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Monetary policy transmission to mortgages in a negative interest rate environment

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Abstract

Do negative policy rates hinder banks' transmission of monetary policy? To answer this question, we examine the behaviour of Italian mortgage lenders using a novel loan-level dataset. When policy rates turn negative, banks with higher ratios of retail overnight deposits to total assets charge more on new fixed rate mortgages. This suggests that the funding structure of banks may matter for the transmission of negative policy rates, especially for long-maturity illiquid assets. Nevertheless, the aggregate economic implications for households are small, suggesting that concerns about inefficient monetary policy transmission to households under modestly negative rates are likely overstated.

JEL classification: E40, E52, E58, G21

Keywords: monetary policy, negative interest rates, bank lending, mortgages

Non-technical summary

The paper examines whether the introduction of negative policy interest rates hinder banks' transmission of monetary policy. To that effect, the paper uses a novel loan-level dataset to compare the behaviour of mortgage lending rates in the Italian market before and after the introduction of a negative deposit facility rate by the ECB in June 2014.

The paper finds that banks with a higher ratio of retail overnight deposits over total assets tend to charge higher interest rates on fixed rate mortgages originated after the introduction of negative deposit facility rates. At the same time, the paper finds no evidence of significant differences in interest rate-setting behaviour for adjustable rate mortgages across banks with different overnight deposit ratios. This divergence between fixed-rate and adjustable-rate mortgages is consistent with the perspective that banks would be more reluctant to transmit negative deposit facility rates to assets (i.e. mortgages) in which their future income is fixed (i.e. 'locked in') than to similar assets where income can adjust based on market conditions (i.e. adjustable-rate mortgages). In addition, there is evidence to suggest that banks with a higher overnight deposit ratio are more likely to originate adjustable rather than fixed rate mortgages after policy rates turn negative.

The paper takes the novel approach of specifically focusing on overnight deposits, in contrast to total deposits, in the presence of negative deposit facility rates. This is because overnight deposits carry rates that are the closest to zero and, therefore, are least likely to be reduced relative to the rates paid out on the various deposit types offered (i.e. overnight, savings, and time deposits). In this way, banks with a greater share of overnight deposits may find their net interest income 'squeezed' once negative deposit facility rates are introduced—lending rates may fall in line with the rate cut but overnight deposit rates may not necessarily follow. In contrast, banks whose assets are funded with other types of deposits (or other liabilities) paying out higher rates have greater freedom to pass through the deposit facility rate cut, thus minimizing pressure on net interest income. These divergences in exposure to the deposit facility rate cut (i.e. net interest income pressure) lead banks to behave differently when setting interest rates on fixed rate mortgages, even after taking into account other borrower, loan, and bank features that could play a role.

As regards the aggregate economic implications of these empirical findings, the paper shows that while the additional charges on new fixed rate mortgages may not be trivial for a few individual households, they are relatively small for the household sector overall. This suggests that concerns about modestly-negative deposit rates impairing the transmission of monetary policy may be less relevant than previously believed.

1. Introduction

The introduction of negative policy interest rates by several central banks (including the ECB) in recent years has raised a number of questions about possible inefficiencies in the transmission of monetary policy once interest rates enter negative territory. More specifically, concerns have been expressed about the existence of financial frictions that may hamper the interest rate pass-through under negative interest rates. A key friction would arise from the reluctance of retail banks to lower deposit rates below zero, given concerns about households or firms withdrawing deposits and the fear of alienating customers.[1]

Under these conditions, the lowering of central bank rates below zero could lead to net interest income being squeezed, to the extent that banks are reluctant to reduce their rates on deposits proportionately to the decline in lending rates. Along this perspective, Brunnermeier and Koby (2017) develop a model with financial frictions in which monetary accommodation beyond a "reversal rate" can prove counterproductive and lead to a contraction in lending if it causes a profitability squeeze. Even under a less dramatic scenario, deposit rate inertia may prompt banks to slow down the pace of transmission of interest cuts to lending rates in order to buttress net interest income, thereby potentially hindering the transmission of monetary policy.

The objective of the present paper is to empirically examine this hypothesis by comparing the behaviour of mortgage lending rates in the Italian market before and after the introduction of a negative deposit facility rate (NDFR henceforth) by the ECB in June 2014. Our analysis provides a number of novel findings. First, we find that banks with a higher ratio of retail overnight deposits over total assets (hereafter, the overnight deposit ratio) charge higher interest rates on fixed rate mortgages originated after the onset of NDFR. Second, we do not find related evidence of significant differences in the setting of interest rates for adjustable rate mortgages across banks with different overnight deposit ratios. This is consistent with the perspective that banks would be more reluctant to transmit NDFR to assets in which their future income is 'locked in' than to similar assets providing income that adjusts based on market conditions. Third, we find evidence to suggest that banks with a higher

[1] While some instances have been recorded where banks lowered deposit rates for large depositors, by and large there is evidence of resistance to such lowering of rates, particularly in the case of households. See IMF (2017) for a detailed discussion.

overnight deposit ratio are more likely to originate adjustable rather than fixed rate mortgages after policy rates turn negative. As regards the aggregate economic implications of these empirical findings, we show that while the additional charges on new fixed rate mortgages may not be trivial for a few individual households, they are relatively small for the household sector overall. This suggests that concerns about modestly-negative deposit rates impairing the transmission of monetary policy may be overstated.

We set up a unique loan-level dataset by combining publicly available data on residential mortgage-backed securities and confidential data on residential mortgage loans pledged with the Eurosystem as part of a temporary expansion of the collateral framework. Using loan-level data allows us to explore whether the consequences for lending rates of the introduction of NDFR depend on the loan fixation type (fixed rate vs. adjustable rate mortgages). Intuitively, the loan interest rate setting behaviour of a bank whose net interest income is 'squeezed' by inertial deposit rates is likely to differ depending on whether it is pricing a fixed or an adjustable rate. Furthermore, differences in response to NDFR are more likely to arise for assets that are both relatively large and with a long maturity, as is typically the case of fixed rate residential mortgages.

We aim to explore heterogeneity across both loan products and bank types in response to a given policy change. It is therefore important to use data from a country that is heterogeneous in both dimensions and for which there exists a sufficient number of observations during the time frame of interest. Data on Italian residential mortgages are a good candidate for various reasons. First, both fixed rate and adjustable rate mortgages are commonly available in Italy, unlike in other euro area countries, where one loan type often dominates the sector. The variety in Italy allows us to examine the presence of asymmetries in monetary policy transmission across loan types. Second, the Italian banking sector is relatively heterogeneous, containing a combination of small local banks, larger regional players, as well as a few global banks.[2] Third, excess liquidity in Italian banks has consistently been low compared with other euro area banks (see Figure A1.1 in Appendix), due in part to stressful market conditions and, after 2015, liquidity-related distributional

[2] This is in contrast to other euro area countries where loan-level data for both types of mortgages exists but the cross-section of banks is smaller (e.g. Belgium).

effects linked to the implementation of non-standard monetary policy measures.[3] As explained in detail below, the lack of excess liquidity helps to isolate in a relatively clean manner the effect of NDFR through the overnight deposit ratio channel from an alternative source of friction of potential relevance (namely, excess liquidity).[4] Moreover, we exploit loan-specific risk indicators to take into account the creditworthiness of borrowers and their demand for mortgage products. In addition, the available dataset contains a sufficient number of mortgage loans originated before and after the introduction of NDFR, which allows focusing the analysis around the onset of NDFR and distinguishing its effect from that of other unconventional policy actions that were implemented shortly afterwards.[5]

A number of studies have analysed the impact of monetary policy on bank lending when policy rates are in a positive territory, and point to the importance of banks' balance sheet composition in this context (see, e.g., Bernanke and Gertler, 1995, Kashyap and Stein, 2000 and Jiménez et al., 2012). Some recent studies have examined the transmission of non-standard monetary policy measures in the euro area (e.g. Altavilla et al., 2016 and Albertazzi et al., 2016) and in the United States (see Chakraborty et al., 2016 and Di Maggio et al., 2016).[6] However, far less is known about the specific impact of the introduction of a NDFR policy on bank behaviour in the euro area[7]. Demiralp et al. (2017), using bank-level data over the 2007-2015 period, find that banks with substantial amounts of excess liquidity reacted to the introduction of NDFR by increasing their holdings of 'safe' assets such as government bonds, expanding their lending supply, and reducing their reliance on wholesale funding.

[3] Indeed, following the implementation of the ECB's large-scale security purchase programmes excess liquidity tended to accumulate in other euro area countries which host large market infrastructure institutions and concentrations of banks specialised in the intermediation of trading activities of institutional investors (Demiralp et al., 2017).

[4] In any case, we control for excess liquidity in our robustness checks and find that it does not play any significant role nor alters our baseline findings. Overall, using data from a single country with sufficient cross-sectional heterogeneity to exploit has the advantage of abstracting from possible interactions of bank characteristics and loan products with each country's institutional features (see Calza et al., 2013 on how cross-country differences in mortgage markets can influence the monetary policy transmission mechanism).

