ISSN: 2281-1346

Department of Economics and Management

DEM Working Paper Series

Monetary transmission models for bank interest rates

Laura Parisi
(Università di Pavia)

Igor Gianfrancesco
(Banco di Desio e della Brianza,)

Camillo Gilberto
(Banca Monte dei Paschi di Siena)

Paolo Giudici
(Università di Pavia)

 # 101 (05-15)

Via San Felice, 5
I-27100 Pavia
http://epmq.unipv.eu/site/home.html

May 2015

Monetary transmission models for bank interest rates

L. Parisi[a,*], I. Gianfrancesco[b], C. Giliberto[c], P. Giudici[a]

[a]*Department of Economics and Management, University of Pavia, Via S. Felice 5, 27100 Pavia (PV), Italy*
[b]*Banco di Desio e della Brianza, Risk Management Division, Via E. Rovagnati 1, 20832 Desio (MB), Italy*
[c]*Banca Monte dei Paschi di Siena, Via Montanini 82, 53100 Siena (SI), Italy*

Abstract

Monetary policies, either actual or perceived, cause changes in monetary interest rates. These changes impact the economy through financial institutions, which react to changes in the monetary rates with changes in their administered rates, on both deposits and lendings.

The dynamics of administered bank interest rates in response to changes in money market rates is essential to examine the impact of monetary policies on the economy. Chong et al. (2006) proposed an error correction model to study such impact, using data previous to the recent financial crisis.

In this paper we examine the validity of the model in the recent time period, characterised by very low monetary rates. The current state of close-to-zero interest rates is of particular relevance, as it has never been studied before.

Our main contribution is a novel, more parsimonious, model and a predictive performance assessment methodology, which allows to compare it with the error correction model.

We also contribute to the literature on interest rate risk modelling propos-

ing a forward looking method to allocate on-demand deposits to non-zero time maturity bands, according to the predicted bank rates.
Keywords: Error Correction Model, Forecasting Bank Rates, Monte Carlo predictions, Interest Rate Risk models
JEL: C15, C20, E47, G32

1. Introduction

Monetary policies, such as variations in the official rate or liquidity injections, cause changes in monetary interest rates. These changes impact the economy mainly in an indirect way, through financial institutions, which react to changes in the monetary rates with changes in their administered rates, on both deposits and lendings.

The dynamics of administered bank interest rates in response to changes in money market rates is essential to examine the impact of monetary policies on the economy. This dynamics has been the subject of an extensive literature; the available studies differ, depending on the used models, the period under analysis and the geographical reference.

The relationship between market rates and administered rates is a complicated one and the evidence presented, thus far, is mixed and inconclusive. Hannan and Berger (1991), for example, examine the deposit rate setting behaviour of commercial banks in the United States and find that (a) banks in more concentrated markets exhibit greater rates rigidity; (b) larger banks

*Corresponding author, Tel. number +39 0382 986152, Fax number +39 0382 22486
Email addresses: laura.parisi01@universitadipavia.it (L. Parisi), igianfrancesco@luiss.it (I. Gianfrancesco), camillogiliberto@gmail.com (C. Giliberto), paolo.giudici@unipv.it (P. Giudici)

exhibit less rates rigidity; and (c) deposit rates are more rigid upwards than downwards. Scholnick (1996), similarly, finds that deposit rates are more rigid when they are below their equilibrium level than when they are above; his finding on lending rate adjustment, however, is mixed. Heffernan (1997) examines how the lending and deposit rates of four banks and three building societies respond to changes in the base rate set by the Bank of England and finds that (a) there is very little evidence on the asymmetric nature of adjustments in both the deposit and lending rates, (b) there is no systematic difference in the administered rate pricing dynamics of banks and building societies, and (c) the adjustment speed for deposit rates is, on average, roughly the same as that for loan rates.

More recent papers on the same issue include: Ballester et al. (2009), Chong et al. (2006), Demirguc-Kunt and Huizinga (1999), Flannery et al. (1984), Maudos et al. (2004), Maudos et al. (2009). Among them, Chong et al. (2006), who applies and extends Engle and Granger (1987) error correction model has become a reference paper, in both the academic and the professional field.

The empirical evidence contained in all the previous papers can be summarized in the following points: (a) bank rates react with a partial and delayed change to changes in the monetary rates; (b) the speed and the degree to which they follow these changes present substantial differences between the various categories of banking products and between different countries.

The previous conclusions have been obtained for a relatively stable time period, previous to the emergence of the recent financial crisis.

After 2008, however, we have witnessed substantial changes. From a macroeconomic viewpoint, monetary interest rates are now, in most developed economies, close to zero, or negative; from a microeconomic viewpoint, bank management has changed substantially, for the compression of interest margins and for the increase in regulatory capital requirements. The effects of the previous changes on the transmission of monetary policies have not been yet fully investigated. In particular, the current state of close-to-zero interest rates is of particular relevance, as it has never been studied before.

When monetary rates are close to zero, the error correction model, albeit formally elegant, does not well capture the dynamic of administered rates, which appears strongly inertial.

The need of adapting the error correction model to the current situation is very relevant, not only from a macroeconomic point of view, but also from a microeconomic bank perspective and, in particular, in the measurement of interest rate risk, and in the related asset and liability management policies.

The current regulatory framework requires that banks measure interest rate risk, and disclose it, within the calculation of the internal economic capital. This implies that the lending activity of a bank should be calibrated also on the basis of the economic capital required to cover the additional interest rate risk. Indeed, in a typical commercial bank, interest rate risk is the second risk in size, after credit risk.

There is a limited scientific literature on interest rate risk modelling. This type of risk has assumed some importance as a result of the crisis of American Savings and Loans of the eighties. Immediately after such breakdown, in fact, economists developed the Federal Reserve Economic Value Model, based on the economic value perspective. Such a model is described, for example, in Houpt and Embersit (1991), English (2002) and

English et al. (2012).

In 2004 the Basel Committee (BIS, 2004) published the final version of the technical document entitled "Principles for the management of the interest rate risk", which proposes a measurement methodology based on the same logic underlying the model developed by the Federal Reserve. The model proposed by the Basel Committee has been the subject of further academic research, carried out, for example, by Fiori and Iannotti (2007), and by Entrop, Wilkens, and Zeisler (2009). A key research issue that has emerged is the treatment of on-demand positions, which are the ones with the highest reactivity to monetary rate changes. Blochlinger (2015) has shown that on-demand positions are very important risky options, and have shown how to hedge their embedded risk.

On-demand positions are present in both the lending and in the deposit side of the balance sheet. However, on-demand deposits are more relevant, being exogenous to the bank, and with a "real" maturity that is much longer than what implied by their on-demand contractual nature. Indeed, regulatory authorities, such as the Basel Committee, suggest that, for the calculation of interest rate risk, on-demand deposits (but not lendings) could be allocated to different time maturity bands, from very short ones (up to one month) to long ones (more than twenty years).

The first aim of this paper is to broaden the error correction model of Chong et al. (2006), in a predictive performance comparison framework. Our results show that the error correction model performs quite well in a predictive sense. We also show that a more parsimonious model, described by only one equations, rather than two, is not inferior in terms of predictive performance, and, therefore, represents a valid alternative.

The second aim of the paper is to propose an allocation structure for on-demand deposits based on the predicted term structure of bank interest rates, based on a forward-looking perspective, rather than on a historical, backward-looking one, as done in the current practice.

Our proposed methods are applied to data from the recent period (1999-2014), of a southern European country, with a traditional banking sector: Italy.

