Determinants of NMD Pass-Through Rates in Eurozone Countries

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Determinants of NMD Pass-Through Rates in Eurozone Countries

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Abstract

Non-Maturing Deposit (NMD) pass-through rate represents a key parameter needed in the process of interest rate management of the banking book (IRRBB). NMD interest rates for retail and corporate segments are usually not directly linked to the market interest rates, but depend rather on the bank's marketing strategy, market competition, liquidity, and possibly on other factors. The ratio in which banks adjust their NMD interest rates to the changes of the interbank market interest rates is known as the NMD pass-through rate. The goal of this paper is to analyse the variability of NMD pass-through rates in the 19 Eurozone countries and identify their possible determinants. The pass-through rates are estimated using cointegration analysis based on datasets available from the ECB Statistical Data Warehouse and the results show significant variability between countries. To analyse the determinants of pass-through rates in the Eurozone, the rates are regressed on 9 aggregates of country-level banking sector including concentration, profitability, or funding. Out of the tested predictors, surprisingly only the ratio of Wholesale Funding to Liabilities proves to impact the pass-through rates significantly, with a positive sign, indicating that countries where banks rely more heavily on wholesale funding exhibit higher pass-through of the market interest rate changes to the NMD deposit rates.

AMS/JEL classification: C32, E43, E58, G21

Keywords: Non-Maturing Deposits (NMD), pass-through rate, IRRBB

1. Introduction

Modelling of Non-Maturing Deposits (NMD) for the purposes of Interest Rate Risk of the Banking Book (IRRBB) management in commercial banks was recently standardized by the Basel Committee on Banking Supervision (BCBS) Standards (BCBS, 2016), and the European Banking Authority (EBA) Guidelines (EBA, 2018). The modelling methodology, described in the BCBS Consultative paper (BCBS, 2015), requires that banks estimate the pass-through rate parameter, corresponding to the "proportion of a market interest rate change that the bank will pass onto its customers in order to maintain the same level of stable deposit balances" (BCBS, 2015), with the pass-through rate effect assessed by the banks "over the time horizon they deem most relevant or until the full effect of the market rate move has been passed through to the customers" (BCBS, 2015).

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To estimate the short-term and long-term pass-through rate of the market interest rate changes into the NMD client rates, banks typically use the Error Correction Model (ECM) (Granger, 1981), which is also among the most commonly used models in academic literature (Hefferman, 1997, Chong et al., 2006, Liu et al., 2008, Wang et al., 2019, or Witzany and Diviš, 2021), including ECB working papers (ECB, 2006). Using the Error Correction Model, banks can estimate the short-term as well as the long-term relationship between their NMD rates and the market rates, allowing them to estimate the pass-through rate in any forecast horizon (Wang et al., 2019). Alternative approaches can be based on the concept static and dynamic NMD portfolio replication, and of a Monte Carlo valuation approach (Maes, Timmermans, 2005, Blöchlinger, 2019), or apply a VAR model with both the change in the composition of the deposits and the deposit rates (Gerlach, 2018). The NMD pass-through parameter is one of key inputs in interest rate risk modelling on the level of an individual bank or on the level of the banking sector and has been studied in a number of empirical papers (see e.g. Maes, Timmermans, 2005, O'Brien, 2000, Hejdová et al., 2017, or Wang et al., 2019). However, we are not aware of any study that would analyse the pass-through-rate determinants over a set of national markets.

In our presented study, we estimate the NMD pass-through rates in different horizons (from 1-month to 10-years) for the retail and corporate deposit rates, for the 19 Eurozone countries based on the datasets available in the ECB Statistical Data Warehouse. In the next step, we analyse the determinants of pass-through rates in the Eurozone by regressing the estimated 1-year pass-through rates for the 19 Eurozone countries, on 9 aggregate metrics of banking sector (i) concentration (Herfindahl Index), (ii) profitability (Return on Assets, Return on Equity, Cost to Income, Risk Costs to Operating Income and Net Interest Income to Assets), and (iii) funding profile (Loan to Deposit ratio, Liquid Assets to Total Assets, Wholesale Funding to Liabilities). The goal is to explain the variability of the pass-through rates in the Eurozone and identify their main drivers.

The rest of the study is organized as follows. Section 2 describes the methodology for estimation of the Error Correction Model and for the Pass-Through rate estimation. Section 3 provides a description of the modelling dataset. Section 4 analyse the results of the pass-through rate estimation in the Eurozone. Section 5 analyses the effect of main determinants of the pass-through rates in the Eurozone, and Section 6 concludes the paper.

2. NMD Client Rate Modelling Methodology

For the modelling of the short-term and long-term relationship between the NMD client rate and the market rate in a given country, the Error Correction Model (ECM) (Granger, 1981) is used, estimated with the Engle-Granger two-step procedure (Engle, Granger, 1987). While the individual Banks and academic researchers may use different modifications of the model, including multiple lags, asymmetries, or time-varying volatility, for the purposes of this study, only the basic version of the model is applied.

In Step 1, we estimate the cointegration regression in the form:

$$y_t = \beta_0 + \beta_1 x_t + \varepsilon_t \qquad (1)$$

where y_t is the NMD client rate and x_t is the market rate. As the interest rate time series can be viewed as integrated of order one in the analysed time-period, residuals of the regression ε_t need to fulfil the stationarity assumption, for the time series y_t and x_t to be cointegrated. To confirm stationarity of ε_t, the Augmented Dickey Fuller (ADF) Unit Root test is used.

In Step 2, the Error Correction Model (ECM) is estimated:

$$\Delta y_t = \gamma_1 \Delta x_t + \theta_1 (y_{t-1} - \beta_0 - \beta_1 x_{t-1}) + \sigma \epsilon_t \quad (2)$$

where Δy_t denotes the change of the NMD client rate and Δx_t is the change of the market rate in period t. Parameter γ_1 measures the immediate reaction of the NMD rate to the market rate, while θ_1 measures the speed of adjustment of the NMD client rate to changes of the market rate, that result in deviations of the long-term equilibrium relationship $y_{t-1} - \beta_0 - \beta_1 x_{t-1}$, estimated with the Step 1 regression (1).

Pass-Through rate estimation

To estimate the pass-through rate in different horizons, we first rewrite the ECM model (1) by separating all of the x and y terms with different lags:

$$y_t = -\theta_1 \beta_0 + \gamma_1 x_t + (-\gamma_1 - \theta_1 \beta_1) x_{t-1} + (1 + \theta_1) y_{t-1} + \sigma \epsilon_t$$

We then define a market rate shock at time t as:

$$x_t^* = x_t + K$$

where x_t^* denotes the post-shock market rate and y_t^* the post-shock NMD client rate.

We then define the cumulative pass-through of a permanent shock K into the client rate y_t^* as:

$$P_t = (y_t^* - y_t)/K$$

which can be computed for different horizons $k = 0, \dots, H$ by rewriting the ECM equation for y_{t+k} and y_{t+k}^* (with the same innovations ϵ_{t+k}) and evaluating recursively the relationship above.

Immediate pass-through at time t is then equal to (for derivation see Appendix 2):

$$P_t = \gamma_1$$

and the cumulative pass-through for any horizon $t + k$ where $k > 0$ is equal to:

$$P_{t+k} = -\theta_1 \beta_1 + (1 + \theta_1) P_{t+k-1}$$

which converges to $P_{t+k} \to \beta_1$ for $k \to \infty$.

3. Dataset description and cleaning

Modelling dataset was downloaded from the ECB Statistical Data Warehouse and consists of the proxy for the short-term market rate (1-Month Euribor), and the average Non-Maturing Deposit (NMD) rates for the Retail and Corporate segments for the 19 Eurozone countries (as of 31. 9. 2021). For ECB Series Keys of the individual time-series, used in the analysis, see Appendix 1.

For most of the countries, the Retail NMD interest rate data start from Jan-2000, or Jan-2003 (France, Luxemburg and Estonia), with the exceptions being Estonia (Mar-2003), Latvia (Jan-2004), Lithuania (Mar-2005), Slovenia (May-2005), Malta (Mar-2007), Cyprus (Jan-2008) and Slovakia (Jan-2008). The Corporate NMD interest rate data start usually from the same date as the retail ones, with the only exceptions being Belgium (Oct-2006), and Finland (Mar-2003).

In addition to shorter history, time series for some of the countries exhibit extensive periods of missing values, affecting especially the Belgian retail rate (Jan-2003 to Sep-2006) and the Ireland retail rate

(Jun-2006 to Nov-2014). Isolated missing values (1 or 2 months of missing values at most) appear also in the retail and corporate rate time series of Malta, Cyprus and Slovakia.

For the purposes of the analysis, all missing values were imputed with linear interpolation based on the nearest observable values before and after the missing period respectively. The Error Correction Model was then estimated separately for each country and segment (retail and corporate) based on the entire available dataset since the first non-missing observation (usually Jan-2000).