[5] For example, the Third Covered Bond and Asset-Backed Securities Purchase Programmes commenced operations in October and November 2014, respectively.

[6] Scharfstein and Sunderam (2016) use US county level data and find that, following a decrease in policy rates, mortgage rates tend to fall more in more competitive mortgage markets. Similarly, Drechsler et al. (2017) also use US county level data and find that counties served by banks having raised relatively-high share of household deposits, relative to other banks, tend to reduce their lending to firms by relatively more than their peers, following a monetary policy rate increase.

[7] Basten and Mariathasan (2018) examine the impacts of NDFR on Switzerland, while Eggertson et al. (2017) focus on Sweden. Bech and Malkhozov (2016) provide some early indications of NDFR impacts on lending rates at the macro level for the euro area, as well as Denmark, Sweden, and Switzerland.

Heider et al. (2018) analyse data on syndicated loans to non-financial corporates and find that, following the introduction of NDFR, banks with high retail deposit ratios tended to lend relatively less and to riskier firms compared to banks with low ratios.

Like the latter two papers, we are interested in understanding how differences in certain bank characteristics, notably their funding profile, can affect bank behaviour under a NDFR policy. However, our analysis differs from them in several key respects. The present paper is the first, to the best of our knowledge, to use loan level data to provide direct evidence on the monetary policy transmission to bank lending rates in a negative policy rate environment. The granular information contained in our data allows us to focus on the residential mortgage market as we can distinguish between loan types that are likely to have different connections to monetary policy rates. Furthermore, we provide evidence on the as-yet little explored role of retail overnight deposits as a potential source of transmission friction following the switch to NDFR, and contrast this category of deposits with others (e.g. time deposits).

The remainder of the paper is organised as follows. Section 2 provides details on the loan level data used in the analysis. Section 3 discusses the empirical strategy, while Section 4 presents the empirical findings and results from various robustness checks. Section 5 discusses the economic implication of the underlying analysis and Section 6 offers concluding remarks.

2. Data

We construct a unique data set by combining publicly available and confidential data at a monthly frequency from various sources. The data set includes public data on Residential Mortgage-Backed Securities (RMBSs), loan-level datasets available within the Eurosystem, bank balance sheet data, national macro-financial statistics, as well as loan credit risk models from third-party providers. Table 1 provides summary statistics on our sample.

In particular, we use loan-level residential mortgage data provided as part of the Eurosystem's collateral eligibility requirements for RMBSs and pools of residential mortgage Additional Credit Claims (RACCs). The loan-level requirements are captured in a specific RMBS template posted on the ECB website, and must be satisfied by any RMBS transaction for it to be eligible as collateral for Eurosystem credit operations (the same approach holds for

RACCs[8]). Loan-level data for RMBSs are available for subscribers (via the European Data Warehouse), while RACC pools are internally available to the Eurosystem. Although our baseline results are robust to examining only RMBS loan-level data or only RACC data, we use data from both sources as this covers a broader cross-section of banks for our analysis.[9]

Each RMBS or RACC pool is required to submit a new template on a quarterly basis or (for RACCs) on a monthly basis. We recover each loan reported in any RMBS transaction or RACC pool, even those that have dropped out at some point (for example, due to banks repurchasing loans or loans defaulting). This creates a rich sample from which to conduct our analysis.

The key information we use for our analysis is the following. First, the interest rate charged on the loan at origination and whether it is an adjustable rate or a fixed rate loan.[10] Second, we make use of a credit model provided by Fitch Ratings (2017, see Appendix 2 for details), which allows us to generate loan-level probability of defaults and loss given default variables at the time of loan origination. This enables us to gauge the relative riskiness of the borrower and loan at the time of origination in a consistent manner across all banks in our sample. Third, we use bank-level data from SNL Financial, which includes details on banks' retail deposits, their total equity, their retail loan and cash balances, and lastly their total assets (which is used to normalise the previous balance sheet variables). In particular, we utilize information on reported breakdowns of retail deposits by type, which include overnight deposits and time deposits.[11]

[8] The residential mortgage ACC template is available on selected websites of euro area National Central Banks and is, for the purposes of this paper, identical to the RMBS templates available on the ECB website.

[9] Certain banks may prefer submitting pools of residential mortgages via ACCs, notably to save on fixed costs associated with securitisations. At the same time, other banks may prefer issuing RMBSs, for example to appeal to a usual set of clients seeking to invest in securitisations.

[10] In particular, we classify as adjustable rate loans those that are reported as having an interest rate type of either "Floating rate loan (for life)" (option 1 in the RMBS/RACC templates), or "Floating rate loan linked to Libor, Euribor, BoE reverting to the Bank's standard variable rate (SVR), ECB reverting to Bank's SVR" (option 2). We classify as fixed rate loans those that are reported with an interest rate type of "Fixed rate loan (for life)" (option 3). Hybrid mortgages at the time of origination (such as fixed with future periodic resets, fixed rate loan with compulsory future switch to floating, or capped interest rates) are not included in the sample.

[11] By overnight deposits, we refer to accounts allowing customers to withdraw money on demand, with no restrictions (including fees or penalties) on the amount of withdrawals. Depending on the classification source, such deposits may be termed 'overnight deposits', 'sight deposits', 'demand deposits', 'deposits redeemable without notice', 'transaction accounts', 'checking accounts', 'current accounts' or other similar terms. In contrast, by 'time deposits' we refer to accounts on which interest is paid for a specific time period and from which funds cannot be withdrawn before the account matures (or are subject to a substantial penalty for early withdrawal). Depending on the classification source, such deposits may be termed 'time deposits', 'term

As discussed in the Introduction, we restrict our main analysis to Italian banks, given the rich cross-section of banks available, from local specialised lenders to multinational 'universal' banks. Moreover, Italian banks have traditionally been issuers of both fixed and adjustable rate mortgages, unlike banks in other euro area countries that have mainly specialized in only one of the two types (e.g. Spanish and Portuguese banks in variable rate mortgages, or French and German banks in fixed rate mortgages). In addition, the lack of excess liquidity in the Italian banking sector during the period before and after the introduction of NDFR (see Figure A1.1 in Appendix 1) allows us to identify the impact of overnight deposits in a relatively clean manner, by reducing the risk of confounding any effects of NDFR via the overnight deposits channel with possible effects of NDFR via the excess liquidity channel (see Demiralp et al. 2017).

One possible concern about our data sample is that we only observe residential mortgage loans that banks wish to either securitise or pledge as RACCs. This could be problematic if residential mortgages destined for securitisation or RACC pools may have been granted under looser lending standards. However, as we argue below it is not a priori clear that there should be systematic differences between our observed loans and a 'typical' residential mortgage loan granted by a bank and we undertake a number of representativeness checks that confirm our intuition.

To begin with, the share of mortgage loans securitised by Italian banks is relatively high (around 22% at the time of the introduction of NDFR). Besides, we are not aware of conclusive evidence that Italian banks have chosen to securitise loans with substantially weaker risk profiles compared to the remainder of their loan books. On the contrary, a recent study by Albertazzi et al. (2015) examined the performance of securitised loans to Italian firms throughout the 2000s and concluded that securitised loans tended to be less risky than those retained. Furthermore, since January 2011 originators of securitisations in the EU have been required to retain at all times at least 5% of the value of the assets they securitise. These 'risk retention requirements' act as a powerful disincentive for originating banks to securitise

deposits', 'deposits maturing within [X period]', 'fixed deposits' or other similar terms. A third intermediate category, between overnight and time deposits, are 'savings accounts', which are primarily interest-bearing accounts that may be restricted by the fact that only a limited number of withdrawals may be made from the account, without penalty, with a certain timeframe.

loans with higher risk profiles than those that are not securitised.[12] Our baseline analysis only considers loans that were originated between January 2013 and December 2015 (i.e. well after risk retention requirements were established), and thus it is fair to assume that our results are not distorted by systematically different credit standards between our set of securitised loans and the broader population of loans in Italy.

In addition to these considerations, we conduct a number of empirical comparisons between our data sample and available statistics for Italian residential mortgages. The comparisons cover the interest rate, the share of adjustable rate mortgages originated each month, the original loan-to-value ratio, and lastly the evolution in residential mortgage lending volumes. The results can be found in Appendix 2, and provide reassurance that our data sample is representative of wider conditions in the Italian residential loan market.