The paper is structured as follows. Section 2 describes the proposed models and, in particular: Section 2.1 describes the error correction model; Section 2.2 motivates and introduces the new proposed model; Section 2.3 provides the predictive performance environment used to compare the two models; Section 2.4 presents our proposal for the allocation of on demand deposits. Section 3 shows the empirical evidence obtained from the application of the models and, in particular: Section 3.1 describes the available data; Section 3.2 presents the estimation results obtained when the models are applied to such data; Section 3.3 compares the models in predictive performance; Section 3.4 contains the application of the models to interest rate risk measurement. Finally, Section 4 concludes with some final remarks.

2. Methodology

2.1. The error correction model

In line with the contribution of Chong et al. (2006), the relationship between monetary rates and administered bank rates can be analyzed with the use of the Error Correction Model (ECM), following the procedure proposed by Engle and Granger (1987). The model is based on two equations. A long-run relationship provides a measure of how a change in the monetary rate is reflected in the bank rate. A short-run equation, which includes an error correction term, analyzes variations of the administered interest rates as a function of variations in the monetary rates.

Indeed, Chong et al. (2006) extended Engle and Granger by allowing the effect of the error correction term to depend on its sign. Their complete model can be formalized as follows:

$$\begin{cases} BR_t = k + \beta \cdot MR_t + \epsilon_t \\ \Delta BR_t = \alpha \cdot \Delta MR_t + \delta_1(BR_{t-1} - \beta \cdot MR_{t-1} - k)+ \\ \qquad + \delta_2(BR_{t-1} - \beta \cdot MR_{t-1} - k) + u_t, \end{cases} \tag{2.1}$$

where

$$\begin{cases} \delta_1 = 0 & \text{if } BR_{t-1} - \beta \cdot MR_{t-1} - k < 0, \\ \delta_2 \neq 0 & \text{otherwise;} \end{cases}$$

$$\begin{cases} \delta_2 = 0 & \text{if } BR_{t-1} - \beta \cdot MR_{t-1} - k > 0, \\ \delta_1 \neq 0 & \text{otherwise.} \end{cases}$$

In equation (2.1) BR_t and MR_t represent, respectively, the bank administered rates and the monetary rates at time t; β is a regression coefficient that gives a measure of the extent of the monetary rate transmitted on bank rates in a long-term perspective: in the case of $\beta = 1$, the whole monetary rate is transmitted on the administered rate, while a value between 0 and 1 means that only a partial transmission mechanism occurs; k is a constant that synthetizes all other factors that, in addition to the dynamics of monetary rates, may affect the transmission mechanism of the monetary policy on bank rates as, for example, the market power and the efficiency of a bank; ϵ is the error term of the long-run equation; δ_1 and δ_2 represent the adjustment speeds converge towards the equilibrium level; finally, u_t is the error term of the short-run equation.

2.2. The proposed model

The aim of this subsection is to propose a bank rate model that, while based on the ECM, is more parsimonious and, therefore, easier to interpret and manage. To achieve this aim we examine the main components of the error correction model, so to establish a statistical methodology for their simplification.

First, it is of interest to check whether the assumption of a double error correction coefficient, introduced by Chong et al. (2006), is justified and strictly necessary. To check this point the previous model can be compared, in a hypotheses testing framework, with the following nested model:

$$\begin{cases} BR_t = k + \beta \cdot MR_t + \epsilon_t \\ \Delta BR_t = \alpha \cdot \Delta MR_t + \delta(BR_{t-1} - \beta \cdot MR_{t-1} - k) + u_t. \end{cases} \tag{2.2}$$

Differently from equation (2.1), the model in (2.2) contains only one adjustment speed, so it does not admit the possibility of an asymmetric convergence of the administered interest rate to its equilibrium level.

Second, the error correction model contains one equation for the level of administered interest rates, and one for its variations. The two can be analyzed separately, with the simple regression models:

$$BR_t = k + \beta \cdot MR_t + \epsilon_t \tag{2.3}$$

$$\Delta BR_t = k + \beta \cdot \Delta MR_t + u_t. \tag{2.4}$$

While model (2.2) explains the levels of banking rates in terms of the level of monetary ones, equation (2.4) is a model for the variations of bank rates in terms of the variations of monetary rates. These models, albeit very simple, should be considered in practical applications, and compared in predictive performance with the error correction model, to check whether the latter can be simplified.

We anticipate that the above models are too simple to lead to a good predictive performance. However, the idea of replacing the error correction model with a one-equation one is tempting and, therefore, we now propose a one equation model that can be a valid competitor of the ECM. To achieve this aim we first examine the economic rationales behind the relationship we would like to investigate.

From a microeconomic viewpoint, as deposits are saving tools in competition with other instruments (such as bonds), it seems quite reasonable to assume that banks decide on the administered rate looking primarily at its level. Starting from the level, one can always obtain its variation through differentiation. A second consideration concerns the determinants of administered bank levels. Again, it is reasonable to think that bank deposit rates depend on both the level and on the variation of monetary rates. A third assumption, particularly important when monetary rates are close to zero, is that the level of deposit rates depends on the previous level of the same quantity, to allow for a slow and partial reaction to monetary rate changes, given that deposit rates affect considerably the income of a bank.

A macroeconomic perspective confirms the previous assumption: in particular, that is correct to consider, as a response variable, the level of the administered rate and not its variations. This because the relevant response variable for an expansion/restriction effect on the economy is represented by the level of the rates; on the explanatory side, we can model administered rate levels as a function of changes in the monetary rates, but also of their levels, which remain important even when close to zero.

On the basis of the above economic rationales, our proposed model is the following:

$$BR_t = k + \beta \cdot MR_{t-1} + \gamma \cdot \Delta MR_t + \delta \cdot BR_{t-1} + \epsilon_t. \tag{2.5}$$

The proposed model can be equivalently written in terms of the variations of the administered rates:

$$\Delta BR_t = k + \beta \cdot MR_{t-1} + \gamma \cdot \Delta MR_t + (\delta - 1) \cdot BR_{t-1} + \epsilon'_t. \tag{2.6}$$

To improve interpretability, the proposed model can also be expressed in a differential form:

$$\frac{\mathrm{d}BR}{\mathrm{d}s} = \beta \cdot \left[\frac{\mathrm{d}MR}{\mathrm{d}s}\right]_{s=t} + \gamma \cdot \left[\frac{\mathrm{d}^2 MR}{\mathrm{d}s^2}\right]_{s=t} + \gamma \cdot \left[\frac{\mathrm{d}BR}{\mathrm{d}s}\right]_{s=t-1}. \tag{2.7}$$

The previous equation shows that the model can be interpreted as a "physical" description of the banking behaviour in terms of deposit interest rates through its differentiation: the derivative of the bank administered rate depends both on the speed and on the acceleration/deceleration of monetary rates, as well as on the derivative of the administered rate with respect to its level in the previous time.

Note that the proposed model can be directly compared with the ECM with one adjustment speed. Comparing equation (2.2) and equation (2.5) it is clear that our proposal is a particular case of the latter, with some constraints on the parameters. By using the notational index 1 for the coefficients of the one-speed ECM and the index 2 for the coefficients referred to the proposed model, such constraints are the following:

$$\begin{cases} -\delta_1 k_1 = k_2, \\ -\delta_1 \beta_1 = \beta_2, \\ \alpha_1 = \gamma_2, \\ \delta_1 + 1 = \delta_2. \end{cases} \tag{2.8}$$

Note, in particular, that the last equation in (2.8) implies that $(\delta - 1)$ represents the adjustment speed to which bank administered rates react to changes in the monetary rates, equivalently as the parameters δ_1 and δ_2 of Chong et al. (2006) Error Correction Model.

A ful comparison of our model with the ECM cannot be easily carried out in a statistical testing framework, as the two models are, evidently, not nested; however, they can be compared in terms of predictive performance and, for this purpose, the next Subsection introduces an appropriate methodology.