In addition to the NMD interest rates for individual countries, average retail and corporate NMD rates in the Eurozone were estimated for each month, based on the interest rate data from all countries that were available in that month. These aggregate time series will serve as proxy for the overall level of NMD interest rates in the Eurozone.

4. ECM Model Empirical Estimates

Cointegration regression results (Step 1)

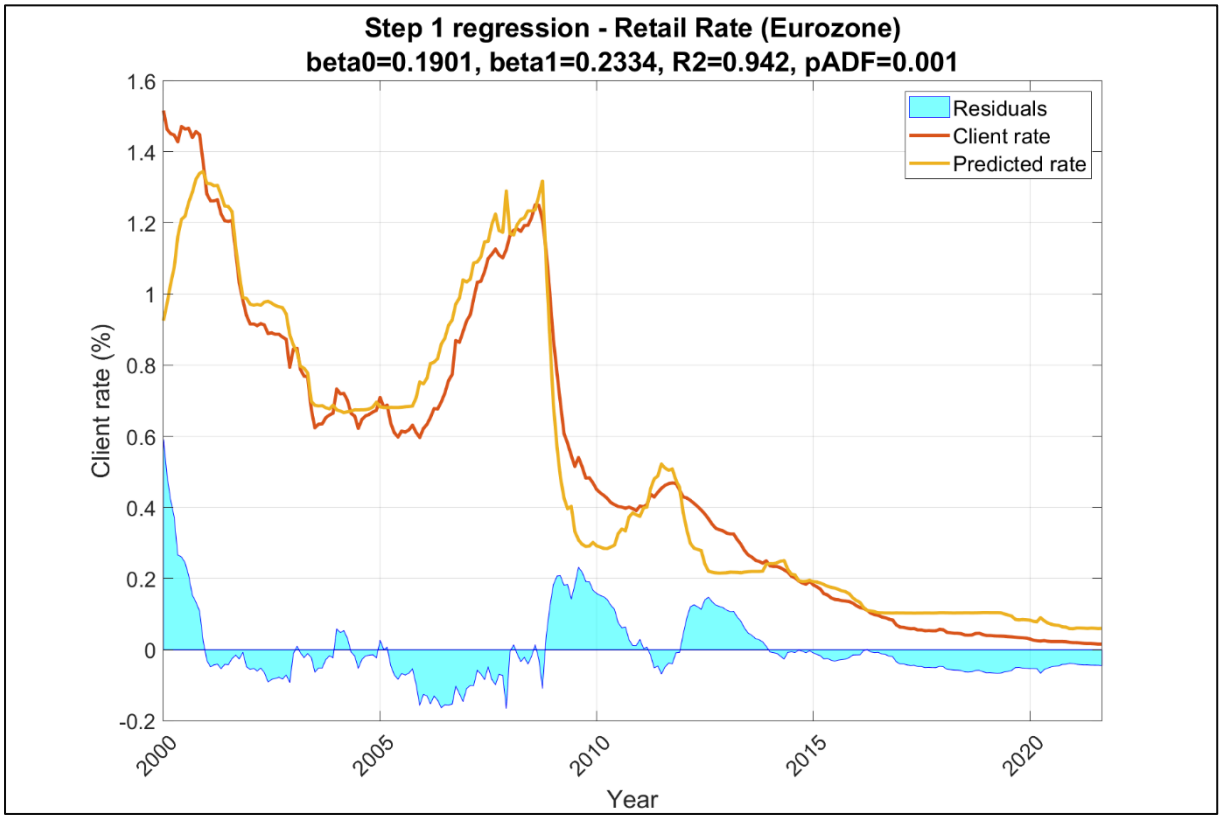
In the first step, cointegration regression was computed, between the retail and corporate NMD interest rates of the Eurozone countries as dependent variable, and the 1-Month Euribor as independent variable. The detailed results are shown in Table 4 (retail) and Table 5 (corporate) in Appendix 3. The tables include the parameter estimates (beta0 and beta1), t-values (t_beta0 and t_beta1), p-values (p_beta0 and p_beta1) and the regression R-squared (R2), as well as the p-values of the Augmented Dickey Fuller test (pADF) applied to the model residuals in order to assess if cointegration between the NMD interest rates and 1-Month Euribor is present.

It is apparent from the Augmented Dickey Fuller test values that for most of the Eurozone countries, we can reject the hypothesis of non-stationarity of model residuals on the 10% confidence level, indicating a presence of cointegration between the retail NMD interest rates and the 1-Month Euribor. Among the countries for which cointegration could not be proved (on the 10% confidence level), ale **Belgium**, **Cyprus** and **Slovakia**. The negative result for Belgium can be explained by the relatively high missing rate in the available time series, as the entire period from Jan-2003 to Sep-2006 is missing and had to be replaced with linear interpolation. In the case of Cyprus and Slovakia, the available time series starts only in Jan-2008, covering almost exclusively a period of a long-term interest rate decrease, which could have negatively affected the results.

For the corporate segment (Table 5), cointegration was confirmed (on a 10% confidence level) for almost all Eurozone countries. The only two exceptions are **Cyprus** and **Italy**, for which the cointegration could be confirmed only on the 15% confidence level.

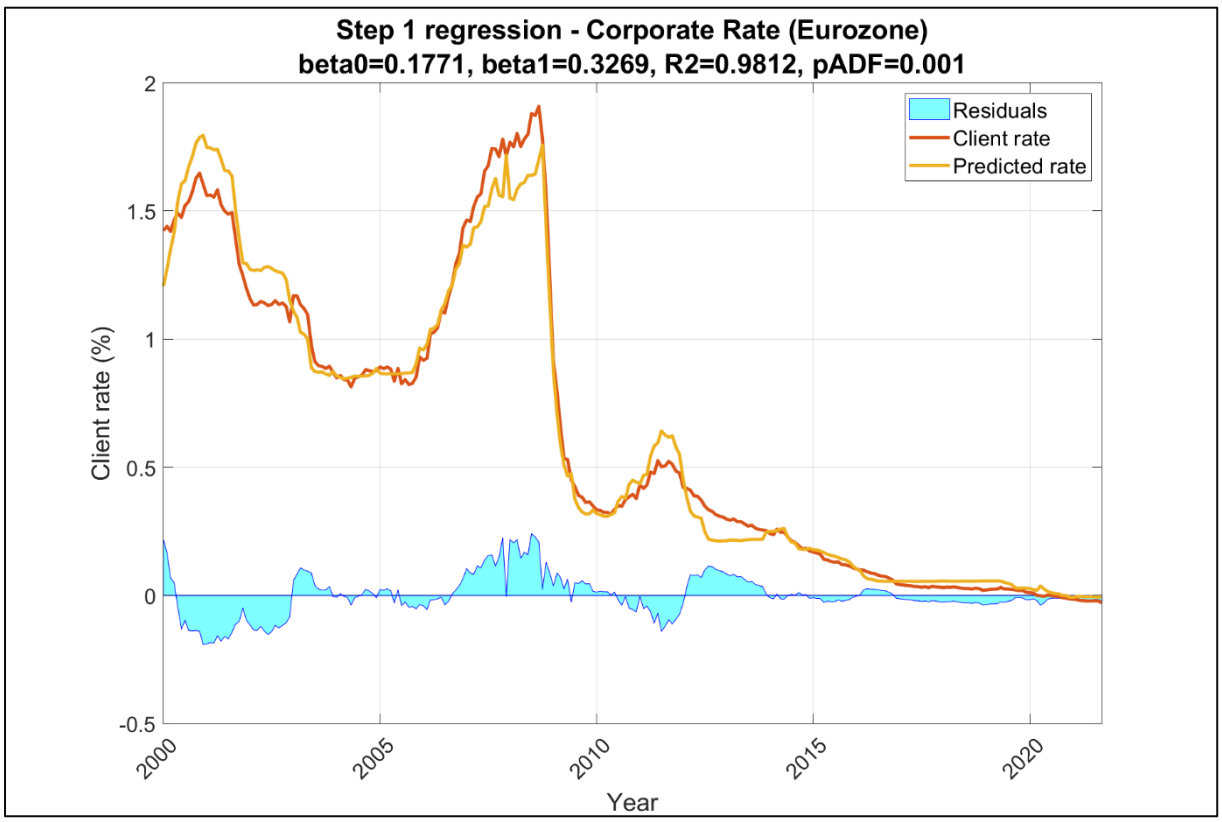
To illustrate the regression fit, we can plot the evolution of the NMD client rates and the predicted rates based on the 1-Month Euribor. Illustration of the fit for the average NMD client rates in the Eurozone is shown on Figure 1 for the retail segment and Figure 2 for the corporate segment.

Figure 1: Average Eurozone NMD Retail rates vs. NMD rates predicted with the 1-Month Euribor



Data source: Authorial computation

Figure 2: Average Eurozone NMD Retail rates vs. NMD rates predicted with the 1-Month Euribor



Data source: Authorial computation

We can see that the pattern of variability of the NMD client rates is closely matching the one predicted by the 1-Month Euribor, with regression residuals oscillating closely around zero.

