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Romanian Interbank Interest Rates and Central Bank's Monetary Policy

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Abstract

Interbank rates are affected by the monetary policy of a country and represent a link to other financial and credit markets. In 2007, Romania became a member of the European Union and its central bank, the National Bank of Romania (NBR), joined the European System of Central Banks (ESCB) but not the Eurosystem. This paper analyses the role of the central bank and the use of its instruments concerning interbank rates. The research evaluates the influence of the Romanian Central Bank on interbank rates and shows that the policy rate and bank liquidity are among the main determinants of interbank rate movements. It is also presented that the NBR's deposit and lending rates can limit the free movements of the interbank rate of interest. This research confirms that interbank interest rates influence bank rates strongly. The methodology used in this research includes cointegration, dynamic econometric measurement and analyses with Granger causality. Our research uses mainly ROBID and ROBOR of different maturities, showing that the influence of the Romanian Central Bank (NBR) on the interbank rate is strong, while the influence of the ECB and Fed is weak.

Keywords: interbank interest rates; Romanian Central Bank (NBR); liquidity; bank interest rates; European Central Bank (ECB); Fed; Eurozone; Robor and Robid.

JEL classification: E430, E520, G170.

1. INTRODUCTION

The importance of interbank interest rates in Romania is well-known based on the influence they have on the banking system's interest rates of both loans and deposits. Simultaneously, the National Bank of Romania (NBR) strongly influences interbank interest rates through fixing the official interest rates as well as through its decisions regarding liquidity.

In particular, interbank rates tend to follow the official rate's movement and can be reduced by an increase in liquidity. There is a relationship between the determination of official interest rates by the NBR and interbank rates. The lending facility usually

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corresponds to a ceiling of overnight rates that is found on the money market. The interest rates on deposit facility correspond to a floor of overnight rates on the money market. These constraints also have an impact on the interbank interest rates of maturities of different periods, from overnight to those of twelve months. In this case, the most important instrument of monetary policy is represented by open market operations. They include repo operations; deposit-taking operations; issuance of certificates of deposit; reverse repo operations- liquidity-absorbing reverse transactions, credit operations against eligible assets as collateral; outright sales/purchases of eligible assets; and foreign exchange swaps. The aforementioned are tools that a central bank can use to change the liquidity available in the money market. This situation can move the interbank interest rates from a low- to a middle- or high-level, from a floor to a ceiling, or *vice versa*. For one-month to annual maturities, market expectations on the future path of official interest rates also become relevant as a further tool that a central bank can use to modify market interest rates. Moreover, in the case of a risk inside or outside a country's interest rate market, internal interest rates could increase, causing a central bank to increase liquidity in order to protect its domestic market.

International competition at the level of the money market generates changes in national and international monetary policies. Decisions made by the ECB and the US Federal Reserve Board (the Fed) certainly influence Romanian interest rates.

There are two different measures for any interbank interest rate maturity. One is ROBID, which represents the demand of operations in the interbank market, while the other is ROBOR, which represents the supply of operations in the interbank market. ROBID is smaller than ROBOR. (However, on two days ROBID is greater than ROBOR for maturities of six and nine months).

This paper is organized as follows: The Romanian monetary policy transmission mechanism with its corresponding literature review is examined, after the introduction, in the 2nd Section. The influence of Romanian interbank rates on bank interest rates is presented in the 3rd Section. The equilibrium relation between interbank interest rates, policy rates and liquidity is analysed in the 4th Section, by means of cointegration techniques. In the 5th Section, the explanatory variables employed in the dynamic equations of interbank interest rates are presented, while dynamic estimated equations are described in the 6th Section. In the 7th Section some conclusions are presented.

2. A SHORT DESCRIPTION OF THE ROMANIAN MONETARY POLICY TRANSMISSION MECHANISM AND A SURVEY OF THE LITERATURE

In 2007, when Romania joined the European Union, the Romanian Central Bank became a member of the European System of Central Banks (ESCB). The central bank members of the ESCB have as their central goal to maintain price stability. The Eurosystem has several important tasks: the first is the definition of monetary policy, followed by the coordination of foreign exchange operations, the management of Euro-area foreign currency reserves and the promotion of an efficient operation of payment systems. Central banks not belonging to the Eurosystem, such as the Romanian Central Bank, are independent, but share similar tasks.

However, Falagiarda et al. (2015) sustain that the Fed influences emerging markets, including Romania, and that "ECB monetary policy announcements" affect Central and

Eastern European countries that "follow inflation targeting monetary policy regime with freely or managed floating exchange rate regimes" such as Romania.

When describing liquidity in Romania, Croitoru (2013) considers that the global financial crisis affected the Romanian "autonomous component of liquidity and liquidity supply composition". The decline in the net autonomous component of liquidity below the levels of liquidity demand brought a liquidity deficit. This author shows that the liquidity deficit generated the increase in the NBR's liquidity supply, causing the Central Bank of Romania to be transformed "from a net debtor to a net creditor of the banking system until March 2010".

According to Ciobanu (2012), for the period from 2007 to 2012, the liquidity premium was stabilized because the increase of investments and the term premium stayed constant at 2.6 percent. These factors implied the possibility for the NBR to indirectly influence interest rates for almost one year, using open market operations with shorter maturities, having rates that kept being cointegrated.

Concerning Romanian interest rates, Enache and Radu (2015) concluded that "changes in the money market interest rate are fully passed on in the long-run to interest rates on new loans and deposits". They also present the importance of consumer credit for Romanian households from 2005 to 2014 (2015, p. 27).

The NBR policy rate affects the interbank interest rates that together with foreign interest rates and risk premiums affect the exchange rate. The interbank interest rate also affects interest rates on loans and deposits that together with the exchange rate, external demand, and fiscal and income policy affect the output, and the GDP gap. The Output gap, inflation expectations and the exchange rate affect inflation. The NBR's transmission mechanism for medium term analysis takes the following form presented in Diagram no. 1.

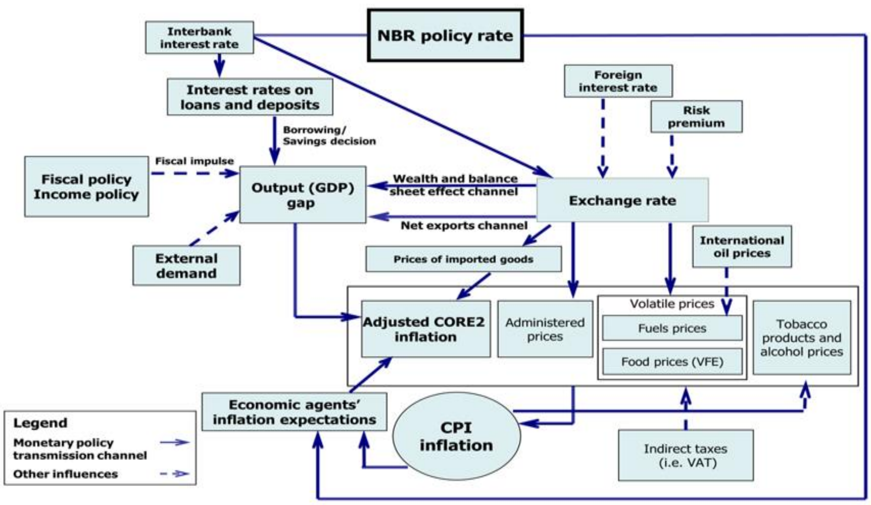


Diagram no. 1 – Monetary Policy Transmission Mechanism
Source: Banca Nationala a Romaniei (2019)

The central bank through its monetary policy affects the financial system and the relationship between commercial banks. In the short-run it is easy for the central bank to control interest rates based on its capacity to manage the liquidity that is available in the market. The only issue here is the time lag between the transmission of monetary policy from the central bank to the real economy, a time lag that depends on the structural characteristics of the domestic economy of the country.

Short-term interest rates are controlled by the central bank and the real economy is affected especially by medium- and long-term deposits and lending rates charged for customers of commercial banks. The level of lending rates in the medium- and long-run depend on the interest rate and on other factors including different expectations concerning inflation and economic growth. The lending rates affect the level of consumption, investment and savings.