A different comparison between the two models can be carried out by looking at their time dynamics. This is of particular interest in the context of interest rate risk modelling. For sake of simplicity we illustrate this comparison for the first three one-month rates and, then, for the general situation.

For the error correction model, we consider the case of $\delta_1 \neq 0$; the other case of $\delta_2 \neq 0$ can be obtained analogously, replacing δ_1 with δ_2. Then, assume that:

$$\begin{cases} \delta_1 \neq 0, \\ BR(0) = BR_0, \\ MR(0) = MR_0; \end{cases}$$

then, for the first month ahead:

$$\begin{aligned} BR_1 &= BR_0 + \Delta BR_1 = \\ &= BR_0(1+\delta_1) + \alpha \Delta MR_1 - \delta_1 \beta MR_0 - \delta_1 k. \end{aligned}$$

For the second and the third month ahead, instead, we obtain:

$$\begin{aligned} BR_2 &= BR_1 + \Delta BR_2 = \\ &= BR_0(1+\delta_1)^2 + \Delta MR_1(\alpha + \delta_1 \alpha - \delta_1 \beta) - \delta_1 \beta MR_0(2+\delta_1) + \\ &\quad + \alpha \Delta MR_2 - 2\delta_1 k; \end{aligned}$$

$$\begin{aligned} BR_3 = {} & BR_0(1+\delta_1)^3 + \Delta MR_1[\alpha + \delta_1(\alpha - \beta)(2+\delta_1)] + \\ & - MR_0 \delta_1 \beta[(1+\delta_1)(2+\delta_1)+1] + \Delta MR_2(\alpha - \delta_1 \beta) - \delta_1 k(3 + 2\delta_1). \end{aligned}$$

For our proposed model, assuming the same initial values BR_0 and MR_0 for the bank and the monetary interest rates, we find the following equation for the first month ahead:

$$BR_1 = MR_0 \beta + \Delta MR_1 \gamma + BR_0 \delta + k.$$

whereas for the second and the third month ahead we obtain:

$$BR_2 = MR_0\beta(1+\delta) + \Delta MR_1[\beta + \delta\gamma] + \Delta MR_2\gamma + BR_0\delta^2 + k(1+\delta);$$

$$\begin{aligned} BR_3 = MR_0\beta(1+\delta+\delta^2) + \Delta MR_1[\beta + \delta(\beta+\delta\gamma)] + \\ + \Delta MR_2[\beta+\delta\gamma] + \Delta MR_3\gamma + BR_0\delta^3 + k\delta(1+\delta). \end{aligned}$$

From the above calculations we can derive a general iterative formula for both models, in order to calculate bank interest rates at any time t (BR_t), as functions of the levels of bank rates at time $t-1$ (BR_{t-1}).

For the error correction model such iterative equation is:

$$BR_t = BR_{t-1}(1+\delta_1) - \delta_1\beta\left[MR_0 + \sum_{s=1}^{t-1}\Delta MR_s\right] + \alpha\Delta MR_t - \delta_1 k. \quad (2.9)$$

Similarly, for our proposed model we obtain:

$$BR_t = \delta BR_{t-1} + \beta\left[MR_0 + \sum_{s=1}^{t-1}\Delta MR_s\right] + \gamma\Delta MR_t + k. \quad (2.10)$$

2.3. Predictive performance assessment

While the assumption of a double error correction coefficient can be easily tested against a one error correction model, other simplifications of the ECM model require a more general set-up. This can be provided, for example, by a predictive performance framework that we are going to illustrate in this subsection. Doing so, we can enrich the error correction model with a validation procedure that is, to our knowledge, not yet available in the literature.

In order to predict bank rates, we need to estimate reasonable future values of the monetary rates. Consistently with the literature, we assume that their variation follows a Wiener process.

More formally, assume that we want to predict the level of monetary rates for each of the next 12 months. Let $\widehat{\Delta MR_i}$ indicate the variation of the monetary rate in a given month. We then assume that $\widehat{\Delta MR_i}$ are independently and identically distributed Gaussian random variables, so that:

$$\begin{cases} \widehat{\Delta MR} \sim N(0, \sigma^2) \\ \widehat{MR_i} = \widehat{MR}_{i-1} + \widehat{\Delta MR_i} \quad \text{i} = 1, ..., 12. \end{cases} \tag{2.11}$$

Equation (2.11) describes a recursive procedure to obtain predictions of the monetary rates for a given year ahead, based on the Wiener process assumption. We can then insert the predicted monetary rates as regressor values in the models of the previous Subsection and, thus, obtain predictions for the administered bank rates. In particular, for model (2.1) we obtain:

$$\begin{cases} \widehat{BR_i} = \widehat{BR}_{i-1} + \widehat{\Delta BR_i}, \\ \widehat{\Delta BR_i} = \alpha \cdot \widehat{\Delta MR_i} + \delta_1(\widehat{BR}_{i-1} - \beta \cdot \widehat{MR}_{i-1} - k) + \\ \qquad\qquad + \delta_2(\widehat{BR}_{i-1} - \beta \cdot \widehat{MR}_{i-1} - k) \end{cases}$$

where

$$\begin{cases} \delta_1 = 0 \quad \text{if } \widehat{BR}_{i-1} - \beta \cdot \widehat{MR}_{i-1} - k < 0, \\ \delta_2 \neq 0 \quad \text{otherwise;} \end{cases}$$

$$\begin{cases} \delta_2 = 0 \quad \text{if } \widehat{BR}_{i-1} - \beta \cdot \widehat{MR}_{i-1} - k > 0, \\ \delta_1 \neq 0 \quad \text{otherwise.} \end{cases}$$

For model (2.5) we obtain that:

$$\widehat{BR}_i = k + \beta \cdot \widehat{MR}_{i-1} + \gamma \cdot \widehat{\Delta MR}_i + \delta \cdot \widehat{BR}_{i-1}.$$

According to the standard cross-validation (backtesting) procedure, to evaluate the predictive performance of a model, we can compare, for a given time period, the predictions of monetary rates obtained with the previous equations with the actual values. To obtain a robust measurement we can indeed generate N scenarios of monetary rates, using (2.11), and obtain the corresponding bank rates, using either (2.1) or (2.5). On the basis of them we can calculate and approximate Monte Carlo expected values and variances of the predictions, as follows.

Let Y be a bank rate to be predicted at time i, with unknown density function $f_Y(y)$. The expected value of Y can then be approximated with

$$\widehat{\mathbb{E}(Y)} = \frac{1}{N} \sum_{k=1}^{N} y^{(k)}, \tag{2.12}$$

and its variance with

$$\widehat{var(Y)} = \frac{1}{N^2} \sum_{k=1}^{N} [y_i - E(\hat{Y})]^2. \tag{2.13}$$

In the next section we will use (2.12) and (2.13) to compare model predictive performances. Before proceeding, we would like to remark that the random number generation at the basis of the Monte Carlo algorithm is pseudo-random, and depends on an initial seed. Different seeds may lead to different results so that models can not be compared equally. We have thus decided to use the same random seed for all models, so that the differences in performances are not biased by the Monte Carlo random mechanism.

2.4. On-demand deposits allocation

The allocation of on-demand customer deposits to an appropriate maturity time is a significant criticality in interest rate risk modelling, as well as in asset and liability management of banks, given their particular characteristics. The latter include: (i) the absence of a contractual maturity, with the correlated ability of the depositor to withdraw the funds at any time; (ii) the stability of the masses in time, along with the diversification of counterparties that makes total volumes basically constant; (iii) the partial and delayed reaction of banks as a result of changes in the monetary rate.