3. Empirical strategy

3.1. Bank exposure to negative deposit rates

We capture banks' exposure to NDFR by examining the relative share of assets funded by overnight deposits, which are the category yielding the lowest interest rates of all deposit rate types, because there is no need to compensate depositors for having restricted access to their deposits (in contrast with time deposits). Figure 1 shows that overnight deposits (normalised by total bank assets) are relatively stable over time.[13] In addition, Figure 2 illustrates that overnight deposit rates have been rather sticky, even as the ECB's deposit facility rate has fallen. In contrast, time deposit rates for both new and existing accounts[14] have fallen largely one-for-one or even more than the deposit facility rate, even after the introduction of NDFR. Put differently, overnight deposit rates are the first among the

[12] One might claim that, when a bank's motivation for securitisation is to reduce its capital requirements (rather than obtain funding), it may have an incentive to securitise loans with different (possibly higher) credit risk characteristics than the loans remaining on its balance sheet. However, such securitisations are extremely rare: we are not aware of any Italian securitisations that have been structured to obtain capital savings for the originator since the start of the 2007/08 global financial crisis.

[13] We use total on balance sheet assets. From a bank's revenue and capital management perspective, this is the most relevant metric for examining the total assets that are being funded by overnight deposits. Note that the majority of EU securitisations since the global financial crisis in 2007/08 have not been structured to allow banks to remove the underlying loans from their balance sheet (the securitisations have instead been structured for funding purposes).

[14] Existing accounts are included, despite the notion that deposit rates would be fixed for such accounts, due to the possibility for banks to adjust rates for these products as well (i.e. the interest rate on a time deposit account might change upon early withdrawal by a borrower).

available retail deposit categories to reach an implicit 'floor', and Figure 2 suggests that, upon the introduction of NDFR, such a floor was indeed reached by overnight deposit rates, but not by time deposit rates. At the same time, banks are clearly unwilling to drive retail depositors away, both for financial reasons and to meet supervisory stable funding requirements. Moreover, retail depositors have little tendency to switch between bank accounts, particularly for older accounts or in the case of multi-product relationships with banks.[15]

Thus, in the presence of NDFR, overnight deposits present the stickiest cost for banks among the set of possible deposit types that they offer. This is because banks with a greater share of overnight deposits may find their net interest income 'squeezed' once negative deposit facility rates are introduced. In contrast, banks whose assets are funded with other types of deposits (or other liabilities) paying out higher rates have greater freedom to pass through the deposit facility rate cut, thus minimizing pressure on net interest income.[16]

3.2. Empirical Specification

We estimate the following equation:

$$Y_{i,b,t} = \beta_1(ODR_{b,\bar{t}} * D_T) + \beta_2 X_{i,t} + \alpha_b + \varphi_t + \varepsilon_{i,b,t} \quad (1)$$

where $Y_{i,b,t}$ denotes the interest rate of a loan *i* that is originated by bank *b* in month *t*. D_T is a time indicator that takes the value of 1 for monthly observations beginning in July 2014 (i.e. when the ECB's deposit facility rate became negative) and 0 otherwise. $ODR_{b,\bar{t}}$ represents the overnight deposit ratio, which varies by bank *b* and reflects balance sheet information as at end-2013 (i.e. $ODR_{b,\bar{t}}$ is pre-determined relative to the period in which the deposit facility rate change takes place).

[15] See for example Deuflhard et al. (2017) who show that many households, especially those with low financial literacy, do not switch to accounts offering higher returns across banks or even in the same bank (e.g. by changing their existing account to an online-only account).

[16] See Demiralp et al. (2017) for a related discussion. Note that Heider et al. (2018) consider banks' exposure via their reliance on total deposits to fund their assets. In particular, they use regression analysis to examine whether the relative importance of total deposits in banks' funding profile leads banks to grant a syndicated loan to riskier non-financial corporates, following the introduction of NDFR (see also Albertazzi et al., 2016). Instead, we categorize banks in terms of relative share of *overnight* deposits in funding their assets, which are likely to capture better the pressure that banks experience when deposit facility rates enter into a negative territory.

$X_{i,t}$ consists of loan characteristics such as probability of default (PD) and loan maturity. We also take into account the time needed for banks to foreclose on residential properties in the event of defaulted loans, based on the region in which the property is located, which is a well-known issue for banks in Italy (Casolaro et al., 2005). These loan-risk indicators allow us to estimate a policy effect net of loan risk characteristics and demand-related factors. It should be noted that, unlike non-financial corporate borrowers, it is quite rare that households would have multiple residential mortgages from different banks. As a result, the concept of the riskiness of a loan coincides with the creditworthiness of the household. In our set-up, controlling for the riskiness of borrowers takes into account a number of borrower characteristics that could influence the demand for mortgages (see Campbell and Cocco, 2003).[17] In the robustness section, we also estimate an extended version of specification (1) to take into account bank-specific characteristics that are time varying and/or are interacted with D_T.

Equation (1) uses bank fixed effects (α_b) to account for any time-invariant differences across banks during the estimation window. Moreover, it incorporates a full set of month-year fixed effects (φ_t) to account, in a flexible way, for unobserved common aggregate factors that vary over months (such as changes in macroeconomic variables). This implies that the level effects of the interaction term $ODR_{b,\bar{t}} * D_T$ are absorbed by bank and month-year fixed effects, respectively.[18]

Our estimation setup is akin to a difference-in-difference specification. According to this specification, a bank with a higher overnight deposit ratio should be more affected by the switch to NDFR than a similar bank with a comparatively lower overnight deposit ratio. The months spanning July 2014 (immediately after deposit facility rates turned negative) and onwards represent the 'post-treatment' period, while months before July 2014 are the 'pre-treatment' period.[19] Thus, our estimate of interest in equation (1) is β_1. Given that the

[17] The results we present remain unchanged in specifications that control instead of loan riskiness indicators for a number of borrower and loan characteristics available in the data (income band, employment status, loan purpose, payment type).
[18] The bank fixed effects also absorb the possibility that banks with a larger share of overnight deposits have lower costs of funding in the first place.
[19] Negative deposit rates entered into force on 11 June 2014, however we assume that banks did not respond until July 2014. Changing the 'post-treatment' period to include June 2014 does not materially alter our results (available on request).

overnight deposit ratio varies by bank, estimated standard errors are clustered at the bank level.

First, we perform our estimation over a time window that focuses on the 6 months before and after the introduction of NDFR in June 2014 (i.e. January 2014 and December 2014). This time window allows sufficient room to detect any pass-through effects of the policy change, yet avoids the interference of major succeeding monetary policy events like the Public-Sector Purchase Programme in March 2015.[20]

Subsequently, we widen our sample period to 12 and to 18 months before and after the onset of negative rates (i.e. our estimation window expands to July 2013 and June 2015, and to January 2013 and December 2015, respectively). The wider sample period allows us to estimate the effects of NDFR on new loan rates that may come with some delay. Moreover, studying different time periods enables us to examine whether there is something distinct about the change in deposit rates into negative territory. That is, we investigate whether our baseline results hold when considering a period during which deposit facility rates did not change (e.g. January – December 2013), or during earlier periods that saw a decline in deposit facility rates, but without turning into negative territory (e.g. before and after the deposit facility rate declines in late 2011, and again in July 2012).

4. Results

4.1. Fixed rate mortgages

Estimated results of equation (1) for fixed rate mortgages are shown in Table 2. First, we show our baseline results over the sample period between January 2014 and December 2014. Specification (1) shows the estimate of interest when bank and month-year fixed effects are taken into account. Specification (2) controls in addition for an interaction term of the originating bank's equity ratio with the post-June 2014 period, to capture the possibility that banks' relative differences in capital strength may translate to different responses in loan

[20] Although the ABS (and Covered Bond) Purchase Programme began during the post-treatment period (October and November 2014, respectively), this programme was widely anticipated by market participants from the beginning of 2014 onwards. Therefore, the effect that we estimate may represent a lower bound for the possible impact of the introduction of NDFR, insofar as both the pre-treatment period and the post-treatment period observed a corresponding improvement in banks' funding costs due to the beneficial effects of the purchase programmes (both real and anticipated) throughout most of 2014.

interest rates following the introduction of NDFR. Lastly, specification (3) also takes into account a set of loan riskiness indicators.

The positive estimate on the interaction term implies that the relative gap between the interest on fixed rate mortgages charged by banks with high and low overnight deposit ratios becomes wider after the onset of NDFR. We find that after deposit facility rates turn negative, banks with a 12 percentage point higher overnight deposit ratio (corresponding roughly to a 1 standard deviation change of the underlying distribution) charge a 16 basis points higher interest rate for new fixed rate mortgages, all else being equal (p value < .01). The estimated effect is virtually unchanged as we progressively add more controls relative to specification (1). In addition, higher risk fixed rate mortgages, as indicated by a higher PD (i.e. in the fourth quartile of the respective distribution), carry a higher interest rate.

Second, we extend the sample period to the 12 months before and after June 2014 (i.e. a 24-month time window)—results are shown in Table 2, specifications (4) to (6)). The estimate of interest (β_1) almost doubles in magnitude compared to the respective one derived for the 6 months before and after time window and remains statistically significant at 1%. More precisely, when policy rates turn negative, a bank with a one standard deviation higher overnight deposit ratio charges 25 basis points higher interest on a fixed rate mortgage, other things equal. Moreover, the implied effect remains unchanged across the three specifications we consider. The last set of results in Table 2 (specifications (7) to (9)) refers to the longest period we consider, namely between January 2013 and December 2015 and suggest similar effects to those derived for the 12-month before and after time window.

