Macroeconomic Environment and Exchange Rate Dynamics: The Case of Romania

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Abstract

The evolution of the exchange rate is a key factor in establishing the macroeconomic environment of emerging economies. Policymakers, the business environment, investors and the population of a country are interested in this matter due the potential negative effects of exchange rate volatility on the general macroeconomic environment. This paper revisits the nexus between the exchange rate and the macroeconomic environment of Romania between January 2000 and December 2018 using wavelet based methodologies. Based upon the wavelet coherency analysis, we found that the exchange rate plays a key role in establishing the evolution of interest rates, inflation, while for the economic cycle the exchange rate is less important. In general, the long-term exchange rate is influenced by inflation, interest rates, and while in short-term and especially during financial crisis periods, the exchange rate acts as the leading role for the two variables. Furthermore, the economic cycle of Romania acts as the leading factor in both normal and turmoil periods of economic growth. Our empirical results reveal the importance of monitoring and controlling the exchange rate by central banks because the nexus between the exchange rate and the macroeconomic environment depends on the time horizon. In addition, our research is important for policy makers who are interested identifying, monitoring and controlling the key macroeconomic factors that influence the evolution of the exchange rate. To the best of our knowledge, there is a limited number of recent studies regarding Romania, which try to identify the linkages between the exchange rate and several macroeconomic factors. Therefore, our study contributes to existing literature, by offering addition empirical evidence regarding which macroeconomic variable acts as an initiator or as lag in the evolution of the exchange rate in emerging economies by using modern methods of analysis like wavelet analysis.

Keywords: exchange rate, volatility, macroeconomic fundamentals, wavelet analysis.

1. Introduction

The analysis of the relation between the macroeconomic environment and the dynamics of the exchange rate has gained a special interest in academia and policymakers in the recent years after the global financial crisis. In general, policymakers, investors or the population of a country are interested in this issue due the potential negative effects of exchange rate volatility on the general economic environment. While the importance of this matter has gradually increased in the recent years, the relationship it's uncertain due to conflicting results in many studies mainly due to different samples of countries, methodology, analysis period or even type of country developed versus emerging economies. The conflicting results found in the exiting

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literature (e.g. Calvo & Reinhart, 2002; Hnatkovska, Lahiri & Vegh, 2013; Sensoy & Sobaci, 2014; Kang, Hernandez & Yoon, 2019) point out that the relationship between the exchange rate and the macroeconomic environment is complex, varies in time and its dependent on the characteristic of each country.

The nexus between the exchange rate and several macroeconomic factors is a key focus not only for investors but also for policymakers. The central banks in emerging economies use the exchange and interest rates as monetary instruments in order to reduce and combat inflation (Holtemöller & Mallick, 2016). In the case of emerging economies, the dynamics of the exchange rate represent a key driver in establishing the monetary policy decisions, as central banks try to not only control the inflation rate but also protect the national economy against shocks caused by the depreciation of the national currency. This raises the question on the effectives of the monetary policy transmission mechanism in emerging economies because a monetary policy that revolves around an inflation-targeting regime, with low inflation rates can limit the effectiveness of central banks to react to shocks in the exchange rate (Ghosh, Ostry & Chamon, 2016). Furthermore, testing the casual relationship between the exchange rate, inflation, interest rate and economic cycle must take into consideration the fact that the relationship is time varying. While, these macroeconomic variable are interconnected their degree of interdependence can vary from one period of analysis to another or from a short-term relationship to a long-term effect. This time varying effect is even more evident in the case of emerging economies that are more heterogeneous than large economies (Kang, Hernandez & Yoon, 2019).

In the case of the Romanian economy, a country member of the European Union who wants to adopt in the near future the EURO currency, analyzing the dynamics between the exchange rate and several key macroeconomic factors can reveal not only the effectives of the monetary policy, but also shed more light into the process of adopting the EURO. While, all the new member states of the European Union will have to adopt the common currency this will also impose dropping the exchange rate as a monetary instrument, which could limit the effectives of the monetary policy for new EURO area member states. After accomplishing specific conditions known as the Maastricht criteria, as well other specific indicators (known as real convergence indicators), the Romanian economy could eventually adopt the Euro as a currency instead of the Romanian Leu (RON). This issue raises the question, what is the nature of the relationship between the evolution of the exchange rate and the macroeconomic environment in Romania?. Therefore, the aim of this study is to test the relationship between the exchange rate and several key macroeconomic factors that are important in the adoption of EURO currency.

To the best of our knowledge, there is a limited number of recent studies regarding Romania, which try to identify the linkages between the exchange rate and several macroeconomic factors. While some of the previous studies either tests only the relationship between the interest rate and exchange rate (Andrieş, Căpraru, Ihnatov & Tiwari, 2017), or use a different period of analysis (Caraiani, 2012) our analysis contributes to existing studies in several ways. Firstly our analysis, contributes to existing literature by distinguishing the effect between nominal and real exchange rates and by including in the analysis addition variables, such as the economic cycle, which is a key driver of the macroeconomic environment of a country. Furthermore, by using a modern method of analysis such as wavelet analysis we offer new insight into to the dynamics between the exchange rate and inflation, interest rate and economic cycle for an emerging economy.