Theoretically, on-demand deposits could be assigned a zero maturity. Doing so, however, the term structure of the liabilities of a bank does not match the term structure of the assets which, especially on the lending side, is characterised by positions with different maturities. Asset and liability management becomes, therefore, based on an incorrect representation of the cash flows of a bank, and this may bias interest rate risk measurement. For example, an increase of monetary rates has a negative impact, lower than it should be, as the duration of liabilities is lower than the real one. Similarly, a decrease of monetary rates has a positive impact, lower than it should be.

Having established that a zero maturity cannot be the right time allocation for on-demand deposits, it remains the issue of finding an appropriate one. On one hand, an allocation shifted towards short maturities reflects the contractual nature of these deposits, which are subject to withdrawal at any time; on the other hand, an allocation shifted towards long maturity reflects their stability as a major source of funding.

From an asset and liability management perspective, a correct procedure seems to allocate on-demand deposits to their actual maturity. This can be estimated statistically, analyzing the observed decay of the volumes of deposits: the approach followed, in current practice, by many banks. In this context, on demand deposits are split between a non core component, which remains at a zero maturity, and a core component, whose volumes in the different maturity bands are estimated by means of a moving average filter, such as that proposed by Hodrick and Prescott (1997).

From an interest rate risk perspective, it is important to consider what regulatory requirements prescribe. The Basel Committee on Banking Supervision does not give specific guidelines in its main documentation on interest rate risk modelling (BIS, 2004); it does so in the recent document on the Net Stable Funding Ratio (BIS, 2014), where it suggests a decay percentage of 5% or of 10% of on-demand deposits in the first year. National regulators are more prescriptive; for example, the Bank of Italy, whose data wil be analysed in the application Section, suggests to allocate 25% of deposits in the non-core component and to allocate the remainder in the following five years, with a 1/60 decay in each month.

Here we join the two perspectives and propose an allocation model that, while consistent with the regulatory methodology on interest rate risk, also takes the asset and liability management view into account. Specifically, we propose that the allocation of on-demand deposits to different time maturity bands is performed, once regulatory requirements are satisfied, using allocation coefficients that are function of the predicted administered rate changes.

More precisely, we propose to allocate the 75% of deposits (core component) proportionally to time band specific weight coefficients. Indicate a time period with j, with initial time i_j and final time f_j. We can allocate in it a volume that is equal to the total core component volume times the following weight:

$$W_j \propto e^{(BR_{f_j} - BR_{i_j}) \cdot (f_j - i_j)}$$

where BR_{f_j} and BR_{i_j} are the bank rates that correspond, respectively, to the final and initial time points of the j-th time band and the proportionality symbol means that, in order to obtain their correct value, the weights should be normalised dividing each of them by their sum.

The rationale behind our proposal is that, rather than using a constant allocation or a historical one, one can use an allocation of on-demand deposits that is based on the possible future evolution of interest rates, according to a forward-looking, rather than a backward-looking perspective. In this perspective, time periods with higher interest rates attract more volumes and, conversely, time bands with lower interest rates attract less volumes.

To calculate the previous weights, we can use the one-month ahead predicted bank rates described in Subsection 3.3. Let $N = f_j$ be, without loss of generality, a specific time point (expressed in terms of months from the current date). The interest rate that corresponds to a maturity equal to N, BR_N, can be obtained as follows:

$$(1 + BR_N)^N = \prod_{j=0}^{N-1} (1 + {}_jBR_1), \tag{2.14}$$

where ${}_jBR_1$ are the forward one month ahead bank administered interest rates predicted at time 0.

For example, for the ECM model:

$$\begin{cases} {}_jBR_i = \widehat{BR}_{i-1} + \widehat{\Delta BR}_i, \\ \widehat{\Delta BR}_i = \alpha \cdot \widehat{\Delta MR}_i + \delta_1(\widehat{BR}_{i-1} - \beta \cdot \widehat{MR}_{i-1} - k) + \\ \qquad + \delta_2(\widehat{BR}_{i-1} - \beta \cdot \widehat{MR}_{i-1} - k) \end{cases}$$

where

$$\begin{cases} \delta_1 = 0 & \text{if } \widehat{BR}_{i-1} - \beta \cdot \widehat{MR}_{i-1} - k < 0, \\ \delta_2 \neq 0 & \text{otherwise;} \end{cases}$$

$$\begin{cases} \delta_2 = 0 & \text{if } \widehat{BR}_{i-1} - \beta \cdot \widehat{MR}_{i-1} - k > 0, \\ \delta_1 \neq 0 & \text{otherwise.} \end{cases}$$

while for our proposed model:

$${}_jBR_i = k + \beta \cdot \widehat{MR}_{i-1} + \gamma \cdot \widehat{\Delta MR}_i + \delta \cdot \widehat{BR}_{i-1}.$$

We remark that our approach could be compared with others, in terms of interest rate risk impact. This in line with what claimed in Esposito et al. (2013), who emphasize the importance of assessing the sensitivity of interest rate risk to different allocations of on-demand deposits. We also remark that an approach for the allocation of on-demand deposits similar to ours has been introduced in Cocozza et al. (2015): the main difference is that, in that paper the authors use, rather than the predicted bank rates, the rates that correspond to a hypothetical ±100 basis point variation of the monetary rate transmitted by the ECM model. Finally, we remark that Blochlinger (2015) propose to hedge on-demand deposits, seen as a risky option, using a forward looking perspective similar to ours, based on a non linear model for deposit rate jumps.

3. Data analysis and results

3.1. Descriptive analysis

The recent financial crisis has had a major impact on the banking sector and, in particular, has led to a change in the relationship between monetary and administered rates and, therefore, to the transmission mechanisms of monetary policies. In the Eurozone, characterized by one monetary authority (the European Central Bank), that regulates still fragmented national markets, this effect is particularly evident: southern european countries, differently from what expected, have benefited very little from the drop of monetary rates that has followed the financial crisis.

To investigate the above issues we focus on a southern european country, Italy, for which the transmission of monetary impulses is particularly problematic, given the importance of the banking sector and the difficult economic situation.

Accordingly, we have collected monthly time series data on monetary rates and on aggregate bank deposits administered rates from the statistical database provided by the Bank of Italy, for the period ranging from January 1999 to December 2014.

For the purposes of our analysis, the monetary rate used in this paper is the 1-month Euribor. This choice has been based on the fact that this rate has a greater correlation with the administered bank rate with respect to the other monetary rates, such as the EONIA and the Euribor at 3 and 6 months, as can be seen in Table 3.1

Figure 3.1 represents the time series of the chosen monetary rates, along with that of the aggregate administered bank rates on deposits, for the considered time period.

	EONIA	Euribor (1m)	Euribor (3m)	Euribor (6m)	Bank Rate
EONIA	1.0000				
Euribor (1m)	0.9904	1.0000			
Euribor (3m)	0.9801	0.9951	1.0000		
Euribor (6m)	0.9701	0.9876	0.9972	1.0000	
Bank Rate	0.9488	0.9512	0.9453	0.9333	1.0000

Table 3.1: Correlation matrix between the EONIA rate, the Euribor rates and the Bank administered rate

From Figure 3.1 note that both the administered and the monetary rates rapidly decreased in 2008 and 2009, while in the last two years they have remained quite stable and close to zero. Moreover, the two curves seem to have the same shape between 1999 and 2008, while the relationship between the two radically changes in the following years, leading to overlaps and different behaviours. In other words, the correlation pattern between the bank administered rate and the monetary rate shows a very heterogenous behaviour: before 2008 they seem to have a stable relationship; in 2008 they both dropped; after that time they look stable and close to zero, with a relationship that is indeed quite different from the one observed before the crisis.

