts. Second part of the paper offers past and recent development of literature. Third part of the paper describes selected data and applied methods. Fourth part of the paper shows results and offers short discussion. Finally, the last part of the paper summarizes results and considers further recommendations for investors and policy makers.

LITERATURE OVERVIEW

In the case of the United States using correlation and scatter plots in the period from 1995 to 2014 industrial production index, GDP, unemployment rate and the long-term interest rates were found to have a significant relationship with the stock market (S&P500, Dow Jones), while the CPI was not significant (Jareño & Negrut, 2016).

Spectral analysis and wavelet coherence confirmed the relationship between financial variables and industrial production in the United States in the period from 1959 to 2001. According to the spectral analysis there is a long-term connection while the lead-lag relationship was conditioned by the business cycle. Wavelet coherence analysis also confirmed the co-movement of the financial variables and the industrial production whose relationship is time and frequency dependent (Kim & In, 2003).

Maximum overlap discrete wavelet transform (MODWT) was used to investigate the relationship between industry performance and the US DJIA stock price data. In the period from 1961 to 2006 results indicated stock market returns leading the level of economic activity and that the relationship was significant only on the lowest frequencies (highest scales) (Gallegati, 2008).

The connection between the industry performances, CPI, oil price and the stock market prices was examined in the case of Greece in the period from 1996 to 2008. Cointegration and VECM approach was employed to examine the original data and VAR was employed to explore the cyclical nature of the variables. Long-term connection was confirmed for oil prices and the CPI. Results revealed negative influence of the oil prices to the stock market and CPI. No effect was found between the oil prices and industry performance and CPI. Finally, industrial performance and the stock market prices were also independent (Filis, 2010).

The relationship of industrial production and the stock market indexes was observed for selected European countries (Greece, Italy Portugal, Spain, Austria, Belgium, Finland, Germany) in the period from 2004 to 2013. Results confirmed asymmetric and symmetric adjustment to long-term equilibrium in the South (Greece, Italy Portugal, Spain) and North (Austria, Belgium, Finland, Germany) respectively. According to Granger causality, direction of the relationship was from the industrial production to the stock market index (Tsagkanos & Siriopoulos, 2015).

Dependence of the macroeconomic variables and the stock market returns was tested in United Kingdom, Germany and France. In the period from 1969 to 2013 results revealed that both interest rates and industry performance explained the half of the annual movement in the stock market prices. Additionally weight of those two has shifted toward industry performance (Peiro, 2016).

The relationships among several economic indicators (industrial production, trade balance, foreign reserves, exchange rate, fiscal deficit, inflation, money supply, call money rate, oil price) and the Indian stock market prices (BSE 500) were examined in the period from 2006 to 2015. According to Granger causality selected variables were not significant (Gurloveleen & Bhatia, 2015). Adjusting this approach with conditional frequency domain unidirectional long-term relationship was confirmed in the period from 1993 to 2011 therefore revealing the stock market price as indicator of industrial production growth (Tiwari, Mutascu, Albulescu, & Kyophilavong, Frequency domain causality analysis of stock market and economic activity in India, 2015).

Using NARDL approach Pakistan stock market was tested in the period from 1997 to 2018. Results confirmed the long term positive influence of industry performance and consumer prices while negative influence of trade balance, exchange rate and interest rate. Nevertheless in the post crisis period from 2008 to 2018 only consumer prices were significant (Chang, Meo, Syed, & Abro, 2019).

Similar approach was used for test the asymmetric effects of the industrial production, real effective exchange rate and the money supply for Turkish stock market prices in the period from 1994 to 2017. Using the non-linear autoregressive distributed lag (NARDL) with special emphasis on post-crisis period results confirmed the hypothesized nature of the relationship with rising asymmetries in the post-crisis period emphasizing negative influence of the restrictive monetary policy (Tiryaki, Ceylan, & Erdoğan, 2019).

There are several studies exploring the Croatian stock market. One of the studies examined the relationship of 14 stock prices and industry performance, interest rates, inflation, market index as well as the oil prices. In the period from 2004 to 2009 selected stocks were mostly influenced by the CROBEX index and positive relationship was confirmed for industry performance, interest rates and the oil prices while inflation was found to have a negative influence (Benaković & Posedel, 2010).