4.2. Adjustable rate mortgages

The results above suggest an association between the introduction of negative deposit facility rates and a resistance by banks with higher overnight deposit ratios in passing through policy rates to their new fixed rate mortgages. Next, we examine whether there is a similar association for adjustable rate mortgages. To this end, we re-estimate the three main specifications of equation (1) discussed above and for the same three time windows—results are shown in Table 3. Estimated effects on the interaction term of interest are negative, but

quantitatively small and statistically insignificant.[21] This suggests that the introduction of NDFR has not significantly affected the pricing of new adjustable rate mortgages across banks with different funding structures.

4.3. Robustness checks

First, we examine whether the effects we have identified for banks' interest rates on fixed rate mortgages are unique to the period during which the DFR became negative. We first consider the same time window as in our first specification (i.e. 12 months) shifted one year earlier (i.e. January 2013 - December 2013), during which the ECB's deposit facility rate and the main refinancing operation or marginal lending facility rates did not change. We re-estimate equation (1) by defining D_T to take the value 0 for the months lasting from January to June 2013, and 1 thereafter, thereby considering the post June 2013 window as a placebo period (i.e. as if the deposit facility rate had turned negative).

As shown in Table 4, the estimated coefficient on the interaction term of the overnight deposit ratio with the post June 2013 dummy is quantitatively unimportant and statistically not different from zero (p-value>.10). This provides support to our baseline results and suggests that the interaction term of deposit rates with the onset of NDFR most likely captures genuine effects. Moreover, given that our estimation strategy uses a difference-in-difference specification, the results of this placebo regression support the validity of the parallel trends assumption between banks with high and low overnight deposit ratios in the period prior to the switch to NDFR.

Second, we gain further support to the parallel trends assumption when we re-estimate our baseline regression over the longer period of 18 months before and after June 2014. This time, instead of a single time dummy denoting post-treatment months, we adopt a more flexible specification that allows the estimated effect of interest to vary across quarters over the entire period. We do this by introducing interaction terms of the overnight deposit ratio quarter dummies that represent the period during 2013Q1 to 2014Q1 (*leads*). Likewise, we control for similar interaction terms over the quarters following the post-treatment period (2014Q2), i.e. 2014Q3 to 2015Q4 (*lags*). Results from this flexible specification are reported

[21] The outcome variable is the margin on the adjustable rate mortgages (relative to a reference index or other standard rate) at the time of origination. Results are virtually unchanged when one considers instead the total interest rate of adjustable rate mortgages at the time of origination.

in Table 4. Estimated coefficients and associated confidence bands in the pre- and post-treatment periods are illustrated in Figure 3.

The estimated effects should be interpreted with reference to the last quarter prior to the onset of NDFR that is omitted (i.e. Q2 2014). According to these, the estimated effect of the overnight deposit ratio interacted with every quarter leading to the onset of NDFR is not statistically different from Q2 2014. Intuitively, these findings confirm the parallel trends assumption: prior to Q2 2014, banks' setting of interest rates on fixed rate residential mortgage loans did not appear to be driven by relative differences in overnight deposit ratios. On the other hand, the respective interaction terms of the post-treatment quarters suggest a progressively stronger effect four quarters after policy rates turn negative (i.e. Q2 2015), whereas over the remaining two quarters the estimated effects level out and remain statistically significant.

Further to the aforementioned checks, we consider the previous period when the DFR was lowered, but before it entered into negative territory. This allows us to examine whether the effects we have estimated are specific to the onset of negative rates or also relate to any reduction in DFR. To this end, we re-estimate our baseline specification over the period from March 2012 to December 2012 (i.e. 10 months[22]), in order to examine the effects of a drop in the DFR from 0.25 to 0.00% on 11 July 2012. Thus, D_T takes the value 1 from August 2012 onwards to denote the relevant decline in DFR. As shown in Table 5, we do not find any significant effect of this drop in DFR on fixed rate mortgage rates.[23]

This further suggests that the baseline effects we have reported in Table 2 are capturing the specific effect, on banks' fixed rate mortgage loan interest rates, of deposit facility rates shifting to a negative rate regime. In other words, this supports the view that the

[22] We use a shorter window (10 months) than our baseline specification (1) due to the presence of multiple DFR changes between 2011 and mid-2012.

[23] In addition, we also examine an even earlier period, when the DFR was lowered from a positive value to a strictly positive value: the reductions in the DFR on 9 November 2011 (from 0.75 to 0.50%) and on 14 December 2011 (from 0.50% to 0.25%). We also do not find any significant effect of this 'positive to strictly positive' drop in DFR on fixed rate mortgage rates. Moreover, we explore more recent reductions in DFR on 9 December 2015 and 16 March 2016, respectively (reducing DFR from -0.20% to -0.30% and then to -0.40%). Obtaining a relatively clean difference-in-difference setup in this time period is challenging, due to the multiple treatments (DFR cuts) in such close succession, as well as the numerous other monetary policy measures in operation during this time window (such as the Expanded Asset Purchase Programme and Targeted Long-Term Refinancing Operations). In any case, we find some evidence (albeit statistically weak) pointing to a further resistance among high overnight deposit ratio banks in passing through the latest DFR cuts to FRM lending rates. Results for both of these further specifications are available on request.

composition of banks' deposit ratios has little effect on their pricing of long-dated fixed rate products when deposit facility rates are close to zero. However, when policy rates enter negative territory, banks face an implicit floor on their funding costs.

In such a situation, banks would often prefer to reduce the rates at which these deposits are remunerated. Their customers, though, would rarely accept to lose money on their deposits and would consider switching to a bank offering non-negative deposit rates. Thus, banks' net interest margins are compressed, compared with a situation of zero or positive deposit facility rates. In particular, banks with a greater share of their assets being funded by such constrained deposit accounts (i.e. overnight deposits) will face a greater compression in net interest margins than banks that rely less on zero or near-zero deposit rate accounts. In order to compensate for the lost net interest income, relatively more constrained banks appear to react via the interest rate charged on loans that are particularly costly for them: fixed rate mortgages with a long maturity (in other words, loans that lock in a particular income stream for a long period of time).[24] Such loans are often the longest-maturity assets that retail banks will originate.

According to this reasoning, the converse should also hold: in a low or zero DFR environment, the introduction of NDFR should not present a constraint for banks relying relatively more on deposits remunerated at non-zero interest rates. In other words, from the perspective of these banks, the introduction of NDFR should simply be treated as a further policy rate cut to be passed through into deposit rates. As we have already discussed, overnight deposits often carry the lowest interest rates, in light of depositors' ability to withdraw funds at any time. In contrast, time deposits often carry the highest interest rates in order to compensate depositors for sacrificing some flexibility on accessing their deposits prior to the end of a pre-determined period.

[24] Other bank responses are possible as well. For example, a bank with a high overnight deposit ratio could also attempt to alleviate the pressure on its net interest income by adjusting the composition of its remaining non retail deposit liabilities toward less costly alternatives, depending on the situation in interbank markets (regarding interbank borrowing) or capital markets (regarding the issuance of debt or equity). Elsewhere, the same bank could adjust the asset side of its balance sheet, for example by moving towards even longer-maturity assets (such as extremely long maturity government bonds or infrastructure finance) or towards loan products with more flexible interest rates. Such responses are all possible, however they should be seen as complementary to our findings. From this perspective, our result that high overnight deposit ratio banks appear to resist reducing interest rates on fixed-rate mortgages should be seen as a conservative lower bound. We further explore the additional response for banks to prefer flexible interest rate products in the next section.

In view of the above, we re-run specification (1) and replace the overnight deposit ratio with the time deposit ratio, while progressively adding on controls in the same manner as discussed above—results are shown in Table 6. The coefficient on the interaction term is negative and significant, suggesting that banks with a greater share of time deposits funding their assets tend to pass on the NDFR rate cut more to fixed rate mortgage loan interest rates, compared with banks that have a smaller share of time deposits. This provides further evidence of our main hypothesis—the composition of banks' deposit types matters for the pass-through of monetary policy in a low interest rate environment. Indeed, replacing the overnight deposit ratio in equation (1) with the total deposits ratio—thus making no distinction for the composition of deposits in the regression—yields an interaction term that is not significantly different from zero regardless of the additional controls introduced (see Table 6).

Furthermore, we provide additional support to our argument that the long maturity of fixed rate mortgages discourages banks from passing on the NDFR rate cut. In particular, we have re-estimated our baseline specifications for sub-groups of fixed rate mortgages that we classify according to their original maturity quartiles: less than 15 years; 15 to 20 years; 20 to 25 years; and 25 years and longer. According to our findings (non-reported, available on request) we estimate a progressively stronger resistance of banks with high overnight deposit ratios in passing on the NDFR rate cut to lending rates for fixed rate mortgages with an increasingly longer maturity.