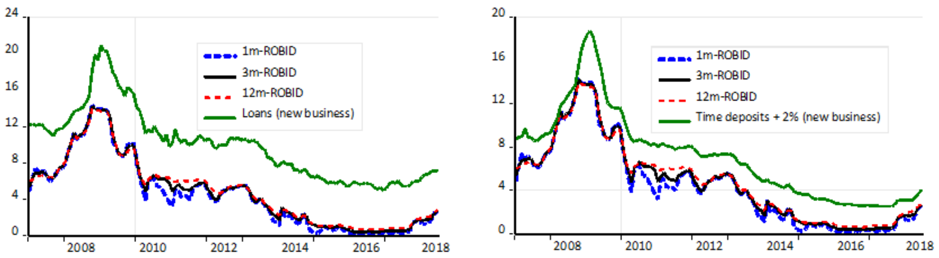
The relationship between exchange rates and interest rates has been studied by Andries et al. (2017).

Overall, the existing literature is interesting, but not ample, in particular with regard to econometric analyses. There is room for a new study on the determinants of interbank interest rates in Romania. For example, bank liquidity seems to play no role in the NBR's transmission mechanism scheme, while it is particularly relevant in the ECB's and Fed's opinions. The question to answer in this context is: *What is the role of bank liquidity in Romanian interbank markets?*

The next parts of this paper present an econometric analysis of Romanian interbank interest rates.

3. THE LINKS BETWEEN ROMANIAN INTERBANK AND BANK INTEREST RATES

The relevance of interbank rates for the formation of loans and bank deposit rates emerges from Figure no. 1. The level of loan and deposit rates is higher and parallel to the interbank rates (from one to twelve months of maturity): the two markets are strongly correlated. Integration tests (Table no. 1) show that all series are I(1), i.e. integrated of the first order. Moreover, all of the cointegration tests indicate that bank and interbank rates are cointegrated. The value of their equilibrium coefficients is near 1, meaning that the value of the bank rates are approximately equal to the interbank interest rates plus a constant. Granger causality tests applied to the same variables (Table no. 2) confirm that the causality comes from the interbank market to the bank market and not *vice versa*. This result is consistent with the hypothesis that the interbank market represents the connection between the credit market and the monetary policy of the NBR.



Loans (new business) *Time deposits (new business)*

Figure no. 1 – Interest rate on loans and interbank rates

Source: Authors' elaboration of Romanian Central Bank's data. Average monthly data, Jan. 2007 – Jun. 2018

Table no. 1 – Interbank and bank interest rates; integration and cointegration tests

		Loans (new business) Unit root test: ADF=0.8107; P-P=0.7083			Time deposits (new business) Unit root test: ADF=0.5907; P-P=0.7273		
		ROBID 1m	**ROBID 3m**	**ROBID1 2m**	**ROBID 1m**	**ROBID 3m**	**ROBID 12m**
Unit root test	ADF	0.6353	0.6632	0.6485	0.6353	0.6632	0.6485
	P-P	0.6950	0.7906	0.7710	0.6950	0.7906	0.7710
No. of CE(s):							
Trace Statistic	None	0.0001***	0.0002***	0.0008***	0.0052***	0.0012***	0.0023***
	At most 1	0.0942*	0.0899*	0.0780*	0.1311	0.1622	0.1971
Max-Eigen Statistic	None	0.0002***	0.0003***	0.0014***	0.0071***	0.0014***	0.0025***
	At most 1	0.0942*	0.0899*	0.0780	0.1311	0.1622	0.1971
Cointegrating Eq.:							
Coint coef.		-0.9679	-0.9664	-0.9528	-0.9477	-0.9422	-0.9239
SE(coef.)		(0.0342)	(0.03225)	(0.0346)	(0.0348)	(0.0245)	(0.0235)
Prob(coef. = -1)		0.3741	0.3328	0.2320	0.1849	0.0502*	0.0174**
Const.		5.458	5.206	5.046	0.650	0.398	0.237

*ADF = Augmented Dickey-Fuller test statistic; P-P = Phillips-Perron test statistic; Average monthly data, Jan. 2007 – Jun. 2018; ***/**/* = Null hypothesis rejected at 1, 5, 10% of probability respectively.*

Source: Authors' elaboration of Romanian Central Bank's data

Table no. 2 – Interbank and bank interest rates; Granger-causality test

		Loans (new business) ROBID			Time deposits (new business) ROBID		
	Coefs of:	**1m**	**3m**	**12m**	**1m**	**3m**	**12m**
Interbank rate does not Granger-cause bank rate	Change t-1	0.0008	0.0811	0.3003	0.0001	0.0455	0.2189*
	Diseq. t-1	-0.31***	0.09***	-0.28***	-0.12**	-0.18***	-0.16***
	Wald test Chi-square	0.000***	0.000***	0.000***	0.031**	0.002***	0.000***
Bank rate does not Granger-cause interbank rate	Change t-1	0.0978	0.1120	0.0811	0.3341*	0.1687	0.0789
	Diseq. t-1	0.0702	0.0994	0.0903*	-0.0639	0.0367	0.0736
	Wald test Chi-square	0.5295	0.2587	0.1306	0.1359	0.5006	0.4382

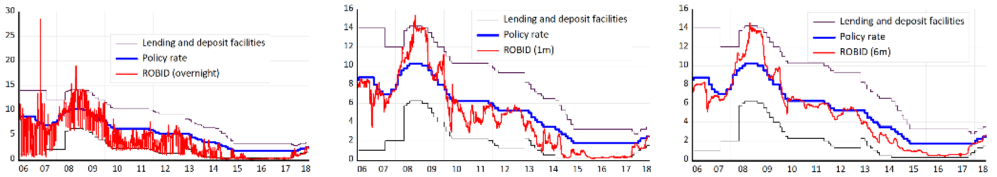
*Wald test: Chi square probability for joint hypothesis of both coefficients = 0; Average monthly data, Jan. 2007 – Jun. 2018; ***/**/* = Null hypothesis rejected at 1, 5, 10% of probability respectively.*

Source: Authors' elaboration of Romanian Central Bank's data

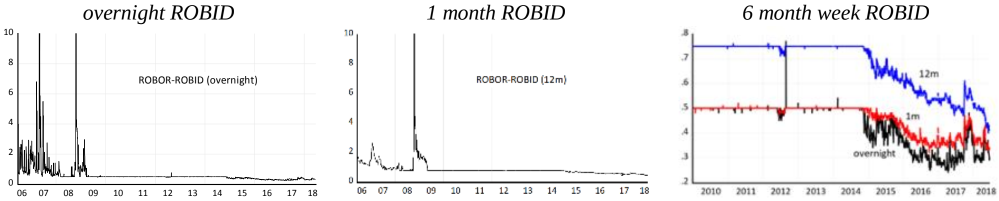
4. INTERBANK INTEREST RATES, POLICY RATES AND LIQUIDITY: THE EQUILIBRIUM

An example of the connection between interbank interest rates and central bank rates is reported in Figure no. 2. In the same figure the Robor-Robid spread is also shown. [*The complete set of figures for different maturities is available on request. The same also applies to the rest of the figures of this article*].

Robid rates tend to follow the NBR's "policy rates" (*NBRpr*), with usually the NBR's lending and deposit facility rates (*NBRlend* and *NBRdep*) respectively usually acting as a sort of ceiling and floor for interbank rates. Robor interest rates are higher and more volatile than Robid interest rates, with both volatilities decreasing with maturity. This is consistent with the well-known hypothesis that long maturity interest rates are connected to the mean values of current and expected future short-term interest rates. Figure no. 2 also shows that the spread between Robor and Robid interest rates is higher for longer maturities. This difference was higher and irregular until 2009, but from 2010 to 2014 the difference between the two rates became smaller and almost constant, decreasing starting in 2015. Nonetheless, Robor and Robid seem strongly connected, meaning that it is possible to study just one of the two rates. Since Robid is less volatile than Robor, the authors decided to select the former since it does not present extreme outliers in the first years. In our integration and cointegration analysis, however, the mean value of Robid and Robor, i.e. (Robor+Robid)/2, has been employed (cleared of their "outlier" values).



overnight ROBID *1 month ROBID* *6 month week ROBID*



overnight ROBOR - ROBID *1month ROBOR - ROBID* *1m and 12m ROBOR – ROBID since 2010*

Figure no. 2 – Interbank interest rates, Policy rate, Lending facility and Deposit facility rate

