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INTEREST RATE PASS THROUGH IN THE DEPOSIT AND LOAN PRODUCTS PROVIDED BY GREEK BANKS

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ABSTRACT

A core input in performing a regulatory stress test is the evolution of interest rates, as it affects the income generated from the assets' side and the expenses from the liabilities' side. In this work, we apply an autoregressive model with distributed lags (ADL) to quantify the pass through rates, that is, the degree and speed of incorporation of the changes of money market rates by banks into their customers deposit and loan rates. In doing so, for the liabilities' side, we differentiate between open and term deposits, as well as between households and non-financial corporates. Our results indicate that for term deposits the long-term pass through rate is very high, exceeding 91% for non-financial corporate customers and 81% for households. For open deposits, the pass through rate dynamics appear less prevalent, amounting to 21% for non-financial corporate customers and 16% for households. When exploring the pass through rate dynamics in the assets' side of the banks, we observe full long-term pass-through of money market rates, for mortgage and consumer loans. By contrast, the non-financial corporate loans rate is stickier and less reactive to money market rates changes, with long-term pass-through adjustment being approximately equal to 40%. Furthermore, our results provide evidence that the Greek sovereign spread movement has practically negligible pass through rate both for loan and deposit products. In particular, it hardly affects the pricing of new term deposits, with a pass through rate of around 5%. This finding can be attributed, among others factors, to the fact that the Greek sovereign credit spread has approached several times non-tradable territories, which makes it an insignificant variable in determining customer rates.

JEL-classifications: G14, G17, C22

Keywords: interest rate pass-through, bank products, stress testing.

Disclaimer: The views expressed on this paper are those of the authors and not of the Bank of Greece.

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1. Introduction and motivation

Many researchers have devoted significant effort to explore the dynamics of the relationship between the monetary policy rate and retail banking rates. Following the global financial crisis of 2008, central banks responded by decreasing significantly the level of their monetary policy rates. The aforementioned policy response affected retail banking rates (i.e. deposit and lending product rates) and forced banks to modify their business models so as to remain profitable under the low interest rate environment.

From a regulatory point of view, analyzing the relationship between the policy rates and retail banking rates is an integral part for translating the impact of macroeconomic scenarios on bank specific balance sheet items. Given that the vast majority of solvency regulatory stress tests are performed using a time horizon of 3 years, it is of paramount importance to timely and accurately project, the Net Interest Income (NII) under different macroeconomic scenarios. In particular, the institutions' Net Interest Income can alleviate the negative impact stemming from an adverse macroeconomic scenario on the credit risk parameters, which would increase the need for extra capital.

This paper enriches the suit of satellite models described in the study of Petropoulos et al. (2018) employed for performing stress testing in the Greek Banking System by providing TD forecasts for the NII components of the bank's balance sheet. To the best of our knowledge, it is the first time that such a tailor made satellite model is developed for the Greek banking sector. The Bank of Greece and supervisors of Greek banks can make use it when conducting their Top-Down projections, as well as in challenging the banks' assumptions used under their internal stress tests. It can also be used to assess the prescribed pass through rates by the European Banking Authority in terms of plausibility and severity, relative to the ones envisaged by the proposed empirical relationship in this study. In addition, the proposed model can be utilized in Supervisory Review and Evaluation Process (SREP), where one of the components to be analyzed by the supervisors is the interest rate risk in the banking book, and how the profitability of the institution is exposed to interest rate movements.

Interest rate pass-through is defined as the degree and speed of incorporation of the monetary policy or market rates changes into banking rates. Most of the research studies investigate the degree and speed of adjustment of retail banking rates from changes in money market rates. In particular, Gigineishvili (2011) built models on the rationale that changes in central bank policy rates cause movements in market rates, which consequently pass through to commercial bank lending and deposit rates. Following the same rationale, we focus our analysis on how the pricing of the new deposit and loan rates is affected by the movement of the money market rates. The choice to use market rates, instead of policy rates, in our models, is prescribed by the fact that under a regulatory stress test there are no projections provided for the evolution of policy rates, though, there are available projections for the market rates. This is to avoid any monetary policy implications of the stress test macroeconomic scenario, as well as not to suggest a future path for policy rates that could be seen as binding for Central Banks.

Considering that regression type of models are mainly used in the current literature, for this type of problem, we opt for using the Autoregressive Distributes Lag (ADL) method (also used in Belke et al (2013), Darracq et al. (2014), etc.) that strikes a balance between complexity and interpretation of results. At the same time, it has enough flexibility to capture cross sectional and time series terms. Our results suggest that for term deposits the long-term pass through rate is very high, that is, over 91% for non-financial corporate customers and 81% for households. Whereas, the pass through rate dynamics appear much less prevalent for open deposits, reaching 21% for non-financial corporate customers and 16% for households. These results confirm our intuition that banks adjust quicker their rates for time deposits, reflecting the "investment-type" characteristics of this product. Regarding the pass through rate dynamics in the asset side of the banks, we observe full long-term pass-through of money market rate to mortgage and consumer loans, reflecting their characteristics as floating rate products. The non-financial corporate loans rate is stickier and less reactive to money market rate changes (i.e. long-term pass-through adjustment around 40%). Last but not least, our results indicate that the Greek sovereign spread movement has practically a negligible pass through rate both for loan and deposit products. That is, it hardly affects the pricing of new term deposits, with a pass through rate of around 5%. This finding can be attributed, among others factors, to the fact that the Greek sovereign credit spread has approached several times non-tradable territories, which makes it an insignificant variable in determining customer rates.

The structure of the remaining part of this study is organized as follows. In section 2, we focus on the related literature review on interest rate pass through modelling. Section 3 describes the data collection and processing. In section 4, we provide details regarding the methodology we pursued in analyzing our dataset. In section 5, we present the results and provide some robustness checks, while in section 6 we conclude and discuss areas for future work.

2. Literature review

Interest rate determinants and pass-through transmission mechanisms were the focus of numerous studies in current academic literature. Andres and Billon (2016) provide an overview of the empirical literature related to the econometric techniques employed in order to examine the interest rate pass through in the euro area.

Regarding the factors that affect pass-through transmission mechanisms, Gigineishvili (2011) showed that per capita GDP, inflation, interest rates, credit quality, competition among banks, excess liquidity, and market volatility affect the level of pass through. Kopecky et al. (2012) and Leuvensteijn et al. (2013), focused on bank competition and showed that the more competitive the market in which a bank was operating, the stronger the transmission mechanism. Zoli (2013) and Illes et al. (2013) discovered that the sovereign spread gets also passed through customers, via a sovereign risk component in the interest rate. Hristov et al. (2014) highlighted the loan and deposit maturity component, showing that the longer the maturities, the stickier the relevant rates (i.e. longer maturities rates resist more). Moreover, they found that tight collateral requirements, high costs of restoring the bank capital position, and weak competition exacerbated the incompleteness of the pass through. Schlüter et al. (2012) showed that in Germany the cost efficiency of banks is one of the determinants in the estimation of credit loan markup, as well as in the smooth set-up of the loan rates provided by the bank. Finally, Perera and Wickramanayake (2016), observed that in addition to above mentioned variables, the long run adjustment in retail interest rates also depends on institutional and governance factors, such as central bank transparency, independence, and financial strength.

The benchmark model in the literature for approaching the issue of pass through mechanism is the Autoregressive Distributes Lag (ADL) model, usually including an error correction term, in either time series or panel form. However, a substantial number of studies pointed that, pass through mechanism exhibits heterogeneity and asymmetries across countries, time periods, and products, so adopting an asymmetrical modelling framework could provide useful insight.

In this setting, Darracq et al. (2014) showed that the interest rate pass through of European Central Bank monetary policy was stronger prior to the sovereign debt crisis (2011-2013). Similarly, Havranek et al. (2015) showed that the strong and almost complete long-term pass through from market rates to lending rates prior to the crisis, weakened after 2008. Leroy and Lucotte (2016) showed that although the monetary policy in Eurozone was common, pass-through mechanisms fluctuated significantly over the countries and the type of retail rates. Belke et al (2013) also detected asymmetries in most of the countries, since the pass through is incomplete and money market rate increases affect loan rates differently from the money market rate decreases, whereas they also confirmed cross-country heterogeneity. Karagiannis et al (2010) explored the behavior of the interest rate transmission mechanism in the euro area and the United States after the 2008 financial crisis, showing that both EU & US banks pass changes of the relevant rate to depositors and borrowers asymmetrically. Finally, Gropp et al (2007) detected asymmetries in the pass through mechanism in deposit products compared to loan products, as interest rates variations are transmitted differently into similar products, such as deposits, with demand and saving deposits being more stable.

This is the first study that empirically tries to approach the issue of pass through mechanism for interest rates in the Greek banking system, during and after the Greek Sovereign Crisis. We do not deviate from the ADL benchmark technique of the literature, but we focus specifically in the sovereign risk component, as in Zoli (2013) and Illes et al. (2013). Sovereign risk was the main risk component in the Greek banking system in the period after 2012, affecting the cost of funding, whereas the low competition structure as formed after a significant banking system concentration, created a peculiar environment in which banks tried to manage their interest rate policy.