As an additional robustness check, and to ensure that our main findings are not driven by an abnormal period in terms of bank deposit-taking behaviour, we replace the overnight deposit ratio at the end of 2013 with the average ratio over 2011-2013. We continue to find a strong indication that banks relying more on overnight deposits to fund their assets tend to resist the transition to NDFR when setting interest rates on fixed rate mortgages.[25]

Moreover, we consider additional controls for bank-level characteristics that are time-varying and are likely to influence the transmission of monetary policy rates. Results from specifications that account for these additional controls are shown in Table 7. In particular, we consider the one-year lag of banks' time-varying equity ratio, retail loans ratio, and total

[25] Results are available from the authors upon request. We also find no evidence that high overnight deposit ratio banks appear to adjust their lending in terms of loan risk profile (in terms of PD or LGD) nor in terms of loan size.

assets. In addition, we examine the extent to which banks' cash holdings (relative to total assets) in the years of our sample window could also influence their responsiveness to NDFR.

Finally, we investigate whether relatively larger banks at the time NDFR was introduced respond differently in terms of the loan interest rates in question. This could arise, for example, due to larger banks being able to rely on economies of scale and scope to provide more competitive pricing than smaller banks, in a manner independent of these two groups' relative differences in overnight deposit ratios. To account for such an effect we add as a control the interaction between the (log of) bank assets with the post-June 2014 time dummy.

Overall, our baseline results remain broadly unchanged after taking into account these various time-varying controls. Our results are also robust to two further checks. First, we consider prepayment risk as an additional loan-level control since this could also affect how banks set interest rates on fixed rate mortgage loans. While penalties on prepayment and other contractual modifications were historically very high in Italy, legislation eliminating penalties for early repayment on new contracts and reducing those on existing contracts was introduced in 2007 (see Brunetti et al. 2017 for a discussion). This change in legislation made prepayment a potential source of risk for banks.[26] In view of this, we use the log of borrower income and, alternatively, the estimated debt-to-income ratio as two possible measures of prepayment risk and find no difference in our baseline results.[27]

As a second robustness check, we consider whether our estimates may be capturing the effect of risks arising from a mismatch in the duration of assets and liabilities, and that overnight deposits are instead capturing this vulnerability. This may be the case if banks with relatively greater shares of overnight deposits funding long-term assets (like residential mortgages) could, compared with banks having a greater share of longer-term deposits funding these same assets, find their margins (i.e. net interest income) compressed due to changes in yield curves induced by short-term policy rate changes. This is not mutually exclusive to the overnight deposit ratio channel we study but could indeed have an influence. To address this concern, we re-estimate our specifications in Table 2 using several possible

[26] The risk is though limited since the constant prepayment rate remained low (between 2% and 5%) over the sample period considered (FitchRatings, 2017).
[27] Borrower income is not always available in the loan-level templates and thus we do not include these findings in our main specifications. The results are available on request.

measures of asset-liability mismatches and our results remain unchanged.[28] This lends further support to overnight deposit ratios representing an independent channel through which NDFR can influence banks' lending rates for residential fixed rate mortgages.

4.4. Originating new fixed rate vs. adjustable rate mortgages

It is plausible that banks finding themselves excessively squeezed by NDFR may have additional reactions to adjusting the interest rates charged on particularly troublesome products in an NDFR environment. For example, banks may also prefer to originate more ARMs in this environment, insofar as ARMs have greater potential to recover interest income should monetary policy rates rise in the future.[29]

Table 8 illustrates the results of a linear specification modelling the likelihood of a mortgage originated during the time window under study to be a fixed-rate one. The covariates used are the same as in the baseline specification. In line with our intuition, we find that, over the months immediately following the introduction of NDFR, mortgages originated by banks with higher overnight deposit ratios were less likely to be fixed rate mortgages (and more likely to be adjustable rate mortgages). As above, we examine whether this effect persists as one progressively widens the sample time window: it appears that these banks' reticence lasted up to one year after the introduction of NDFR and that, afterwards, banks had adapted (in part due to their adjusted interest rate regime). Taken together, these results suggest that, when deposit facility rates enter negative territory, banks with a higher overnight deposit ratio tend to substitute fixed rate for adjustable rate mortgages, and resist passing through the change in deposit facility rates to the fixed rate mortgages that they originate.

[28] In particular, we use the ratio of loans maturing in 5 years or more vs. overnight deposits, the ratio of loans maturing in 5 years or more vs. total deposits, the ratio of all retail loans vs. overnight deposits, and lastly the ratio of all retail loans vs. total deposits (all ratios are as at end 2013).

[29] One could in principle argue that the opposite situation might hold instead, namely that banks expect interest rates to stay negative and prefer fixed rate mortgages, which protects them against cuts in their net interest margins. This later claim is also supported by Brunnermeier and Koby (2018). However, for long-maturity products such as residential mortgages, it appears far less likely that the future time window between loan origination and loan maturity would include a greater number (and magnitude) of interest rate cuts, rather than interest rate rises. Thus, in a historically-low interest rate environment, banks would prefer interest rate types that insulate them against future rate rises over the long-term (i.e. FRMs) rather than interest rate types that insulate them against future rate cuts over the long-term (i.e. ARMs).

5. Economic implications

The results presented in the previous section seem to suggest that there may be some justification for concerns about interest rate pass-through under negative interest rates being hampered, due to financial frictions related to a zero bound on deposit rates. Indeed, our empirical analysis provides evidence that, once policy rates turn negative, banks with a larger reliance on overnight deposits may end up charging higher rates on new fixed rate mortgages than banks with less reliance on these deposit types. While this result appears to be resilient to a number of robustness checks, a more general question concerns its economic implications for borrowers.

In order to assess the economic impact of the estimated extra charge of fixed rate mortgages for households, it is useful to evaluate it in nominal terms assuming different scenarios for the overnight deposit ratio of the lending bank. Taking as a benchmark the average characteristics of fixed rate mortgages in our sample, we assume that a borrower takes a 20-year loan with an original principal value of EUR 105,000 and that this is repaid on a monthly basis using the equal instalment amortisation scheme most commonly applied by Italian banks. According to the distribution of end-2013 overnight deposit ratio across the banks in our sample the value of the 25th percentile of the distribution corresponds to 32.1%, compared to 45.4% for the 75th percentile. Based on our baseline estimate from specification 4 in Table 2 (i.e. 0.021), an interquartile range of 13 percentage points implies an extra charge on a new fixed rate mortgage loan of around 27 basis points.

In nominal terms, 27 basis points would be equivalent to around EUR 180 on an annual basis for a loan with the characteristics mentioned above. If we compare instead the values of the end-2013 overnight deposit ratios for the 10% and 90% percentiles (23.5% and 52.6%, respectively), the calculations yield an extra annual charge in nominal terms of around EUR 400. These amounts are not negligible for those households holding fixed rate mortgages from banks with high overnight deposit ratios and are in line with recent evidence showing that many consumers fail to identify the most suitable mortgage products (see Agarwal et al., 2017). However, they are small for the household sector as a whole, as the new fixed rate mortgages at the time NDFR appeared accounted for about one quarter of all

new mortgage loans, but only an estimated 11% of the Italian households had outstanding mortgages.[30]

6. Conclusions

The introduction of negative policy rates by the ECB and other major central banks has prompted a debate about the merits of this non-standard monetary policy tool (e.g. Bernanke, 2016). Prominent policymakers have expressed doubts about the merits of negative interest rates, once their potential costs for the banking sector and other segments of the financial system are factored in (e.g. Rosengren, 2016). In particular, several concerns have been expressed about the potential impact on banks' interest rate margins and, ultimately, on monetary policy transmission if banks are unable to pass the cost of negative interest rates to deposit bank rates.

Given the short experience with negative policy rates, the existing literature provides limited insights in answering these questions. Indeed, to our knowledge, the empirical evidence on the behaviour of banks under a negative rate policy, particularly in the euro area, is very limited (e.g. Heider et al., 2018; Demiralp et al., 2017, Altavilla et al., 2017). The present paper adds to the literature by empirically studying the hypothesis that banks facing difficulties to cut deposit rates below zero may change their lending rate-setting behaviour in order to shore up their profitability.

To this end, we analyse the behaviour of Italian mortgage lenders before and after the introduction by the ECB in June 2014 of negative rates in its deposit facility for banks. We find statistically significant evidence that certain aspects of the funding profile of a bank, notably the relative importance of overnight deposits in its balance sheets, can influence the interest rates charged by the bank on fixed-rate mortgages originated after the onset of a NDFR policy. More specifically, when policy rates enter negative territory, banks with greater ratios of overnight deposits to total assets tend to charge higher rates on new fixed rate mortgages. By contrast, the introduction of NDFR does not seem to affect the setting of the interest rates on adjustable-rate mortgages. At the same time, our analysis suggests that banks

[30] See Banca d'Italia (2015). It should be also noted that households who took a mortgage at that time are rather unlikely to come from the bottom-end of the income distribution. According to micro survey data from the 2014 Survey on Household Income and Wealth (SHIW) the median net household income of mortgagors (EUR 35,600) is roughly 40% higher than the median net household income in the general population.

with a higher overnight deposit ratio are more likely to originate adjustable rather than fixed rate mortgages after policy rates turn negative.