Our study contributes to existing literature that tries to quantify the relationship between the exchange rate dynamics and the macroeconomic environment for a small emerging economy. One of the major contribution of our paper relates to using wavelet methodology in order to test the degree of interdependence between the macroeconomic variables. Furthermore, we contribute to existing literature that focuses on the effectives of the mechanism of transmission of the monetary policy in emerging economies.

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The rest of the paper is organized as follows: section 2 presents the data and methodology, section 3 presents the empirical results, section 4 discusses the main findings of our research, and section 5 concludes.

2. Data and methodology

2.1 Data

The main objective of our analysis is to test the interaction between the exchange rate dynamics in Romania and several macroeconomic factors. Therefore, we use in our analysis a series of key indicators to investigate the relationship between the exchange rate and the macroeconomic environment. Table 1 presents a general description of variables and the source of the data.

One of the issues when testing the effect of the macroeconomic environment is the type of exchange rate we use in our analysis. We must choose between nominal and real exchange rates, the exchange rates between one national currency against a foreign currency (e.g. versus US dollars or versus the Euro), or the timeframe we take into consideration from daily, to weekly or monthly changes. Because we want to test the influence of several macroeconomic factors like the business cycle, the inflation rate or the interest rate, which the data is only available monthly, we will use monthly data in our analysis. Furthermore, because we want to isolate the effect of the inflation rate on the evolution of the exchange rate, we will use both the nominal and the real exchange rate indexes. While, the nominal exchange rate takes into consideration the effect off the inflation rate, when we use the real exchange rate the effect of the inflation is eliminated. Therefore, we will use in our analysis monthly data between January 2000 until December 2018, which is collected from several data sources described in Table 1.

Table 1. Variables used in the analysis of the relation between the exchange
rate dynamics and the macroeconomic environment in Romania

Variable	Description	Source of data
Macroeconomic factors		
$Exchrate_{nom}$	Nominal Exchange Rate Index, as a proxy for the exchange rate dynamics in Romania	BIS – Bank of International Settlements
$Exchrate_{real}$	Real Exchange Rate Index, another measure of exchange rate dynamics in Romania that doesn't take into consideration inflation	BIS – Bank of International Settlements
IPI	Seasonally adjusted monthly industrial production index value, as a measure for the economic cycle	Eurostat
$Inflation$	Monthly inflation rate value - Harmonized Index of Consumer Prices as a measure for Inflation	Eurostat
$Rate$	The monthly interest rate on 3-month interbank loans in Romania as a proxy for the average interest rate	NBR – National Bank of Romania

Source: Authors Definitions

We prefer to use Harmonized Index of Consumer Prices as a proxy for inflation because it takes into consideration the effect of imported goods on the evolution of inflation. Meanwhile, we use the 3-month interbank interest rate as a proxy for the interest rate because this type of interest rate takes into consideration not only the monetary policy in a country but also the liquidity and the money demand in the banking sector. Table 2 presents the descriptive statistics of the data used in the analysis.

Table 2. Descriptive statistics of the data used in the analysis

	$Exchrate_{nom}$	$Exchrate_{real}$	$Inflation$	IPI	$Rate$
Mean	111.9621	95.73329	77.43202	80.92061	11.85066
Median	102.4700	97.67500	82.62500	77.80000	7.150000
Maximum	208.9700	119.3100	105.2600	125.1000	61.98000
Minimum	90.87000	77.37000	24.01000	51.30000	0.330000
Std. Dev.	24.11153	9.238574	23.11215	17.96669	13.25959
Skewness	2.211541	-0.298203	-0.660827	0.583729	1.602455
Kurtosis	8.021787	2.373933	2.244514	2.275051	4.923729
Jarque-Bera	425.4290	7.102761	22.01652	17.94084	132.7357
Probability	0.000000	0.028685	0.000017	0.000127	0.000000
Observations	228	228	228	228	228

Source: Authors Estimates

2.2 *Methodology*

The wavelet analysis methodology provides a complex set of instruments for testing the interaction between two independent time series. While the wavelet methodology offers a wide range of advantages over the traditional methods of testing interaction between two variable we prefer to use this method of analysis because of three specific advantages. The first one is that wavelet analysis can test simultaneously the interactions between two variables in both time and frequency domain. Therefore, we can observe when and if an interaction occurred between the two variables but also note if the effect is between short or long-term exchange rate dynamics. The second advantage of the wavelet analysis is the ability of testing interactions on a scale-by-scale approach as some interaction are specific to a certain period of analysis. Finally, the ability of wavelet analysis to be "energy-preserving" allows us to test if the interactions between the exchange rate and certain macroeconomic variables differs not only by scale but also by period of analysis. For a more in depth view, of the advantages of using wavelet analysis in time series data analysis see Gençay, Selçuk and Whitcher (2002), and Aguiar-Conraria and Soares (2014) which present in detail practical application of wavelet analysis.