Croatian stock market index was further tested for selected macroeconomic variables, German market index and Euro area government bond yield in the period 1997-2010. Real GDP, M1/GDP ratio, German market index, Euro area government bond yield were found to have a positive influence while public deficit to GDP, domestic interest rate, rising exchange rate and inflation were found to have a negative influence (Hsing, 2011).

Using the CRR (Chen-Rolls-Ross) model for capital asset pricing market index in Croatia was found to be the most important explanatory factor. Nevertheless, liquidity, employment and oil price had marginal explanatory power. Industrial production was not significant (Dolinar, Orsag, & Sudar, 2014).

One of the recent studies examined the relationship among industrial performance, exchange rate and the stock market prices in Croatia in the period 1998-2014. According to Johansen method analysis revealed no long-term relationship between the dynamics of the selected variables. As a part of the vector auto-regression model (VAR) using Granger causality testing results indicated direction of influence from the exchange rate to the industrial performance and direction of influence from industry performance to CROBEX. This was inconsistent with theoretical consideration CROBEX being the leading variable for the industry performance as a proxy of the aggregate economic activity (Tomić & Sesar, 2015). Using similar methodology another study tested the relationship between the stock market returns in the hospitality industry and the macroeconomic variables (industry performance, CPI (consumer price index), exchange rate and the number of tourist arrivals) in the period 2008-2018. Granger causality confirmed the direction of influence from the consumer price index to hospitality stock market returns (Bogdan, 2019).

Depending on selected methodological approach and sample selection relationship between the stock market index and industrial production is not straightforward. Some papers found no significant relationship while others suggesting different causative relationship. Therefore, using a wavelet coherence approach this paper adds to the body of literature examining this relationship.

DATA AND METHODOLOGY

Stock market index data is available on the official site of the Zagreb stock exchange on daily basis from January 1998. Zagreb stock exchange was firstly established in 1907 and later reestablished in 1991 becoming the central capital market of Croatia and during the last three decades experienced significant trading growth.

Monthly average of the CROBEX is calculated according to the following equation (1):

$$CROBEX^{m} = \frac{\sum_{1}^{n} CROBEX^{d}}{n} \tag{1}$$

Monthly log return of the CROBEX is calculated as the change in the average monthly value according to the following equation (2):

$$R^{m}(t) = \log(CROBEX_{t}^{m}) - \log(CROBEX_{t-1}^{m}) \tag{2}$$

Development of the monthly CROBEX and CROBEX log returns for the selected period from January 1998 to November 2019 are given in Table 1 and Appendix 1.

Table 1. Descriptive statistics for monthly CROBEX and CROBEX log returns

	CROBEX	CROBEX log returns
Min.	523,9	-0.2661
1st Qu.	1160,2	-0.0224
Median	1771,4	0.0009
Mean	1810,3	0.0025
3rd Qu.	1961,8	0.0319
Max.	5263,1	0.2017

Source: own estimates

In the period 1998-2019 average monthly CROBEX value ranged from 523,9 to 5263,1 while the average monthly return oscillated from -0,2661 to 0,2017. The period from 2004 to 2007 was characterized by the rising optimism increasing the number of market investors' consequently in October reaching the historical high of 5263,1 points. Most significant rise of the monthly CROBEX value happened in April 2007 equal to 568,7 points. Nevertheless crash happened in October 2007 when the monthly CROBEX value fell -761,2 points. The bottom low of the CROBEX value was reached in March 2009. After this point volatility of the CROBEX value was soothed. Average monthly log return for the observed period was 0,0025. The highest positive monthly return 0,2017 was marked in December 1999 and the highest negative monthly return -0,2661 in October 2008.

Since the gross domestic product (GDP) data is published quarterly industrial production volume index is the most accurate monthly indicator of the economic activity. Seasonally adjusted monthly data of industrial production volume index in the period from 1998-2019 was retrieved from the official site of the Croatian Central Bureau of statistics. Monthly industry growth is calculated according to the following equation (3):

$$IG^m(t) = \log(IP_t^m) - \log(IP_{t-1}^m) \quad (3)$$

Development of the industrial performance for this period is observable in Table 2 and Appendix 2.