Overall, our results provide robust statistical evidence that specific features of the funding structure of banks may influence the pass-through of monetary policy to mortgage lending rates in a negative interest rate environment. Nevertheless, we find that the implied aggregate losses for households due to the higher lending rates charged by banks with relatively high deposit ratios are relatively modest. As a result, the frictional effect of a zero bound on deposit rates on monetary policy transmission under modestly negative rates may be less relevant than previously believed.

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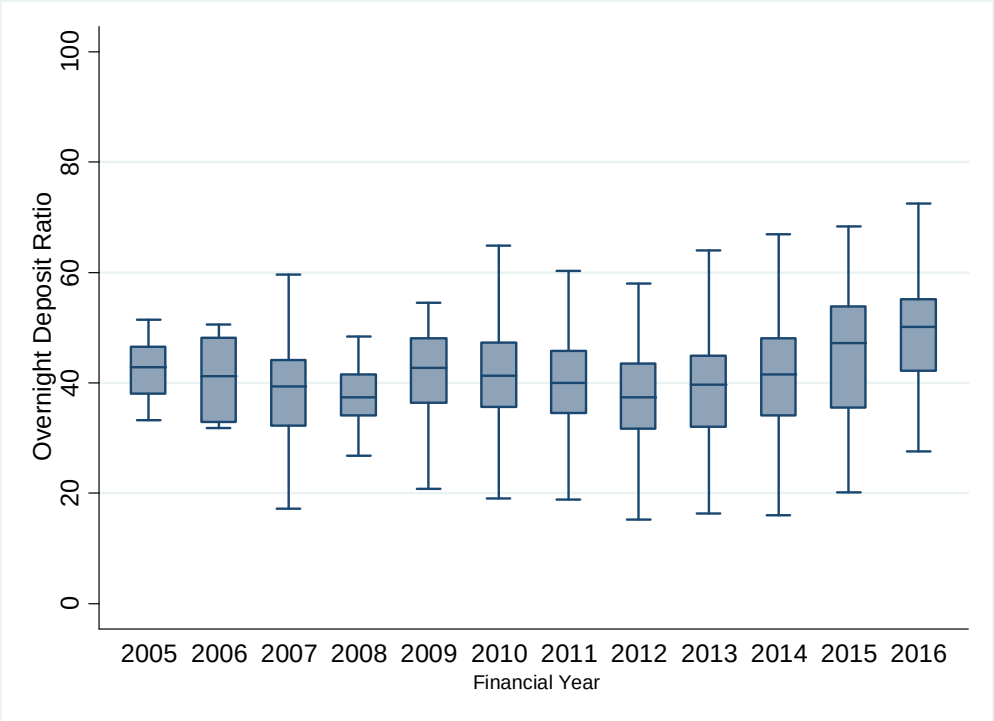
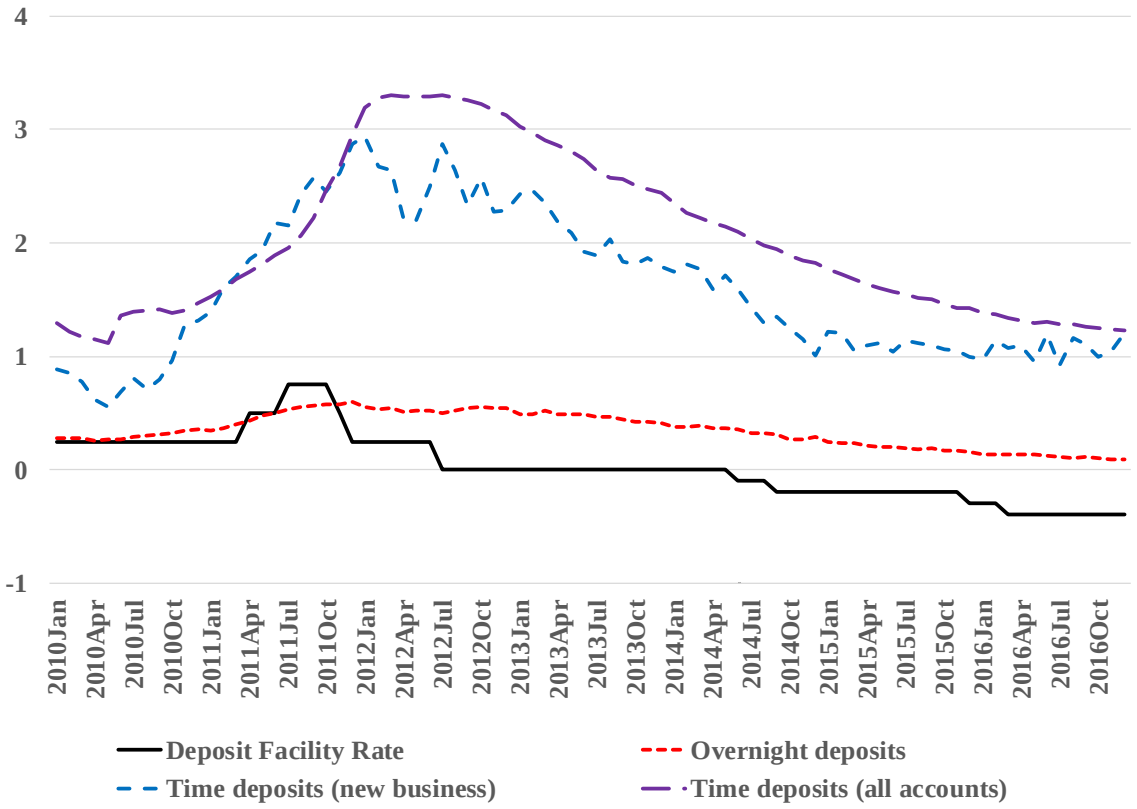
Figures and Tables

Figure 1: Evolution of Italian banks' overnight deposit ratios over time



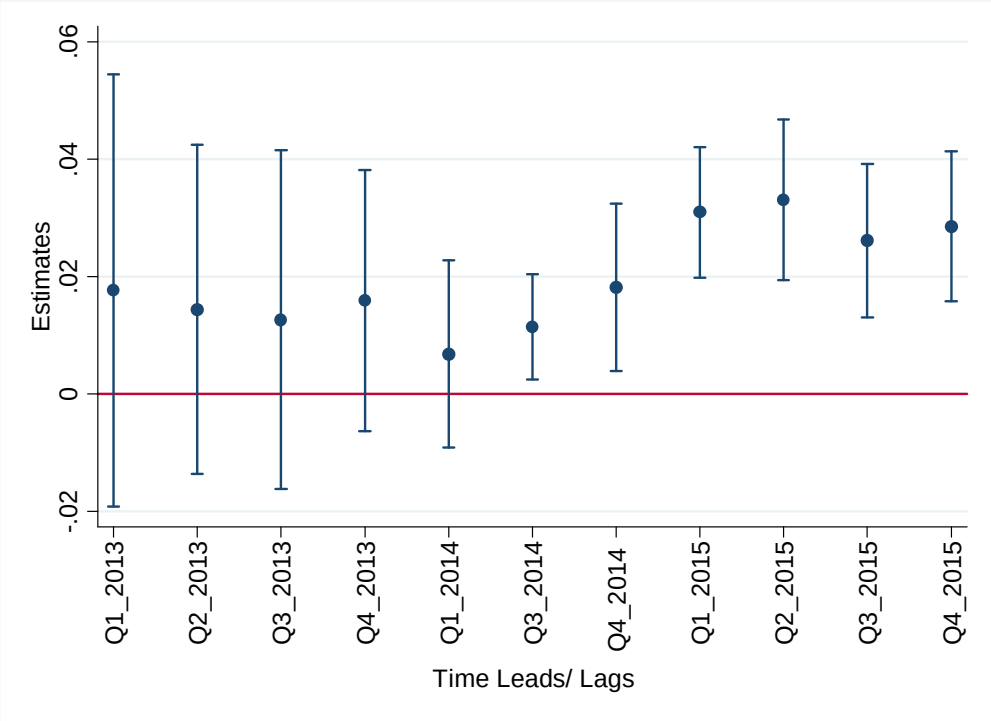
Sources: SNL Financial, author's calculations
For each box, the figure displays, from top to bottom, the upper adjacent value (the data point equal to the 75th percentile plus 1.5 times the interquartile range), the 75th percentile (i.e. the top of the box), the median (horizontal line), the 25th percentile (bottom of the box), and the lower adjacent value (the data point equal to the 25th percentile less 1.5 times the interquartile range). Data covers an average of 135 banks per year since 2005 (177 banks per year since 2010).

Figure 2: Evolution of Italian deposit rates and euro area deposit facility rate



Vertical dotted line indicates start of negative deposit facility rates.