2.2.1 *The continuous wavelet transform*

The continuous wavelet transform (CWT), was developed by Torrence and Compo (1998) as a method of testing the presence of delays or synchronizations between two time series. From the initial studies that focused primarily on testing delays between several atmospheric factors, in the recent years the CWT analysis, has gained more in more popularity in many fields of science including economics. In general, the CWT analysis decomposes time series data into different functions called wavelets, which contain information from both time and frequency domain $\psi_{\tau,s}(t)$. These small function called "waves" are obtained by translating specific wavelet filters on the time series data, which provides us with a time function translation parameter τ and a s scale parameter. Rua and Nunes (2009) argues that both, the translation parameter τ or the scale s parameter contain information regarding the frequency of analysis as in formula (1).

$$\psi_{\tau,s}(t) = \frac{1}{\sqrt{s}} \psi \left(\frac{t - \tau}{s} \right) \tag{1}$$

Meanwhile, Gençay et al. (2002) considers that by projecting a mother wavelet ψ_0 onto an existing time series x_n the continuous wavelet transform (CWT) depends on the type of wavelet filter used in the analysis. If we use the Morlet filter in the CWT analysis our formula becomes (Grinsted, Moore & Jevrejeva, 2004):

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$$W_x(\tau, s) = \frac{1}{\sqrt{s}} \sum_{t=1}^{N} x(t)\psi^*\left(\frac{t-\tau}{s}\right) \qquad (2)$$

In formula (2), $W_x(\tau, s)$ is the local phase of the frequency domain given by n data, while x is the time domain in our data. Therefore, we can depict simultaneously both the time values with the x data and the frequency domain as in the n data.

2.2.2 *Wavelet Coherence*

The wavelet coherency analysis allows testing the presence of interactions between two times series X and Y in a bivariate framework. This method of analysis involves computing the continuous wavelet analysis for each individual series and then comparing it to the results of the spectrum product of each series, in both time and frequency information. Grinsted et al. (2004) considers that the general method of computing the wavelet coherency between two variables is presented in formula (3):

$$R_{xy}(\tau, s) = \frac{\left|S\left(s^{-1}W_{xy}(\tau, s)\right)\right|^2}{S(s^{-1}|W_x(\tau, s)|^2).\,S\left(s^{-1}\left|W_y(\tau, s)\right|^2\right)} \qquad (3)$$

Where: $W_x(\tau, s)$ and $W_y(\tau, s)$ are the continuous wavelet transforms (CWT) of the time series X and Y, and S (.) is the smoothing operator for the s wavelet scale.

Previous empirical results of Grinstead et al. (2004) revealed that the best wavelet filter than can be used in the wavelet coherency analysis is the Morlet wavelet as it has Fourier period equal to the scale, which allows for better results. Therefore, if we use the Morlet wavelet in our wavelet coherency analysis the smoothing operator can be written as in formula (4):

$$S(W) = S_\tau\left(S_{time}\left(W_n(s)\right)\right) \qquad (4)$$

In the previous formula S_τ represents the effect of a smoothing operation against the wavelet axis, while S_{time} is the result of a smoothing effect in general (Rua & Nunes, 2009). Furthermore, when using the smoothing operators we can compare our results against a Monte Carlo simulation to test the presence of interactions between our macroeconomic variables. As suggested by Grinstead et al. (2004) we can interpret wavelet coherency coefficients similar to statistics correlation coefficients, where high values represent switching moments between variables. Thus, if in the graphical representation of our variables we find distinct zones with high wavelet coherency coefficients we interpret them as the result of interaction between our variables. Furthermore, if we find the high coefficients in the reduced frequency range we will consider that the interaction between the exchange rate and out macroeconomic variables is on the short-term exchange rate dynamics, while if we find the same coefficients in high frequency range we will note the effect of long-term exchange rate on our macroeconomic variables.

2.2.3 *Wavelet Phase-Difference*

Another advantage of using the wavelet analysis in testing the interactions between two or more variables is the ability to determine which variables acts as a leading role in our analysis. By computing the wavelet phase-difference between two time series we can determine whether there is synchronization or delay between two time series in both time and frequency domain. The wavelet phase-difference between two variables can be computed as in formula (5):

$$\phi_{x,y}(\tau, s) = tan^{-1}\left(\frac{\Im\left(W_{xy}(s,\tau)\right)}{\Re\left(W_{xy}(s,\tau)\right)}\right) \tag{5}$$

Where: $\phi_{x,y}(\tau, s)$ is the wavelet phase-difference between two variables;

$W_{xy}(\tau, s)$ – is the wavelet continuous transform between two time series x and y b using the τ time and s frequency.