Source: Authors' elaboration of Romanian Central Bank's data. The spread ROBOR-ROBID has been cut at 10%. Daily data, Jun. 2006 – Jun. 2018

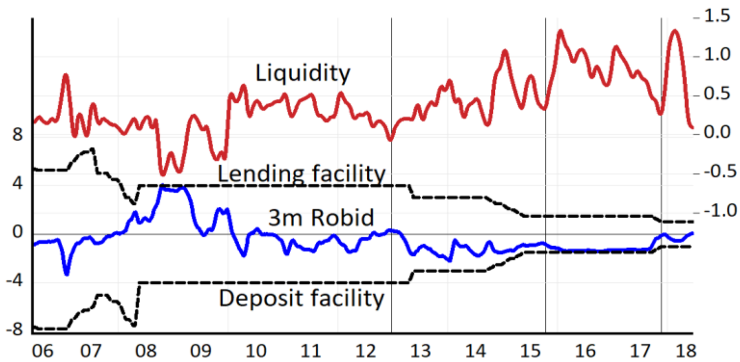


Figure no. 3 – Spread to Policy rate of Interbank interest rates, Lending facility and Deposit facility rate, and amount of liquidity

Source: Authors' elaboration of Romanian Central Bank's data; Three month moving average

Figure no. 3 shows the influence of liquidity (*Kliq*) on the interbank interest rate (3m-Robid minus the policy interest rate NBRpr), where liquidity Kliq is measured by the difference between the amount of deposit and lending facilities[1].

The inverse relationship between the interest rate spread and liquidity is apparent. It is also apparent that the relationship is stronger when Robid is father from the interest rates of the Lending and Deposit facility. For example, when Robid is near the Deposit facility rate, an increase in liquidity cannot reduce the interbank interest rate significantly owing to the "floor effect" due to the deposit facility rate.

Integration tests are reported in Table no. 3. They refer to mean interbank interest rates of maturity *m* (RODID*m*+ROBOR*m*)/2, the policy rates (*NBRpr*, *NBRdep* and *NBRlend*) and liquidity *Kliq*. All interest rates are I(1), i.e. integrated of the first order, apart from Klig that is I(0), i.e. stationary.

Table no. 3 – Integration tests for Romanian interbank and policy interest rates

variables	**maturity**					
	1w	**1m**	**3m**	**6m**	**12m**	**overnight**
ROBIDm	0.8629	0.7824	0.9079	0.9811	0.9928	0.4999
NBRpr	0.8753					
Kliq	0.0039***					
NBRdel	0.6269					

*Integration test: ADF. Cointegration test between ROBID and NBRpr with liquidity Kliq as exogenous variable; Hypothesized No. of CE(s): Trace Statistic, MacKinnon-Haug-Michelis (1999) p-values; normalized cointegrating coefficients (standard error in parentheses), four lags. Period: 20/06/2006-24/04/2007, 16/05/2007-15/10/2008, 3/11/2008-20/06/2018. ***/**/* = Null hypothesis rejected at 1, 5, 10% of probability respectively.*

Source: Authors' elaboration of Romanian Central Bank's data

In Table no. 4 the cointegration tests between the interbank rates and the NBR's monetary policy rate and liquidity are reported. Unfortunately, cointegration results obtained by means of Johansen's procedure could not answer all of the questions about the equilibrium coefficient of interbank interest rates. Interbank and NBRpr are cointegrated, but coefficient values come from 1.17 (overnight) to 1.33 (12m maturity) while in the Eurozone the corresponding value is near 1 (e.g. Hlebik and Verga, 2015).

Table no. 4 – Johansen estimations of (ROBIDm+ROBORm)/2 interbank rate equilibrium

			maturities					
			overnight	**1w**	**1m**	**3m**	**6m**	**12m**
Cointegration test: Interbank rate and NBRpr	No of CE(s)(°)	None	0.000***	0.000***	0.002***	0.010***	0.030**	0.049**
		At most 1	0.5863	0.5943	0.6685	0.6999	0.8792	0.8859
	Coint. vector NBRpr		-1.1750	-1.2659	-1.3649	-1.3537	-1.3423	-1.3326
			(0.0459)	(0.0520)	(0.0879)	(0.0813)	(0.0802)	(0.0835)
Cointegration test: Interbank rate and NBRpr (exogenous variable: Kliq(t-1))	No of CE(s)(°)	None	0.000***	0.000***	0.000***	0.000***	0.000***	0.002***
		At most 1	0.6853	0.7004	0.5391	0.2232	0.0731*	0.0587*
	Coint. vector NBRpr		-0.9143	-1.0189	-1.0949	-1.0857	-1.0625	-1.0690
			(0.0557)	(0.0587)	(0.0944)	(0.0849)	(0.0920)	(0.0997)
	dyn coef of Kliq(t-1)		-0.442^^^	-0.154^^^	-0.032^^^	-0.020^^^	-0.014^^^	-0.011^^^

*Interbank rates ° = (ROBIDm+ROBORm)/2; lags=2; Period: 21/06/2006-20/04/2007, 11/05/2007-15/10/2008, 29/10/2008-20/06/2018; (°) Trace Statistic: MacKinnon-Haug-Michelis (1999) p-values; ***/**/* = Null hypothesis rejected at 1, 5, 10% of probability respectively; ^^^ Null hypothesis of coefficient=0 rejected at 1% of probability. In brackets (): standard deviation.*

Source: Authors' elaboration of Romanian Central Bank's data

When liquidity is introduced as an exogenous variable, NBRpr equilibrium coefficients become nearer to one, but it is known that the usual cointegration tests lose validity when exogenous variables exist; also the number of cointegration vectors is not well-defined. Nonetheless, in the next paragraphs it will be found that the coefficients of Kliq in the interbank rate variations are negative and highly significant. In other terms, cointegration analysis confirms that BNRpr and liquidity are relevant for interbank rates, but doubts remain about the policy rate coefficient. Some more information will be obtained when examining the dynamic of ROBID.

5. DYNAMIC EQUATIONS OF INTERBANK INTEREST RATES: THE EXPLANATORY VARIABLES

The equations considered in estimating the daily dynamics of Romanian interbank interest rates include the following list of variables. They were selected both on a theoretical and empirical basis, and can be divided into six groups: (i) Romanian official interest rates, (ii) foreign interbank market interest rates, (iii) interbank market risk, (iv) expectations about the future monetary policy rate, (v) liquidity, (vi) other indicators of liquidity tension in the banking system.

The detailed list of all regressors is reported here.

1. The *dependent variable*, i.e. the Romanian interbank market interest rates, was identified with ROBID's of the following maturities: overnight, 1w, 1 month, 3, 6, and 12 month (ROBID*m*, where *m* is the maturity) All series are daily, and the period considered is 20/06/2006-20/06/2018. (Source: NBR).

2. *The Romanian official interest rate* (NBRpr): it corresponds to the NBR's monetary "policy rate"; (before Sept. 2011 it was named "*NBR's reference interest rate").* However, "deposit facility" (NBRdep) and "lending facility" (NBRlend) rates are also relevant for interbank rate dynamics. They represent, respectively, a sort of (flexible) ceiling and floor to the interbank market interest rates (source: NBR).

3. *Foreign interbank interest rates*: foreign rates may influence Romanian rates. The most representative are Euribor (E*m*) for the Eurozone, and dollar Libor (U*m*) for the US. Not all maturities are available for Libor, and in this case we selected the nearest to the maturity of any dependent variable ROBID*m*. Foreign interest rates are introduced in variations (De*m* and Du*m*) since their levels were not significant (source: ECB, Fed and EMMI).

4. *Euro interbank market risk* can affect the risk of the corresponding Romanian interbank market. Euro interbank market risk ERISK*m* (where *m* indicates the maturity) is defined as the spread between Euribor and Eurepo of the corresponding maturities (i.e. the spread between the corresponding return on unsecured and secured interbank operations). Before 2002 and since 2014 Eurepo data are not available, but in both periods interbank risks were small in the Euro-area.

