EXPLAINING THE DYNAMICS OF EUROISATION USING ELECTRIC CIRCUITS MODELS WITH EMPIRICAL EVIDENCE*

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Abstract
This paper aims to explain the process of euroisation using the models of electric circuits. The factors that are affecting the dynamics of euroisation of deposits are analyzed using mathematical models from the field of electrical engineering. The results obtained from the model of electric circuits suggest that changes in the currency structure of deposits as a consequence of changes in the interest rate differential can be compared to the electricity flow. The speed of adjustments is defined by the time constant. The theoretical findings are then econometrically tested based on the samples for Serbia in the period from January 2004 to December 2012. the results obtained using the VAR methodology suggest that euroisation of deposits reacts to the change in interest rate differential set in favor of euro-deposits, and this effect diminishes after four months.

Keywords: *euroisation, financial system, foreign exchange rate, depreciation, interest rate spread, R-L circuits, electricity flow, VAR methodology*.

1. INTRODUCTION

Laws from the field of physics have been widely used in explaining different economic phenomena (Săvoiu, 2009). The purpose of this paper is to show the connection between the dynamics of financial euroisation and the rules in electrotechnical science. The flow of local and foreign currency in the financial system is linked to the electricity flow in R-L circuits. Theoretical background covers 8 countries from Central and South-Eastern Europe, while the empirical model is derived on the basis of Serbian data, from January 2004 to May 2012.

Highly euroised countries often suffer from the high dependence on exchange rate movements, since sudden depreciations may jeopardize financial stability as well as the overall economic environment. Probably the most important problem connected with the high euroisation is the fact that liabilities are mainly denominated in the foreign currency and that high depreciations increase the costs of servicing that liabilities expressed in the local currency. In order to act in a way apt to promote macroeconomic stability, and lower the impact of the exchange rate movements on the financial stability, it is necessary to define the strategy that will result in a reduced level of financial euroisation.

Financial euroisation (asset substitution) is an informal form of euroisation which assumes that foreign currency dominates local currency in its function as a store of value. This form of euroisation assumes the euroisation of interest-bearing assets and liabilities. Euroisation of deposits and loans is a problem that concerns many Central and South-Eastern European countries outside the euro area. The level of euroisation varies among the countries from very high levels in Serbia, Croatia, Romania, to lower levels in Poland and the Czech Republic (Table no. 1). What all these countries have in common is the fact that all of them suffered from the macroeconomic crisis in the early 1990s, which resulted in the loss of a confidence into a local currency. High inflation rates from this period eroded the value of local-currency deposits but also resulted in a loss of confidence into local banking sector, which means that savings were placed not only in foreign currency, but also outside the banking sector ("under the mattresses") instead of in bank deposits. Some important changes occurred in 2000s, when the banking sector in these countries started to develop increasingly. Increased competition in the market has played a key role in restoring confidence in the banking sector. After many years, lending activity revived, and the presence of foreign banks made foreign loans more accessible and less expensive, which only intensified further financial euroisation. Although significant progress was made, confidence in the local currency is still not fully regained. This resulted is increase in banking deposits as well as in increased lending activity, but in the first place it intensified the process of euroisation in these countries. Evidence from the recent literature suggests that as long as euroisation promotes financial depth it is considered as positive (De Nicolo, Honohan and Ize, 2005). On the other hand, there is much more evidence in favor of the negative sides of euroisation, such as balance sheet mismatches, fear of floating, weakened interest rate transmission channels. Among those who point to the negative effects of this phenomenon, the most important is the exaggerated impact of exchange rate on monetary and economic trends, which suggests that countries with high levels of financial euroisation become "hostages to fear of floating" (Honohan, 2007), since exchange rate depreciations may threaten the financial stability of the country. Also, the interest rate transmission mechanism becomes weakened due to the fact that the key policy rate has no effect on loans denominated in foreign currency, but only to those in the local (Aleksić, Palić, Đurđević and Tasić, 2008). In this sense, the research is mainly conducted in the way of defining strategies that will result in de-euroisation of the financial system. When defining the optimal strategy, one

should take into account the specific issues of the region and the respective country due to the fact that the process of de-euroisation requires a long period of time.