If we take into consideration the values of the wavelet phase-difference between two variables, $\phi_{x,y}(\tau, s)$ we can determine if the two variables influence each other at the certain frequency as follows:

- *The two series are synchronized* if $\phi_{x,y}(\tau, s) = 0$, and in the graphical representation the arrow is horizontal and pointing to the right;

- *The two series are in sync but the first series is leading* if $\phi_{x,y} \in \left(0, \frac{\pi}{2}\right)$, and in the graphical representation the arrow is pointing to upper right;

- *The two series are in sync but the second series is leading* if $\phi_{x,y} \in \left(-\frac{\pi}{2}, 0\right)$, and in the graphical representation the arrow is pointing to lower right;

- *The two series are anti-cyclical* if $\phi_{x,y} = \pi$ or $\phi_{x,y} = -\pi$ and in the graphical representation the arrow is horizontal and pointing to the left;

- *The two series are desynchronized and the second variable is leading* if $\phi_{x,y} \in \left(\frac{\pi}{2}, \pi\right)$ and in the graphical representation the arrow is pointing to the upper left;

- *The two series are desynchronized and the first variable is leading* if $\phi_{x,y} \in \left(-\pi, -\frac{\pi}{2}\right)$ and in the graphical representation, the arrow is pointing to the lower left.
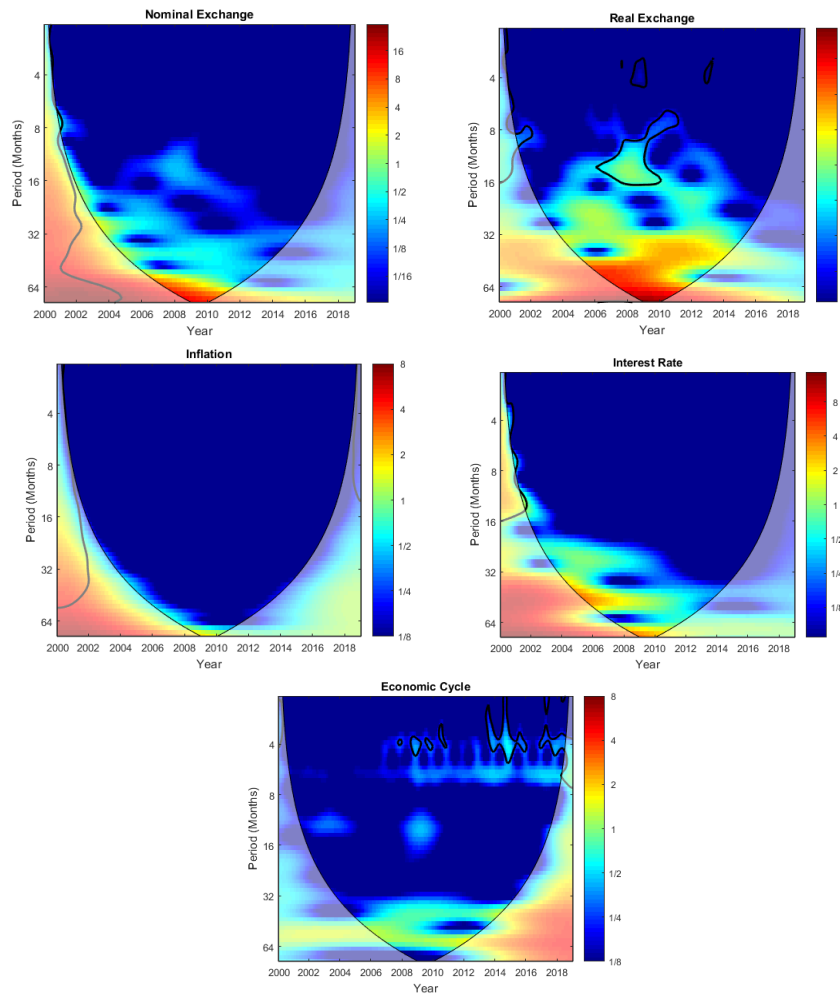
3. Results

The main objective of our analysis is to test the interaction between the exchange rate dynamics of the Romanian currency (Romanian New Leu – RON) and a series of key macroeconomic indicators. In our analysis we will use the wavelet methodology to test the interaction between of variables using a set of key indicators: wavelet power and wavelet coherency analysis. In the following section, we present the results of our analysis.

3.1 *Results from the Continuous Wavelet Transform Analysis – Wavelet Power*

In Figure 1 we present the results of the Continuous Wavelet Transform Analysis – CWT for each of our variables used in the analysis: nominal exchange rate, real exchange rate, inflation, interest rate and economic cycle.

The CWT results, from Figure 1 is similar to a graphical representation of the descriptive statistics for the data used in the analysis. This graphical representation, also called wavelet power depicts on the horizontal line the time axis from the year 2000 until 2018 and on the vertical axis, we note the frequency of the data, from short term: 4 months until longer periods of 64 months. The value of the wavelet coefficients ranges from low values, depicted in blue to high values depicted in red. Furthermore, if at any time or scale from our analysis there were crucial moments in the evolution of that certain indicator they are marked with black outlines in the graphical representation.