5. *Expectations about the future Romanian monetary policy rate*. This variable is more relevant the longer the maturity, and various procedures are available to approximate market expectations. In particular: (i) aggregations of available surveys, (ii) interpreting central bank official communications, and (iii) estimating a sort of central bank's reaction function. We selected the third method, and approximated market expectations of the future change in NBRpr by regressing its actual future change on a group of regressors and

taking its estimated value as a proxy for market expectations. In particular, we supposed that the future change in the Romanian official interest rate depends positively on (i) the excess of actual inflation (ro_infl1) over the NBR's target (infl_target) (i.e.: ro_infl1 - infl_target), (ii) the current annual devaluation of RON with respect to the euro (Dev), (iii) the euro official interest rate (Repo), and (iv) the difference between the Romanian and the ECB's 2 percent inflation target (infl_target - 2).

The equation follows a partial adjustment scheme:

$$E_t[D_h NBRpr_t] \equiv E_t[NBRpr_{t+h} - NBRpr_t] = b_0 + \lambda \, NBRpr_t + b_1 \, (ro\_infl1_t - infl\_target_t) + b_2 \, DEV_t + b_3 \, Repo_t + b_4 \, (infl\_target_t - 2)$$

The expected parameters signs of the regression are $\lambda < 0$, $b_1 > 0$, $b_2 > 0$, $b_3 >$, $b_4 > 0$. We also expect $b_3 \cong b_4 \cong -\lambda$

Since the value of inflation known in *t* refers to the inflation of the previous month, inflation has been introduced in the regression with a one- month delay (Table no. 5). Furthermore, since Robid is listed before the market could know the new official rates and the exchange rates, in all equations explaining interbank market rates, our approximation of the expected future change of NBRpr is introduced with a one-day lag (source: our elaborations on the NBR's and ECB's data).

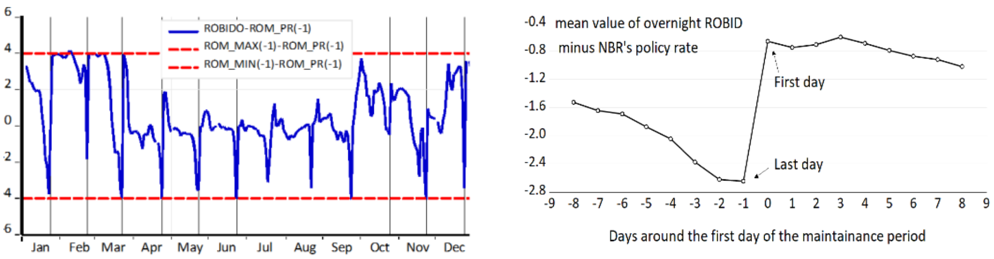
6. *Banks liquidity and NBR's operations with banks*. A first measure of liquidity is the variable kliq (related to the net month liquidity between deposit and lending facilities), and already considered in the previous paragraph and described in note 1. However, the total net daily NBR's liquidity net operations (Net_op) have also been introduced as a further possible explanatory variable for interbank interest rates dynamics[2] (source: our elaborations on NBR's data).

7. *Further indices of bank liquidity and interest rates "seasonality"*. Unfortunately, daily data are not available for Romanian kliq. In any case, it is well-known that the spread between Overnight Robid (ROBIDo) and the NBR's monetary policy rate (NBRpr) is inversely connected to daily bank liquidity, and so its past values may be considered an index of lagged daily liquidity variable. From Figure no. 4, however, it is apparent that a significant "maintenance reserve" cycle of $ROBIDo\text{-}NBRpr_{t-1}$ exists, even if it changes through time. In particular, the spread tends to diminish when moving toward the last days of the "maintenance period", followed by an opposite jump in the first day of the new period (see again Figure no. 4). Since this seasonality changes, slowly, through time, it is not possible to represent it by means of deterministic dummies. Among the explanatory variables of Robid we therefore decided to also include the spread ($ROBIDo\text{-}NBRpr_{t-1}$) at t-1. For the first day of the maintenance period we also included an *ex-ante naïve* approximation of the above mentioned jump (JUMPo)[3], while two dummies (D1 and D5) were introduced for the last 1-5 and 6-10 days of any maintenance period. These two dummies have been multiplied, but the spreads on day t-1 (source: our elaborations on NBR's data for the overnight Robid) also the difference between $ROBIDo_{t-1}$ and its moving average[4] of the previous month (i.e. $MA(ROBIDo_{t-2})\text{-}ROBIDo_{t-1}$) were found to be significant in our estimations.

Table no. 5 – Future change estimations in NBR's policy rate $E_t[D_h NBRpr_t] \equiv E_t[NBRpr_{t+h} – NBRpr_t]$

		1m	3m	6m	1m	3m	6m
C	b0	0.286***	0.867***	1.547***	0.290***	0.874***	1.600***
$NBRpr_t$	λ	-0.132***	-0.382***	-0.646***	-	-	-
(ro_infl1_t - $infl\_target_t$)	b1	0.048***	0.137***	0.211***	0.049***	0.142***	0.238***
Dev_t	b2	0.017***	0.041***	0.045***	0.017***	0.042***	0.048***
$Repo_t$	b3	0.133***	0.405***	0.775***	-	-	-
($infl\_target_t$-2)	b4	0.136***	0.347***	0.444***	-	-	-
Prob($-\lambda=b_3=b_4$)		0.944	0.565	0.022	-	-	-
$Repo_t$ +(infl_target-2)-$NBRpr_t$		-	-	-	0.132***	0.390***	0.692***
Adj R2		0.403	0.669	0.662	0.403	0.669	0.652
SE		0.157	0.262	0.483	0.157	0.263	0.489

Dependent variable: NBRprt+h – NBRprt. HAC standard errors & covariance (Bartlett kernel, Newey-West fixed bandwidth = 9.0000).



Year 2009 *Spread between overnight interbank interest rate and the policy rate: (mean value in 2005-2018)*

Figure no. 4 – The cycle of the overnight interbank interest rate in the required reserve period
Source: Authors' elaboration of Romanian Central Bank's data; Vertical lines indicate the last day of reserve maintenance period.

6. DYNAMIC EQUATIONS OF INTERBANK INTEREST RATES: THE RESULTS

The interest rate employed as a dependent variable in the dynamic analysis is ROBID, that is less volatile than ROBOR, and just with a few anomalous observations. The integration degree of the explanatory variable is 1 only for the NBR's policy rate. Also, the Eurozone (E*m*) and US (U*m*) interbank interest rates (Euribor and Libor) are I(1) (Tables no. 3 and no. 6), but both foreign interest rates appear in our dynamic equations only in variations (i.e. I(0)) since their levels were not found to be significant. The Euro interbank market Risk was I(1) for maturities longer than three months, but it is actually a sort of dummy, being high only during the financial crisis of 2008-2009 and the sovereign debt crisis of 2011-2012. The other variables are all I(0): in practice, the only relevant I(1) explanatory variable is the Romanian official rate NBRpr (and previous cointegration analysis showed it influences the equilibrium value of ROBID of different maturities (ROBID*m*)).

The hypothesis at the base of our interest rates' dynamic equations is that ROBIB*m* follows a so-called "error correction model" of the type:

$$dROBIBm = a + b1NBRprt\text{-}1 + b2ROBIBmt\text{-}1 + j(L)x; \text{ (L is the lag operator)},$$

where NBRpr is the official rate (we verified if b1 = - b2), and x is a set of I(0) explanatory variables[5] influencing the interbank rate.

We expect the variables related to liquidity (Kliq and Net_op) to have a negative influence on the market interest rate[6]. The foreign interest rates (dE*m* and dU*m*) and the risk ERISK*m* are instead supposed to exert a positive effect on ROBID; the same is true also for the expected increase in the Romanian official rate (E[DhNBRpr]). The sign of the variable JUMPo is of course positive in the overnight ROBID (ROBIDo) regression.

Table no. 6 – Integration degree of explanatory variables not included in Table no. 3

variables	test	maturity				
		1w	1m	3m	6m	12m
E*m*	ADF	0.7633	0.7831	0.7447	0.7529	0.7539
	PP	0.7740	0.7701	0.8056	0.8147	0.8188
U*m*	ADF	-	0.0873*	0.1214	0.1141	0.1252
	PP	-	0.0699*	0.1644	0.1477	0.1062
ERISK*m*	ADF	0.0005***	0.0010***	0.0981*	0.1692	0.2764
	PP	0.0000***	0.0015***	0.0595*	0.1255	0.1980
Net_op	ADF	0.000***				
	PP	0.000***				
$ROBIDo\text{-}NBRpr_{t\text{-}1}$	ADF	0.000***				
	PP	0.000***				
	KPSS	<5% ^^				

*Period: June 2006-June2018; For ROBIDo-NBRprt-1 27/04/2007-30/04/2007 excluded. ADF and PP (Philips-Perron) test: ***/**/* = null Hypothesis of a unit root rejected at 1, 5, 10% of probability respectively; KPSS (Kwiatkowski-Phillips-Schmidt-Shin.1992): ^^ = null Hypothesis of stationarity rejected at 5% of probability.*

A problem to be taken into account when estimating the short-run ROBID dynamics is the possible well-known effect of floor and ceiling exercised by the NBR's Lending facility (NBRlend) and Deposit facility (NBRdep) rates, respectfully. Those boundaries, however, do not seem "rigid" and may create some problems in deciding the best econometric tool to estimate the equations.