3. Data sample description

The dataset of deposit rates covers the rates offered by Greek banks to their customers, on a monthly basis, between January 2003 and June 2020. Deposit products redeemable with no specified maturity are considered as new production. The whole amount of these categories is included in our analysis, and reside in the category open deposits (i.e. sight and saving deposits). On the other hand, from the deposit products with specified maturity (i.e. term deposits), only the new production of term deposits is incorporated in our dataset. Our data covers more than 99% of the new deposits provided by banks operating in the Greek Market.

On top of that, we differentiate our analysis based on the type of depositor, that is, households vs. non-financial corporates[1]. Thus, our data is comprised of monthly observations for open and term deposits broken down by customer type, i.e. household and non-financial corporate customers. The EURIBOR 1 month (EUR001M Index) was used as the money market rate. Moreover, in order to explore the way Greek sovereign spread affects the pricing of the new deposits, we have extracted a Greek spread indicator from the difference of 10 year Greek (GGGB10YR Index) and the 10 year German (GDBR10 Index) benchmark yield rates. The aforementioned market rates were retrieved from Bloomberg.

In figure 1, the evolution of the money market rate, the Greek spread indicator, and the deposit with no specified duration for non-financial customers (DCORPO), are presented. In Greece, the global financial crisis of 2008 was followed by the sovereign debt crisis, and ended up, at the beginning of the 2012, with the private sector involvement (PSI). Around the time of the PSI, the Greek spread reached levels with no financial meaning due to sovereign debt restructuring uncertainty and its implications for

[1] To enhance transparency and to avoid any misinterpretation, the classification of the depositors follows the definitions of Governor's Act 2496/28.5.2002 and the Regulation of the European Central Bank ECB/2001/18.

the real economy. Post the period of PSI, the Greek spread tightened, as market participants acknowledged the implementation of austerity measures taken by Greek Government, and at the beginning of the second half of the 2014 it approached the level of 4.5%. Nevertheless, starting from the rumors of the impending impossibility of political parties to agree in the election of President of Hellenic Republic in second half of 2014, and concluding with the referendum and the capital controls imposed in June 2015, the Greek sovereign spread again moved to a non-tradable zone by reaching 15%. The sustained political stability since then, has caused a significant decrease in the Greek sovereign risk level. The Greek sovereign spread dropped from 15% to levels below 1.5%.

In the same figure, we observe the evolution of the 1-month Euribor. Although before the financial crisis of 2008 it exceeded 5%, key policy rates have subsequently decreased significantly, and the economic environment has altered to a persistent low interest rate environment. From the beginning of 2015 and onwards, 1-month Euribor passed into negative rate territory where it has remained. At the time of writing (August 2020), the 10-year euro swap rate (vs. Euribor 6 month) is moving around 15 bps below zero. Concurrently, the deposit rates offered for non-term products to non-financial corporates in Greece remain marginally above 0%.

Similar to figure 1, the evolution of the Greek Sovereign spread, the money market rate, and the deposit rate offered for term products to non-financial customers (DCORPTD), for non-term products to household customers (DHHO) and for term products to household customers (DHHTD), are presented in figures 2, 3 and 4, respectively. We observe that a similar trend is also observed, but with slight differences in the level of the rate (i.e. banks offer better pricing to their customers for term deposits compared to "overnight"[2] products)

[Insert Figures 1,2,3,4]

[2] We consider all products with no specified duration as overnight products

The new loan production dataset covers the period from June 2010 to June 2020[3]. We include in our analysis loans provided to non-financial corporates (LCORP), consumer loans (LCONS), and mortgage loans (LMORT). The evolution of the loan rates for the aforementioned loan categories is presented in figures 5-7, respectively.

[Insert Figures 5,6,7]

Similar to the case of deposits, where the 1-month Euribor was used as the money market rate, as this choice simultaneously covers overnight deposits and deposits with longer maturity, we also use the 1-month Euribor for the loan rates. Moreover, when investigating the correlation of the 1-month vs 3-month Euribor series, we found out that both rates comove over time (see figure 5). Specifically, the Pearson correlation was equal to 99.7%, while Spearman and Kendall were equal to 99.3% and 95.5%, respectively. Therefore, the choice of the 1-month Euribor does not seem to be a factor that can alter our main conclusions.

The dataset of new monthly production for deposits and loans used, is composed by the regulatory dataset submitted by Greek banking institutions to the Bank of Greece. The Greek sovereign spread and Euribor money market rate were retrieved by Bloomberg. To the best of our knowledge, we are not aware of any other study that explores the pass through dynamics of the money market rate changes to such an extended range of Greek deposit and loan products.

[Insert Figure 8]

4. Methodology

It has to be noted that the properties of the dataset used (i.e. unit roots, existence of strong cointegration relationship etc.) and the principal aim of each research study, affect the selection of the appropriate model (e.g. marginal cost pricing model, error correction model, autoregressive distributed lag model, etc.) in the examination of the interest rate pass-through modeling. Hence, the first step of the analysis is to test all the variables (i.e.

[3] The classification of the loans follows the definitions in accordance with Governor's Act 2496/28.5.2002 and the Regulation of the European Central Bank ECB/2001/18.

deposit rates, money market rate, and Greek Government spread indicator) for unit roots and determine their order of integration. The Augmented Dickey Fuller test is performed via using the "tseries" package in R. The results (table 1) indicate that all level variables are I(1), so that their first differences are stationary.

[Insert Table 1]

The stationarity of the 1st difference for the loans rates was also examined using the same test, and the results are presented in table 2.

[Insert Table 2]

In the second step, we examine the existence of cointegration of deposit and loans rates relative to the market variables. Specifically, we explore the potential long-term (i.e. structural) relationship between money market rates (1-month Euribor), and deposit and loan rates. The existence of strong cointegration (or not) will guide our choice to include or not the error correction term in our models. Following the Engle and Granger approach, we see no merit to include the error correction term in our analysis, since no strong cointegration between money market, and deposit and loan rates exists. In particular, in table 3 we provide the p-values of the Augmented Dickey Fuller test to examine the stationarity of the residuals extracted from the Engle-Granger two step approach. In all cases, we observe that the null hypothesis of stationarity cannot be rejected.

[Insert Table 3]

[Insert Figures 9,10]

So far, we have shown that our time series are I(1) and no cointegration exists for deposit and loan rates, relative to the money market rates (1m Euribor). We have to mention here, that the use of an extended time period coupled with the significant structural changes realized in the world and Greek economy during the period considered here, do not facilitate the build-up of such a relationship.

We divide our dataset into two parts, in order to assess the robustness of the models developed. The first 75% is the in-sample, and the remaining 25% is the out-of-sample used for validation purposes. The pass through rates are estimated in the in-sample part of the dataset using an autoregressive model with distributed lags, also denoted as ADL(p,r), which can be written as

$$f(L)y_t = a + b(L)x_t + e_t, \quad (1)$$

where

$$f(z) = 1 - \sum_{k=1}^{p} f_k z^k \quad (2)$$

and

$$b(z) = \sum_{k=0}^{r} b_k z^k. \quad (3)$$

The permanent change in the level of $x_t$is captured by the long run multiplier lamda (λ) which is estimated by the following relationship

$$\lambda = \frac{\sum_{k=0}^{r} b_k}{1-\sum_{k=1}^{p} f_k}, \quad (4)$$

while the short term pass through rate is equal to the numerator of the lamda coefficient.

Our time series are I(1) and the maximum number of lags considered is 5. The vast majority of the Greek loan products is directly linked to a specific money market rate index, and the updated rate is usually redefined on a monthly basis. Moreover the banks' committees responsible to determine the loan and deposit rates offered to customers, are usually taking place on a monthly basis, thus it is not expected the repricing period to exceed the six months significantly. To confirm our expectation, we assessed lags up to 12m and no statistical significant coefficients were discovered.

Thus, the delta (i.e. first differences) of deposit and loan rates at time t will be regressed against the deltas of 1m Euribor and Greek sovereign spread of the same month t as well as on the changes of the previous 5 months. The pass through equations take the following form:

$$\Delta dr_t = \alpha + \sum_{k=0}^{5} b_k \Delta Euribor_{t-k} + \sum_{k=0}^{5} c_k \Delta GrSpread_{t-k} + \sum_{k=0}^{5} g_k \Delta dr_{t-k-1} \quad (5)$$

$$\Delta lr_t = \alpha' + \sum_{k=0}^{5} b'_k \Delta Euribor_{t-k} + \sum_{k=0}^{5} c'_k \Delta GrSpread_{t-k} + \sum_{k=0}^{5} g'_k \Delta lr_{t-k-1} \quad (6)$$

The final choice of the lags to be included in our model is determined by applying the Akaike information criterion (AIC) in a stepwise algorithm, by employing the function "step" in R platform. Finally, we confirm the absence of autocorrelation in the residuals of the selected models, by regressing the consecutive residuals against each other and test for a significant slope coefficient (detailed outputs are presented in Annex A).