The rest of the paper is organized as follows: the first section deals with problems that countries in the Central and South-Eastern Europe are exposed to due to high levels of euroisation, and historical factors that caused euroisation. In the second part of the paper the model of the dynamics of euroisation based on a model of RL circuit is presented. The third section presents the empirical evidence on the dynamics of euroisation for the case of Serbia, based on the results of the VAR models and impulse response functions. The last part deals with the conclusions and the implications for the monetary policy of euroised country, as well as the possible areas for further researches.

2. THE PROBLEM OF EUROISATION IN CESEE COUNTRIES

Countries from Central and South-Eastern Europe that are not members of the euro zone are suffering from the problem of eurosiation. The data on the level of euroisation of interest bearing deposits and loans for Poland, the Czech Republic, Serbia, Croatia, Romania, Bulgaria, Albania and Turkey are collected from the respective National Banks' statistics and are presented in Table no. 1. Countries that exhibit lower levels of deposit euroisation mostly also exhibit lower levels of loan euroisation and vice versa. This suggests that banks are trying to match the currency structure of deposits and loans in order to hedge against currency risks.

Table no. 1 Euroisation of deposits and loans in some CESEE countries

Country	Euroisation of deposits	Euroisation of loans
Poland	8.0	34.0
Czech Republic	5.4	8.3
Serbia	88.7	72.4
Croatia	85.3	70.0
Romania	36.5	64.0
Bulgaria	52.7	63.9
Albania	45.0	64.9
Turkey	39.3	32.5

Source: **PNB, CZNB, NBS, HNB RNB, BNB, ANB, TNB and author's calculations**

The data in Table no. 1 also suggest that in these countries the problem of euroisation is not causing the currency mismatch problem to banks, since the currency structure of loans is matched to those of sources of financing, but it may have as a result that in a cases when clients go default, banks become unable to service their liabilities. Many studies have confirmed (Ivkovic, 2008; Luca and Petrova, 2005) that banks match the currency structure of loans with the currency structure of the sources of funding (dominantly savings) in order to hedge against the currency risk. Banks are not exposed to the risk that they will be unable to repay interest on deposits due to different currency structure of active and passive interest rates. The problem for the banks, and consequently for the whole economy, lies in the fact that currency structure of the residents' income and liabilities is not matched. The residents' income is largely denominated in the local currency (in many countries this is regulated by law), while the currency structure of the loans is largely set in favor of the euro (Table no. 1). If residents' liabilities are denominated in foreign currency, the pace of repayment will largely be determined by movements in exchange rates. The increased significance of this phenomenon is obtained in cases of sudden depreciation shocks, resulting in increased local-currency debt payments related to foreign currency. In such cases, the problem for the banking system, as well as for the whole economy, is that in cases of high depreciations, debtors are unable to repay bank debt, which may have banking crisis as a result.

From the data on deposit and loan euroisation, we can conclude that the above-mentioned countries differ in the level of euroisation. Since all these countries started from the high levels of euroisation in 1990s, we can conclude that they experienced different dynamics in de-euroisation. Deposit euroisation in Poland fell from about 80% in 1990s to below 10% in 2012, while euroisation in Serbia remained persistent and is still moving around the level of above 80%. The common factor for all these countries, except for Croatia and Bulgaria, is inflation targeting (IT) framework and managed floating exchange rate regime (Bulgaria adopted the currency board in 2003 and Croatia's exchange rate regime is tightly managed). According to the most prominent literature in this field, inflation targeting combined with freely floating exchange rate should lead to decrease in euroisation levels (Ize and Yeyati, 2003). The intuition behind this is quite clear, since the agents decide to save in a less risky currency. As long as home-currency savings are less risky relative to foreign-currency savings, the increase in home-currency savings will come as a result. The evidence from the Central and South-Eastern European countries suggests that there exist some other factors that drive the dynamics of euroisation.