Table 2. Descriptive statistics for seasonally adjusted monthly industrial production volume index and industry growth

	DIP	DIP growth
Min.	80	-0.0939
1st Qu.	96	-0.0136
Median	102	0.0000
Mean	101,1	0.0007
3rd Qu.	106,9	0.0142
Max.	122,1	0.0836

Source: own estimates

In the period 1998-2019 monthly industrial production volume index ranged from 80 to 122,1 while the monthly industry growth returns oscillated from -0,0939 to 0,0136. Following the basic description of data research starts with the most conventional approach. Based on described data first step was to calculate the Pearson correlation coefficient for the CROBEX and industrial performance and their relationship is examined by the linear regression model. In order to avoid the limitations of the conventional approach and to derive insights into time and frequency domain this paper further applies adapted Wavelet methodology developed for European stock markets (Tiwari, Mutascu, & Albulescu, 2016). In order to examine the relationship of the observed variables, necessary estimates were calculated using Morlet wavelet which is represented by the following equation (4):

$$\psi^M(t) = \pi^{-\frac{1}{4}} e^{i\omega_0 t} e^{-\frac{1}{2}t^2} \quad (4)$$

while ω_0 represents the central frequency representing the number of oscillations and t represent the time enabling time reliant amplitude and different frequency phasing. The continuous wavelet transform is represented by the following equation (5):

$$W_x(\tau, s) = \frac{1}{\sqrt{s}} \int_{-\infty}^{\infty} x(t) \overline{\psi\left(\frac{t-\tau}{s}\right)} dt \quad (5)$$

while $x(t)$ represents selected time series while s represent scale and τ location determining the position of the wavelet. According to the wavelet transform selected time series $x(t)$ is represented in terms of wavelets. Furthermore wavelets enable the examination of direction, size and significance of the local relationship between the two time series depending on time frame and period. To examine direction, size and significance of the local correlation between stock market and industry performance as the two observed time series, cross wavelet transformation and cross wavelet power is further determined. The cross wavelet transformation of the observed two time series $x(t)$ and $y(t)$ is represented by the following equation (6):

$$W_{xy}(\tau,s) = W_x(\tau,s)\overline{W_y(\tau,s)} \tag{6}$$

while $W_x(\tau,s)$ represents continuous wavelet transformation of the observed time series $x(t)$ and $\overline{W_y(\tau,s)}$ represent complex conjugate continuous wavelet transform of the observed time series $y(t)$. The power of the cross wavelet is estimated by $|W_{xy}(\tau,s)|$. Finally, the squared wavelet coherence coefficient is represented by the equation (7):

$$R^2(\tau,s) = \frac{\left|S\left(s^{-1}W_{xy}(\tau,s)\right)\right|^2}{S(s^{-1}|W_x(\tau,s)|^2)S\left(s^{-1}|W_y(\tau,s)|^2\right)} \tag{7}$$

while S being the smoothing operator. Squared wavelet coherence coefficient is similar to Pearson falling into zero-one interval. Additionally, wavelet coherence analysis enables phase differences between observed time series. Wavelet coherence phase difference calculation is given by the equation (8):

$$\varphi(\tau,s) = tan^{-1}\left(\frac{\Im\left(W_{xy}(\tau,s)\right)}{\Re\left(W_{xy}(\tau,s)\right)}\right) \tag{8}$$

where $\Im$ represent the imaginary and $\Re$ represent the real part of the cross wavelet transform given by the equation (8). Phase difference is represented by arrows. A zero phase difference points out that the observed time series are positively correlated. Direction of the wavelet arrows render which of the variables is the leading and which of the variables is lagging as well as the sign of the correlation. If the arrow is oriented right and up time series are positively correlated and the first variable is to be leading by the right angle. If the arrow is oriented right and down time series are positively correlated and the second variable is the leading by the right angle. If the arrow is oriented left and down times series are negatively correlated and the second variable is leading by the right angle. Finally, if the arrow is oriented left and up times series are negatively correlated and the first variable is leading by right angle. Furthermore, the higher scale (lower frequency) represents the long-term relationship and the lower scale (higher frequency) represents the short-term relationship.

RESULTS AND DISCUSSION

Results of the conventional approach are given in Table 3 and Table 4. According to the Pearson correlation coefficients, CROBEX was significantly positively correlated with industrial production volume index r=0,81 (p=0,00). Linear regression relationship between the CROBEX and the industrial production volume index was representative (F=504; p=0,00) explaining 66,06% of the variations. Nevertheless, Pearson correlation coefficients was not significant for CROBEX returns and industry growth r=-0,02 (p=0,70) and linear model representation was not confirmed (F=0,1425; p=0,706).