The short-term and long-term pass through rates of money market rates into deposit rates[4] are presented in the next formulas:

$$short\ term\ pass\ through\ rate = \sum_{k=0}^{5} b_k \quad (7)$$

$$long\ term\ pass\ through\ rate = \frac{\sum_{k=0}^{5} b_k}{1-\sum_{k=0}^{5} g_k} \quad (8)$$

5. Results & robustness checks

Tables 4 and 5 present a synopsis of the models developed using the aforementioned approach. The detailed output of the models is presented in Annex B. More specifically for each deposit and loan rate category we provide the respective coefficients α, b_k, c_k, g_k.

[Insert Tables 4,5]

Our results indicate that the Greek sovereign spread has an insignificant pass through rate for almost all categories of loan and deposit rates. Indeed, it only slightly affects the pricing of the new term deposit product (i.e. less than 5%). This observation may not hold for other economies, where the level of the sovereign credit risk never approached non-tradable territories such as that reached by Greece (see figure 1). It is worth noting that the choice of EBA ST 2020 methodology to set proportionally greater gamma factors for term deposits (i.e. minimum pass through rates of the changes in the sovereign bond spread under the adverse scenario) compared to non-term deposits (as shown in box 25 and box 26 in the 2020 EU wide Stress Test Methodological Note[5] for the gamma and lamda factors respectively), is aligned to our results. Nevertheless, our analysis for the case of Greece implies much lower pass through rates relative to those prescribed by the EBA ST 2020 methodology. So, it seems that the EBA methodology

[4] Similar formulas are also applicable to loan rates.
[5] https://eba.europa.eu/sites/default/documents/files/document_library//2020%20EU-wide%20stress%20test%20-%20Methodological%20Note.pdf

overstates the impact arising from increased funding cost on Greek banks, due to the Sovereign credit spread widening.

By contrast, the dynamics of money market rates transmission to the pricing of deposit and loan products is stronger. Specifically, in the case of term deposits the long-term pass through rate for non-financial corporate customers exceeds 91%. Similarly, for term deposits offered to household customers the long-term pass through rate is around 81%. The corresponding dynamics for the non-term deposits, are less strong around 15-20%. Regarding the money market rate pass through rates on loan products, they are more pronounced in the mortgage and consumer loans categories, relative to loans provided to non-financial corporates. More specifically, banks pass practically the whole movement of the money market rate to mortgage and consumer loans, as the long-term adjustment is approximately equal to 107% and 104% respectively. On the other hand, the non-financial corporate loans rates are stickier and less impacted by money market rate changes, with long-term pass through approximately equal to 40%. It is worth noting that the overshooting (i.e. long-term pass-through above 100%) in the mortgage and consumer loans, could be potentially be explained by the asymmetric information costs. The margin component was slightly decreased in the period after the outbreak of crisis, because banks were providing new loans to customers with better credit quality, in their attempt to decrease the chances of new defaults. The pass through rates (long and short term) of the money market transmission to deposit and loan products, are presented in table 6.

Loans pricing is more responsive to money market rate changes (i.e. higher pass through rates) comparing to deposit rate pricing. This observation is mainly due to fact that the majority of the Greek loan products is directly linked to a specific money market rate index (e.g. 1-month Euribor, 3-month Euribor, etc.), while for the majority of the Greek deposit products the rate offered to customers is determined internally by banks' committees. This is also the reason for the weaker pass through rates observed in corporate loans, in comparison to other loan products. A significant amount of loans under the corporate loans category (LCORP) is fixed rate loans, and bank committees typically determine the loan rates offered to their customers.

When comparing the transmission of money market rate changes for open and term deposit products, we have to consider the characteristics of the deposit products market. Households and corporations in Greece, consider open deposits equivalent to cash at hands and working capital. Those amounts are liquid and redeemable at any time. Thus, banks always offer smaller rates for open deposit products in contrast to term deposit products. Moreover, the deposit products pricing seems to incorporate an implied floor of 0%, whereas, although money market rates are well beyond 0%, none of the deposit product rates is below zero. Term deposit products had the ability to absorb greater part of the money market rate decrease, and, in tandem, not violate the prevailing implied floor of 0% mentioned above.

[Insert Table 6]

In order to more clearly articulate what these pass through rates imply for the evolution of loan and deposit rates, we present below how a hypothetical increase of money market rates and Greek sovereign spreads by 100 bps would affect deposit rates. The dynamics of the aforementioned changes are illustrated in figures 11 and 12, both from the pass through rate perspective, as well as from the evolution of the level of the new deposit rate, respectively. Such an approach would not only facilitate banks in projecting loan and deposit rates under a baseline or/and adverse scenario, but also supervisory authorities in quality assuring the projections provided by the banks.

[Insert Figures 11,12]

Finally, we assess the performance of the selected models by using the Mincer-Zarnowitz regression to the out-of-sample part of the dataset. The performance in the out of sample is considered acceptable based on the error term in the fitting.

The Mincer-Zarnowitz regression shows that we cannot reject the hypothesis of zero intercept and slope of one, when regressing the residuals of the out-of-sample predictions against a constant, so that no systematic bias is indicated in the historical forecasts. Detailed outputs of the joint hypothesis test are presented in Annex C. In addition, we have compared the predicted values of the models versus the realized values, and estimated the mean square errors, where we found similar values. The relevant results are presented in Annex D.

6. Conclusions & areas of future research

In this paper we explore the dynamics of interest rate pass through in the loan and deposit products offered by Greek institutions. We employ an autoregressive model with distributed lags in order to determine the mechanics of the transmission of money market rates. The maximum number of lags considered is 5, thus the delta (i.e. first differences) of deposit and loan rates at time t is regressed against the deltas of 1-month Euribor and Greek spread of the same month t, and the changes of the previous 5 months.

Our main finding is that long term pass through for time deposits, is higher for non-financial corporate customers compared to household customers (91% vs 81%). Concurrently, the pass through rate transmission appear less prevalent for open deposits (21% for non-financial corporate customers and 16% for household customers). Exploring the pass through rate dynamics for the loan products offered to Greek customers, we conclude that transmission of money market rate changes to mortgage and consumer loans is considered complete. For the non-financial corporate loans products, the rate is stickier and less reactive to money market rate changes, with long-term pass-through being circa 40%. By contrast, the Greek sovereign spread movement has practically negligible pass through rate, both for loan and deposit products, mainly due to the fact that the Greek sovereign credit spread has approached several times non-tradable territories, which makes it an insignificant variable in determining customer deposit and loan product rates.

This paper can provide banking supervisors and market practitioners with a significant insight on the pass through mechanism of money market rates into the loan and deposit products offered by Greek banks. As such, the model developed in this study can be used as a core component in predicting Non Interest Income (NII) when performing a top-down stress test. Most importantly, when this model is coupled with satellite models for credit risk parameters (see Petropoulos et al. 2018), it enables banking supervisors to conduct a holistic balance sheet stress testing exercise.

Our next step, is to expand our analysis by using additional independent market variables, such as long-term swap rates, as well as macroeconomic variables, such as real GDP growth and the unemployment rate, in order to enhance our model prediction of the pricing of Greek banking loan and deposit products. Moreover, the enhanced models will be used to an expanded dataset covering additional euro area countries.

Annex A – Augmented Dickey Fuller tests

Table 1: Augmented Dickey Fuller statistic/p-value

Name	ADF p-value	ADF statistic
DCORPO	0.305	-2.647
DCORPTD	0.350	-2.538
DHHO	0.085	-3.228
DHHTD	0.585	-1.980
GGGB10Y_GDBR10Y	0.571	-2.013
EURIBOR1M	0.298	-2.664
diff(DCORPO_1)	0.010	-4.941
diff(DCORPTD_1)	0.010	-4.211
diff(DHHO_1)	0.010	-4.747
diff(DHHTD_1)	0.010	-4.328
diff(GGGB10Y_GDBR10Y_1)	0.010	-5.372
diff(EURIBOR1M_1)	0.010	-4.255

Table 2: Augmented Dickey Fuller statistic/p-value for loan rates variables

Name	ADF p-value	ADF statistic
diff(LCORP_ 1)	0.01	-8.07
diff(LMORT_ 1)	0.01	-4.76
diff(LCONS_ 1)	0.01	-6.29

Table 3: ADF p-values for residuals of Engle-Granger two step approach.