To obtain further insights, in Figure 3.2 we present the histogram and the corresponding density estimate of the two rates.

Figure 3.2 reveals that bank administered interest rates are more concentrated around their mean value, while monetary rates are quite spread.

It is also interesting to compare the distributions of the variations of the two rates, represented in Figure 3.3.

From Figure 3.3 note that the variations of the administered bank rates

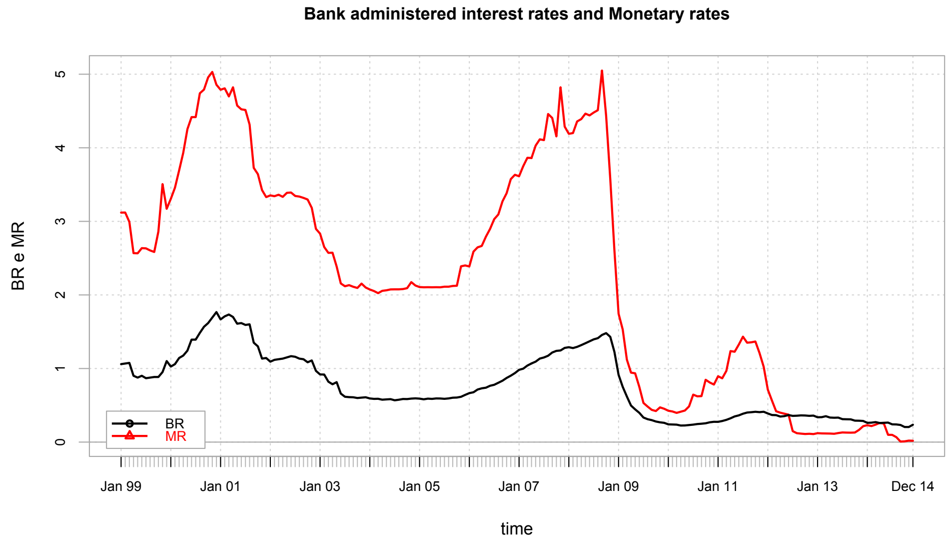

Figure 3.1: The observed monetary and administered bank rates

are more concentrated around zero, while monetary rates seem to have broader variations. Indeed, the behaviour of ΔMR justifies the assumption of considering the variations of monetary interest rates as a Wiener process, so that they can be modelled according to equation (2.11).

We have previously commented on the change in the relationship between the two rates, comparing the situation before and after 2009. This switching behaviour can be easily seen by looking at the correlation between the rates and their variations. Table 3.2 shows the correlations between the rates and between their variations in the two periods (1999-2008) and (2009-2014), before and after the financial crisis.

From Table 3.2 note that the correlation between the levels of bank and monetary rates has decreased after 2009, while the correlation between the variations of the administered bank rates and those of the monetary rates

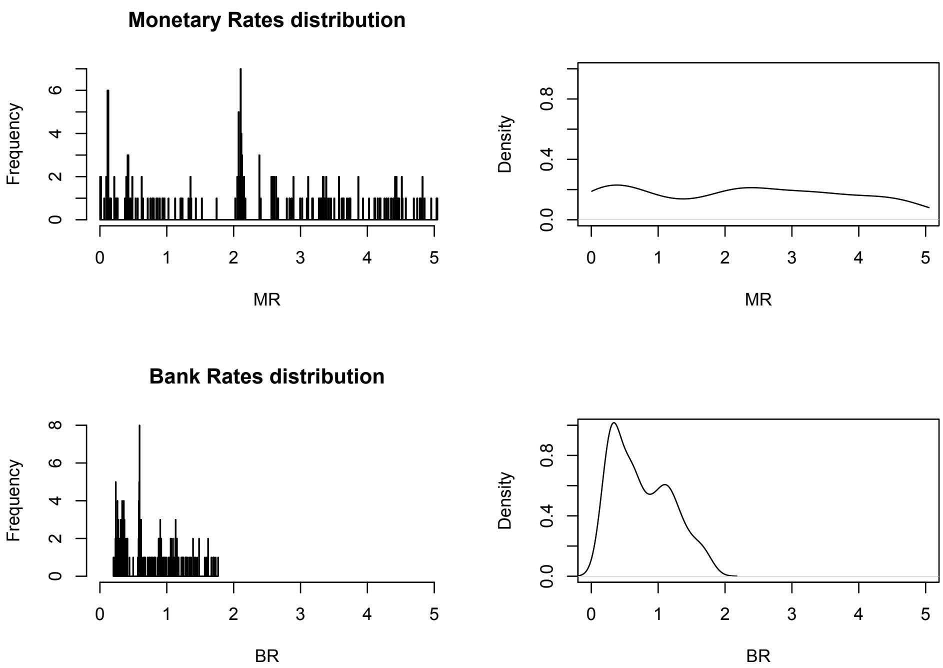

Figure 3.2: Distribution of the monetary and the administered bank rates

has increased during the same period.

3.2. Model estimates

For the models proposed in Section 3.1 and 3.2 we now show the corresponding parameter estimates, considering the following four time series: (a) data from 1999 to 2007; (b) data from 1999 to 2008; (c) data from 2009 to 2013; (d) data from 1999 to 2013. This choice of data windows is consistent with the aim of investigating the switching behaviour in the correlation structure of interest rates, which has occurred during the years 2008 and 2009. On the basis of this windows selection we intend to obtain predictions for the years 2008, 2009 and, finally, for the last available year, 2014. Predictions that can be compared with the actual occurred value,

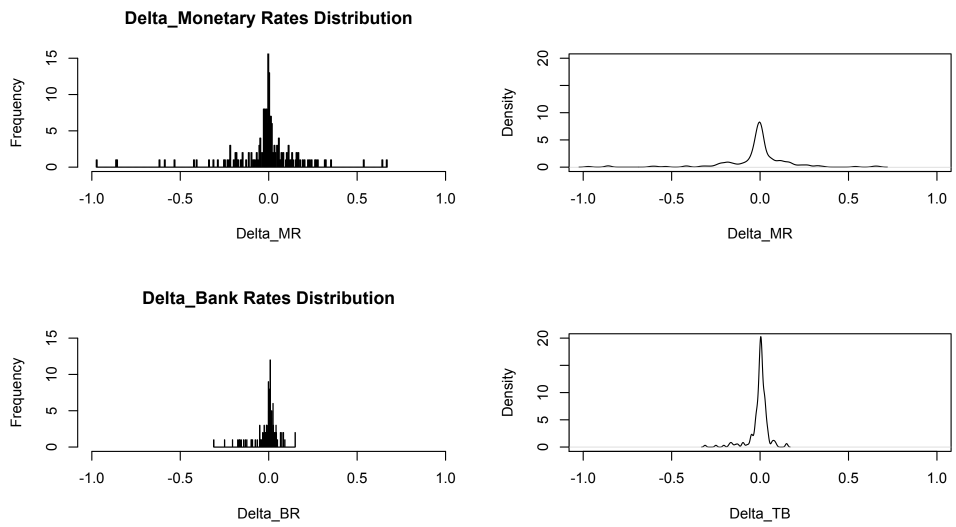

Figure 3.3: Distribution of the variations of monetary and administered bank rates

	1999 - 2008	2009 - 2014	1999 - 2014
BR, MR	0.95	0.71	0.96
ΔBR, ΔMR	0.43	0.83	0.58

Table 3.2: Correlation matrix between rates and their variations, in different periods

thus giving a measure of model predictive performance.

We now show the parameter estimates for all the considered models, including the two simple univariate linear models, and the four periods we have chosen. For each estimate we also report the corresponding t-value, and the R^2 contribution of each model.