Table 3. Pearson correlation coefficients results

Variable relationships	t-value	df	p-value	95% CI	Pearson
CROBEX & industrial production	22,45	259	0,00	0,76-0,85	0,81
CROBEX returns & industry growth	-0,37	258	0,70	0,14-0,09	-0,02

Source: own calculation

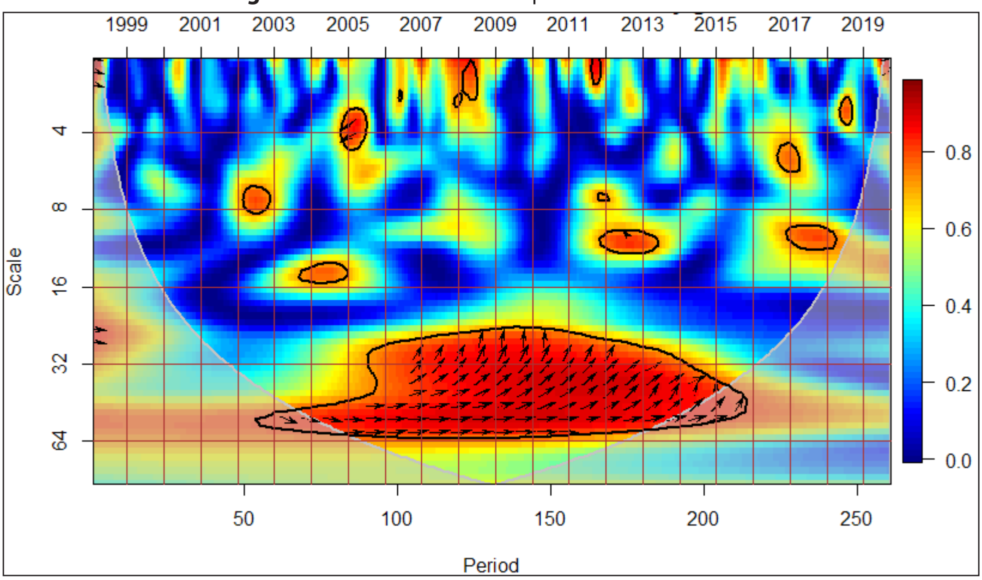
Table 4. Linear regression models results

Dependent variable	Industrial production		Industry growth	
Coefficients	Intercept	CROBEX	Intercept	CROBEX returns
Estimate	8,61E+04	8,27E+00	0.000809	-0.010235
Std. Error	7,46E+02	3,69E-01	0.0016695	0.0271167
t value	115,46	22,45	0,485	-0,377
Pr(>|t|)	<2e-16	<2e-16	0,628	0.706
R-squared	0,6606		0,0005519	
F-statistics	504		0,1425	
p-value	<2e-16		0,7061	

Source: own calculation

Consequently to limitations present in the conventional approach specification of the linear regression model may be incorrect. Wavelet approach avoiding these limitations provides frequency and time domain observation distinguishing the long and the short term as well as the leading and the lagging variables. Relationship between the CROBEX and the industrial production index by the Wavelet approach is represented in Figure 1.