Rate vs Euribor	p.value for ADF test - Residual Stationarity
DCORPO	0.663
DCORPTD	0.785
DHHO	0.236
DHHTD	0.902
LCORP	0.544
LCONS	0.768
LMORT	0.763

Annex B – Synopsis of models outputs

Table 4: Coefficients and standard error (in parenthesis) of the models for Deposit Rates

		DCORPO	DCORPTD	DHHO	DHHTD
Constant	**a**	0.00 (0.00)	0.01 (0.01)	0.00 (0.00)	0.00 (0.01)
Money Market Rate	**b0**	-	0.24 (0.10)	-	-
	b1	0.06 (0.02)	0.36 (0.11)	0.02 (0.01)	0.34 (0.07)
	b2	0.06 (0.02)	0.15 (0.11)	0.08 (0.01)	0.13 (0.08)
	b3	0.10 (0.02)	0.27 (0.10)	0.09 (0.01)	0.27 (0.08)
	b4	0.04 (0.02)	-	0.07 (0.01)	-
	b5	0.05 (0.02)	-0.22 (0.10)	-	-0.24 (0.08)
Greek Spread Indicator	**c0**	-	-	-0.00 (0.00)	-
	c1	-	-	-	-
	c2	-	0.01 (0.01)	-0.00 (0.00)	-
	c3	-	0.02 (0.01)	-	-
	c4	0.01 (0.00)	-	-	0.01 (0.00)
	c5	-	0.01 (0.01)	0.00 (0.00)	0.01 (0.00)
lagged deposit rate	**g0**	-0.45 (0.08)	-	-0.13 (0.07)	0.13 (0.08)
	g1	-0.27 (0.08)	-	-0.12 (0.06)	0.13 (0.08)
	g2	-0.12 (0.08)	-	-0.08 (0.05)	0.17 (0.07)
	g3	-0.12 (0.07)	-	-	0.12 (0.08)
	g4	-	-	0.07 (0.05)	-0.16 (0.07)
	g5	-	0.12 (0.07)	-	-

Table 5: Coefficients and standard error (in parenthesis) of the models for Loan Rates

		LCORP	LCONS	LMORT
Constant	a'	- 0.03 (0.03)	0.01 (0.01)	0.01 (0.02)
Money Market Rate	b'0	-	2.04 (0.74)	0.78 (0.24)
	b'1	-	-	0.42 (0.28)
	b'2	0.94 (0.47)	1.14 (0.83)	-
	b'3	-	-	-
	b'4	-	-	0.66 (0.24)
	b'5	-	-1.02 (0.71)	-
Greek Spread Indicator	c'0	-	-	-
	c'1	-	-	-
	c'2	-	-	-
	c'3	-	-	-
	c'4	-	-	-
	c'5	-	-	-
lagged deposit rate	g'0	-0.54 (0.10)	-0.44 (0.10)	-0.34 (0.01)
	g'1	-0.34 (0.10)	-0.46 (0.10)	-
	g'2	-	-	-
	g'3	-0.20 (0.10)	-0.16 (0.10)	-0.40 (0.01)
	g'4	-0.29 (0.10)	-	-
	g'5	-	-	-

Table 6: Short & Long Term Pass Through Rates per deposit category

	DCORPO	DCORPTD	DHHO	DHHTD
Short Term PTR Euribor	30.58%	80.02%	26.17%	49.62%
Long Term PTR Euribor	15.50%	91.07%	20.86%	81.12%

	LCORP	LCONS	LMORT
Short Term PTR Euribor	94.36%	215.23%	185.49%
Long Term PTR Euribor	39.69%	104.32%	107.06%

Annex C – Assessment of autocorrelation

To examine the absence of autocorrelation in the residuals of our selected models we regress the consecutive residuals against each other and test for a significant slope.

Table 7: DCORPO - Consecutive Residuals regression (e_t vs e_{t-1})

Coefficients:	**Estimate**	**Std.Error**	**z-value**	**Pr(>|z|)**
(Intercept)	0.000	0.003	-0.036	0.971
res[-1]	0.002	0.083	0.018	0.985

Residual standard error: 0.0403 on 147 degrees of freedom				
Multiple R-squared: 2.262e-06, Adjusted R-squared: -0.0068				
F-statistic: 0.0003325 on 1 and 147 DF, p-value: 0.9855				

Table 8: DCORPTD - Consecutive Residuals regression (e_t vs e_{t-1})

Coefficients:	**Estimate**	**Std.Error**	**z-value**	**Pr(>|z|)**
(Intercept)	-0.001	0.016	-0.043	0.966
res[-1]	-0.030	0.082	-0.369	0.713

Residual standard error: 0.199 on 147 degrees of freedom				
Multiple R-squared: 0.0009245, Adjusted R-squared: -0.005872				
F-statistic: 0.136 on 1 and 147 DF, p-value: 0.7128				

Table 9: DHHO - Consecutive Residuals regression (e_t vs e_{t-1})

Coefficients:	**Estimate**	**Std.Error**	**z-value**	**Pr(>|z|)**
(Intercept)	0.000	0.002	-0.041	0.967
res[-1]	-0.080	0.082	-0.979	0.329

Residual standard error: 0.02248 on 147 degrees of freedom				
Multiple R-squared: 0.006479, Adjusted R-squared: -0.0002793				
F-statistic: 0.9587 on 1 and 147 DF, p-value: 0.3291				

Table 10: DHHTD - Consecutive Residuals regression (e_t vs e_{t-1})

Coefficients:	Estimate	Std.Error	z-value	Pr(>|z|)
(Intercept)	-0.001	0.011	-0.047	0.963
res[-1]	-0.046	0.082	-0.557	0.578

Residual standard error: 0.1335 on 147 degrees of freedom
Multiple R-squared: 0.002105, Adjusted R-squared: -0.004683
F-statistic: 0.3101 on 1 and 147 DF, p-value: 0.5785

Table 11: LCORP - Consecutive Residuals regression (e_t vs e_{t-1})

Coefficients:	Estimate	Std.Error	z-value	Pr(>|z|)
(Intercept)	0.002	0.032	0.071	0.943
res[-1]	0.014	0.112	0.129	0.897

Residual standard error: 0.2896 on 80 degrees of freedom
Multiple R-squared: 0.0002089, Adjusted R-squared: -0.01229
F-statistic: 0.01671 on 1 and 80 DF, p-value: 0.8975

Table 12: LCONS - Consecutive Residuals regression (e_t vs e_{t-1})

Coefficients:	Estimate	Std.Error	z-value	Pr(>|z|)
(Intercept)	-0.004	0.047	-0.077	0.939
res[-1]	0.002	0.112	0.015	0.988

Residual standard error: 0.4292 on 80 degrees of freedom
Multiple R-squared: 2.783e-06, Adjusted R-squared: -0.0125
F-statistic: 0.0002226 on 1 and 80 DF, p-value: 0.9881

Table 13: LMORT - Consecutive Residuals regression ($\boldsymbol{e_t}$ $\boldsymbol{vs}$ $\boldsymbol{e_{t-1}}$)

Coefficients:	Estimate	Std.Error	z-value	Pr(>|z|)
(Intercept)	-0.003	0.015	-0.187	0.852
res[-1]	-0.018	0.110	-0.160	0.873

Residual standard error: 0.132 on 80 degrees of freedom
Multiple R-squared: 0.00032, Adjusted R-squared: -0.01218
F-statistic: 0.02561 on 1 and 80 DF, p-value: 0.8733

Annex D – Detailed output of the selected models

Table 14: DCORPO – Model output

Coefficients:	Estimate	Std.Error	z-value	Pr(>|z|)	
(Intercept)	0.001	0.003	0.182	0.856	
Diff_DCORPO_t1	-0.453	0.080	-5.682	0.000	***
Diff_DCORPO_t2	-0.275	0.084	-3.269	0.001	**
Diff_DCORPO_t3	-0.121	0.079	-1.541	0.126	
Diff_DCORPO_t4	-0.124	0.072	-1.719	0.088	.
Diff_EURIBOR1M_t1	0.056	0.021	2.711	0.008	**
Diff_EURIBOR1M_t2	0.061	0.022	2.771	0.006	**
Diff_EURIBOR1M_t3	0.095	0.022	4.273	0.000	***
Diff_EURIBOR1M_t4	0.044	0.023	1.882	0.062	.
Diff_EURIBOR1M_t5	0.049	0.024	2.079	0.039	*
Diff_GGGB10Y_GDBR10Y_t4	0.005	0.002	3.181	0.002	**

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.04147 on 139 degrees of freedom
Multiple R-squared: 0.3872, Adjusted R-squared: 0.3431
F-statistic: 8.782 on 10 and 139 DF, p-value: 4.576e-11

Table 15: DCORPTD – Model output

Coefficients:	Estimate	Std.Error	z-value	Pr(>|z|)	
(Intercept)	0.005	0.017	0.303	0.762	
Diff_DCORPTD_t6	0.121	0.071	1.718	0.088	.
Diff_EURIBOR1M	0.238	0.102	2.343	0.021	*
Diff_EURIBOR1M_t1	0.365	0.106	3.443	0.001	***
Diff_EURIBOR1M_t2	0.147	0.106	1.380	0.170	
Diff_EURIBOR1M_t3	0.269	0.105	2.567	0.011	*
Diff_EURIBOR1M_t5	-0.218	0.099	-2.194	0.030	*
Diff_GGGB10Y_GDBR10Y_t2	0.013	0.009	1.489	0.139	
Diff_GGGB10Y_GDBR10Y_t3	0.016	0.008	1.915	0.058	.
Diff_GGGB10Y_GDBR10Y_t5	0.014	0.009	1.608	0.110	