This paper tries to explain that there are other factors that determine the dynamic of euroisation/de-euroisation of deposits. The model presented in this paper is based on the model from Rajković and Rajković (2013) and deals with empirical findings for the case of Serbia. This model differs from the above mentioned in the fact that it deals only with the euroisation of interest bearing deposits.

The subject of this paper is the dynamics of de-euroisation as a result of changes in interest rate differential in favor of one of the currencies. Bearing in mind that the interest rate differential is a cost for borrowers and an income for those who save, we tried to explain the dynamics of de-euroisation using the model of RL circuit assuming that incentives come in the form of interest rate differential.

3. MODEL R-L CIRCUIT

As long as interest rates in the short run follow uncovered interest rate parity (UIP), higher depreciation rates will result in higher levels of deposit euroisation in the short term, and due to the high persistence, this trend is

likely to continue in the future. Uncovered interest rate parity assumes that the spread between local-currency deposits interest rates and foreign currency deposits interest rates is set to be equal to the expected depreciation. If the interest rate on domestic deposits is higher than that on foreign currency deposits, home currency must depreciate in the following period, otherwise, there would exist the possibility for arbitrage.

Assuming that the economic activity is carried out in the bi-currency system, and since the euro is dominant foreign currency in the currency structure of deposits and loans, we refer to euro as a foreign currency. This assumption is reasonable given that more than 70% of loans and deposits in foreign currencies are denominated or indexed in euros.

Agents' decisions on the currency structure of savings or borrowings are based on the real interest rates. Real interest rates on home-currency or foreign-currency deposits and loans are given by the following expressions:

$$r_{t+1}^{H} = i^{H} - \pi_{t+1} \quad (1)$$

$$r_{t+1}^{F} = i^{F} + e_{t+1} - \pi_{t+1} \quad (2)$$

where r^H and r^F are the real interest rates on home-currency and foreign-currency deposits (loans), respectively, i^H and i^F stand for the nominal interest rates, e for the rate of change of the nominal exchange rate and π for the rate of inflation. Nominal interest rates are assumed to be fixed during the life of the contract. If we assume that at the beginning of the period nominal interest rates are determined to satisfy the uncovered interest parity condition, any deviation from this parity comes from the difference in the rates of depreciation.

The real interest rate differential is defined as expected difference between real interest rates on deposits in foreign currency and those in local currency ($E_t(r_{t+1}^F - r_{t+1}^H)$). If uncovered interest rate parity holds than $E_t(r_{t+1}^F - r_{t+1}^H)=0$ and agents are indifferent between savings or borrowings in home or foreign currency, because they will earn the same interest. On the other hand, whenever the UIP condition is violated, one of the options will be more profitable. The deviations from the UIP come from the unexpected depreciations of the local currency. For example, if in period t+1, depreciation rate is higher than the one predicted by UIP condition, than interest rate differential will be in favor of foreign currency deposits.

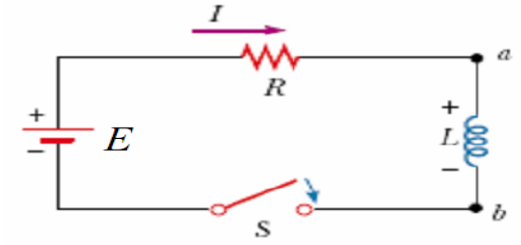
This model assumes that at the beginning of the period, UIP holds, and that agents make their decisions based on other factors. At the end of the first period, they can observe the interest rates, as well as realized depreciation rate and then make decisions on the reallocation of their savings. In this setup, the interest rate differential is what drives the process of euroisaiton (de-euroisation).

We used the RL circuit for the modelling of the dynamics of the financial euroisation (de-euroisation). The increase in domestic-currency savings, or a decrease in financial euroisation will occur if over some period of time real interest on domestic-currency savings is higher than that for foreign currency savings.