In this paper, therefore, we have decided to employ three different methods:

- OLS. The usual ordinary least squares, that do not consider the boundary problem (we employed OLS as a sort of econometric benchmark).
- NLS (non-linear least squares as in Hlebik and Verga (2015). If $ROBID^{FREE}$ is the unconstrained equation, the estimation is done under the form:

$$ROBID = ROBID^{FREE} (ROBID^{FREE} \geq NBRdep) (ROBID^{FREE} \leq NBRllend) + NBRdep (ROBID^{FREE} < NBRdep) + NBRlend (ROBID^{FREE} > NBRlend),$$

where with a generic (x>y) corresponds to 1 if x>y is true, otherwise zero. An alternative could have been a TOBIT estimate, but it has the disadvantage of having to specify the presence or not of a "rigid" constraint

- Diseq_LL (The disequilibrium minimum likelihood method). This estimation is based on the assumption that there are always two alternatives: the first one corresponds to the "free" equation, the other corresponds to the floor or ceiling connected to the interest rates on deposit and lending facilities. The estimation corresponds to their average weighted with their corresponding probabilities:

$$R_t = R_t^{FREE} P_1 + R_t^{MIN} P_2 + R_t^{MAX} P_3$$

where P1 is the probability that R1 is a free interest rate (i.e. influenced by neither the floor nor the ceiling interest rates); P2 and P3 are respectively the probability for Rt to be limited by either the floor or the ceiling interest rate. Of course, if P2>0, P3=0; if P3>0, P2=0

The estimation is obtained by maximum likelihood by weighting the probability of being on the unconstrained and on one of the two constrained equations (an outline of this method is given in the "Annex". See also: Kremp and Sevestre (2013) as its main starting point of the procedure). $R^{MIN}t$ and Rt^{MAX} are the measures of floors and ceilings. They are supposed to be connected to deposit and loan facility rates and to be influenced by their lagged values. Their equations are:

$$R_t^{MIN} = NBRdep_{t-1} + \beta_1 + \beta_{12} (R_{t-1} - NBRdep_{t-2}) \text{ and}$$
$$R_t^{MAX} = NBRlend_{t-1} + \beta_2 + \beta_{22} (R_{t-1} - NBRlend_{t-2})$$

- For the overnight rate, the corresponding policy rates known on day t are those on the same day; for the other maturities, the corresponding policy rates known on day t are those of t-1.

Estimated equations are reported in Tables no. 7, no. 8 and no. 9[7]. Lagged variables are consistent with the fact that interbank rates, apart from the overnight rate, are communicated in the morning of every day, i.e. before other variables are known.

The estimations of overnight ROBID (ROBIDo) does not include some variables relevant for other maturities, as the expected change in the official interest rates and Eurozone interbank risk, since they cannot be relevant for a very short maturity (and they were actually not found to be significant). Also, foreign interest rates were not found relevant.

The only important economic variable is the liquidity stock ($Kliq_{t-1}$). Of the other variables, only the change in lagged central bank's operations $d(Net\_op_{t-1})$ exerts a significant and negative impact on the overnight ROBID. The equality between the absolute values of the coefficients of the lagged values, ROBIDo and NPRpr (meaning an equilibrium coefficient of one between them), cannot be rejected only when the Diseq-LL estimator is employed. Particularly relevant are the variables related to the overnight ROBID "seasonality" in the reserve maintenance period: $D1\cdot(ROBIDo_{t-1}\text{-}NBRpr_{t-2})$, $D5\cdot(ROBIDo_{t-2}\text{-}NBRpr_{t-2})$, jump, $MA(ROBIDo_{t-2}, 22)$ $-ROBIDo_{t-1}$, i.e. the variables related to the "seasonality" of the daily changes in the overnight interest rate.

When the estimator employed is Diseq-LL, the relations for ceiling and floor constraints differ. Both constants β_1 and β_2 are significant and negative, but the absolute coefficient is higher for the ceiling (β_1). Moreover, in the floor case, there is a significant persistence ($\beta_{12} > 0$); the value of ROBITo on day t depends on its value on day t-1: $NBRdep_{t-1} -0.0718 + 0.1711(ROBIDo_{t-1} - NBRdep_{t-2})$.

ROBID*m*'s with maturity from one week to 12 months have many characteristics in common, but, at the same time, there are also differences related to their maturity.

The null hypothesis of equality between the absolute value of the coefficients of the dependent variable and of the official rate cannot usually be rejected, confirming a one-to-one equilibrium relation between the two variables for any maturity: this result actually solves a question that remained ambiguous when cointegration was employed. For maturities over three months, however, estimations reported in our tables are explicitly based on the assumption of equality between the two coefficients since only in that case the parameter significance is sufficiently high. The coefficient of $d(ROBIDm_{t-1})$ is always positive, meaning that interbank rate variations are partially persistent. The negative coefficients of lagged $RBODm_{t-1}$ are lower the longer the maturity, meaning that the same rule is true also for the relative speed of adjustment.

Table no. 7 – dROBIDm estimations for overnight and 1-week maturities

m	overnight			1 week		
Explanatory variables:	**OLS**	**NLS**	**Diseq-LL**	**OLS**	**NLS**	**Diseq_LL**
const	0.0055	0.0082	-0.189***	0.0281	0.0643*	0.0139
ROBID*m* (t-1)	-0.053***	-0.113***	-0.140***	-0.043**	-0.068***	-0.110***
NBRpr (t-1)	0.029**	0.093***	0.153***	0.033	0.059**	0.112***
d(ROBID*m*) (t-1)	0.074***	0.092***	0.077***	0.197***	0.237***	0.234***
d(Net_op) (t-1)	-28.86**	-30.22**	-36.92***	-12.99*	-11.03	-17.45***
Net_op (t-1)	0.8508	2.9089	1.0262	-	-	-
ROBIDo-ROMpr (t-1)	-	-	-	0.0129	0.0131	0.0262***
D1(ROBIDo-NBRpr$_{t-1}$) (t-1)	-0.1085**	-0.0997**	-0.0305*	-0.140***	-0.136***	-0.142***
D5(ROBIDo-NBRpr$_{t-1}$) (t-1)	0.067	0.045	-0.010	0.084***	0.071***	0.065***
Kliq (t-1)	-0.12**	-0.65***	-1.12***	-0.12***	-0.44***	-0.63***
jump	0.898***	0.893***	1.041***	-	-	-
MA(ROBIDo,22)(t-2)–ROBIDo(t-1)	-0.037*	-0.080***	-0.134***	-	-	-
dU*m*	-	-	-	0.2176	0.3199	0.4687***
dE*m*	-	-	-	-0.0391	0.1415	0.1465***
ERISK*m* (t-1)	-	-	-	0.1217	0.1726**	0.0622
dERISK*m*	-	-	-	0.1492	0.0493	0.0691
$E_{t-1}[d_h NBRpr_t]$ (^)	-	-	-	0.475***	0.395***	0.308
β_1	-	-	-0.122***	-	-	0.232***
β_{12} (ROBID*m*- NBRlend) (t-1)	-	-	-0.0043	-	-	0.027***
β_2	-	-	-0.072***	-	-	-0.020***
β_{12} (ROBID*m*- NBRdep) (t-1)	-	-	0.171***	-	-	0.516***
$1/\sigma_1$	-	-	1.454***	-	-	2.834***
ρ	-	-	0.821***	-	-	-0.467***
$1/\sigma_2$	-	-	9.255***	-	-	25.017***
Prob of Chi-square test: coef of ROBIDo(t-1)=-coef of NBRpr(t-1)	0.0001***	0.0165**	0.1189	0.0325**	0.0793*	0.6502
Adj R2	0.9654	0.9656	-	0.9906	0.9906	-
SE	0.6878	0.6861	-	0.3633	0.3634	-
DW	1.9495	1.8832	-	2.0175	1.8965	-
Log likelihood	-3204.9	-3197.0	-1664.5	-1218.2	-1219.4	25.7
Avg. log likelihood	-	-	-0.5417	-	-	0.0085
Number of Coefs.	11	11	18	15	15	22
obs	3073	3073	3073	3016	3016	3016