Table 3.3 shows the parameter estimates for the error correction model proposed by Chong et al. (2006) which, we recall, has two equations and, correspondingly, two R^2 measures.

From Table 3.3 note that, for the error correction model with two adjustment speeds, the results confirm a radical change in the relationship

	1999 - 2007		1999 - 2008		2009 - 2013		1999 - 2013	
	Coeff.	t	Coeff.	t	Coeff.	t	Coeff.	t
k	-0.133	-3.426	-0.100	-2.542	0.263	12.265	0.146	7.896
β	0.351	29.741	0.341	29.425	0.138	4.836	0.271	41.114
α	0.107	4.412	0.0909	4.863	0.096	4.430	0.126	7.455
δ_1	-0.286	-5.028	-0.288	-5.513	-0.348	-11.214	-0.175	-5.154
δ_2	-0.209	-4.194	-0.220	-4.680	-0.032	-0.813	-0.109	-3.008
R^2 long	0.893		0.880		0.287		0.905	
R^2 short	0.443		0.485		0.902		0.449	

Table 3.3: Parameter estimates for the error correction model with two adjustment speeds

between the variables during the period under analysis: remembering that the long-run equation models the levels of interest rates, while the short-run equation is a function of the variations of the rates, it is clear that in the last few years the levels of the rates have become less and less important, while their variations have gained exploratory capacity.

Table 3.4 shows the parameter estimates for the error correction model with one adjustment speed.

	1999 - 2007		1999 - 2008		2009 - 2013		1999 - 2013	
	Coeff.	t	Coeff.	t	Coeff.	t	Coeff.	t
k	-0.133	-3.426	-0.100	-2.542	0.263	12.265	0.146	7.896
β	0.351	29.741	0.341	29.425	0.138	4.836	0.271	41.114
α	0.111	4.620	0.096	5.300	0.145	5.316	0.131	7.903
δ	-0.242	-6.388	-0.250	-7.132	-0.235	-6.707	-0.144	-5.721
R^2 long	0.893		0.880		0.287		0.905	
R^2 short	0.437		0.480		0.822		0.444	

Table 3.4: Parameter estimates for the error correction model with one adjustment speed

From Table 3.4 note that the error correction model with only one adjustment speed shows results very similar to those reported in Table 3.3: in particular, it has similar R^2 values, meaning that this simplified version of the error correction model fits past data quite well and, therefore, it may suffice. As a further confirmation, it can be shown that the equality assumption $\delta_1 = \delta_2$ in Chong et al. (2006) model is rejected only in one of the four considered time windows.

Table 3.5 shows the parameter estimates for the simple linear model in terms of the levels of the bank interest rates.

	1999 - 2007		1999 - 2008		2009 - 2013		1999 - 2013	
	Coeff.	t	Coeff.	t	Coeff.	t	Coeff.	t
k	-0.133	-3.426	-0.100	-2.542	0.263	12.265	0.146	7.896
β	0.351	29.741	0.341	29.425	0.138	4.836	0.271	41.114
R^2	0.893		0.880		0.287		0.905	

Table 3.5: Parameter estimates for the linear model in terms of the levels of bank interest rates

From Table 3.5 note that the estimates obtained with the univariate linear model for interest rates are similar to those obtained by using the long-run equation of the error correction model.

Table 3.6 shows the parameter estimates for the simple linear model in terms of variations of bank interest rates.

	1999 - 2007		1999 - 2008		2009 - 2013		1999 - 2013	
	Coeff.	t	Coeff.	t	Coeff.	t	Coeff.	t
β	0.149	5.444	0.131	6.344	0.278	11.28	0.162	9.592
R^2	0.219		0.254		0.683		0.341	

Table 3.6: Parameter estimates for the linear model in terms of the variation of bank interest rates

From Table 3.6 it is clear that the univariate linear model for the variations of administered bank interest rates, calculated as a function of the variations of monetary rates, shows different results: first of all, the intercept term is not significant; secondly, R^2 values have an opposite trend with respect to those in 3.5, increasing during the last period. This result is a further confirmation of the changing regime after 2009.

Table 3.7 shows the parameter estimates for our proposed model.

	1999 - 2007		1999 - 2008		2009 - 2013		1999 - 2013	
	Coeff.	t	Coeff.	t	Coeff.	t	Coeff.	t
k	-0.064	-4.394	-0.061	-4.561	0.077	8.498	-	-
β	0.100	9.369	0.098	10.992	-	-	0.042	6.205
γ	-	-	-	-	-	-	0.091	4.750
δ	0.743	25.695	0.746	30.454	0.731	24.544	0.869	40.836
R^2	0.986		0.987		0.974		0.998	

Table 3.7: Parameter estimates for the proposed model

Table 3.7 shows that our new model presents an interesting behaviour. For the whole period 1999-2013 all variables (apart from the intercept) are significant to describe the administered interest rates. But the situation changes if one concentrates on the first or on the second period: within the years 1999-2007 and 1999-2008 the variations of the monetary rates do not affect the level of bank rates; on the contrary, during the last period the only significant variable is the autoregressive component.

This is a clear evidence of the fact that, when rates are close to zero as in the last few years, administered interest rates are not affected by monetary rates, or by their variations, but, rather, they depend only on their past values.

3.3. *Predictive performances*

After having estimated the coefficients of the different models we then predict monthly administered bank interest rates and their variations for 2008, 2009 and 2014, using a range of monetary rates scenarios, simulated from a Wiener process as previosuly described. In particular, for the 2014 prediction we performed the simulations by using the coefficients obtained both by considering the whole period (1999-2013) and the second part of the time range under examination (2009-2013). In Figure 3.4 a comparison between the predictions for 2014 (data from 1999 until 2013) obtained with the error correction model and our proposed model is shown.

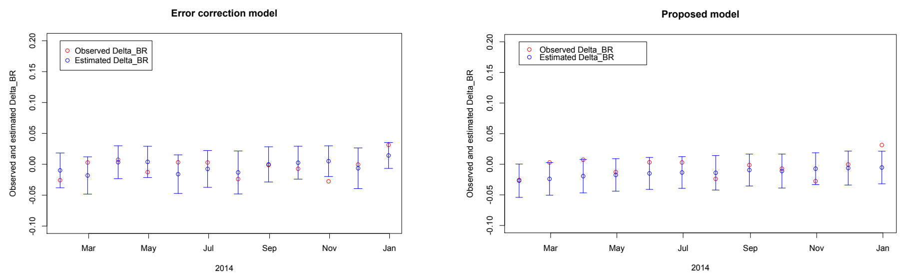

Figure 3.4: The estimated variations of administered interest rates for 2014, obtained with the error correction model and with our proposed model by using coefficients calculated on the whole period 1999 - 2013.

As a measure of predictive performance we have calculated the root mean square errors of the predictions from all models. Here we present the prediction results in terms of variations of bank rates rather than on their levels. This because, in this case, all the predictions are more challenging, being the variations on a smaller scale.

In Table 3.8 the root mean square errors of the predicted variations of administered interest rates obtained with the error correction model and our proposed new model are reported.

Model	2008 (1999-2007)	2009 (1999-2008)	2014 (2009-2013)	2014 (1999-2013)
Error correction model	0.055	0.171	0.016	0.003
Proposed model	0.065	0.069	0.014	0.018

Table 3.8: A comparison between the root mean square errors of the predictions of ΔBR

The first column of Table 3.8 refers to the prediction errors for the year 2008, obtained with the two selected models, and using coefficients estimated on data from 1999 to 2007. Similarly, the second and the third column report root mean square errors for 2009 and 2014. We decided to compare predictions on these crucial years because they represent the breaking points before and after which the relationship between the rates radically changes. The objective is thus to verify whether the two models can adapt to such strong variations in the underlying economic system. Note that the last two columns both refer to estimations for 2014, but the first one uses coefficients estimated only the second period data, while the second one is based on estimations on the entire period 1999-2013.