Savings in local currency will be more profitable than savings in the foreign currency if the differential between the interest rates on the local and foreign currency deposit higher than depreciation. This means that the depreciation of the dinar, which is above that accrued in the nominal interest rate according to the uncovered interest parity, increases the euroisation of deposits, while depreciation below the expected level reduces the euroisation of deposits.

The assumption of fixed nominal interest rates is in accordance to the fact that interest rates are mostly determined by the contract, and do not change until the termination of the contract, and on the other side exchange rates are changing on a daily basis. Periods in which the exchange rate is growing rapidly are alternating periods when the rate may fluctuate or decline slightly.

The model of RL circuit is presented in the Figure no. 1.



(1)

Figure no. 1 The model of RL circuit.
Source: Authors' illustrations

The same form of the circuit is used to explain the dynamics of financial euroisation depending on the movements of interest rate parity and exchange rate changes. The parameters R and L in electretechnics stand for resistance and inductance, and have their physical units: R_u is measured in Ω (ohm) and L_u is expressed in H (henry). Parameters R and L determine the time constant τ.

In the model of financial euroisation, *E* (Expression no. 3) is an incentive for borrowing in local currency and in foreign currency (voltage in electrical circuits). In this model, E is the differential in real interest rates on savings deposits in home currency and foreign currency deposits in the event of deposit euroisation. It is given by the following expression:

$$E = r_{t+1}^{H} - r_{t+1}^{F} \quad (3)$$

The incentives for changes in the currency composition of savings and loans occur if the uncovered interest rate parity condition is violated, or if the interest rate differential is such that favors one of the currencies. Expression E stands for the interest in investing in home-currency or foreign currency savings to achieve interest or to preserve the value of money. E can be thought of as "financial force" that in the "financial circuit" is driving the money flow.

When E <0, the deposit euroisation rate increases, (euros are flowing through the circuit). When E> 0, euroisation rate decreases (local currency is flowing through the circuit).

Periods in which home-currency savings are more profitable than foreign-currency savings alternate with the

periods in which foreign-currency savings are more profitable, and so on. We expect that agents will react on the change in interest rate differential by switching from home-currency deposits to foreign-currency deposits depending on the sign of interest rate differential.

Reactions of the euroisation share may be presented by different models of RL circuits with different values of time constant τ (Figure no. 2). This figure shows two different RL circuits depending on the time constant τ. When the time constant is low, the shock in independent variable will be spilled over the dependent variable in very short period of time, while in the case of high time constant, this process will last for a longer time.

Both of these circuits are of the same shape, the only thing they differ in are parameters R and L, and the time constant they determine τ = R / L

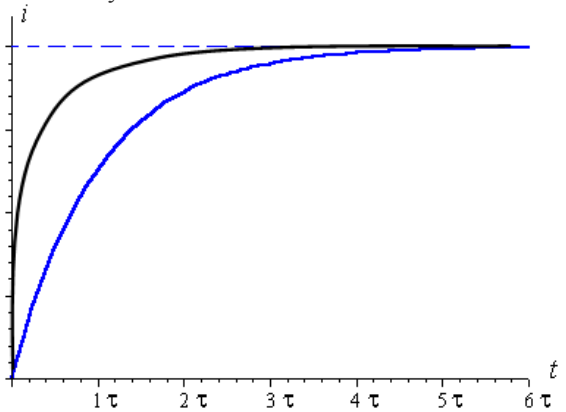


Figure no. 2 Graphic I = f (t) in the time constant τ1- reduction dinar savings and τ2 - time constant increases dinar savings

Source: Authors' illustrations

In the electric circuit, I stands for the electric power, the amount of electrical charge per unit of time elapsed through the circuit. It is explained by the following expression:

$$I=dQ/dt \quad (4)$$

In this model, I is actually the amount of the units of local currency or euros, which is placed as savings, or raised from the bank in the unit of time.

In addition to the graphic representation of the model in the form of an electric circuit (Figure no. 2), the model can also be displayed in a mathematical form, and solved by the rules and fundamentals the theory of electrical circuits.