Figure 3: Regression estimates (and 95% confidence intervals) of leads/ lags dummies for interest rates of FRMs



Regression estimates are reported in specification (2), Table 4.

Table 1: Summary Statistics

Banks sample (a)	**Mean**	**Median**	**Std. dev.**
Overnight Deposits Ratio	38.31	39.66	11.76
Total Deposits Ratio	47.99	47.04	12.01
Time Deposits Ratio	7.21	5.74	7.87
Equity Ratio	7.73	7.53	2.74
Retail Loans Ratio	69.90	70.58	13.89
Cash Ratio	8.28	4.82	9.38
Total Assets	43.02	3.96	184.6
Loans sample (b)	**Mean**	**Median**	**Std. dev.**
Probability of Default	2.67	0.81	12.73
Recoveries (c)	100.97	80.71	54.98
Foreclosure Timing (years)	6.15	6.01	1.24
Maturity (years)	20.85	20.08	6.84
FRM: Original Interest Rate	3.65	3.48	1.09
ARM: Original Interest Rate	2.84	2.81	0.88
Sample size			
Number of Banks	71		
Number of Loans	116,223		
Share of FRMs	21.54		

Note: Figures refer to the Jan. 2013 - Dec. 2015 period

(a) As a percentage of total on balance sheet assets, unless otherwise stated.

(b) In percentage points, unless otherwise stated.

(c) Expected recoveries from the sale of collateral, as a share of the loan's original balance.

Table 2: Baseline regression results for interest rates of FRMs

	January 2014 - December 2014: +/- 6M			July 2013 - June 2015: +/- 12M			January 2013 - December 2015: +/- 18M		
Covariates	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ODR*post-June 2014	**0.013*** **	**0.013*** **	**0.012*** **	**0.021*** **	**0.021*** **	**0.022*** **	**0.016***	**0.016** **	**0.021*** **
	(0.004)	**(0.004)**	**(0.003)**	**(0.006)**	**(0.004)**	**(0.004)**	**(0.009)**	**(0.007)**	**(0.007)**
Equity ratio*post-June 2014		-0.002	-0.001		0.052***	0.047***		0.062***	0.063***
		(0.024)	(0.019)		(0.016)	(0.015)		(0.020)	(0.018)
PD - 2nd quartile			0.020			0.052			0.048
			(0.064)			(0.036)			(0.033)
PD - 3rd quartile			0.099			0.149***			0.128**
			(0.079)			(0.050)			(0.051)
PD - 4rth quartile			0.336***			0.252***			0.201***
			(0.098)			(0.067)			(0.064)
Recovery rate			0.001			0.001***			0.001**
			(0.001)			(0.000)			(0.000)
Foreclosure time			0.002			0.004**			0.004***
			(0.003)			(0.002)			(0.001)
Loan maturity			-0.000			0.011***			0.015***
			(0.006)			(0.002)			(0.002)
Bank fixed-effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Month-year fixed-effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	3,875	3,875	3,389	12,697	12,697	10,951	25,008	25,008	21,465
R-squared	0.335	0.335	0.383	0.416	0.418	0.449	0.425	0.428	0.458

The sample consists of fixed rate mortgages originated over the three periods under study (6, 12 and 18 months before and after the introduction of NDFR). *ODR* refers to the bank-specific overnight deposit ratio at the end of 2013. *Post-June 2014* is a binary indicator taking the value one for months with NDFR (i.e. July 2014 and onwards). *Equity ratio* is based on total equity, and both *ODR* and *Equity ratio* have been normalised by total (on balance sheet) assets using values as at the end of 2013. *PD* refers to the loan-specific one-year probability of default at the time of origination and is accounted for by dummies denoting quartiles of the underlying distribution. *Recovery rate* refers to the percentage of the loan balance, at the time of origination, that is expected to be recovered in a default scenario. *Foreclosure time* (in years) measures the expected duration of proceedings to recover collateral from a defaulted borrower. *Loan maturity* (in years) is measured starting from the loan origination date. Reported estimates are from a difference-in-difference specification (equation 1) in which the outcome variable is the interest rate of fixed rate mortgages at the time of origination. Reported standard errors (in parentheses) are clustered at the bank level and are robust to heteroskedasticity. ***, ** and * indicate significance at 1%, 5% and 10%, respectively.

Table 3: Baseline regression results for interest rates of ARMs

	January 2014 - December 2014: +/- 6M			July 2013 - June 2015: +/- 12M			January 2013 - December 2015: +/- 18M		
Covariates	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ODR*post-June 2014	**-0.002**	**-0.002**	**-0.001**	**-0.001**	**-0.002**	**-0.001**	**-0.002**	**-0.003**	**-0.002**
	(0.002)	**(0.002)**	**(0.002)**	**(0.002)**	**(0.003)**	**(0.003)**	**(0.003)**	**(0.004)**	**(0.004)**
Equity ratio*post-June 2014		-0.002	0.001		0.006	0.008		0.009	0.010
		(0.008)	(0.008)		(0.009)	(0.009)		(0.015)	(0.014)
PD - 2nd quartile			0.081***			0.081***			0.075***
			(0.027)			(0.020)			(0.018)
PD - 3rd quartile			0.146***			0.145***			0.139***
			(0.023)			(0.018)			(0.018)
PD - 4rth quartile			0.249***			0.258***			0.244***
			(0.046)			(0.046)			(0.044)
Recovery rate			0.001			0.001			0.001
			(0.001)			(0.001)			(0.000)
Foreclosure time			0.003***			0.003***			0.003***
			(0.001)			(0.001)			(0.001)
Loan maturity			0.010*			0.010**			0.011***
			(0.006)			(0.005)			(0.004)
Bank fixed-effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Month-year fixed-effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	34,764	34,764	31,534	64,213	64,213	58,132	90,364	90,364	81,599
R-squared	0.220	0.220	0.255	0.239	0.239	0.275	0.300	0.300	0.331

See note in Table 2. Reported estimates are from a difference-in-difference specification (equation 1) in which the outcome variable is the margin on the adjustable rate mortgages (relative to a reference index or other standard rate) at the time of origination. Reported standard errors (in parentheses) are clustered at the bank level and are robust to heteroskedasticity. ***, ** and * indicate significance at 1%, 5% and 10%, respectively.

Table 4: Regression results for interest rates of FRMs from a pre-period estimation and a specification using leads/lags

	January 2013 - December 2013: +/- 6M	January 2013 - December 2015: +/- 18M
Covariates	(1)	(2)
ODR*post-June 2013	-0.001	
	(0.005)	
Leads		
ODR*Q1-2013		0.018
		(0.019)
ODR*Q2-2013		0.014
		(0.014)
ODR*Q3-2013		0.013
		(0.015)
ODR*Q4-2013		0.016
		(0.011)
ODR*Q1-2014		0.007
		(0.008)
Lags		
ODR*Q3-2014		0.011**
		(0.005)
ODR*Q4-2014		0.018**
		(0.007)
ODR*Q1-2015		0.031***
		(0.006)
ODR*Q2-2015		0.033***
		(0.007)
ODR*Q3-2015		0.026***
		(0.007)
ODR*Q4-2015		0.029***
		(0.007)
Bank fixed-effects	yes	yes
Month-year fixed-effects	yes	yes
Observations	4,826	25,008
R-squared	0.355	0.428

The sample consists of fixed rate mortgages originated over 6 months (column 1) and 18 months (column 2) before and after the introduction of NDFR in June 2014. *ODR* refers to the bank-specific ratio of overnight deposits to on balance sheet assets at the end of 2013. In column 1, *Post-June 2013* is a binary indicator taking the value one for placebo months with NDFR (i.e. July 2013 up to December 2013). In column 2, the end-2013 overnight deposit ratio is interacted with quarter dummies representing the period during 2013Q1 to 2014Q1 (leads, vs. 2014Q2) and during 2014Q3 to 2015Q4 (lags, v. 2014Q2). Reported estimates are from a difference-in-difference specification (equation 1) in which the outcome variable is the interest rate of fixed rate mortgages at the time of origination. Reported standard errors (in parentheses) are clustered at the bank level and are robust to heteroskedasticity. ***, ** and * indicate significance at 1%, 5% and 10%, respectively.