From the analysis of Table 3.8 some interesting conclusions emerge: (a) both models predict quite well future variations of bank interest rates; (b) the error correction model works better on the whole period and, most interestingly, (c) our proposed model supplies great improvements for the crucial year 2009. This means that the new model is much more flexible than the Error Correction Model, and it is able to capture essential changes in the economy not only from an estimation fit point of view, as seen in the last subsection, but also in a predictive perspective.

3.4. Application to interest rate risk

Movements in interest rates can have a negative impact on both the income results and on the economic value of a bank. This has given rise to two distinct, albeit complementary, perspectives to measure the exposure to interest rate risk: the income perspective and the economic value perspective. In the first one the analysis is based on the impact of changes in monetary rates on short-term profits and losses of banks; in the second one, instead, the attention is focused on the sensitivity of the assets and the liabilities of a bank to changes in monetary rates.

In this application we confine our risk measurement to on-demand deposits. For the evaluation of interest rate risk, we consider the allocation of such deposits in time maturity periods as described in Section 3.4. For ease of illustration, we consider only a one year period ahead. Table 3.9 and Table 3.10 describe the weight coefficients that result, respectively, from the application of the ECM and of the proposed model.

Maturity	1999-2007 (2008)	1999-2008 (2009)	2009-2013 (2014)	1999-2013 (2014)
Up to 1 month	0.0835	0.0793	0.0834	0.0834
From 1 to 3 months	0.1660	0.1644	0.1667	0.1666
From 3 to 6 months	0.2500	0.2516	0.2501	0.2511
From 6 months to 1 year	0.5005	0.5047	0.4998	0.4989

Table 3.9: Allocation weights for ECM

By comparing Table 3.9 with Table 3.10 note that allocation coefficients are quite stable across time periods: this is consistent with the fact that, for the predicted years (2008, 2009 or 2014), the monthly variations of administered bank rates are quite stable. The allocation weights are, therefore,

Maturity	1999-2007 (2008)	1999-2008 (2009)	2009-2013 (2014)	1999-2013 (2014)
Up to 1 month	0.0842	0.0803	0.0833	0.0838
From 1 to 3 months	0.1666	0.1667	0.1667	0.1682
From 3 to 6 months	0.2499	0.2511	0.2500	0.2513
From 6 months to 1 year	0.4993	0.5019	0.5000	0.4967

Table 3.10: Positioning coefficients for the proposed model

essentially a function of the number of months in each time maturity period. If the allocation were done proportionally to the number of months, as suggested by some regulators, we would indeed get similar results.

Note also that the ECM and the proposed model lead to very similar allocations, and this is a further evidence that our model, being more parsimonoius, should be preferred.

The measurement of the exposure to interest rate risk in the banking book from the income perspective takes place over a short-term period (called gapping period); in operating practice, this is usually equal to 1 year. According to this approach we can use the repricing gap model, which calculates the expected change in the interest margin (IM) as the result of a change in monetary rates. The corresponding formula is the following:

$$\widehat{\Delta IM} = \widehat{\Delta MR}_j \cdot \sum_{\substack{j \\ (t_j \leq T)}} G'_{t_j} \cdot (T - t_j^*) = \widehat{\Delta MR}_j \cdot G_T^w, \tag{3.1}$$

where G'_{t_j} indicates a marginal time gap ($= assets - liabilities$), $t_j^* = \frac{t_j + t_{j-1}}{2}$ represents the average time maturity, and G_T^w indicates the cumulative gap.

In Table 3.11 we present, for each node in the term structure of interest rates, the impact on the interest margin of a positive change of 200 basis points (the Basel II level) in the level of monetary rates, when the ECM model is used to allocate volumes and it is assumed to consider core on-demand deposits totalling to 100 euro.

Maturity	$T - t_j^*$	1999-2007 (2008)	1999-2008 (2009)	2009-2013 (2014)	1999-2013 (2014)
Up to 1 month	0.9583	-0.1600	-0.1521	-0.1598	-0.1599
From 1 to 3 months	0.8333	-0.2768	-0.2740	-0.2778	-0.2777
From 3 to 6 months	0.6250	-0.3125	-0.3145	-0.3126	-0.3138
From 6 months to 1 year	0.2500	-0.2502	-0.2523	-0.2499	-0.2495
		-0.9995	-0.9929	-1.0001	-1.0009

Table 3.11: Expected changes in the interest margin for ECM

In Table 3.12 we present, for each node in the term structure of interest rates, the impact on the interest margin of a positive change of 200 basis points (the Basel II level) in the level of monetary rates, when our proposed model is used to allocate volumes.

Maturity	$T - t_j^*$	1999-2007 (2008)	1999-2008 (2009)	2009-2013 (2014)	1999-2013 (2014)
Up to 1 month	0.9583	-0.1614	-0.1540	-0.1597	-0.1605
From 1 to 3 months	0.8333	-0.2776	-0.2778	-0.2778	-0.2804
From 3 to 6 months	0.6250	-0.3124	-0.3139	-0.3125	-0.3141
From 6 months to 1 year	0.2500	-0.2496	-0.2509	-0.2500	-0.2483
		-1.0010	-0.9966	-1.0000	-1.0033

Table 3.12: Expected changes in the interest margin for the proposed model

Comparing Table 3.11 with Table 3.12 note that, as could be expected from the corresponding volume allocation tables, there are not substantial differences between the two models and across the different time periods, as could be expected for the similar allocation weights in Tables 3.9 and 3.10.

We remark that, in the above tables, we have considered the impact of an increase in monetary rates. The impact of a decrease is obviously opposite.

The measurement of the exposure to interest rate risk in the economic perspective can be based on the regulatory approach described in Basel II (BIS, 2004), which relies on the concepts of duration and modified duration. For a given (net) position, let F_t be the cash flow and t its corresponding maturity; MR represents the interest rate at maturity, and NP is the total net position market value. The duration D can be calculated as

$$D = \sum_{t=1}^{T} t \cdot \frac{F_t}{\frac{(1+MR)^t}{NP}}, \tag{3.2}$$

while the modified duration is

$$MD = \frac{D}{1+MR}. \tag{3.3}$$

It is well known that variations in the market value of a position can be expressed by the formula

$$\frac{\partial NP_i}{\partial MR_i} = -NP_i \cdot MD_i, \tag{3.4}$$

so that the variation of the economic value of a bank can be expressed by

$$\mathrm{d}\, EV = \sum_i \sum_j \mathrm{d}\, NP_{ij}, \tag{3.5}$$

where i specifies a time slot (fourteen, according to BIS, 2014), while j considers different currencies.

The previous equations refer to the general case: remembering that net positions are defined as the difference between assets and liabilities, the sign in the second member of equation (3.4) becomes positive if we consider only on-demand deposits. Moreover, equation (3.5) can be simplified by considering its discrete version:

$$\Delta EV = -\sum_i \sum_j NP_{ij} \cdot MD_{ij} \cdot \Delta MR_{ij}, \tag{3.6}$$

In Table 3.13 we present, for each node in the term structure of interest rates, the impact on the economic value of a positive change of 200 basis points (the Basel II level) in the level of the monetary rate, when the ECM model is used to allocate volumes and it is assumed to consider core on-demand deposits totalling to 100 euro. We have employed the approximate duration suggested by the Basel Committee (BIS, 2004).