*OLS and NL: HAC standard errors & covariance using outer product of gradients (Bartlett kernel, Newey-West fixed bandwidth = 9.0000); Diseq LL: Method: Maximum Likelihood (BFGS / Marquardt steps). Period: 20/06/2006-20/06/2018, daily data; ***/**/* = significant at 1, 5, 10% of probability respectively; Adj R2 refer to dependent variables expressed in levels; (^) = estimated in table 5.*

Table no. 8 – dROBIDm estimations for maturities of 1 and 3 months

m	1 month			3 months		
Explanatory variables:	**OLS**	**NLS**	**Diseq_LL**	**OLS**	**NLS**	**Diseq_LL**
const	0.0189	0.0302**	0.0088	0.0151	0.0164*	0.0079
ROBID*m* (t-1)	-0.0094**	-0.013***	-0.0140***	-0.0078**	-0.0072**	-0.0041***
NBRpr (t-1)	0.0063	0.0100**	0.0145***	0.0058	0.0050	0.0037**
d(ROBID*m*) (t-1)	0.158**	0.184**	0.241***	0.210***	0.219***	0.187***
d(Net_op) (t-1)	-3.656*	-3.693*	-4.093***	-1.342	-1.329	-0.865
ROBIDo-ROMpr (t-1)	-0.6221	-0.6617	-0.7089*	-0.3178	-0.4250	-0.4728**
D1(ROBIDo-NBRpr$_{t-1}$) (t-1)	-0.020***	-0.018***	-0.019***	-0.005***	-0.0037**	-0.0032***

m	1 month			3 months		
Explanatory variables:	**OLS**	**NLS**	**Diseq_LL**	**OLS**	**NLS**	**Diseq_LL**
D5(ROBIDo-$NBRpr_{t-1}$) (t-1)	0.0069	0.0027	0.0061***	0.0027	0.0015	0.0006
dU*m*	0.1195	0.2405**	0.1827***	0.1341*	0.1396*	0.0762**
dE*m*	0.0854	0.0500	0.1278	0.2415	0.2491	0.0513
ERISK*m* (t-1)	0.0317*	0.0396**	-0.0114	0.0217**	0.0256***	0.0080
dERISK*m*	0.1017	0.1663	0.0781	0.0333	0.0014	0.2334***
$E_{t-1}[d_h NBRpr_t]$ (^)	0.126***	0.139***	0.153***	0.026***	0.025***	0.021***
Kliq (t-1)	-0.049***	-0.098***	-0.106***	-0.034***	-0.035***	-0.030***
β_1	-	-	0.661*	-	-	0.582***
β_{12} (ROBIDo- NBRdep) (t-1)	-	-	0.077*	-	-	0.073***
β_2	-	-	0.0023	-	-	-
β_{12} (ROBIDo- NBRlend) (t-1)	-	-	0.438***	-	-	-
$1/\sigma_1$	-	-	9.326***	-	-	17.051***
ρ	-	-	-0.972***	-	-	-0.973***
$1/\sigma_2$	-	-	21.237***	-	-	14.469***
Prob of Chi-square test: coef of ROBID*m*(t-1)=-coef of NBRpr(t-1)	0.1492	0.1196	0.6909	0.1828	0.1340	0.5740
Adj R2	0.9987	0.9987	-	0.9995	0.9995	-
SE	0.1401	0.1386	-	0.0823	0.0833	-
DW	2.0171	1.9518	-	2.0390	1.9613	-
Log likelihood	1706.0	1739.4	2712.7	3359.5	3322.8	4089.8
Avg. log likelihood	-	-	0.8728	-	-	1.3159
Number of Coefs.	15	15	22	14	14	19
obs	3108	3108	3108	3108	3108	3108

*OLS and NL: HAC standard errors & covariance using outer product of gradients (Bartlett kernel, Newey-West fixed bandwidth = 9.0000); Diseq LL: Method: Maximum Likelihood (BFGS / Marquardt steps). Period: 3/01/2005 26/04/2007 11/05/2007 31/12/2019, daily data; ***/**/* = significant at 1, 5, 10% of probability respectively; Adj R2 refer to dependent variables expressed in levels; (^) = estimated in Table 5.*

Table no. 9 – dROBIDm estimations for maturities of 6 and 12 months

m	6 months			12 months		
Explanatory variables:	**OLS**	**NLS**	**Diseq_LL**	**OLS**	**NLS**	**Diseq_LL**
const	0.0027	0.0027	0.0036	0.0014	0.0014	0.0046*
ROBID*m* (t-1)	-0.0051**	-0.0050**	-0.003***	0.0042**	-0.0042**	-0.0018**
NBRpr (t-1)	[0.0051**]	[0.0050**]	[0.003***]	[0.0042**]	[0.0042**]	[0.0018**]
d(ROBID*m*) (t-1)	0.2796***	0.2856***	0.2324***	0.2643***	0.2707***	0.1881***
d(Net_op) (t-1)	-1.1078	-1.0915	-0.6301	-1.1908*	-1.1754*	-0.7971
ROBIDo-ROMpr (t-1)	-0.0452	-0.0532	-0.1554	-0.0854	-0.0951	0.0088
D1(ROBIDo-$NBRpr_{t-1}$) (t-1)	-0.0026**	-0.0026**	-0.0015*	-0.003***	-0.003***	-0.0016**
D5(ROBIDo-$NBRpr_{t-1}$) (t-1)	0.0018	0.0018	-0.0001	0.0030**	0.0030**	0.0014*
dU*m*	0.2017***	0.2006***	0.1747***	0.1800***	0.1762**	0.1152***
dE*m*	0.0423	0.0227	-0.0156	0.0347	0.0067	0.0826
ERISK*m* (t-1)	0.0123***	0.0125***	-0.0063*	0.0100***	0.0101***	0.0038
dERISK*m*	0.2122	0.1562	0.1864***	0.2485*	0.2013	0.1291***
$E_{t-1}[d_h NBRpr_t]$ (^)	0.0133***	0.0134***	0.0102***	0.0130***	0.0131***	0.0113***
Kliq (t-1)	-0.019***	-0.019***	-0.018***	-0.017***	-0.017***	-0.016***
β_1	-	-	0.1584***	-	-	0.2925***
β_2	-	-		-	-	
$1/\sigma_1$	-	-	24.291***	-	-	26.592***
ρ	-	-	-0.978***	-	-	-0.995***
$1/\sigma_2$	-	-	21.693***	-	-	17.050***

m	6 months			12 months		
Explanatory variables:	OLS	NLS	Diseq_LL	OLS	NLS	Diseq_LL
Prob of Chi-square test: coef of ROBID*m*(t-1)=-coef of NBRpr(t-1)	0.7221	0.7061	0.0020***	0.0955*	0.0986*	0.9744
Adj R2	0.9998	0.9998	-	0.9998	0.9998	-
SE	0.0534	0.0537	-	0.0485	0.0486	-
DW	2.0454	2.0170	-	2.0432	2.0137	-
Log likelihood	4702.5	4686.6	5136.6	5004.3	4992.8	5396.8
Avg. log likelihood	-	-	1.6527	-	-	1.7364
Number of Coefs.	13	13	17	13	13	17
obs	3108	3108	3108	3108	3108	3108

*OLS and NL: HAC standard errors & covariance using outer product of gradients (Bartlett kernel, Newey-West fixed bandwidth = 9.0000); Diseq LL: Method: Maximum Likelihood (BFGS / Marquardt steps). Period: 3/01/2005 26/04/2007 11/05/2007 31/12/2019, daily data; ***/**/* = significant at 1, 5, 10% of probability respectively; Adj R2 refer to dependent variables expressed in levels; (^) = estimated in Table 5.*

The influence of economic variables on ROBID is the following: liquidity stock ($Kliq_{t-1}$) always reduces interbank rates significantly, while an increase in the NBR's net operation reduced interest rates only if maturities are shorter than three months. The change in the US Libor has some influence on the Romanian interest rate, but Euribor does not. Eurozone interbank risk, either in level or in variations, affects Romanian interest rates positively, but only when maturity is longer than one month. Expectations ($E_{t-1}[d_hNBRpr_t]$) on future increases in Romanian interest rates make all interbank rates, apart from overnight maturity, move upward significantly.