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In the case of the Romanian economy, our results indicate the presence of sudden changes in the evolution of the real exchange rate and the economic cycle of Romania between 2008 and 2010 in the 4 months frequency range, but also for longer periods of time of 16-32 months. This is indirect evidence that the recent economic crisis affected the Romanian economy in the late 2008 and affected the macroeconomic environment until longer periods of time late 2011 and the beginning of 2012. During this timeframe, the effects of the recent economic crisis had a lastly effect on Romanian economy and its national currency. Furthermore, if we at look evolution of the economic cycle in Romania, we observe that the beginning of the year 2014 marked another key moment in the recovery of the Romanian economy after the crisis. In the case of the nominal exchange rate, the presence of the recent economic crisis is not as obvious but we do note changes in the same period of 2008-2010 but for longer periods of 8-16 months. The difference in the evolution between the nominal and the real exchange can be attributed to the high inflation rate in Romania, which varied from 7% to 15.72% in the same period. By excluding the effect of the inflation using the real exchange rate, we note the ample changes in 2008-2010 while, in the case of the nominal exchange rate the changes are less evident due to high inflation rates. Overall, our results are similar to the results of Caraiani (2012), which compared the influence of the economic and business cycle on the evolution of the real and nominal exchange rates of Romania between 1993- 2010.

Source: Authors Estimates

Figure 1. Results of the Continuous Wavelet Transform Analysis – Wavelet Power

The results for the other two macroeconomic variables used in our analysis, namely the inflation and the interest rate, reveal changes in the long–term horizon, consistent which the gradual reduction of these variables during our analysis period. The wavelet power graphs for these variable, point out that the disinflation process was ongoing from 2000 until the beginning of 2014, which was also accompanied by a reduction in the interest rates on the interbank market. The red and yellow bands present for longer periods of 8-64 months proves this phenomenon. This is consistent with the reduction of monthly inflation rate of more than 40% in 2000 until vales of 1-2% in 2014. Similarly, the interest rates declined from 60% in the beginning of 2000 to 1-2% in 2014.

3.2 *Results of the Wavelet Coherency Analysis*

The second part of our analysis focuses on the actual testing of the interactions between several macroeconomic variables and the two types of exchange rate we use in our analysis. Therefore, the results of the wavelet coherency analysis depicted in Figure 2 present the key component of our analysis. Overall, our results reveal some intriguing aspects regarding the dynamics between the exchange rate and three macroeconomic indicators for Romania.

One of the main directions of our results revels that, as expected there is a higher degree of interdependence between the nominal exchange rate and the other variables, rather than between the real exchange rate and the other variables. The higher degree of interdependence or comovement between the nominal exchange rate rather than the real exchange rate proves that inflation is a key factor in establishing the general economic environment in Romania. Furthermore, we also note that there is a higher degree of interaction between the exchange rates and inflation and interest rates, while the interaction between the economic cycle and the exchange rate dynamics is weaker.

The second important conclusion of our analysis reveals that the relationship between these variables depends also on the time-window of analysis. We note, higher degrees of interaction between our variables in the long-term, or during turmoil periods such as 2008-2011. There are many specific differences among our variables, yet we observe interaction between the exchange rate, inflation, interest rate and economic cycles for the short period timeframe of 3-4 month in 2008-2011. This is clear evidence of radical changes in the Romanian economy during that period. Furthermore, we notice that after the recent financial crisis, the short-term and long-term linkages are weaker with only small periods of high wavelet coherency coefficients around 2014, 2016 and late 2018.

While, the first two conclusions depicted the general environment, our results also point out to specific moments interactions between our variables. In the case of the bivariate analysis between nominal exchange rate and inflation, we find that the interaction refers mostly to the long term exchange rate fluctuations as we find that for longer periods of 24 months (2 years), these variables are almost anticyclical (the direction arrow is pointing to the left). This anticyclical behavior points out that when the inflation rate in Romania increases we notice a depreciation of the national currency on the long run. This behavior is consistent to the well-established Purchasing Power Parity theory of Cassel (1918) who argues that exchange rate between two currencies is influenced by the inflation and purchasing power of the respective currencies. On the long run, the dynamics of the nominal exchange rate from Romania depends on the inflation rate. Meanwhile, when we look at the relationship between the real exchange rate and the inflation we observe that both variables were in sync during periods of crisis (2008-2012) in 1-16 months' time window.