Figure 1. CROBEX and industrial production volume index

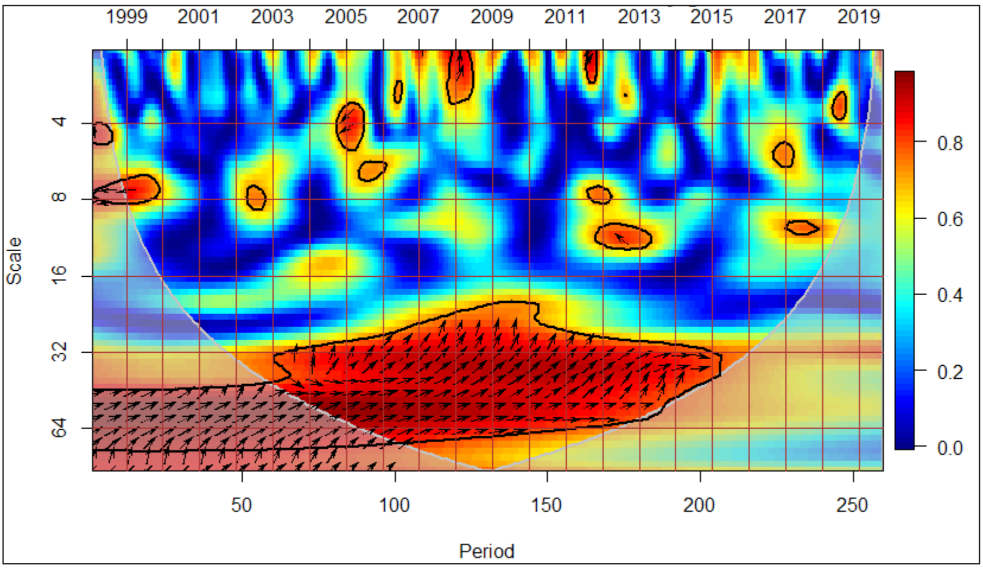


Source: own calculation

The co-movement between the CROBEX and industrial production was significant and positive in the long-run from the second half of 2002 to the end of 2016. This co-movement was present even in the crisis period from 2004 to 2009. Arrows are pointing to the right representing positive correlation. It is important to emphasize there was no leading variable on higher scales (arrows pointing horizontally right) and with lowering the scale arrows are pointing upwards therefore CROBEX becoming the leading variable. In the period from 1998 to 2003 and from 2016 to 2019 this co-movement was not significant. In summary, the stock market prices and industry production had a significant co-movement relationship for 13 years which is more than half of the observed period. This relationship was not affected by the last global financial crisis. In ordered to retrieve more insights about this relationship same analytics were applied for CROBEX log returns and the industrial growth.

Relationship between the CROBEX log returns and the industrial growth by the Wavelet approach is represented in Figure 2. The result is even more important for the investors since it represents the relationship between the actual returns on the Croatian capital market and the industry growth.

Figure 2. CROBEX log returns and industry growth



Source: own calculation

According to the Wavelet representation, co-movement between the CROBEX returns and the industry growth is significant and positive in the long-term for even longer periods of time. This relationship cease to exist after 2015. This relationship confirms the previous result and the CROBEX log returns are revealed as the leading variable for the entire period of the relationship. Therefore results reveal significant co-movement of the CROBEX and industrial performance in the long run for most of the observed period regardless the volatility. Furthermore CROBEX is identified as the leading variable implying that the capital market sentiment is more sensitive to publicly available information and that the industrial production is lagging the capital market sentiment. CROBEX incorporates investor expectations about the future including domestic and global economic activity. This relationship was confirmed in another study observing seven emerging stock markets (Brazil, China, India, Indonesia, Mexico, Russia and Turkey) emphasizing regional influence as more prominent then intercontinental (Bilgehan, 2018). Therefore it may be expected that some Croatian stock market sentiment is transferred from the capital markets of other countries.

CONCLUSION

This paper brings several insights into relationship among CROBEX and industry performance. Results of the research confirmed the significant long-term co-movement of the capital market index and industrial production in the period from 2002 to 2016. This relationship was even more emphasized for the stock market returns and the industry growth in the period from 1998 to 2015. In the case of Croatia CROBEX was found to be the leading variable for the industry performance. Although significant relationship was present during time of crisis the co-movement was not confirmed in the period from 2015 to 2019. Disentanglement of the underlying factors causing the change in the relationship of the CROBEX and industry performance after 2015 should be further examined. Results of this research add to the body of knowledge regarding the relationship of the macroeconomic variables and the stock market revealing important implications for investors and policy makers. Investors may benefit from the knowledge that the domestic industry performance may not be suitable for deriving the short term trading strategies in Croatia and that they should consider other more prominent indicators. Furthermore, policy makers may benefit from the knowledge that the stock market index movement may be useful in creating more efficient macroeconomic policies countering the economic cycles.

LITERATURE

Benaković, D., & Posedel, P. (2010). Do macroeconomic factors matter for stock returns? Evidence from estimating a multifactor model on the Croatian market. *Business Systems Research, 1-2*, str. 39-46.

Bilgehan, T. (2018). Toda-Yamamoto causality between E7 countries stock markets. *Casopis za ekonomiju i tržišne komunikacije, 2*, str. 201-210.

Bogdan, S. (2019). Macroeconomic impact on stock returns in the Croatian Hospitality industry. *Zbornik Veleučilišta u Rijeci, 1*, str. 53-68.