Error Correction Model and Passthrough rate estimation (Step 2)

In Step 2, the Step 1 regression residuals were used to estimate the Error Correction Model (ECM) for each of the Eurozone countries. From the ECM estimates we then derived the pass-through rates in the 1-month (pass1M), 1-year (pass1Y) and 10-year (pass10Y) horizons. Detailed results of the estimation are shown in Appendix 3, Table 6 (retail) and in Table 7 (corporate).

We can see that for the Retail segment (Table 6) the ECM parameters correspond to the expectations for most of the countries, with gamma1 being positive, indicating a positive immediate reaction of the NMD client rates to the changes of the market rate, and theta1 being negative, indicating convergence of the client rates towards their long-term equilibrium relationship with the market rate. Among the main exceptions is **Lithuania**, for which the gamma1 was estimated as negative, indicating a counterintuitively negative immediate reaction of the NMD interest rates to the changes of the 1-Month Euribor, and **Belgium**, for which the theta1 was estimated as positive, indicating that the Retail NMD interest rates do not adjust their deviations from Euribor in the long-term. Regarding the statistical significance of the results, gamma1 turned out as statistically significant (on the 10% confidence level) for all of the Eurozone countries, while theta1 turned out as statistically significant for all countries except for **Belgium** and **Slovakia**.

In the Corporate segment (Table 7), parameter estimates correspond to the expectations (positive gamma1 and negative theta1) for all countries in the Eurozone, except for **Malta**, for which both parameters have the wrong sign. Gamma1 was further estimated as statistically significant (on the 10% level) for all countries except for **Lithuania** and **Slovenia**, while theta1 turned out as statistically significant for all countries except for **Malta**.

Results for both segments confirm appropriateness of the ECM model for the modelling of pass-through rates in the Eurozone, as apart from few outlier countries, the cointegration relationship between NMD client rates and market rates was proved, and the ECM model parameter estimates are statistically significant and with the correct signs.

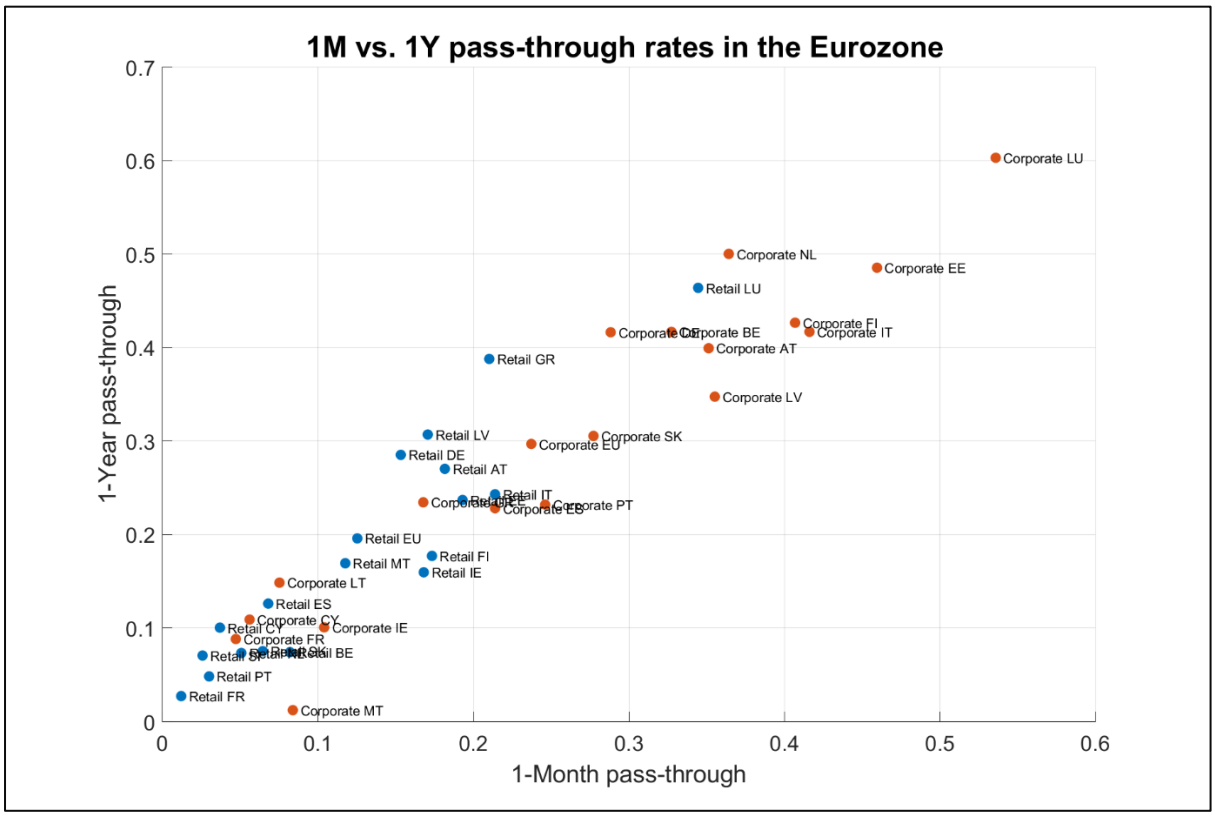
In Figure 3, we compare the magnitudes of the 1-month and 1-year pass-through rates in the Eurozone countries. A clear tendency can be observed of the corporate pass-through rates to be higher than the retail ones, which is in accordance with economic intuition, as corporate clients tend to switch banks more readily, with the goal to optimize their interest rate income, forcing banks to adjust their NMD deposit rates more speedily to the interest rate changes on the money markets.

Average **Eurozone NMD corporate pass-through rate** in the 1-year horizon is estimated at **29.71%,** indicating that almost 30% of the 1-month Euribor changes get passed to the corporate customers in the Eurozone in the 1-year horizon, while for the **retail rate** it is only **19.61%.** At the same time, relatively large cross-country variability in the pass-through rates seems to be present.

The highest 1-year Corporate pass-through rate is observed in **Luxemburg (60.31%)**, where more than 60% of the 1-Month Euribor rate changes get passed to the customers in the 1-year horizon. High corporate pass-through rates are further observed in **Netherlands (50.03%)** and **Estonia (48.55%)**, followed by **Finland (42.67%)**, **Italy (41.70%)**, **Belgium (41.70%)**, **Germany (41.65%)**, and **Austria (39.95%).** On the other hand, **the lowest 1-year Corporate** pass-through rate can be observed in **Malta (1.24%)** (with the result, however, being affected by the counterintuitive model parameter estimates), followed by **Slovenia (7.54%)**, **France (8.84%)**, **Ireland (10.08%)** and **Cyprus (10.92%)**.

The highest 1-year Retail pass-through rates are again observed in **Luxemburg (46.40%)**, followed by **Greece (38.80%)**, **Latvia (30.71%)**, **Germany (28.54%)** and **Austria (27.04%). The lowest 1-year Retail** pass-through rates are observed in **France (2.73%)**, **Portugal (4.84%)**, **Slovenia (7.08%)**, **Belgium (7.43%)** and **Slovakia (7.55%)**.

Figure 3: Comparison of the 1-Month and 1-Year pass-through rates for all Eurozone countries