The short-term synchronization between inflation and real exchange rate, as well as nominal exchange rate is also consistent with the well-established economic theory of sticky prices

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based upon the portfolio theory. Branson, Halttunen and Masson (1977), consider that there is negative relationship between the exchange rate and the interest rate or inflation in a country, because when an interest bearing assets in country become more attractive the local interest rates will increase which would lead to an appreciation of that country's currency. Therefore in the short-term we will notice that either the exchange rate or the inflation will lead for certain periods of time. In the case of Romania, we find that usually the exchange rate leads, while the inflation acts as a follower.
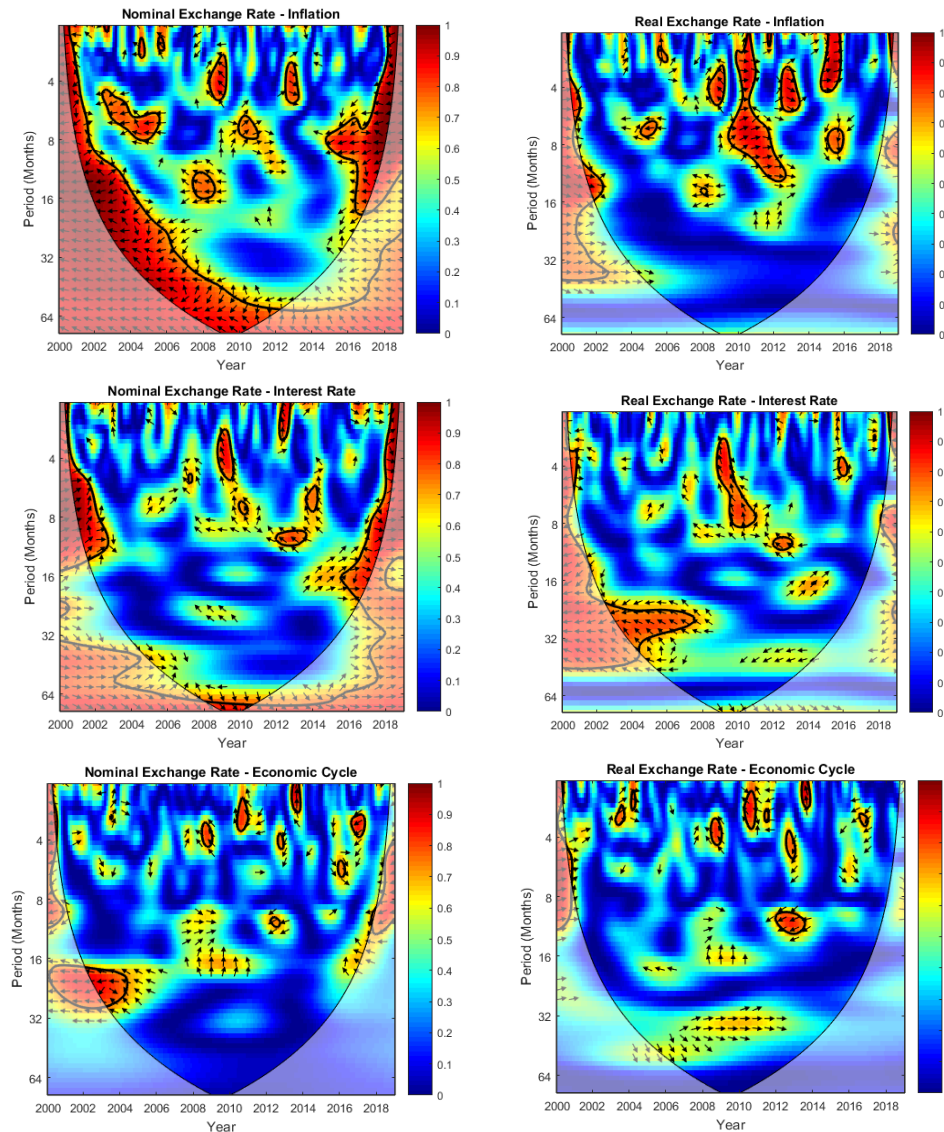
Note: Contours with black represent a 5% significance estimated on the basis of Monte Carlo simulations. The colours used to represent the wavelet range from blue (low power) to red (high power). The Y-Scale indicates the frequency range from the shortest (4 months) to the longest (64 month). The X-Scale depicts the period of analysis in years. The relationship between two macroeconomic variables is indicated by the direction of the arrows is as follows: 1. if the arrow indicates the direction to the right, the variables are synchronized. 2. the first variable leads if the arrow points to the upper right; 3. the first variable is lagging if the arrow indicates the right and the direction is down; 4. the variables are out of sync (exerting anti-cyclic effects between them) if the arrow points to the left; 5. desynchronized and the first variable leads if the arrow points to the left and top; 6. De-synchronized and the first variable lags if the arrow indicates the left-most direction. *Source: Authors Estimates*

Figure 2. Results from the wavelet coherency analysis

In the case of the interaction between interest rates and both types of exchange rates, our results confirm once again that in the short-term we notice the prevalence of the sticky price theory (Branson, Halttunen & Masson, 1977), while on the long rung we observe the prevalence of Purchasing Power Parity theory of Cassel (1918). Furthermore, we note that in general the interest rate takes the leading role on short term and especially during financial crisis periods, while on the long run the nominal exchange rate is in sync with the interest rate. These results are in line with the previous result of Hacker, Karlsson and Mansson (2012), for small emerging economies or the results of Andrieş, Căpraru, Ihnatov and Tiwari (2017), in the case of Romania.