Chang, B. H., Meo, M. S., Syed, Q. R., & Abro, Z. (2019). Dynamic analysis of the relationship between stock prices and macroeconomic variables: An empirical study of Pakistan stock exchange. *South Asian Journal of Business Studies, 3*, str. 229-245.

Dolinar, D., Orsag, S., & Sudar, A. (2014). Macroeconomic factors and stock returns–evidence from Croatian stock market. *In Western Decision Sciences Institute forty third annual meeting.*

Durovic, M., & Mutibaric, J. (2011). Microeconomic Factors That Contribute to Stock Market Oscillations. *Casopis Za Ekonomiju I Trzisne Komunikacije, 2*, str. 212-223.

Filis, G. (2010). Macro economy, stock market and oil prices: Do meaningful relationships exist among their cyclical fluctuations? *Energy Economics, 4*, str. 877--886.

Gallegati, M. (2008). Wavelet analysis of stock returns and aggregate economic activity. *Computational Statistics & Data Analysis, 6*, str. 3061-3074.

Gurloveleen, K., & Bhatia, B. S. (2015). An impact of macroeconomic variables on the functioning of Indian stock market: A study of manufacturing firms of BSE 500. *Journal of Stock & Forex Trading, 1*, str. 160-167.

Hsing, Y. (2011). Macroeconomic variables and the stock market: the case of Croatia. *Economic research-Ekonomska istraživanja, 4*, str. 41-50.

Jareño, F., & Negrut, L. (2016). US stock market and macroeconomic factors. *Journal of Applied Business Research, 1*, str. 325-340.

Kim, S., & In, F. H. (2003). The relationship between financial variables and real economic activity: evidence from spectral and wavelet analyses. *Studies in Nonlinear Dynamics & Econometrics, 4*.

Peiro, A. (2016). Stock prices and macroeconomic factors: Some European evidence. *International Review of Economics & Finance, 41*, str. 287-294.

Ross, S. (1976). The arbitrage theory of capital asset pricing. *Journal of Economic Theory, 13*(3), pp. 341-360.

Tiryaki, A., Ceylan, R., & Erdoğan, L. (2143-2154 2019). Asymmetric effects of industrial production, money supply and exchange rate changes on stock returns in Turkey. *Applied Economics, 20*.

Tiwari, A. K., Mutascu, M. I., & Albulescu, C. T. (2016). Continuous wavelet transform and rolling correlation of European stock markets. *International Review of Economics & Finance*, str. 237-256.

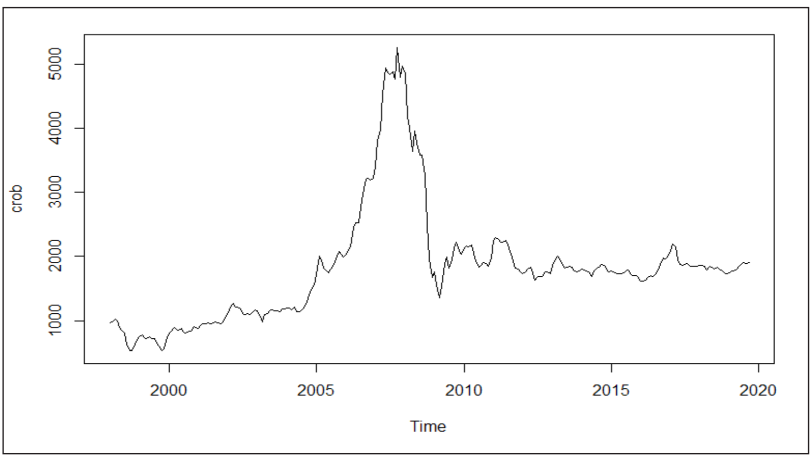
Tiwari, A. K., Mutascu, M. I., Albulescu, C. T., & Kyophilavong, P. (2015). Frequency domain causality analysis of stock market and economic activity in India. *International Review of Economics & Finance*, str. 224-238.

Tomić, B., & Sesar, A. (2015). Interdependence of industrial production index and capital market in Croatia: VAR model. *Journal of Accounting and Management*, str. 17-32.

Tsagkanos, A., & Siriopoulos, C. (2015). Stock markets and industrial production in north and south of Euro-zone: Asymmetric effects via threshold cointegration approach. *The Journal of Economic Asymmetries, 2*, str. 162-172.