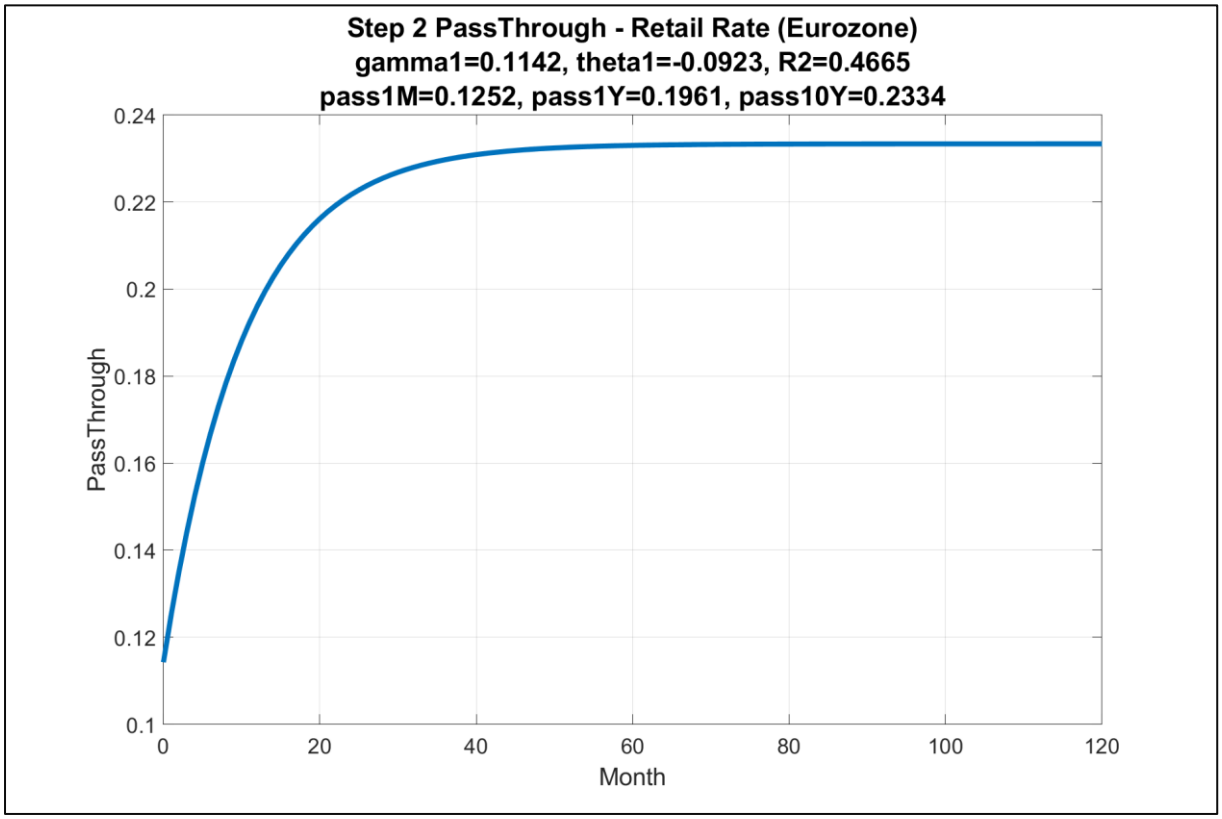


Data source: Authorial computation

As the pass-through rates can be calculated from the ECM model for any horizon into the future, it also allows us to assess the speed of adjustment of the NMD client rates to the market rates. For illustration, we show the result for the average Eurozone NMD client rates in the retail and corporate segments in Figure 4 (retail) and Figure 5 (corporate).

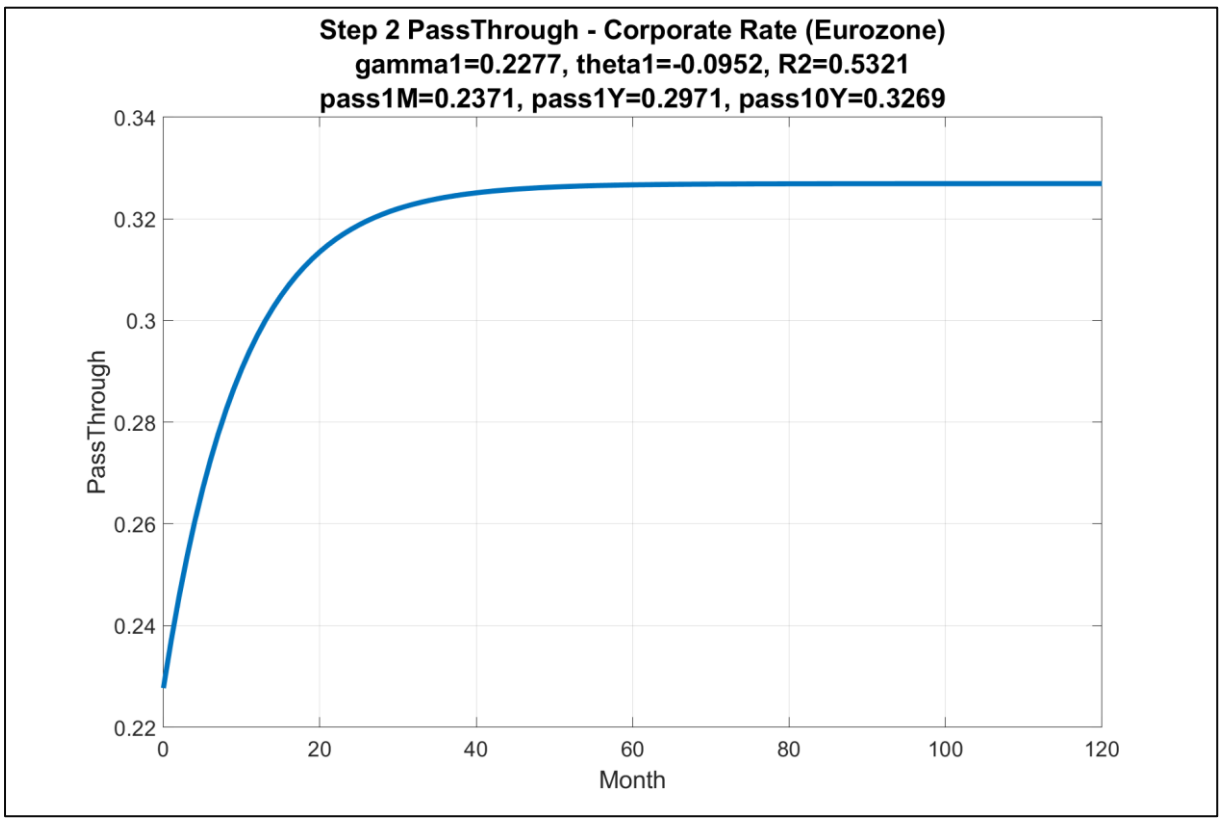
The results show that it may take up to 3 years for the full effect of the market rate changes to get reflected in the NMD rates for the retail and corporate segments in the Eurozone. Nevertheless, as majority of the adjustment occurs in the 1-year horizon, and this is also the horizon most often used by commercial banks for the IRRBB risk management purposes, we will use primarily the 1-year pass-through rates in the analysis of the pass-through rate determinants in the next section.

Figure 4: NMD pass-through rate for horizons ranging from 0 to 120 months (Eurozone, Retail)



Data source: Authorial computation

Figure 5 – NMD pass-through rate for horizons ranging from 0 to 120 months (Eurozone, Corporate)



Data source: Authorial computation

5. Determinants of NMD pass-through rates in the Eurozone

In the previous section, we have estimated the NMD pass-through rates for the Retail and Corporate segments for all 19 Eurozone countries. The pass-through rates seem to exhibit high variability among the Eurozone countries, with the 1-year retail pass-through rates ranging from 2.73 % (France) to 46.40 % (Luxemburg), while the corporate pass-through rates range from 7.54 % (Slovenia) to 60.31 % (Luxemburg).

Apart from intuitive finding that corporate pass-through rates tend to be higher than the retail ones, there does not seem to be any clear trend explaining the variability of pass-through rates in the Eurozone, as the level of the pass-through rates does not seem to depend on country size (large countries, such as Germany vs. France have vastly different pass-through rates, and the same holds for small countries such as Luxemburg and Malta), neither on how recently the country joined the Eurozone (Latvia and Lithuania have vastly different pass-through rates).

To identify true drivers of the pass-through rates in the Eurozone, we regress the estimated 1-year pass-through rates on 9 aggregate variables describing the banking sector characteristics in each country, namely its: **(i) concentration** (Herfindahl Index), **(ii) profitability** (Return on Assets, Return on Equity, Cost to Income, Risk Costs to Operating Income and Net Interest Income to Assets), and **(iii) funding profile** (Loan to Deposit ratio, Liquid Assets to Total Assets, Wholesale Funding to Liabilities).

The banking sector characteristics for the 19 Eurozone countries were downloaded from ECB Statistical Data Warehouse in the form of annual time series (see Appendix 2). As the pass-through rates in the previous section are estimated based on the years 2000-2021, we compute average value of the banking sector characteristics over the available history (which unfortunately often starts later than in 2000) and use it as predictor of the NMD pass-through rates in the Eurozone. Summary of the dataset is provided in Table 8 (Appendix 3), with the StartDate and EndDate showing the available time series history, and the Mean, Std.Dev, Min and Max, showing the statistics of the averages computed on the Eurozone-country level.

For some of the countries only shorter history of some of the predictors was available, in which case the averages used in the analysis were computed over the shorter history. Additionally, the Wholesale Funding [% liabilities] measure was not available for France, and its values were thus replaced with the sample averages computed based on available data from the other countries for each year.

In the first step of the analysis, **univariate regressions** are computed, between the average values of each predictor for each country, as independent variable, and the 1-Year Passthrough rates, estimated for the Retail and the Corporate segments, as the dependent variable. The results of the univariate regressions are shown in Table 1 (retail) and Table 2 (corporate).