According to Ohm's law for the transition process, which occurs in the circuit, after turning the switch S (Figure no. 1), the following differential equation can be written:

$$E = RI + L\frac{dI}{dt} \quad (5)$$

Differential equation (5) can be written in the form:

$$E - IR - L\frac{dI}{dt} = 0 \quad (6)$$

The equation will be solved by introducing the following:

$$x = \frac{E}{R} - I \qquad dx = -dI \quad (7)$$

$$x + \frac{L}{R}\cdot\frac{dx}{dt} = 0 \quad (8)$$

$$\frac{dx}{x} = -\frac{R}{L}dt \quad (9)$$

$$\ln\left(\frac{x}{x_0}\right) = -\frac{R}{L}t \quad (10)$$

$$x = x_0 \cdot e^{-\frac{Rt}{L}} \quad (11)$$

Based on the initial conditions: I = 0, at time t = 0, x_0 is calculated:

$$x_0 = \frac{E}{R} \quad (12)$$

$$x = \frac{E}{R}\cdot e^{-\frac{R}{L}t} \quad (13)$$

$$\frac{E}{R} - I = \frac{E}{R}\cdot e^{-\frac{R}{L}t} \quad (14)$$

$$I = \frac{E}{R}\cdot\left(1 - e^{-\frac{R}{L}t}\right) \quad (15)$$

The time constant τ is defined as follows:

$$\tau = L / R \quad (16)$$

and Equation (14) can be written as:

$$I=E/R(1-e^{-\tau t}) \quad (17)$$

4. EMPIRICAL EVIDENCE

The results from the model presented in the previous section are econometrically tested on the data set for Serba from January 2004 to May 2012. We considered only interest-bearing deposits of households and entreprises (transaction deposits are excluded from the analysis). Since the time series on the currency structure of interest rates on deposits is very short (from September 2010), we estimated the real interest rate spread by depreciation rates (Rajković, 2012). The euroisation share is approximated by the share of interest-bearing deposits denominated or indexed in euros in total interest bearing deposits. In Serbia this ratio varied within the range of 81% to 89% which is a very high level.

In this model, depreciation rates stand for E, which is actually the driver of changes in the currency structure of depostis. We expect that higher depreciation rates will lead to changes in the currency structure of deposits towards the foreign-currency depostis. We also do not expect that the whole amount of depostis will be converted to foreign-currency deposits, since there are other factors different from the profit-maximization that drive the dynamics of euroisation.