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.2041 on 140 degrees of freedom
Multiple R-squared: 0.3419, Adjusted R-squared: 0.2996
F-statistic: 8.082 on 9 and 140 DF, p-value: 1.35e-09

Table 16: DHHO – Model output

Coefficients:	Estimate	Std.Error	z-value	Pr(>|z|)	
(Intercept)	0.000	0.002	0.143	0.886	
Diff_DHHO_t1	-0.125	0.077	-1.635	0.104	
Diff_DHHO_t2	-0.124	0.056	-2.235	0.027	*
Diff_DHHO_t3	-0.076	0.051	-1.485	0.140	
Diff_DHHO_t5	0.071	0.046	1.541	0.126	
Diff_EURIBOR1M_t1	0.024	0.012	2.060	0.041	*
Diff_EURIBOR1M_t2	0.077	0.012	6.287	0.000	***
Diff_EURIBOR1M_t3	0.091	0.014	6.642	0.000	***
Diff_EURIBOR1M_t4	0.070	0.014	4.859	0.000	***
Diff_GGGB10Y_GDBR10Y	-0.002	0.001	-1.621	0.107	
Diff_GGGB10Y_GDBR10Y_t2	-0.002	0.001	-2.208	0.029	*
Diff_GGGB10Y_GDBR10Y_t5	0.003	0.001	2.690	0.008	**

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.02329 on 138 degrees of freedom
Multiple R-squared: 0.6414,   Adjusted R-squared: 0.6128
F-statistic: 22.44 on 11 and 138 DF, p-value: < 2.2e-16

Table 17: DHHTD – Model output

Coefficients:	Estimate	Std.Error	z-value	Pr(>|z|)	
(Intercept)	0.004	0.011	0.333	0.740	
Diff_DHHTD_t1	0.126	0.079	1.609	0.110	
Diff_DHHTD_t2	0.125	0.079	1.582	0.116	
Diff_DHHTD_t3	0.174	0.072	2.412	0.017	*
Diff_DHHTD_t4	0.122	0.077	1.583	0.116	
Diff_DHHTD_t5	-0.159	0.068	-2.336	0.021	*
Diff_EURIBOR1M_t1	0.338	0.069	4.882	0.000	***
Diff_EURIBOR1M_t2	0.128	0.079	1.622	0.107	
Diff_EURIBOR1M_t3	0.270	0.079	3.418	0.001	***
Diff_EURIBOR1M_t5	-0.240	0.079	-3.031	0.003	**
Diff_GGGB10Y_GDBR10Y_t4	0.014	0.006	2.502	0.014	*
Diff_GGGB10Y_GDBR10Y_t5	0.013	0.006	2.245	0.026	*

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.1381 on 138 degrees of freedom
Multiple R-squared: 0.5164,   Adjusted R-squared: 0.4778
F-statistic: 13.4 on 11 and 138 DF, p-value: < 2.2e-16

Table 18: LCORP – Model output

Coefficients:	Estimate	Std.Error	z-value	Pr(>|z|)	
(Intercept)	-0.027	0.033	-0.802	0.425	
Diff_LCORP_t1	-0.539	0.101	-5.315	0.000	***
Diff_LCORP_t2	-0.342	0.102	-3.350	0.001	**
Diff_LCORP_t4	-0.202	0.100	-2.015	0.047	*
Diff_LCORP_t5	-0.294	0.101	-2.907	0.005	**
Diff_EURIBOR1M_t2	0.944	0.473	1.995	0.050	*

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.296 on 77 degrees of freedom
Multiple R-squared: 0.4006, Adjusted R-squared: 0.3617
F-statistic: 10.29 on 5 and 77 DF, p-value: 1.396e-07

Table 19: LCONS – Model output

Coefficients:	Estimate	Std.Error	z-value	Pr(>|z|)	
(Intercept)	0.007	0.050	0.141	0.888	
Diff_LCONS_t1	-0.445	0.104	-4.273	0.000	***
Diff_LCONS_t2	-0.458	0.103	-4.434	0.000	***
Diff_LCONS_t4	-0.160	0.102	-1.570	0.121	
Diff_EURIBOR1M	2.038	0.745	2.736	0.008	**
Diff_EURIBOR1M_t2	1.139	0.827	1.377	0.173	
Diff_EURIBOR1M_t5	-1.024	0.714	-1.435	0.155	

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.4417 on 76 degrees of freedom
Multiple R-squared: 0.3478, Adjusted R-squared: 0.2963
F-statistic: 6.755 on 6 and 76 DF, p-value: 9.173e-06

Table 20: LMORT – Model output

Coefficients:	Estimate	Std.Error	z-value	Pr(>|z|)	
(Intercept)	0.007	0.016	0.434	0.666	
Diff_LMORT_t1	-0.337	0.099	-3.397	0.001	**
Diff_LMORT_t4	-0.395	0.100	-3.958	0.000	***
Diff_EURIBOR1M	0.779	0.245	3.184	0.002	**
Diff_EURIBOR1M_t1	0.418	0.276	1.512	0.135	
Diff_EURIBOR1M_t4	0.658	0.237	2.773	0.007	**

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.137 on 77 degrees of freedom
Multiple R-squared: 0.384, Adjusted R-squared: 0.3441
F-statistic: 9.602 on 5 and 77 DF, p-value: 3.764e-07

Annex E – Mincer-Zarnowitz regression in the selected models

Table 21: DCORPO – Mincer-Zarnowitz regression

Coefficients:	Estimate	Std.Error	z-value	Pr(>|z|)
(Intercept)	0.003	0.002	1.229	0.225

Residual standard error: 0.01663 on 51 degrees of freedom

Table 22: DCORPTD – Mincer-Zarnowitz regression

Coefficients:	Estimate	Std.Error	z-value	Pr(>|z|)	
(Intercept)	0.010	0.006	1.714	0.093	.

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.04162 on 51 degrees of freedom

Table 23: DHHO – Mincer-Zarnowitz regression

Coefficients:	Estimate	Std.Error	z-value	Pr(>|z|)
(Intercept)	0.001	0.001	1.209	0.232

Residual standard error: 0.007092 on 51 degrees of freedom

Table 24: DHHTD – Mincer-Zarnowitz regression

Coefficients:	Estimate	Std.Error	z-value	Pr(>|z|)
(Intercept)	0.006	0.004	1.648	0.105

Residual standard error: 0.02621 on 51 degrees of freedom

Table 25: LCORP – Mincer-Zarnowitz regression

Coefficients:	Estimate	Std.Error	z-value	Pr(>|z|)
(Intercept)	0.074	0.072	1.018	0.317

Residual standard error: 0.397 on 29 degrees of freedom				

Table 26: LCONS – Mincer-Zarnowitz regression

Coefficients:	Estimate	Std.Error	z-value	Pr(>|z|)
(Intercept)	-0.088	0.153	-0.574	0.570

Residual standard error: 0.8369 on 29 degrees of freedom				

Table 27: LMORT – Mincer-Zarnowitz regression

Coefficients:	Estimate	Std.Error	z-value	Pr(>|z|)
(Intercept)	0.009	0.025	0.369	0.715

Residual standard error: 0.139 on 29 degrees of freedom				

Annex F – Model validation (in sample vs out of sample)

We compare each observation y_i with the predicted by the model $\hat{y_i}$ and then we calculate the mean square error for in the sample and out of the sample using the following formulas.

$$MSE = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \hat{y_i})^2}{n}}$$

Having performing the aforementioned analysis, we conclude to the following MSE estimations for the models under investigation.