Meanwhile, the interaction between the economic cycle and both types of exchange rate not only is it least significant compared to the other variables, but it also has some additional particularities. In general, we observe that the economic cycle is either acting as the leading role on lung run for the nominal exchange rate, or on the short term for the real exchange rate, but also during normal periods 2000-2006 or crisis periods 2008-2011. This implies that, there is a lower degree of influence of the exchange rate on the economic cycle of Romania. Our results, are in line with the previous results of Aguiar-Conraria and Soares (2011), for the European Union but also the results of Caraiani (2012) for Romania between 1992-2010.

4. Discussions

While the results from the wavelet power analysis proved that there were significant changes in the evolution of the economic cycle and the real exchange rate during the recent financial crisis, the results from the wavelet coherency analysis offer the general perspective of the interactions between the exchange rate and some key macroeconomic indicators. By using both the nominal and the real exchange rates we tested the influence of the exchange rate dynamics, by including or ignoring the influence of the inflation, which pointed to some intriguing results, that require some additional considerations.

One of the main conclusion of our analysis is that for the Romanian economy the dynamics of the inflation rate is one of the key drivers in the dynamics of the exchange rate. Therefore, monetary authorities in Romania need to take into consideration both the nominal exchange rate, but also the real exchange rate as their dynamics may differ significantly, due to the direct influence of the inflation rate. Furthermore, this result raises the question of the effectiveness of the central bank to respond to exchange rate volatility in Central and Eastern European Countries, because a monetary policy that revolves around an inflation-targeting regime, which promises low inflation, can ultimately limit the ability of central banks to react to foreign exchange shocks (Ghosh, Ostry & Chamon, 2016). While, reducing the inflation rate in a country, we are also limit the effectiveness of central banks to respond to foreign exchange volatility.

Another important contribution of our study is identifying that the dynamics between the exchange rate and several macroeconomic factors depends on the period of analysis and frequency of analysis. Due to the specific advantages of using wavelet analysis, we were able to plot simultaneously not only time but also the frequency domain, which showed the effect of the recent economic crisis between 2008 and 2011, but also long-term linkages between our variables. This proves, that while a long term relationship exists between our variables there are also moments when the degree of interaction between these variables is higher, and this is especially true during crisis periods. Therefore, national monetary authorities need to monitor closely the linkages between our variables all the time and take extra precautions during financial crisis periods when the comovement is higher (Hacker, Karlsson & Mansson, 2014).

With respect to the interactions between each individual variables and both types of exchange rate our results raise some additional issues. In the case of the nexus between the exchange rate and inflation, we find that in the short term exchange rate takes the leading role

while on the long run the relationship follows the implication of the Purchasing Power Parity theory. This implies that, monetary authorities in Romania need to monitor closely the evolution of the exchange rate, especially during turmoil periods as this variable can increase the domestic inflation rate. On the long run, we notice that the two variables align in consistence with existing economic theory. The same behavior is observed between the exchange rate and interbank interest rates in the Romanian economy. Meanwhile, the interactions between the economic cycle and exchange rate are weaker, but are also important not only during turmoil periods, but also on the long run.

Overall, our results stress the necessity of central banks from small emerging economies, to monitor closely the interactions between the exchange rate and several macroeconomic factors, because central banks in emerging economies tend to use the interest and exchange rates policies as measures to combat and reduce inflation, but also to encourage and sustain economic growth (Holtemöller & Mallick, 2016).

5. Conclusions

Our analysis tested the interactions between the exchange rate and several macroeconomic factors for the Romanian economy between January 2000 and December 2018 using wavelet based methodologies. We use the continuous wavelet transform analysis, wavelet coherence analysis and wavelet phase-difference in order to test what is the degree of interaction between the nominal or real exchange rates and inflation, interest rate and economic cycle.

While the result from the continuous wavelet transform analysis revealed the presence of the recent economic crisis, the results from the wavelet coherency analysis revealed several key moments of interaction between our variables of interest in both normal and turmoil periods. Therefore, analyzing the interconnections between the exchange rate and several macroeconomic factors is even more important now when the uncertainty is the main factor in the future development of the world economy.

Overall, our results indicate that the exchange rate plays a key role in the evolution of interest rates and inflation while in the case of the economic cycle the exchange rate is less important. Furthermore, we note a different behavior between our variables in the short run versus the long run. In general, the nexus between exchange rate and inflation or interest rate follows the sticky price model, while on the long run we find evidence of the Purchasing Power Parity theory by using both nominal and real exchange rates. Therefore, during periods of crisis, the exchange rate takes the leading role in relation to inflation and interest rate, while on the long run they are mostly in sync. In the case of the nexus between economic cycle and exchange rate, the degree of interactions is much lower but nevertheless especially during periods of crisis the economic cycle acts as the leading role, the latter followed by the exchange rate.