In general, the most relevant variables determining the Romanian interbank interest rates are domestic: NBRpr, Kliq, $E_{t-1}[d_hNBRpr_t]$ (and sometimes d(Net_op)). Foreign variables, i.e. dU*m*, dE*m* and RISK*m*, are not always significant. However, the ECB's official interest rate (Repo) has an indirect effect of ROBIDm through expectations $E_{t-1}[d_hNBRpr_t]$ since it is one of its regressors variable (see again Table no. 5). The same is true for Romanian currency depreciation.

Overnight ROBID "seasonality" during the reserve maintenance period is relevant for all maturities, but especially for the shorter ones.

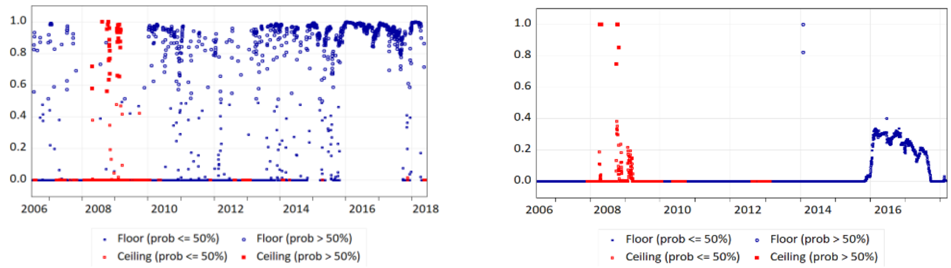
The estimated equations for ceiling and floor constraints obtained by Diseq-LL are summarized in Table no. 10.

Table no. 10 – equations for floor and ceiling estimated by diseq-LL divided by maturity

	Overnight	1w	1m	3m	6m	12m
NBRlend + β	-	-	-	-	x	x
NBRlend + β1	x	x	x	x	-	-
NBRdep + β2	x	x	x	x	-	-
+ β12(ROBIDm - NBRlend) (t-1)	x	x	x	-	-	-
+ β21(ROBIDm - NBRdep) (t-1)	x	x	x	-	-	-

Source: eqs. 7-9

The form becomes simpler the longer the maturity. Actually, Figure no. 5 (see the Annex for the formula) reporting the probability for floor and ceiling being effective, shows that both constraints are less relevant the longer the maturity.



Overnight *3m*

Figure no. 5 – Probability of interbank interest rates being influenced by the floor and ceiling of official rates

Source: Authors' elaboration from DISEQ-LL estimations

A comparison of the goodness of fit of the three different estimators can be based on their correspondent residual SE or on the likelihood values reported in Tables no. 7-9. NLS is better than OLS, at least when the maturity is less than 6 months, while Diseq-LL seems the best in terms of LL. However, a more useful comparison is based on the corresponding dynamic forecasts (see Table no. 11 and Figure no. 6)[8]. The table reports the residuals SE and the mean absolute values of the dynamic residuals, while the figure reports the actual values of interbank rates along with their dynamic forecasts. NL and, in particular, Diseq-LL estimators are superior to OLS (residual dispersion is smaller) and therefore their estimators should be preferred.

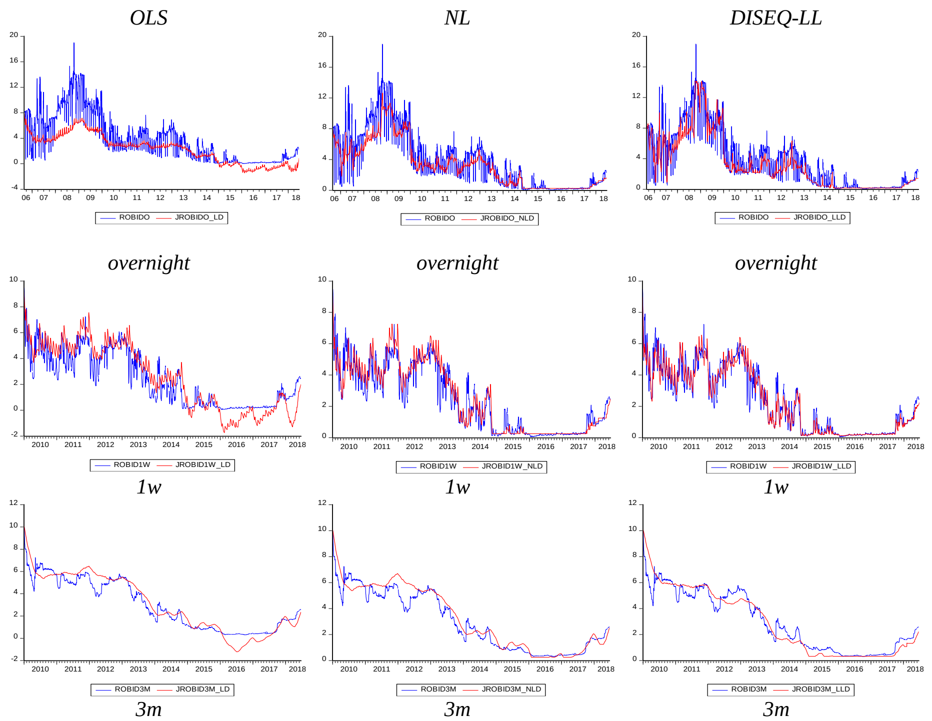


Figure no. 6 – Actual values and dynamic forecasts divided by estimator and maturity

Source: Authors' dynamic forecasts of equations in Tables no. 7-9

Table no. 11 – Standard deviations and mean absolute deviations of dynamic forecasts divided by estimator and maturity

	Standard deviation			**mean absolute deviation**		
	OLS	**NL**	**Diseq_LL**	**OLS**	**NL**	**Diseq_LL**
overnight	2.0996	1.4814	1.4787	1.9539	1.1248	1.1238
1w	1.0705	0.6988	0.5312	0.8841	0.4642	0.3496
1m	1.1527	0.7510	0.5650	0.9996	0.5779	0.3891
3m	0.7434	0.6343	0.6584	0.6005	0.4979	0.4792
6m	0.7319	0.5650	0.5792	0.5856	0.4381	0.4427
12m	0.7776	0.6151	0.5993	0.6307	0.4970	0.5270

Period: 30/08/2006 - 20/06/2018.

Source: Authors' dynamic forecasts of equations in Tables no. 7-9.

The smallest dispersions (best estimations) are in bold.

7. CONCLUSIONS

In conclusion, Romanian interbank interest rates are particularly sensitive to the NBR's decisions, both about policy interest rates and liquidity. Conversely, any direct influence coming from the ECB and Fed is weak.

When analysing Romanian interbank and bank interest rates, Granger causality tests confirmed that causality comes from the interbank to the bank market and not *vice versa*. On the other hand, cointegration suggests that the impact of interbank rates on bank rates is particularly strong.

In the short-run, Robid rates tend to follow the NBR's policy rate (*NBRpr*), with the NBR's lending and deposit facility rates (*NBRlend* and *NBRdep*) acting as a sort of ceiling and floor for interbank rates. Robor interest rates are higher and more volatile than Robid interest rates, with volatility decreasing with maturity, consistent with the hypothesis that long maturity interest rates are related to the mean value of current and expected future short-term interest rates.

Cointegration results, obtained by Johansen's procedure, could not answer all of the questions about the equilibrium of interbank interest rates. Interbank and NBRpr are cointegrated, but coefficients come from different values, of 1.17 (overnight) to 1.33 (12m maturity) while in the Eurozone the corresponding value is near 1. When liquidity is added, coefficients shift toward 1, but some test validity problems emerge.