Table 28: In the sample MSE estimations vs out of the sample MSE

	MSE in the sample	MSE out of sample
DCORPO	0.070	0.065
DCORPTD	0.045	0.055
DHHO	0.036	0.050
DHHTD	0.033	0.042
LCORP	0.048	0.076
LCONS	0.051	0.058
LMORT	0.041	0.039

Annex E – Figures

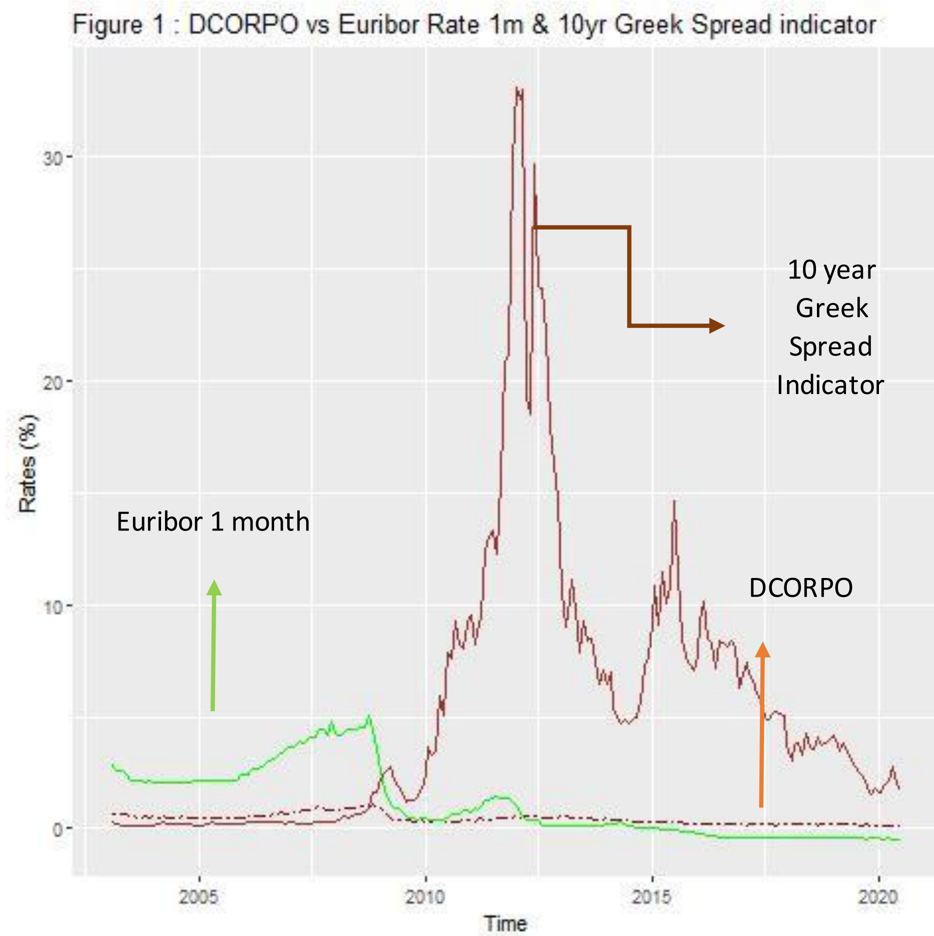


Figure 2 : DCORPTD vs Euribor Rate 1m & 10yr Greek Spread indicator

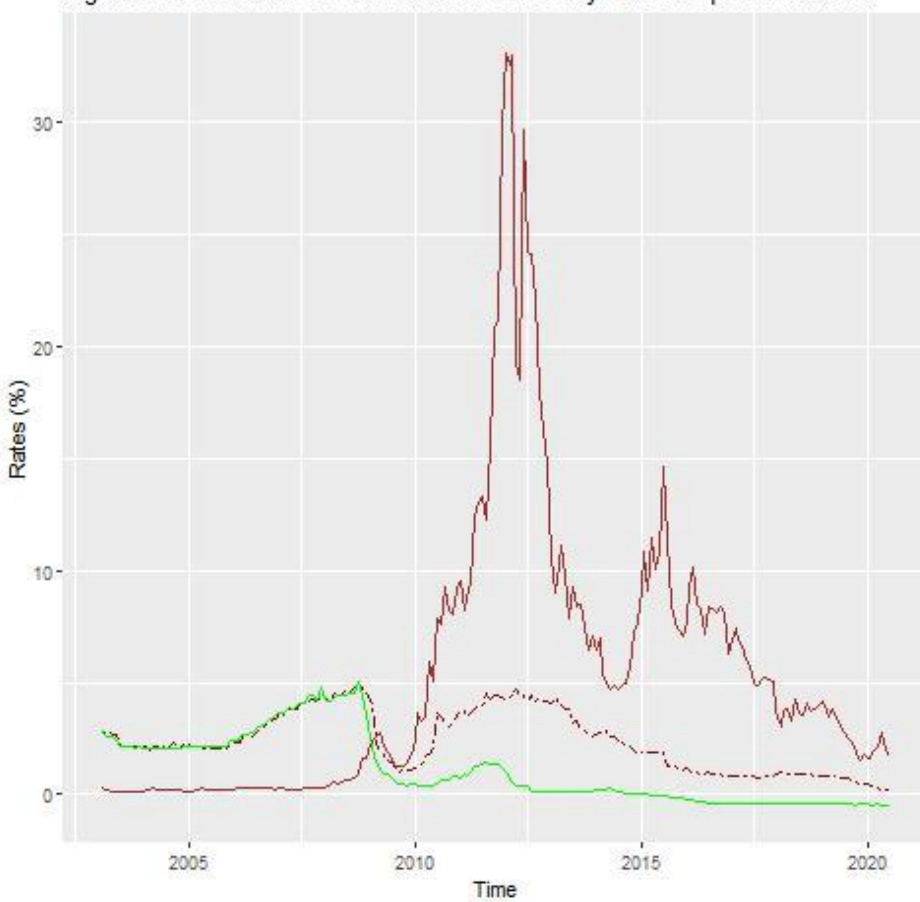


Figure 3 : DHHO vs Euribor Rate 1m & 10yr Greek Spread indicator

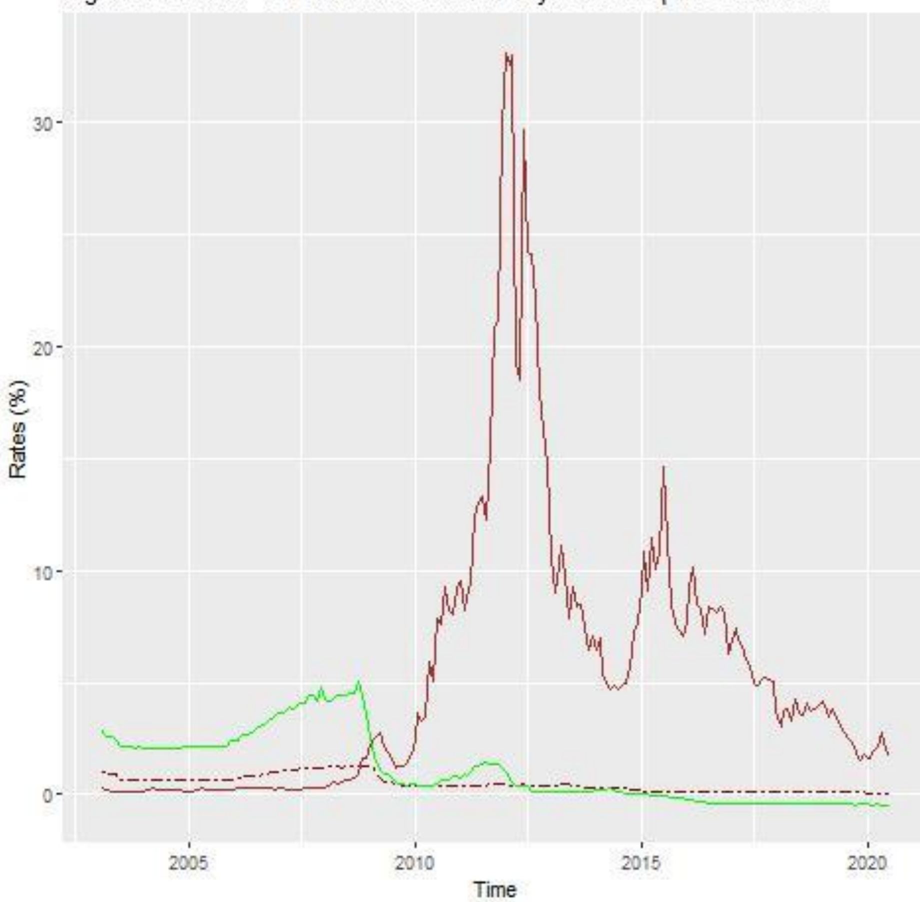
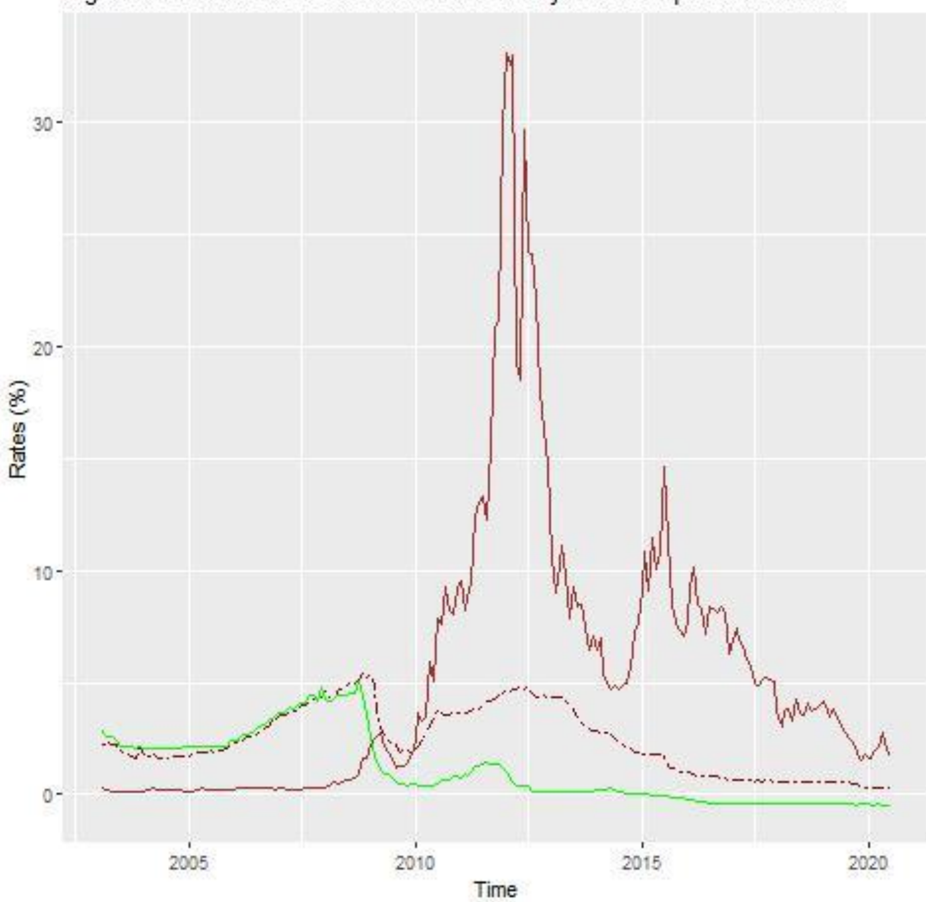