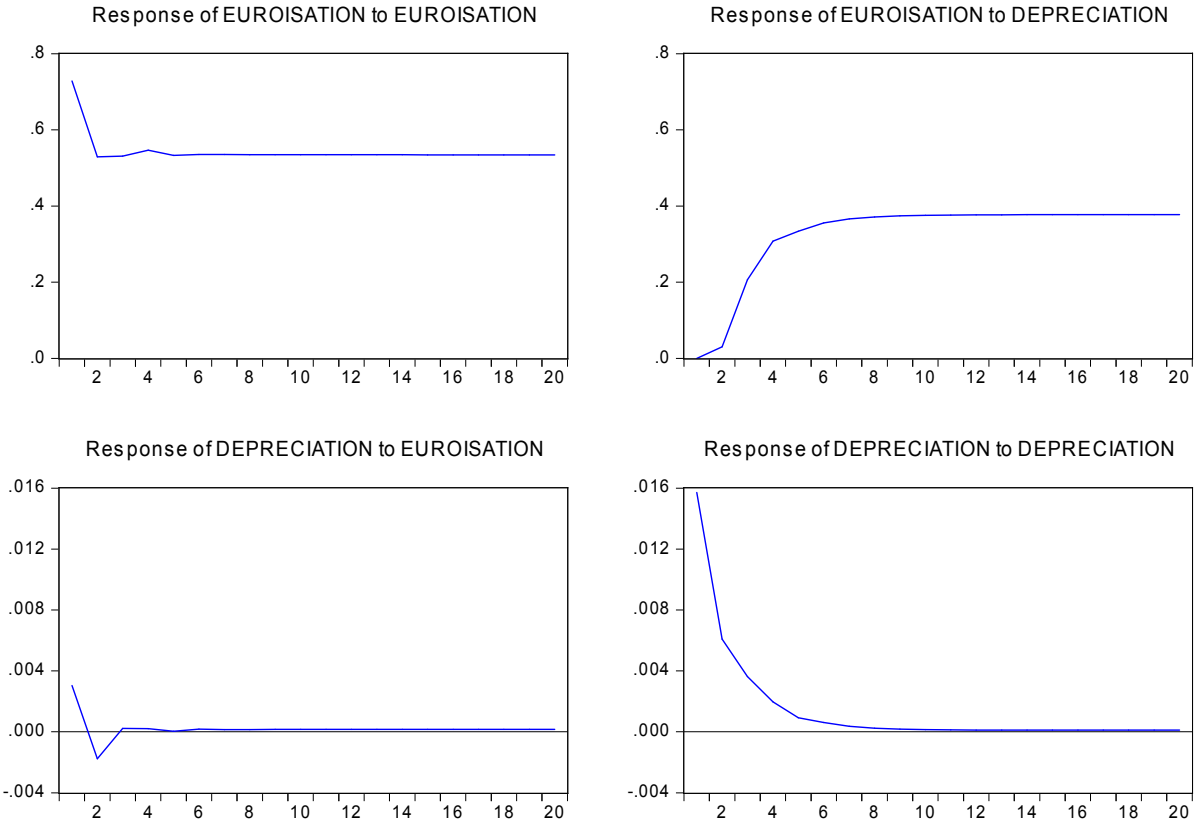
In order to econometrically test the findings from the theoretical model, we estimated VAR model for deposit euroisation and then estimated the impulse response function. The graphical representation of impulse response function is given by Figure no. 3. As expected, estimated coefficient for the depreciation rates is statistically significant and possitive, which suggest that increases in relative value of euro increase euroisation share. If agents

maximize the profit expressed through interest rates, they will react on depreciaiton of the dinar by switching their depostis to euro-denominated deposits.

Figure no. 3. presents how the euroisation share reacts to the shock of depreciation rates. The shape of the impulse response function looks like the function from the Figure no. 2 with the low time constant. This means that, for the case of Serbia, the currency structure of deposits is very sensitive to the changes in interest rate differential. This analysis proves the relationship between the increase in euroisation as a consequence of sudden depreciation.

Econometrical analysis suggests that the number of periods after whics effects of depreciation on euroisation share will diminish will dissapear is 4. This confirms the statement that the proces for Serbia may be defined by the low time constant. What is not formally tested in this paper is what determines the value of time constant, and this may be the topic for the further research.

Figure no. 3. Impulse response function from the regression of deposit euroisation to depreciation rates



Source: Authors' calculations

5. CONCLUSION

The results of this study may be important in explaining the dynamics of deposit euroisation. The analogy observed between the motion of electrons under the influence of electromotive force in the electric circuit and the cash flow under the influence of interest rates, explains why the interest rate differential set in favor of the foreign currency leads to an increase in euroisation.

For the financial circuits we applied the equations for Kirchhoff's laws and Ohm's law and the electric circuit.

The model derived in this paper points to the importance of confidence in the local currency when determining the dynamics of de-euroisation.

In the process of euroisation, what matters is the time constant. In the case of Serbia it is estimated at 4, which means that after four periods (in this case four months) the effects of depreciation to euroisation share will disappear. By increasing the time constant, the dynamics of euroisation would change and the deposits would not be converted from local-currency to foreign currency that quickly. The value of the time constant is determined by the level of confidence in the currency. With the growth of confidence in the local currency, the time constant would be increased, and incentives for de-euroisation in the form of interest differentials would be relatively quickly resulted in the overflow of the euro-deposits in the local-currency deposits.

The theoretical model presented in this paper provide a good basis for further research on this topic, as well as space for empirical work to determine the numerical values of the coefficients that determine the dynamics of dinarisation.

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