Table 1: Univariate regression results between banking sector aggregates and the 1-year NMD pass-through rate (Retail)

Equation: PassThrough1Y(i) = const + slope*X(i) + Res(i)							
Predictor	**const**	**slope**	**t_const**	**t_slope**	**p_const**	**p_slope**	**R2**
Herfindahl Index	0.2145	-0.2973	4.0710	-0.8344	0.08%	41.56%	3.93%
Return on Assets	0.1784	-0.0039	5.5214	-0.0633	0.00%	95.03%	0.02%
Return on Equity	0.1764	0.0007	5.8943	0.1640	0.00%	87.17%	0.16%
Cost-to-income [%]	0.2174	0.0007	1.3616	0.2539	19.11%	80.26%	0.38%
Risk-costs-to-op-income	0.1581	-0.0011	3.8965	-0.6795	0.12%	50.60%	2.64%
Net interest income [% assets]	0.2216	-0.0278	2.4293	-0.5093	2.65%	61.71%	1.50%
Loan-to-deposit ratio	0.3223	-0.0017	1.9608	-0.8941	6.65%	38.37%	4.49%
Liquid assets [% assets]	0.2268	-0.0026	2.4271	-0.5539	2.66%	58.69%	1.77%

Wholesale funding [% liabilities]	-0.0579	0.0058	-0.5815	2.4439	56.86%	2.57%	26.00%

Data source: Authorial computation

It is apparent that the only predictor that statistically significantly (on the 10% confidence level) predicts the 1-year NMD pass-through rate for the **Retail segment** is the ratio of **Wholesale funding as % of liabilities**, with a p-value of 2.57 %. The parameter of the regression is **positive**, indicating that banks in the countries that rely more heavily on wholesale funding tend to adjust the NMD client rates for their retail clients more readily to the changes of the Euribor rates.

Table 2: Univariate regression results between banking sector aggregates and the 1-year NMD pass-through rate (Corporate)

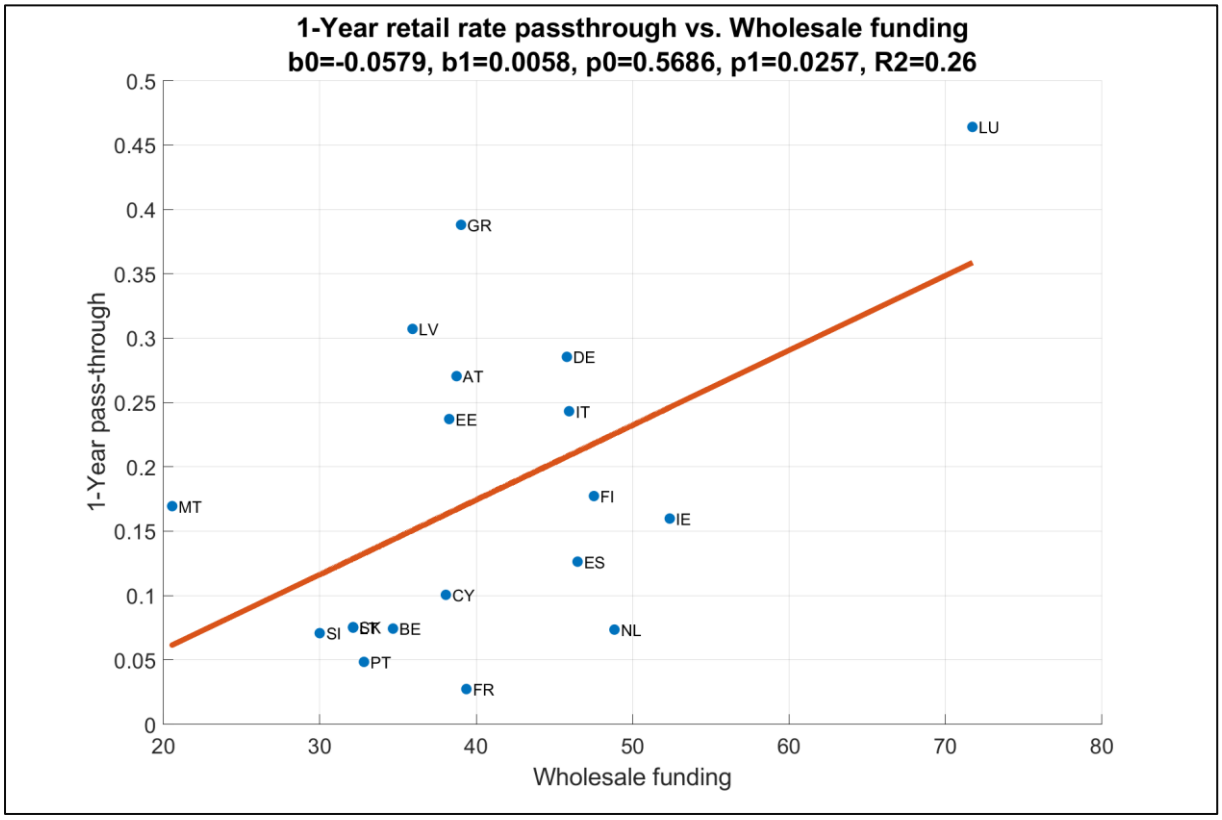
Equation: PassThrough1Y(i) = const + slope*X(i) + Res(i)							
Predictor	**const**	**slope**	**t_const**	**t_slope**	**p_const**	**p_slope**	**R2**
Herfindahl Index	0.2678	0.1951	3.6075	0.3888	0.22%	70.22%	0.88%
Return on Assets	0.2668	0.1094	6.2683	1.3597	0.00%	19.17%	9.81%
Return on Equity	0.2744	0.0109	7.3263	1.9725	0.00%	6.50%	18.62%
Cost-to-income [%]	0.2336	-0.0010	1.0551	-0.2686	30.61%	79.15%	0.42%
Risk-costs-to-op-income	0.3311	0.0021	5.9745	0.9967	0.00%	33.29%	5.52%
Net interest income [% assets]	0.4511	-0.1002	3.7343	-1.3881	0.17%	18.30%	10.18%
Loan-to-deposit ratio	-0.1346	0.0049	-0.6467	2.0806	52.65%	5.29%	20.30%
Liquid assets [% assets]	0.4276	-0.0071	3.3918	-1.1304	0.35%	27.40%	6.99%
Wholesale funding [% liabilities]	-0.0859	0.0093	-0.6635	3.0157	51.59%	0.78%	34.85%

Data source: Authorial computation

For the **Corporate segment**, the ratio of **Wholesale funding as % of liabilities** proved to be the most statistically significant predictor as well, with a p-value of 0.78 %. The sign of the relationship is positive as for the retail segment. Additionally, the **Return on Equity** (positive relationship) and **Loan-to-deposit ratio** (positive relationship) seem to also be significant predictors of the 1-year pass-through rate in the corporate segment, although only on the 10% confidence level.

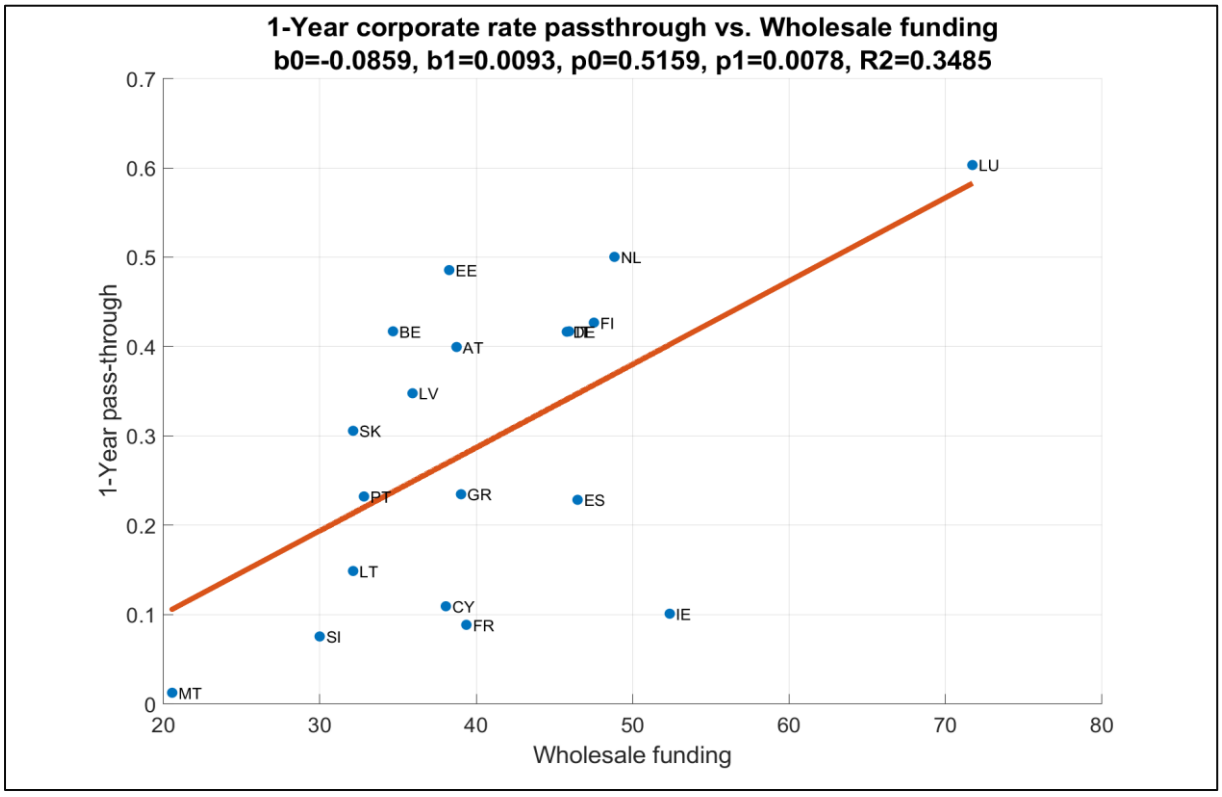
For illustration, we show the univariate regression fit between the 1-Year NMD passthrough rates and the Wholesale funding as % of liabilities, which is by far the strongest predictor in both of the segments. The figures are shown in Figure 6 (retail) and Figure 7 (corporate).