Figure 4 : DHHTD vs Euribor Rate 1m & 10yr Greek Spread indicator



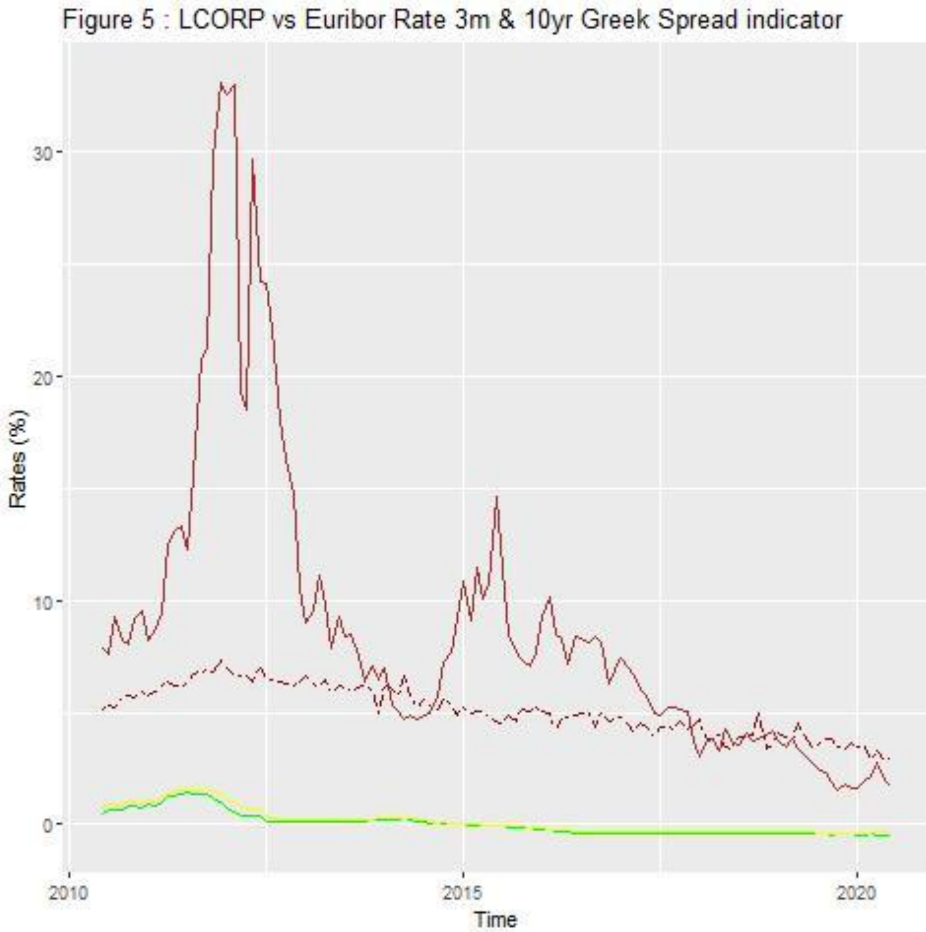


Figure 5 : LCORP vs Euribor Rate 3m & 10yr Greek Spread indicator
Rates (%)
30
20
10
0
2010
2015
2020
Time