The different degrees of interactions between our variables, which are time and frequency dependent offer not only investment and arbitrage opportunities, but also raises questions regarding the effectives of the mechanism of transmission for the monetary policy in Romania. One important, observation of our study is that the nominal exchange rate dynamics in Romania is highly sensitive to the evolution of the inflation and interest rates. Therefore, as the monetary authorities in Romania focus on reducing the inflation via an inflation targeting regime, what is the role of the exchange rate in this equation. Can we use the exchange rate as effective instrument to combat inflation, or by combating the inflation, we reduce the effectives of combating the volatility in the foreign exchange market. Understanding and solving this dilemma would help increase the effectives of the transmission mechanism for the monetary policy not only in Romania, but for other emerging economies as well.

References

Aguiar-Conraria, L., & Soares, M. J. (2011). Business cycle synchronization and the Euro: A wavelet analysis. *Journal of Macroeconomics*, *33*(3), 477-489. https://doi.org/10.1016/j.jmacro.2011.02.005

Aguiar-Conraria, L., & Soares, M. J. (2014). The Continuous Wavelet Transform: Moving beyond uni- and bivariate analysis. *Journal of Economic Surveys*, *28*(2), 344-375. https://doi.org/10.1111/joes.12012

Andrieș, A. M., Căpraru, B., Ihnatov, I., & Tiwari, A. K. (2017). The relationship between exchange rates and interest rates in a small open emerging economy: The case of Romania. *Economic Modelling*, *67*, 261-274. https://doi.org/10.1016/j.econmod.2016.12.025

Branson, W. H., Halttunen, H., & Masson, P. (1977). Exchange rates in the short run: The dollar-dentschemark rate. *European Economic Review*, *10*(3), 303-324. https://doi.org/10.1016/S0014-2921(77)80002-0

Calvo, G. A., & Reinhart, C. M. (2002). Fear of Floating. *The Quarterly Journal of Economics*, *117*(2), 379-408. https://doi.org/10.1162/003355302753650274

Caraiani, P. (2012). Stylized facts of business cycles in a transition economy in time and frequency. *Economic Modelling*, *29*(6), 2163-2173. https://doi.org/10.1016/j.econmod.2012.06.014

Cassel, G. (1918). Abnormal Deviations in International Exchanges. *The Economic Journal*, *28*(112), 413-415. https://doi.org/10.2307/2223329

Gençay, R., Selçuk, F., & Whitcher, B. (2002) *An introduction to wavelets and other filtering methods in finance and economics*. San Diego, CA: San Diego Academic Press.

Ghosh, A. R., Ostry, J. D., & Chamon, M. (2016). Two targets, two instruments: Monetary and exchange rate policies in emerging market economies. *Journal of International Money and Finance*, *60*, 172-196. https://doi.org/10.1016/j.jimonfin.2015.03.005

Grinsted, A., Moore, J. C., & Jevrejeva, S. (2004). Application of the cross wavelet transform and wavelet coherence to geophysical time series. *Nonlinear Processes in Geophysics*, *11*(5/6), 561-566. https://doi.org/10.5194/npg-11-561-2004

Hacker, R. S., Karlsson, H. K., & Månsson, K. (2012). The relationship between exchange rates and interest rate differentials: A wavelet approach. *The World Economy*, *35*(9), 1162-1185. https://doi.org/10.1111/j.1467-9701.2012.01466.x

Hacker, R. S., Karlsson, H. K., & Månsson, K. (2014). An investigation of the causal relations between exchange rates and interest rate differentials using wavelets. *International Review of Economics & Finance*, *29*, 321-329. https://doi.org/10.1016/j.iref.2013.06.004

Hnatkovska, V., Lahiri, A., & Vegh, C. A. (2013). Interest rate and the exchange rate: A non-monotonic tale. *European Economic Review*, *63*, 68-93. https://doi.org/10.1016/j.euroecorev.2013.06.001

Holtemöller, O., & Mallick, S. (2016). Global food prices and monetary policy in an emerging market economy: The case of India. *Journal of Asian Economics*, *46*, 56-70. https://doi.org/10.1016/j.asieco.2016.08.005

Kang, S. H., Arreola Hernandez, J., & Yoon, S. M. (2019). Who leads the inflation cycle in Europe? Inflation cycle and spillover influence among Eurozone and non-Eurozone economies. *International Economics*, *160*, 56-71. https://doi.org/10.1016/j.inteco.2019.10.001

Rua, A., & Nunes, L. C. (2009). International comovement of stock market returns: A wavelet analysis. *Journal of Empirical Finance*, *16*(4), 632-639. https://doi.org/10.1016/j.jempfin.2009.02.002

Sensoy, A., & Sobaci, C. (2014). Effects of volatility shocks on the dynamic linkages between exchange rate, interest rate and the stock market: The case of Turkey. *Economic Modelling*, *43*, 448-457. https://doi.org/10.1016/j.econmod.2014.09.005

Torrence, C., & Compo, G. P. (1998). A practical guide to Wavelet Analysis. *Bulletin of the American Meteorological Society*, *79*(1), 61-78. https://doi.org/10.1175/1520-0477(1998)079<0061:APGTWA>2.0.CO;2