Figure 6: OLS regression fit between Wholesale funding [% liabilities] and the 1-year NMD pass-through rate (retail)



Data source: Authorial computation

Figure 7: OLS regression fit between Wholesale funding [% liabilities] and the 1-year NMD pass-through rate (Corporate)



Data source: Authorial computation

In the next step, we estimate a **multivariate regression model**, using all of the potential predictors of the pass-through rates in a single model. The results for both segments (**retail** and **corporate**) are shown in Table 3.

Table 3: Multivariate regression results between banking sector aggregates and the 1-year NMD pass-through rate

Equation: PassThrough1Y(i) = const + XVec(i)'*CoeffVec + Res(i)						
Segment	**Retail**			**Corporate**		
Predictor	**coeff**	**t-val**	**p-val**	**coeff**	**t-val**	**p-val**
Constant	0,0593	0,1175	90,90%	-0,1043	-0,1410	89,10%
Herfindahl Index	0,3176	0,6928	50,59%	0,6202	0,9226	38,03%
Return on Assets	0,1069	0,6007	56,28%	0,0347	0,1329	89,72%
Return on Equity	0,0029	0,2141	83,52%	0,0037	0,1903	85,33%
Cost-to-income [%]	-0,0035	-0,7634	46,47%	0,0002	0,0239	98,15%
Risk-costs-to-op-income	-0,0019	-0,4593	65,69%	0,0025	0,4037	69,59%
Net interest income [% assets]	0,0337	0,4275	67,91%	0,0962	0,8329	42,65%
Loan-to-deposit ratio	-0,0067	-2,2254	5,31%	-0,0012	-0,2624	79,89%
Liquid assets [% assets]	-0,0045	-0,4040	69,57%	-0,0102	-0,6313	54,36%
Wholesale funding [% liabilities]	0,0105	3,2248	1,04%	0,0125	2,6209	2,78%

Data source: Authorial computation

While in the **corporate segment**, only the **ratio of Wholesale funding** achieved statistical significance in the multivariate model (p-value = 2.78 %), in the **retail segment**, the **Loan-to-deposit ratio** managed to achieve statistical significance as well (on the 10% confidence level). In both multivariate models, the ratio of wholesale funding has a positive impact on the passthrough rates, while the loan-to-deposit ratio has a negative impact. Nevertheless, as in the univariate model for the corporate segment, the loan-to-deposit ratio had a positive sign (while being significant on the 10% confidence level), it is questionable whether it can be viewed as reliable predictor of the pass-through rates.

6. Conclusion

Non-Maturing Deposit (NMD) pass-through rates were estimated in different horizons for the 19 Eurozone countries based on datasets available from the ECB Statistical Data Warehouse. The 1-year NMD pass-through rates for the corporate segments were shown to be higher (29.71%) than for the retail segment (19.61%), in accordance with expectations that the corporate segment is more competitive. The highest corporate pass-through rates in the Eurozone were observed in Luxemburg (60.31%), followed by Netherlands (50.03%) and Estonia (48.55%), while the lowest ones were observed in Malta (1.24%), Slovenia (7.54%) and France (8.84%). Highest retail pass-through rates were observed in Luxemburg (46.40%), followed by Greece (38.80%) and Latvia (30.71%), while the lowest ones were observed in France (2.73%), Portugal (4.84%) and Slovenia (7.55%). To analyse the determinants of pass-through rates in the Eurozone, we regressed the estimated 1-year pass-through rates on 9 country-level banking sector aggregates of concentration, profitability, and funding. Out of the tested predictors, only the ratio of Wholesale Funding to Liabilities proved to significantly impact the 1-year pass-through rates (p-value of 1.04% for retail and 2.78% for corporate), with a positive sign, indicating that countries where banks rely more heavily on wholesale funding exhibit higher pass-through rates of the market interest rate changes to the NMD deposit rates.

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8. Appendices

8.1. Appendix 1: Dataset replicability

All datasets were downloaded from the **ECB Statistical Data Warehouse**.

For replicability purposes, we provide the used time-series identification codes below.

Note: For the country-specific datasets, the following **country codes** should be used for **XX**:

XX = {"AT","BE","CY","EE","FI","FR","DE","GR","IE","IT","LV","LT","LU","MT","NL","PT","SK","SI","ES")

1-month Euribor:

FM.M.U2.EUR.RT.MM.EURIBOR1MD_.HSTA

Retail NMD interest rates:

MIR.M.**XX**.B.L21.A.R.A.2250.EUR.N

Corporate NMD interest rates:

MIR.M.**XX**.B.L21.A.R.A.2240.EUR.N

Herfindahl Index (total assets):

SSI.A.**XX**.122C.H10.X.U6.Z0Z.Z

Return on Assets:

CBD2.A.**XX**.W0.67._Z._Z.A.A.I2004._Z._Z._Z._Z._Z._Z.PC

Return on Equity:

CBD2.A.**XX**.W0.67._Z._Z.A.A.I2003._Z._Z._Z._Z._Z._Z.PC

Cost-to-income ratio [%]:

CBD2.A.**XX**.W0.67._Z._Z.A.A.I2100._Z._Z._Z._Z._Z._Z.PC

Risk costs to operating income:

CBD2.A.**XX**.W0.67._Z._Z.A.F.I2525._Z._Z._Z._Z._Z._Z.PC

Net interest income [% of total assets]:

CBD2.A.**XX**.W0.67._Z._Z.A.A.I2410._Z._Z._Z._Z._Z._Z.PC

Loan-to-deposit ratio:

CBD2.A.**XX**.W0.67._Z._Z.A.A.I3006._Z._Z._Z._Z._Z._Z.PC

Liquid assets [% of total assets]:

CBD2.A.**XX**.W0.67._Z._Z.A.A.I3018._Z._Z._Z._Z._Z._Z.PC

Wholesale funding [% of total liabilities]:

CBD2.A.**XX**.W0.67._Z._Z.A.A.I3050._Z._Z._Z._Z._Z._Z.PC

8.2. Appendix 2: Derivation of the pass-through rate formula

Step 1 regression:

$$y_t = \beta_0 + \beta_1 x_t + \varepsilon_t$$

Step 2 regression:

$$\Delta y_t = \gamma_0 + \gamma_1 \Delta x_t + \theta_1 (y_{t-1} - \beta_0 - \beta_1 x_{t-1}) + \epsilon_t$$

Rewriting the Step 2 equation:

$$y_t - y_{t-1} = \gamma_0 + \gamma_1 (x_t - x_{t-1}) + \theta_1 (y_{t-1} - \beta_0 - \beta_1 x_{t-1}) + \epsilon_t$$

$$y_t = \gamma_0 - \theta_1 \beta_0 + \gamma_1 x_t + (-\gamma_1 - \theta_1 \beta_1) x_{t-1} + (1 + \theta_1) y_{t-1} + \epsilon_t$$

Shock at time t:

$$x'_t = x_t + K$$

Shock effect at time t:

$$P_t = \frac{y'_t - y_t}{K}$$

Rewrite equation for t:

$$y_t = \gamma_0 - \theta_1 \beta_0 + \gamma_1 x_t + (-\gamma_1 - \theta_1 \beta_1) x_{t-1} + (1 + \theta_1) y_{t-1} + \epsilon_t$$

$$y'_t = \gamma_0 - \theta_1 \beta_0 + \gamma_1 x'_t + (-\gamma_1 - \theta_1 \beta_1) x_{t-1} + (1 + \theta_1) y_{t-1} + \epsilon_t$$

$$y'_t = \gamma_0 - \theta_1 \beta_0 + \gamma_1 (x_t + K) + (-\gamma_1 - \theta_1 \beta_1) x_{t-1} + (1 + \theta_1) y_{t-1} + \epsilon_t$$

$$y'_t - y_t = \gamma_1 K$$

$$P_t = \gamma_1$$

$$\Delta P_t = \gamma_1$$

Rewrite equation for t+1:

$$y_{t+1} = \gamma_0 - \theta_1\beta_0 + \gamma_1 x_{t+1} + (-\gamma_1 - \theta_1\beta_1)x_t + (1+\theta_1)y_t + \epsilon_t$$

$$y'_{t+1} = \gamma_0 - \theta_1\beta_0 + \gamma_1 x'_{t+1} + (-\gamma_1 - \theta_1\beta_1)x'_t + (1+\theta_1)y'_t + \epsilon_t$$