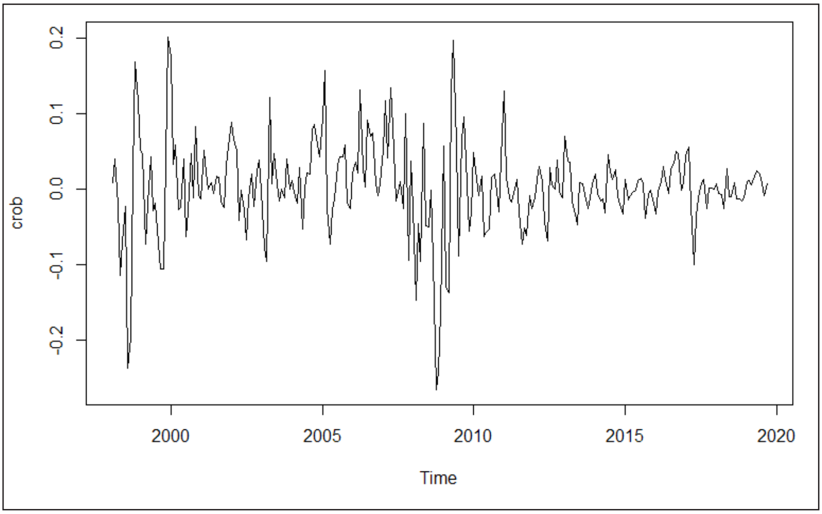
APPENDIX

Figure 3. CROBEX monthly value in the period 1/1998-9/2019



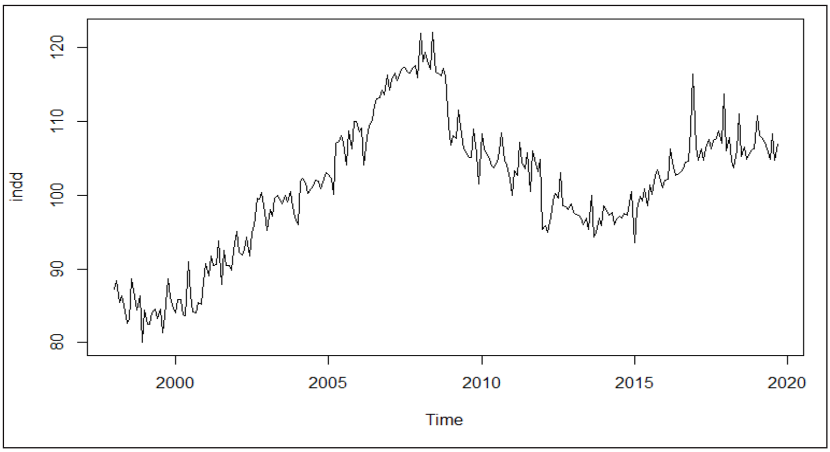
Source: own calculation

Figure 4. CROBEX monthly return value in the period 1/1998-9/2019



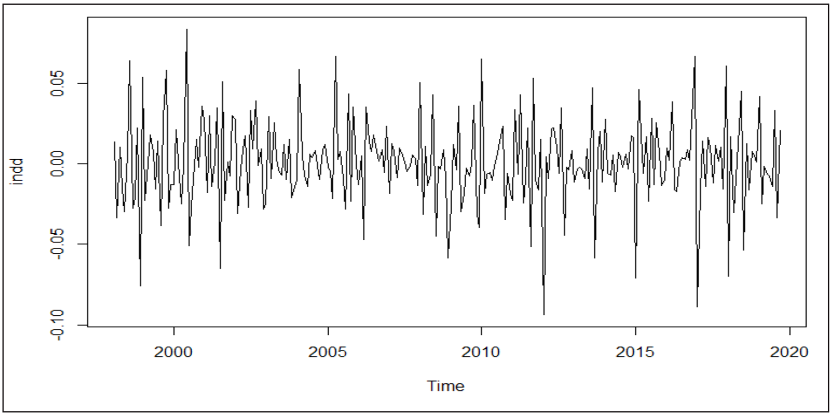
Source: own calculation

Figure 5. Seasonally adjusted monthly industrial production in the period 1/1998-9/2019



Source: own calculation

Figure 6. Seasonally adjusted monthly industrial production growth in the period 1/1998-9/2019



Source: own calculation