Maturity	Duration	1999-2007 (2008)	1999-2008 (2009)	2009-2013 (2014)	1999-2013 (2014)
Up to 1 month	0.0400	-0.0067	-0.0063	-0.0067	-0.0067
From 1 to 3 months	0.1600	-0.0532	-0.0526	-0.0533	-0.0533
From 3 to 6 months	0.3600	-0.1800	-0.1811	-0.1801	-0.1808
From 6 months to 1 year	0.7100	-0.7106	-0.7166	-0.7097	-0.7084
		-0.9505	-0.9566	-0.9498	0.9492

Table 3.13: Expected changes in the economic value for ECM

In Table 3.14 we present, for each node in the term structure of interest rates, the impact on the economic value of a positive change of 200 basis points (the Basel II level) in the level of the monetary rate, when our proposed model is used to allocate volumes, under the same assumptions as before.

Maturity	Duration	1999-2007 (2008)	1999-2008 (2009)	2009-2013 (2014)	1999-2013 (2014)
Up to 1 month	0.0400	-0.0067	-0.0064	-0.0067	-0.0067
From 1 to 3 months	0.1600	-0.0533	-0.0533	-0.0533	-0.0538
From 3 to 6 months	0.3600	-0.1799	-0.1808	-0.1800	-0.1809
From 6 months to 1 year	0.7100	-0.7090	-0.7126	-0.7100	-0.7053
		-0.9489	-0.9531	-0.9500	-0.9468

Table 3.14: Expected changes in the economic value for the proposed model

Comparing Table 3.13 with Table 3.14 note that, for the economic capital as well, there are not substantial differences between the two models and across the different time periods, as expected.

A comparison between the interest rate risk in the income rather than in the economic perspective shows that the main difference between the two is due to the different consideration of the time factor $(T - t^*)$ for the former and the duration for the latter.

4. Conclusions

The main contribution of this paper is in the understanding and improvement of the Error Correction Model, used in standard professional practice to model variations of the administered bank rates as a function of monetary rates. We add to the model a predictive methodology, that allows its validation, and propose a simpler to interpret one equation model, that can be seen as a special case of the ECM itself.

We also contribute to the literature in interest rate risk by suggesting a forward looking method to allocate on-demand deposits to non-zero time maturity bands, according to the predicted bank rates.

We have shown the implications of our proposals on data for the aggregate Italian banking sector, that concerns the recent period, characterised by a substantial shift in the relationship between monetary and bank rates, with the former getting close to zero.

Future research in this topic may involve the use of time-inhomogeneous stochastic differential equations and dynamic linear models, in order to improve the model ability to adapt to dynamic changes.

From an applied viewpoint, it may be of interest to analyze the relationship between monetary and bank rates also on the asset side, and derive a spread measurement.

Finally, a further extension should consider the microeconomic impact of the found relationships on the probability of default of both financial and non financial corporates, enriched with a systemic correlation perspective.

5. Acknowledgements

The Authors thank the Italian Association for financial risk management (AIFIRM) and the MIUR PRIN project MISURA: Multivariate statistical models for risk assessment, for financial support.

The Authors also remark that the present work actually stems from the solution of a professional risk management problem suggested by Camillo Giliberto and Igor Gianfrancesco, within the AIFIRM association.

Finally, the views expressed in this paper are those of the authors and they do not reflect the views or policies of their Institutions: Banco di Desio e della Brianza, Monte dei Paschi di Siena, University of Pavia.

6. References

Ballester, L., Ferrer, R., Gonzales, C., Soto, G.M., 2009. Determinants of interest rate exposure of the Spanish banking industry. Working Paper, University of Castilla-La Mancha.

Basel Committee on Banking Supervision, 2004. Principles for Management and Supervision of Interest Rate Risk.

Basel Committee on Banking Supervision, 2014. Net Stable Funding Ratio disclosure standards.

Blocklinger, A., 2015. Identifying, valuing and hedging of embedded options in non-maturity deposits. Journal of Banking and Finance 50, 34-51

Chong, B. S., Liu, M., Shrestha, K., 2006. Monetary transmission via the administered interest rates channel. Journal of Banking and Finance 30(5), 1467-1484.

Cocozza, R., Curcio, D., Gianfrancesco, I., 2015. Non maturity deposits and bank's exposure to interest rate risk: issue arising from the Basel Regulatory framework. Journal of Risk 17(4), forthcoming.

Demirguc-Kint, A., Huizinga, H., 1999. Determinants of commercial bank interest margins and profitability: some international evidence. World Bank Economic Review 13(2), 379-408.

Engle, R. F., Granger, C. W. J., 1987. Co-integration and error correction: representation, estimation, and testing. Econometrica 55(2), 251-276.

English, W.B., 2002. Interest rate risk and bank net interest margins. BIS Quarterly Review, 67-82.

English, W.B., Skander J. Van den Heuvel, Zakrajsek, E., 2012. Interest rate risk and bank equity valuations. Finance and Economics Discussion

Series, 2012-2026.

Entrop, O., Wilkens, M., Zeisler, A., 2009. Quantifying the Interest Rate Risk of Banks: Assumptions Do Matter. European Financial Management 15(5), 1001-1018.

Esposito, L., Nobili, A., Ropele, T., 2013. The management of interest rate risk during the crisis: evidence from Italian banks. Working Paper, Bank of Italy.

Fiori, R., Iannotti, S., 2007. Scenario Based Principal Component Value-at-Risk: An Application to Italian Bank's Interest Rate Risk Exposure. Journal of Risk 9(3), 63-99.

Flannery, M.J., James, C.M., 1984. The effect of interest rate changes on the common stock returns of financial institutions. The Journal of Finance 39, 1141-1153.

Gambacorta, L., 2005. How do banks set interest rates?. European Economic Review 52(5), 792-819.

Gambacorta, L., Iannotti, S., 2007. Are there asymmetries in the response of bank interest rates to monetary shocks?. Applied Economics 39(19/21), 2503-2517.

Hannan, T., Berger, A., 1991. The rigidity of prices: Evidence from banking industry. American Economic Review 81, 938-945.

Heffernan, S.A., 1997. Modelling British interest rate adjustment: An error correction approach. Economica 64, 211-231.

Hodrick, R., Prescott, E.C., 1997. Postwar U.S. Business Cycles: An Empirical Investigation. Journal of Money, Credit, and Banking 29(1), 1-16.

Houpt, J. V., Embersit, J. A., 1991. A Method for Evaluating Interest Rate Risk in U.S. Commercial Banks. Federal Reserve Bulletin 77(2), 625-

637.

Kleimeier, S., Sander, H., 2004. Convergence in euro-zone retail banking? What interest rate pass-through tells us about monetary policy transmission competition and integration. Journal of International Money and Finance 23(3), 461-492.

Kleimeier, S., Sander, H., 2006. Expected versus unexpected monetary policy impulses and interest rate pass-through in euro-zone retail banking markets. Journal of Banking and Finance 30(7), 1839-1870.

Maudos, J., Guevara, J.F., 2004. Factors explaining the interest margin in the banking sectors of the European Union. Journal of Banking and Finance 28(9), 2259-2281.

Maudos, J., Solis, L., 2009. The determinants of net interest income in the Mexican banking system: an integrated model. Journal of Banking and Finance 33(10), 1920-1931.

Resti, A., Sironi, A., 2007. Risk Management and Shareholders' Value in Banking: From Risk Measurement Models to Capital Allocation Policies. John Wiley, New York.

Scholnick, B., 1996. Asymmetric adjustment of commercial bank interest rates: evidence from Malaysia and Singapore. Journal of International Money and Finance 15(3), 485-496.

Sierra, G. E., Yeager, T. J., 2004. What Does the Federal Reserve Economic Value Model Tell Us About Interest Rate Risk at U.S. Community Banks?. The Federal Reserve Bank of St. Louis Review 86(6).