Figure 6 : LCONS vs Euribor Rate 3m & 10yr Greek Spread indicator

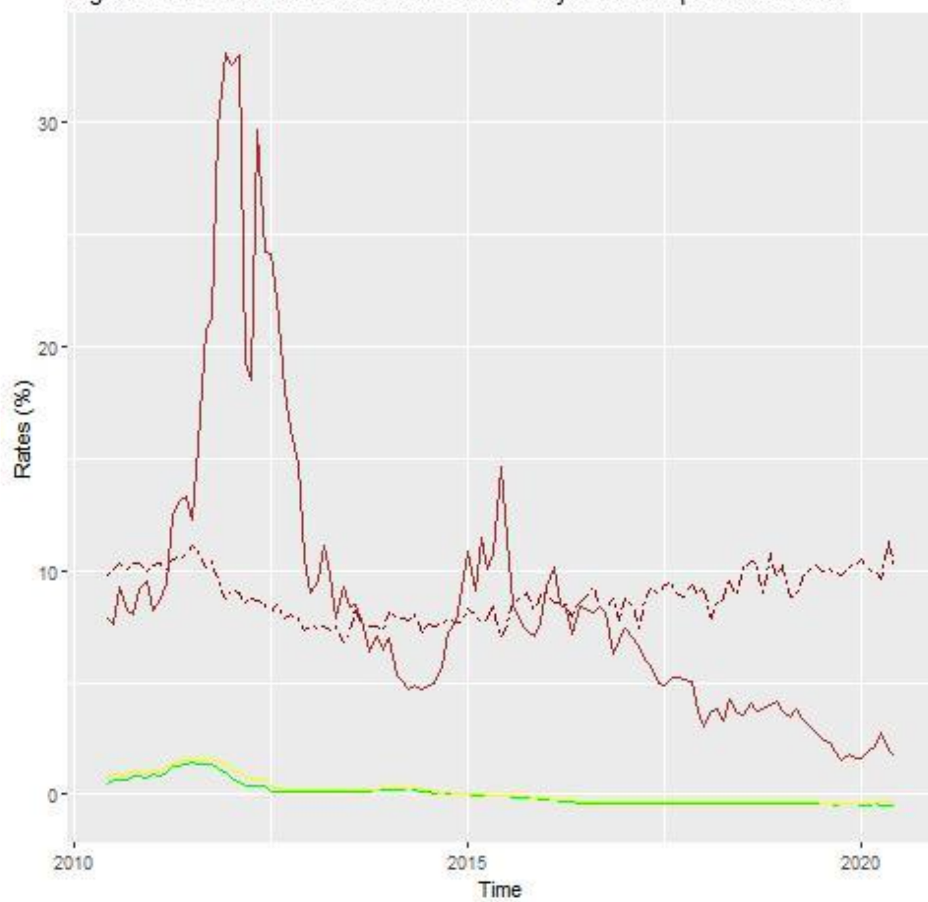


Figure 7 : LMORT vs Euribor Rate 3m & 10yr Greek Spread indicator

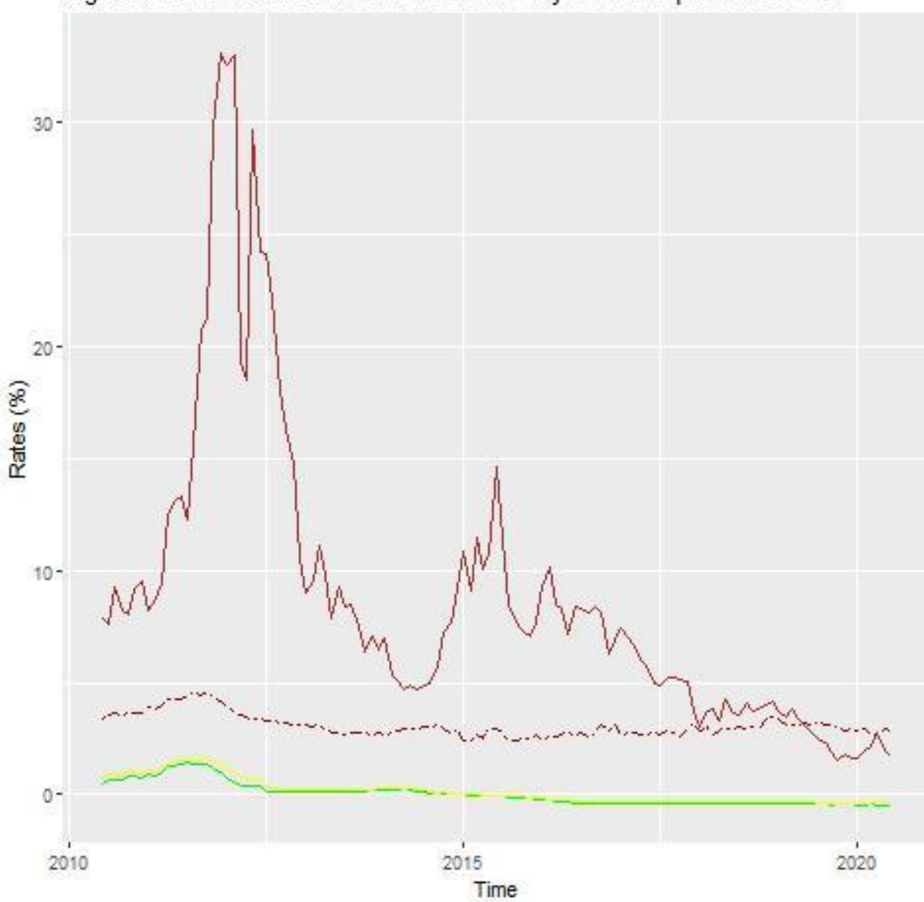


Figure 8 : EURIBOR 1m vs Euribor Rate 3m

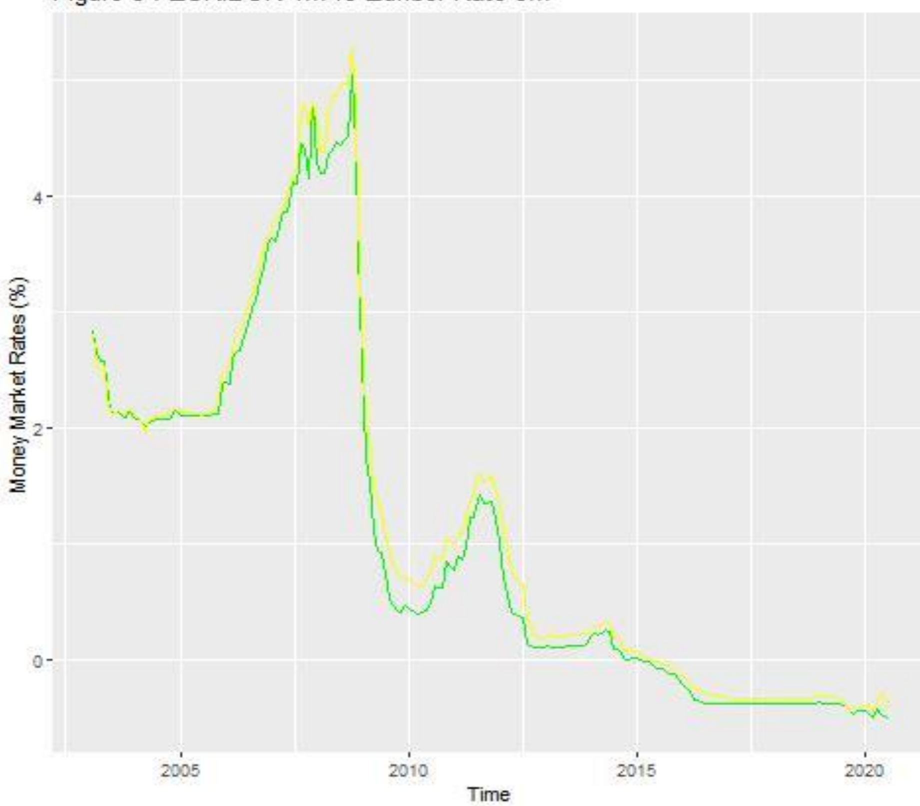


Figure 9: Plot of residuals under the Granger and Engle approach (Deposit Rates)

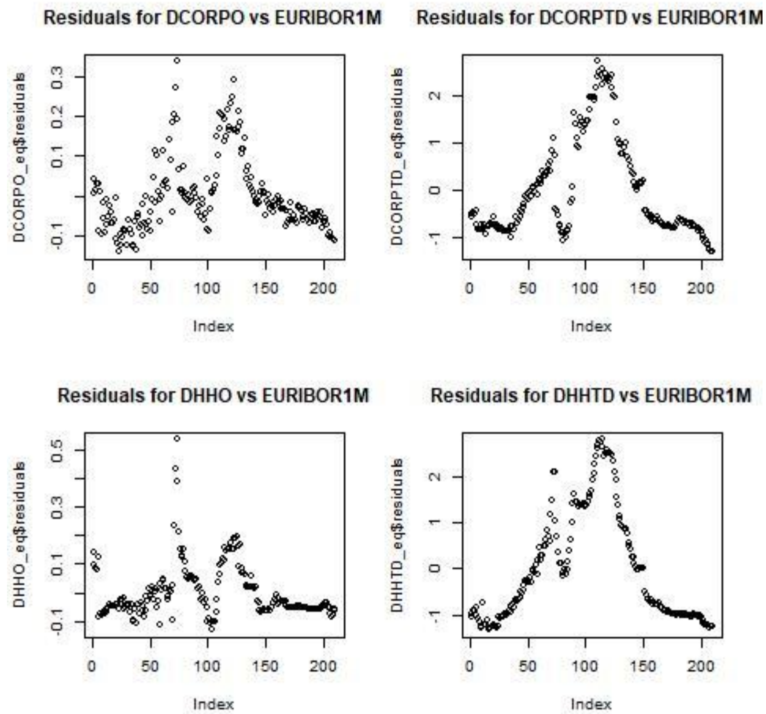


Figure 10: Plot of residuals under the Granger and Engle approach (Loan Rates)

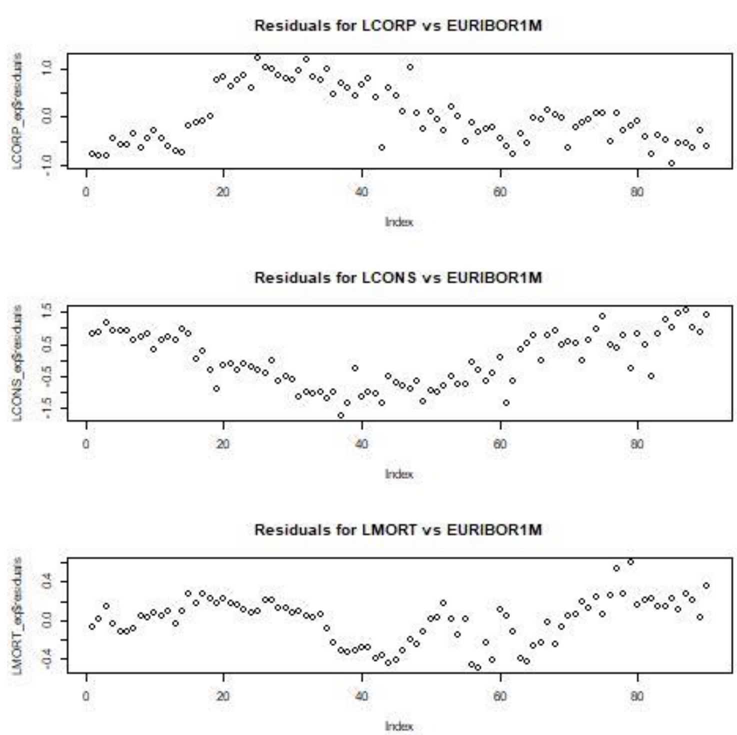


Figure 11: Pass Through Rate evolution under a hypothetical scenario of +100bp

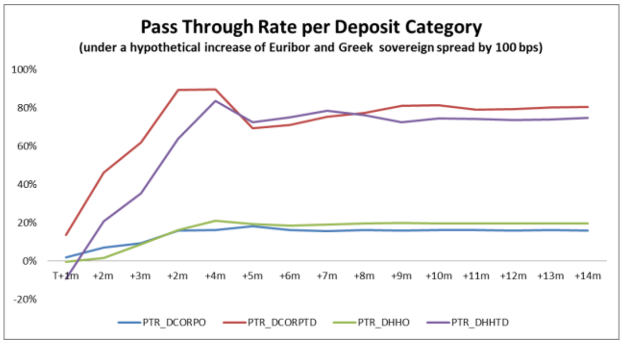
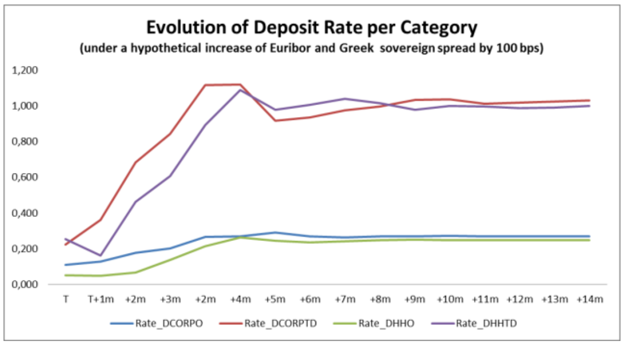


Figure 12: Evolution of new deposit rates under a hypothetical scenario of +100bp



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