According to the set of regressors employed in our dynamic estimations, we found that the speed of adjustment is higher the shorter the maturity. The equilibrium coefficient between the interbank and policy rate is not significantly different from 1 (a problem unresolved by cointegration), but a reserve cycle exists in short-term interbank rates. Liquidity is an important instrument that central bank can use to influence interest rates. Foreign interbank market risk influences the Romanian interbank market, and expectations about the future Romanian monetary policy rate influence Romanian interest rates when maturities are longer than one week. In particular, future Romanian interest rate policy changes depend on inflation above the NBR's target values, devaluation of the Romanian currency, the Eurozone's official interest rate, and the difference between Romanian and the ECB's target inflation rate.

The "flexible constraints" due to the NBR's lending and deposit interest rates makes OLS an inappropriate tool for econometric estimations, especially when dynamic forecasts are concerned.

In summary, the daily influence of explanatory variables on ROBID is mainly based on the movement in Romanian policy rates and liquidity stock ($Kliq_{t-1}$) that always reduces interbank rates significantly. An increase in the NBR's net operation can reduce interest rates only if maturities are shorter than three months. The change in the US Libor has some influence on the Romanian interest rate, but Euribor does not. The Eurozone interbank risk (either in level or in variations) affects Romanian interest rates positively, but just for maturities longer than one month.

It must be recognized, however, that some topics have not been discussed in depth in this article. In particular, the forecast of future policy rates does not take into account official NBR releases, which must therefore be analysed. Secondly, the relevance of ceilings and floors for interbank interest rate movements has not been the subject of a theoretical analysis of consistency between various maturities. Also, the relation between Robid and Robor can be explained explicitly. A last crucial problem refers to liquidity data frequency: information about deposit and lending stocks with the NBR are only available monthly, and this greatly reduces the estimation efficiency of short-term interbank rates.

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ANNEX

The disequilibrium model is estimated by means of a simultaneous model (Maddala and Nelson, 1974, Laffont and Garcia, 1977; Kremp and Sevestre, 2013), originally composed by a demand equation Y_t^d, a supply equation Y_t^s , and a transaction condition for the actual Y_t.
In particular, by following Kremp and Sevestre, 2013:

$$Y_t^d = b_1 x_{1t} + u_{1t} \quad (1)$$
$$Y_t^s = b_2 x_{2t} + u_{2t} \quad (2)$$
$$\text{transaction condition: } Y_t = \min(Y_t^d, Y_t^s) \quad (3)$$

where x_{1t} and x_{1t} are explanatory vectors, b_1 and b_2 their coefficients and u_{1t} and u_{2t} are their disturbance terms.
Define:

$$\sigma_1 = \sigma(u_{1t}) \text{ and } \sigma_2 = \sigma(u_{2t}), \quad (4)$$
$$\rho = \text{correlation between } u_{1t} \text{ and } u_{2t}. \quad (5)$$
$$\varphi(.) = \text{normal N(0,1) density function} \quad (6)$$
$$\Phi(.) = \text{cumulative normal N(0,1) density function} \quad (7)$$

The component of u_{1t} independent of u_{1t} (correspondent to the residuals of the regression u_{1t} on u_{2t}), and vice-versa, are given by:

$$u_{1t}' = u_{1t} - (\rho\sigma_1/\sigma_2)u_{2t} \quad (8)$$
$$u_{2t}' = u_{2t} - (\rho\sigma_1/\sigma_2)u_{1t} \quad (9)$$

The standard deviations of u_{1t}' and $u_{1t}'$are

$$\sigma_1' = \sigma_1(1 - \rho^2)^{1/2} \quad \text{and} \quad (10)$$
$$\sigma_2' = \sigma_2(1 - \rho^2)^{1/2} \quad \text{respectively} \quad (11)$$

Since $Y_t = \min(Y_t^d, Y_t^s)$, the probability for actual Y_t to be a demand is higher the lower the probability for a supply Y_t^s to be as small as Y_t. In other term, the probability P_1 of Y_t to be a demand is given by:

$$P_1 = [1-\Phi(u_{1t}'/ \sigma_1')] \quad (12)$$

Since $Y_t = \min(Y_t^d, Y_t^s)$, the probability for actual Y_t to be a supply is higher the lower the probability for a demand Y_t^d to be as small as Y_t. In other term, the probability P_1 of Y_t to be a supply is given by:

$$P_2 = [1-\Phi(u_{2t}'/ \sigma_2')] \quad (13)$$

The contribution to the likelihood of an observation Y_t is therefore the probability for a demand to equal Y_t times the probability that Y_t is a demand, plus the probability for a supply to equal Y_t times the probability that Y_t is a supply:

$$[\varphi (u_{1t}'/\sigma_1')/\sigma_1')]P_1 + [\varphi (u_{1t}'/\sigma_2')/\sigma_2')]P_2, \quad (14)$$

that can be easily estimated by maximum likelihood techniques.

The probability of $Y_t = Y_t^s$, since $Y_t^d > Y_t^s$, is given by

$$\Pr(\text{Partial rationing}|NL_{it})= \varphi_2(L_{it})(1-\Phi_1(L_{it})/[\varphi_1(L_{it})(1-\Phi_2(L_{it})+ \varphi_2(L_{it})(1-\Phi_1(L_{it}))] \quad (15)$$

The previous scheme can be easily adapted to cases of flexible floor and ceiling constraints on interest rates.
In fact, in case of a flexible floor constraint R_t^{MIN} it is:

$$R_t^{FREE} = Y_t^d = b_1 x_{1t} + u_{1t} \quad (16)$$
$$R_t^{MIN} = Y_t^s = b_2 x_{2t} + u_{2t} \quad (17)$$

$$R_t = \max(R_t^{FREE}, R_t^{MIN}) \text{ or } -R_t = \min(-R_t^{FREE\ d} - R_t^{MIN}) \quad (18)$$

While, if some flexible ceiling constraint R_t^{MAX} exists:

$$R_t^{FREE} = Y_t^d = b_1 x_{1t} + u_{1t} \quad (19)$$

$$R_t^{MAX} = Y_t^s = b_3 x_{3t} + u_{3t} \quad (20)$$

$$R_t = \min(R_t^{FREE}, R_t^{MAX}) \quad (21)$$

When examining interbank interest rates, it is apparent that a floor can be relevant only if $R_t<NBRpr_{t-1}$ (where NBRpr is the monetary policy rate), while a ceiling only if $R_t >NBRpr_{t-1}$.

In other terms:

$$R_t^{FREE} = Y_t^d = b_1 x_{1t} + u_{1t} \quad (19)$$

$$R_t^{MIN} = Y_t^{s1} = b_2 x_{2t} + u_{3t}$$

$$R_t^{MAX} = Y_t^{s2} = b_3 x_{3t} + u_{3t} \quad (20)$$

transaction condition:

$$R_t = \min(-R_t^{FREE}, -R_t^{MIN}) \text{ if } R_t<NBRpr_{t-1} + \min(R_t^{FREE}, R_t^{MAX}) \text{ if } R_t>NBRpr_{t-1} \quad (22)$$

(The suffix t-1 of NBRpr comes from the fact that interbank rates are priced before the NBR's rate is communicated on the same day).

The correspondent Eviews-10 code, written by us and employed in this paper estimations, is available on request.

Notes

[1] The amount of deposit and lending facility are given by the NBR only on a monthly basis. Since the other data we employed are daily, we took the central moving average of the monthly data in order to avoid a jump at the beginning of every month. From our analysis we found that the impact of liquidity on the interbank interest rate is not linear; it is something similar to a square root. For this reason we measured liquidity as the square root of the absolute value of the difference between deposit and lending facilities preceded by the sign (positive or negative) of their difference.

[2] This variable corresponds to the central bank's daily Repo Operations minus Reverse Repo Operations, Issuance of certificates of Deposit, and Deposit-taking Operations, while all previous operations expiring in the same day have been subtracted. In order to get the corresponding net daily stock (Net_op), the above data were summed through time.

[3] The jump is approximated by the difference between the mean value of the spread from 11-15 days before the new day of the cycle minus its value in the last day of the previous cycle.

[4] The moving average MA is made of 22 days, since one month is made of 22 operating days on average.

[5] Eurozone risk included, even if it is formally I(1) in some cases.

[6] Of course, the expected sign of (ROBIDo-NBRpr) is positive since it is a proxy for a low liquidity.

[7] Data and Eviews codes are available on request.

[8] Dynamic forecasts are particularly sensitive to the dynamic goodness of estimated equations by calculating the lagged dependent variables by iteration, each time taking the estimated value of the previous observation as a lagged dependent variable.