$$y'_{t+1} = \gamma_0 - \theta_1\beta_0 + \gamma_1(x_{t+1} + K) + (-\gamma_1 - \theta_1\beta_1)(x_t + K) + (1+\theta_1)(y_t + \gamma_1 K) + \epsilon_t$$

$$y'_{t+1} - y_{t+1} = \gamma_1 K + (-\gamma_1 - \theta_1\beta_1)K + (1+\theta_1)\gamma_1 K$$

$$P_{t+1} = -\theta_1\beta_1 + (1+\theta_1)P_t$$

$$\Delta P_{t+1} = -\gamma_1 - \theta_1\beta_1 + (1+\theta_1)\gamma_1$$

Rewrite equation for t+2:

$$y_{t+2} = \gamma_0 - \theta_1\beta_0 + \gamma_1 x_{t+2} + (-\gamma_1 - \theta_1\beta_1)x_{t+1} + (1+\theta_1)y_{t+1} + \epsilon_t$$

$$y'_{t+2} = \gamma_0 - \theta_1\beta_0 + \gamma_1 x'_{t+2} + (-\gamma_1 - \theta_1\beta_1)x'_{t+1} + (1+\theta_1)y'_{t+1} + \epsilon_t$$

$$y'_{t+2} = \gamma_0 - \theta_1\beta_0 + \gamma_1(x_{t+2} + K) + (-\gamma_1 - \theta_1\beta_1)(x_{t+1} + K) + (1+\theta_1)y'_{t+1} + \epsilon_t$$

$$y'_{t+1} = y_{t+1} + \gamma_1 K + (-\gamma_1 - \theta_1\beta_1)K + (1+\theta_1)\gamma_1 K$$

$$y'_{t+2} - y_{t+2} = +\gamma_1 K + (-\gamma_1 - \theta_1\beta_1)K + (1+\theta_1)(y'_{t+1} - y_{t+1})$$

$$P_{t+2} = -\theta_1\beta_1 + (1+\theta_1)P_{t+1}$$

$$\Delta P_{t+2} = (1+\theta_1)\Delta P_{t+1}$$

General formulas for t+k:

$$P_{t+k} = -\theta_1\beta_1 + (1+\theta_1)P_{t+k-1}$$

$$\Delta P_{t+k} = (1+\theta_1)\Delta P_{t+k-1}$$

8.3. Appendix 3: Tables with detailed empirical results

Table 4: Step 1 – Cointegration regression of NMD Retail interest rates in the Eurozone on the 1-Month Euribor

Equation: ClientRate(t) = beta0 + beta1*MarketRate(t) + Res1(t)											
Series	**StartDate**	**EndDate**	**nObs**	**beta0**	**beta1**	**t_beta0**	**t_beta1**	**p_beta0**	**p_beta1**	**R2**	**pADF**
Retail Rate (Austria)	1/1/2000	1/9/2021	261	0.306	0.319	24.841	58.484	0.00%	0.00%	0.930	0.86%
Retail Rate (Belgium)	1/1/2000	1/9/2021	261	0.200	0.262	13.077	38.620	0.00%	0.00%	0.852	15.66%
Retail Rate (Cyprus)	1/1/2008	1/9/2021	165	0.468	0.358	16.693	16.336	0.00%	0.00%	0.621	20.32%
Retail Rate (Estonia)	1/3/2003	1/9/2021	223	0.067	0.243	5.976	39.522	0.00%	0.00%	0.876	0.10%
Retail Rate (Finland)	1/1/2000	1/9/2021	261	0.187	0.182	20.640	45.416	0.00%	0.00%	0.888	1.14%
Retail Rate (France)	1/1/2003	1/9/2021	225	0.056	0.032	30.075	31.482	0.00%	0.00%	0.816	0.10%
Retail Rate (Germany)	1/1/2000	1/9/2021	261	0.299	0.356	22.346	59.942	0.00%	0.00%	0.933	3.02%
Retail Rate (Greece)	1/1/2000	1/9/2021	261	0.198	0.505	2.699	15.522	0.74%	0.00%	0.482	0.10%
Retail Rate (Ireland)	1/1/2000	1/9/2021	261	0.256	0.127	10.758	12.022	0.00%	0.00%	0.358	5.07%
Retail Rate (Italy)	1/1/2000	1/9/2021	261	0.160	0.267	19.865	74.836	0.00%	0.00%	0.956	1.64%
Retail Rate (Latvia)	1/1/2004	1/9/2021	213	0.194	0.330	11.636	35.537	0.00%	0.00%	0.857	0.10%
Retail Rate (Lithuania)	1/3/2005	1/9/2021	199	0.108	0.130	6.416	13.652	0.00%	0.00%	0.486	1.04%
Retail Rate (Luxembourg)	1/1/2003	1/9/2021	225	0.315	0.498	30.171	86.996	0.00%	0.00%	0.971	0.10%
Retail Rate (Malta)	1/3/2007	1/9/2021	175	0.168	0.219	22.907	47.768	0.00%	0.00%	0.930	0.10%
Retail Rate (Netherlands)	1/1/2000	1/9/2021	261	0.252	0.123	27.326	29.991	0.00%	0.00%	0.776	9.66%
Retail Rate (Portugal)	1/1/2003	1/9/2021	225	0.048	0.051	17.779	34.280	0.00%	0.00%	0.840	0.10%
Retail Rate (Slovakia)	1/1/2008	1/9/2021	165	0.194	0.150	22.846	22.687	0.00%	0.00%	0.759	19.42%
Retail Rate (Slovenia)	1/5/2005	1/9/2021	197	0.086	0.093	17.793	33.895	0.00%	0.00%	0.855	1.32%
Retail Rate (Spain)	1/1/2000	1/9/2021	261	0.151	0.187	14.486	40.457	0.00%	0.00%	0.863	2.05%
Retail Rate (Eurozone)	1/1/2000	1/9/2021	261	0.190	0.233	23.406	64.844	0.00%	0.00%	0.942	0.10%

Data source: Authorial computation

Table 5: Step 1 – Cointegration regression of NMD Corporate interest rates in the Eurozone on the 1-Month Euribor

Equation: ClientRate(t) = beta0 + beta1*MarketRate(t) + Res1(t)											
Series	**StartDate**	**EndDate**	**nObs**	**beta0**	**beta1**	**t_beta0**	**t_beta1**	**p_beta0**	**p_beta1**	**R2**	**pADF**
Corporate Rate (Austria)	1/1/2000	1/9/2021	261	0.245	0.485	13.444	59.990	0.00%	0.00%	0.933	5.08%
Corporate Rate (Belgium)	1/10/2006	1/9/2021	180	0.150	0.428	23.195	111.396	0.00%	0.00%	0.986	0.10%
Corporate Rate (Cyprus)	1/1/2008	1/9/2021	165	0.252	0.223	19.744	22.313	0.00%	0.00%	0.753	10.08%
Corporate Rate (Estonia)	1/3/2003	1/9/2021	223	0.071	0.496	4.439	56.095	0.00%	0.00%	0.934	0.10%
Corporate Rate (Finland)	1/1/2003	1/9/2021	225	0.098	0.442	8.034	66.071	0.00%	0.00%	0.951	0.24%
Corporate Rate (France)	1/1/2003	1/9/2021	225	0.174	0.097	34.210	34.697	0.00%	0.00%	0.844	0.10%
Corporate Rate (Germany)	1/1/2000	1/9/2021	261	0.165	0.461	16.581	104.632	0.00%	0.00%	0.977	0.10%
Corporate Rate (Greece)	1/1/2000	1/9/2021	261	0.227	0.267	8.197	21.699	0.00%	0.00%	0.645	0.10%
Corporate Rate (Ireland)	1/1/2000	1/9/2021	261	0.165	0.092	10.331	12.986	0.00%	0.00%	0.394	4.05%
Corporate Rate (Italy)	1/1/2000	1/9/2021	261	0.360	0.422	16.821	44.418	0.00%	0.00%	0.884	13.06%
Corporate Rate (Latvia)	1/1/2004	1/9/2021	213	0.081	0.348	7.871	60.282	0.00%	0.00%	0.945	0.10%
Corporate Rate (Lithuania)	1/3/2005	1/9/2021	199	0.071	0.149	9.014	33.455	0.00%	0.00%	0.850	0.10%
Corporate Rate (Luxembourg)	1/1/2003	1/9/2021	225	0.164	0.605	9.805	66.252	0.00%	0.00%	0.952	0.10%
Corporate Rate (Malta)	1/3/2007	1/9/2021	175	0.157	0.269	18.473	50.436	0.00%	0.00%	0.936	0.10%
Corporate Rate (Netherlands)	1/1/2000	1/9/2021	261	0.331	0.578	22.912	90.386	0.00%	0.00%	0.969	0.65%
Corporate Rate (Portugal)	1/1/2003	1/9/2021	225	0.069	0.231	9.905	60.399	0.00%	0.00%	0.942	0.10%
Corporate Rate (Slovakia)	1/1/2008	1/9/2021	165	0.068	0.316	6.933	41.204	0.00%	0.00%	0.912	0.10%
Corporate Rate (Slovenia)	1/5/2005	1/9/2021	197	0.109	0.090	14.895	21.711	0.00%	0.00%	0.707	0.10%
Corporate Rate (Spain)	1/1/2000	1/9/2021	261	0.269	0.261	15.266	33.506	0.00%	0.00%	0.813	5.66%
Corporate Rate (Eurozone)	1/1/2000	1/9/2021	261	0.177	0.327	27.916	116.349	0.00%	0.00%	0.981	0.10%

Data source: Authorial computation

Table 6: Step 2 – Error Correction Model between NMD Retail interest rates in the Eurozone and 1-Month Euribor

Equation: dClientRate(t) = gamma1*dMarketRate(t) + theta1*Res1(t-1) + Res2(t)											
Series	**nObs**	**gamma1**	**theta1**	**t_gamma1**	**t_theta1**	**p_gamma1**	**p_theta1**	**R2**	**pass1M**	**pass1Y**	**pass10Y**
Retail Rate (Austria)	260	0.168	-0.090	8.644	-4.947	0.00%	0.00%	33.27%	18.15%	27.04%	31.92%
Retail Rate (Belgium)	260	0.083	0.004	10.149	0.616	0.00%	53.87%	26.50%	8.19%	7.43%	-2.00%
Retail Rate (Cyprus)	164	0.030	-0.020	1.806	-2.766	7.28%	0.63%	-2.70%	3.69%	10.05%	32.88%
Retail Rate (Estonia)	222	0.182	-0.177	4.601	-4.367	0.00%	0.00%	12.76%	19.29%	23.71%	24.29%
Retail Rate (Finland)	260	0.173	-0.052	11.051	-2.603	0.00%	0.98%	37.27%	17.33%	17.73%	18.23%
Retail Rate (France)	224	0.009	-0.123	1.867	-4.076	6.33%	0.01%	8.09%	1.20%	2.73%	3.20%
Retail Rate (Germany)	260	0.133	-0.092	10.847	-8.692	0.00%	0.00%	51.13%	15.32%	28.54%	35.56%
Retail Rate (Greece)	260	0.184	-0.081	4.758	-13.257	0.00%	0.00%	36.44%	21.01%	38.80%	50.50%
Retail Rate (Ireland)	260	0.169	-0.020	7.427	-1.800	0.00%	7.30%	19.06%	16.80%	15.98%	13.05%
Retail Rate (Italy)	260	0.210	-0.070	16.284	-3.785	0.00%	0.02%	57.64%	21.38%	24.32%	26.73%
Retail Rate (Latvia)	212	0.140	-0.161	3.292	-5.453	0.12%	0.00%	17.95%	17.05%	30.71%	33.02%
Retail Rate (Lithuania)	198	-0.141	-0.124	-4.455	-5.484	0.00%	0.00%	16.38%	-10.74%	7.50%	13.03%
Retail Rate (Luxembourg)	224	0.322	-0.129	13.467	-4.924	0.00%	0.00%	50.77%	34.44%	46.40%	49.78%
Retail Rate (Malta)	174	0.111	-0.063	4.604	-1.518	0.00%	13.08%	9.90%	11.75%	16.95%	21.92%
Retail Rate (Netherlands)	260	0.048	-0.034	4.736	-2.669	0.00%	0.81%	10.22%	5.07%	7.35%	12.15%
Retail Rate (Portugal)	224	0.025	-0.177	3.251	-5.361	0.13%	0.00%	17.70%	3.00%	4.84%	5.09%
Retail Rate (Slovakia)	164	0.063	-0.012	6.879	-0.955	0.00%	34.11%	18.34%	6.44%	7.55%	13.09%
Retail Rate (Slovenia)	196	0.019	-0.096	2.166	-4.464	3.15%	0.00%	12.51%	2.57%	7.08%	9.28%
Retail Rate (Spain)	260	0.060	-0.060	4.680	-4.162	0.00%	0.00%	14.31%	6.80%	12.63%	18.67%
Retail Rate (Eurozone)	260	0.114	-0.092	13.983	-7.949	0.00%	0.00%	46.65%	12.52%	19.61%	23.34%

Data source: Authorial computation

Table 7: Step 2 – Error Correction Model between NMD Corporate interest rates in the Eurozone and 1-Month Euribor

Equation: dClientRate(t) = gamma1*dMarketRate(t) + theta1*Res1(t-1) + Res2(t)											
Series	**nObs**	**gamma1**	**theta1**	**t_gamma1**	**t_theta1**	**p_gamma1**	**p_theta1**	**R2**	**pass1M**	**pass1Y**	**pass10Y**
Corporate Rate (Austria)	260	0.346	-0.040	15.967	-2.922	0.00%	0.38%	51.66%	35.12%	39.95%	48.35%
Corporate Rate (Belgium)	179	0.305	-0.183	9.431	-2.904	0.00%	0.41%	34.00%	32.72%	41.70%	42.79%
Corporate Rate (Cyprus)	164	0.050	-0.034	2.547	-1.856	1.18%	6.53%	0.79%	5.60%	10.92%	22.02%
Corporate Rate (Estonia)	222	0.455	-0.110	10.110	-3.431	0.00%	0.07%	32.05%	45.94%	48.55%	49.55%
Corporate Rate (Finland)	224	0.404	-0.074	16.250	-3.179	0.00%	0.17%	55.25%	40.68%	42.67%	44.17%
Corporate Rate (France)	224	0.038	-0.150	2.377	-4.111	1.83%	0.01%	8.12%	4.71%	8.84%	9.67%
Corporate Rate (Germany)	260	0.265	-0.116	13.763	-5.185	0.00%	0.00%	46.38%	28.82%	41.65%	46.10%
Corporate Rate (Greece)	260	0.157	-0.097	5.423	-8.098	0.00%	0.00%	21.28%	16.77%	23.46%	26.66%
Corporate Rate (Ireland)	260	0.104	-0.026	5.782	-1.986	0.00%	4.81%	13.07%	10.40%	10.08%	9.21%
Corporate Rate (Italy)	260	0.416	-0.017	19.597	-1.487	0.00%	13.82%	63.13%	41.60%	41.70%	42.09%
Corporate Rate (Latvia)	212	0.360	-0.386	7.368	-7.043	0.00%	0.00%	29.95%	35.51%	34.76%	34.76%
Corporate Rate (Lithuania)	198	0.010	-0.471	0.255	-8.152	79.87%	0.00%	25.59%	7.52%	14.87%	14.87%
Corporate Rate (Luxembourg)	224	0.509	-0.281	6.679	-5.379	0.00%	0.00%	18.61%	53.58%	60.31%	60.50%
Corporate Rate (Malta)	174	0.089	0.030	3.744	0.852	0.02%	39.53%	10.26%	8.38%	1.24%	-604.16%
Corporate Rate (Netherlands)	260	0.343	-0.088	16.403	-5.260	0.00%	0.00%	55.97%	36.41%	50.03%	57.77%
Corporate Rate (Portugal)	224	0.250	-0.225	9.074	-4.985	0.00%	0.00%	39.57%	24.61%	23.21%	23.12%
Corporate Rate (Slovakia)	164	0.272	-0.115	8.620	-2.980	0.00%	0.33%	29.63%	27.71%	30.56%	31.57%
Corporate Rate (Slovenia)	196	-0.026	-0.160	-1.343	-4.898	18.09%	0.00%	11.00%	-0.77%	7.54%	8.97%
Corporate Rate (Spain)	260	0.212	-0.033	10.540	-2.470	0.00%	1.41%	34.99%	21.38%	22.83%	26.04%
Corporate Rate (Eurozone)	260	0.228	-0.095	17.190	-3.953	0.00%	0.01%	53.21%	23.71%	29.71%	32.69%

Data source: Authorial computation

Table 8: Aggregate statistics of Banking sector performance for Eurozone countries (ECB Statistical Data Warehouse)

Predictor	StartDate	EndDate	nYears	nObs	Mean	St.Dev	Min	Max
Herfindahl Index	2020	1997	24	19	0.12	0.08	0.02	0.32
Return on Assets	2020	2007	14	19	0.23	0.49	-0.97	1.09
Return on Equity	2020	2007	14	19	1.61	6.77	-19.36	9.54
Cost-to-income [%]	2020	2007	14	19	-59.70	11.34	-88.50	-37.51
Risk-costs-to-op-income	2020	2014	7	19	-18.53	19.06	-75.73	-4.08
Net interest income [% assets]	2020	2007	14	19	1.59	0.54	0.67	2.67
Loan-to-deposit ratio	2020	2014	7	19	87.35	15.76	59.03	118.27
Liquid assets [% assets]	2020	2014	7	19	19.12	6.37	7.39	30.85
Wholesale funding [% liabilities]	2020	2016	5	19	40.54	10.82	20.56	71.72

Data source: Authorial computation

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