Table 5: Regression results for interest rates of FRMs from alternative time periods

	March 2012 - December 2012: +/- 5M		
Covariates	(1)	(2)	(3)
ODR*post-DFR cut	**0.007**	**0.007**	**0.007**
	(0.005)	**(0.005)**	**(0.005)**
Equity ratio*post-DFR cut		-0.003	0.000
		(0.036)	(0.034)
PD - 2nd quartile			0.084
			(0.063)
PD - 3rd quartile			0.146*
			(0.073)
PD - 4rth quartile			0.259***
			(0.081)
Recovery rate			0.083*
			(0.049)
Foreclosure time			0.003
			(0.002)
Loan maturity			0.000
			(0.004)
Bank fixed-effects	yes	yes	yes
Month-year fixed-effects	yes	yes	yes
Observations	5,888	5,888	4,672
R-squared	0.447	0.447	0.482

See note in Table 2. The sample consists of fixed rate mortgages originated over alternative time windows when adjustments to deposit facility rates were made. March 2012 to December 2012 covers the 10-month period incorporating the July 2012 DFR cut from 25 basis points to 0 basis points. *Post-DFR cut* is a binary indicator taking the value one for August 2012 onwards. Reported estimates are from a difference-in-difference specification (equation 1) in which the outcome variable is the interest rate of fixed rate mortgages at the time of origination. Reported standard errors (in parentheses) are clustered at the bank level and are robust to heteroskedasticity. ***, ** and * indicate significance at 1%, 5% and 10%, respectively.

Table 6: Regression results for interest rates of FRMs from alternative deposit ratios measures

	January 2014 - December 2014: +/- 6M					
Covariates	(1)	(2)	(3)	(4)	(5)	(6)
Time deposits ratio*post-June 2014	**-0.006***	**-0.012****	**-0.011*****			
	(0.003)	**(0.006)**	**(0.004)**			
Total deposits ratio*post-June 2014				**0.002**	**0.004**	**0.005**
				(0.007)	**(0.008)**	**(0.006)**
Equity ratio*post-June 2014		-0.047	-0.046		0.020	0.020
		(0.043)	(0.033)		(0.035)	(0.030)
PD - 2nd quartile			0.016			0.020
			(0.065)			(0.063)
PD - 3rd quartile			0.100			0.099
			(0.078)			(0.079)
PD - 4rth quartile			0.338***			0.337***
			(0.098)			(0.098)
Recovery rate			0.001			0.001
			(0.001)			(0.001)
Foreclosure time			0.002			0.003
			(0.003)			(0.003)
Loan maturity			0.000			-0.000
			(0.006)			(0.006)
Bank fixed-effects	yes	yes	yes	yes	yes	yes
Month-year fixed-effects	yes	yes	yes	yes	yes	yes
Observations	3,872	3,872	3,388	3,875	3,875	3,389
R-squared	0.333	0.334	0.383	0.333	0.333	0.382

See note in Table 2. The sample consists of fixed rate mortgages originated over the 6-month period before and after the introduction of NDFR). *Time deposits ratio* refers to the bank-specific time deposit ratio at the end of 2013. *Total deposits ratio* refers to the bank-specific total deposits ratio, and includes both overnight, savings, time, and any other deposit categories reported at the end of 2013. Reported estimates are from a difference-in-difference specification (equation 1) in which the outcome variable is the interest rate of fixed rate mortgages at the time of origination. Reported standard errors (in parentheses) are clustered at the bank level and are robust to heteroskedasticity. ***, ** and * indicate significance at 1%, 5% and 10%, respectively.

Table 7: Regression results for interest rates of FRMs, including time-varying bank characteristics

	January 2013 - December 2015: +/- 18M			
Covariates	(1)	(2)	(3)	(4)
ODR*post-June 2014	**0.021****	**0.028*****	**0.013****	**0.018*****
	(0.008)	(0.007)	(0.006)	(0.005)
Equity ratio*post-June 2014			0.040*	0.038*
			(0.023)	(0.020)
Bank assets*post-June 2014			-0.077*	-0.101**
			(0.040)	(0.041)
Equity ratio t-1	-0.039	-0.033		
	(0.029)	(0.030)		
Bank assets t-1	0.404	0.460*		
	(0.250)	(0.247)		
Retail loans ratio t-1	0.009	0.009*		
	(0.006)	(0.005)		
Cash ratio t-1	-0.021	-0.019		
	(0.020)	(0.021)		
PD - 2nd quartile		0.048		0.046
		(0.033)		(0.033)
PD - 3rd quartile		0.129**		0.126**
		(0.052)		(0.052)
PD - 4rth quartile		0.200***		0.197***
		(0.064)		(0.064)
Recovery rate		0.001***		0.001**
		(0.000)		(0.000)
Foreclosure time		0.003***		0.003***
		(0.001)		(0.001)
Loan maturity		0.015***		0.015***
		(0.002)		(0.002)
Bank fixed-effects	yes	yes	yes	yes
Month-year fixed-effects	yes	yes	yes	yes
Observations	24,997	21,451	25,003	21,462
R-squared	0.43	0.461	0.429	0.460

See note in Table 2. The sample consists of fixed rate mortgages originated over the 18-month period before and after the introduction of NDFR. *Bank assets* refers to the bank-specific natural log of total on balance sheet assets at the end of 2013. *Equity ratio t-1* and *bank assets t-1* refer to the one-year lag (time-varying) bank-specific equity ratio and bank assets (i.e. reported in end-2012, end-2013, and end-2014). *Retail loans ratio t-1* refers to the one-year lag (time-varying) bank-specific retail loans relative to its on balance sheet assets (i.e. reported in end-2012, end-2013, and end-2014). *Cash ratio t-1* refers to the one-year lag (time-varying) bank-specific total cash balances (including balances held with central banks) relative to its on balance sheet assets (i.e. reported in end-2012, end-2013, and end-2014). Reported estimates are from a difference-in-difference specification (equation 1) in which the outcome variable is the interest rate of fixed rate mortgages at the time of origination. Reported standard errors (in parentheses) are clustered at the bank level and are robust to heteroskedasticity. ***, ** and * indicate significance at 1%, 5% and 10%, respectively.

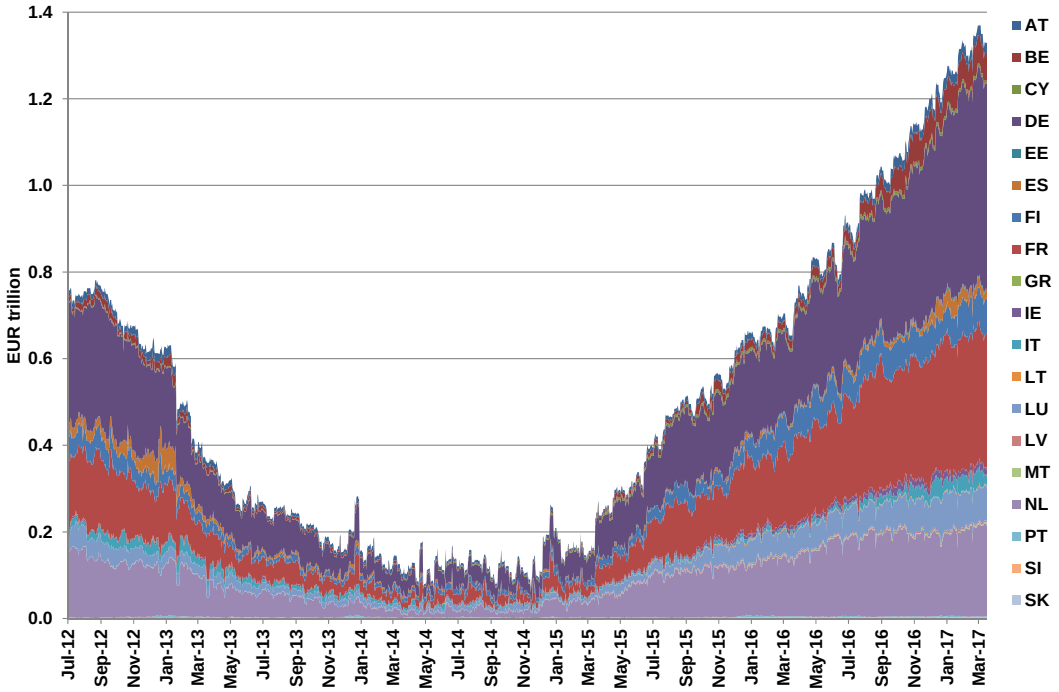
Table 8: Regression results for the likelihood of an originated loan to be FRM

	January 2014 - December 2014: +/- 6M			July 2013 - June 2015: +/- 12M			January 2013 - December 2015: +/- 18M		
Covariates	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ODR*post-June 2014	**-0.001***	**-0.001***	**-0.000**	**-0.003****	**-0.004****	**-0.003***	**-0.002**	**-0.002**	**-0.002**
	(0.000)	**(0.000)**	**(0.000)**	**(0.002)**	**(0.002)**	**(0.002)**	**(0.002)**	**(0.002)**	**(0.003)**
Equity ratio*post-June 2014		-0.001	-0.001		0.003	0.004		-0.000	0.001
		(0.001)	(0.001)		(0.007)	(0.007)		(0.010)	(0.010)
PD - 2nd quartile			0.003			0.003			0.001
			(0.008)			(0.010)			(0.013)
PD - 3rd quartile			-0.001			-0.007			-0.012
			(0.014)			(0.018)			(0.022)
PD - 4rth quartile			-0.028			-0.044			-0.052*
			(0.022)			(0.028)			(0.031)
recov			-0.000			-0.000			-0.000
			(0.000)			(0.000)			(0.000)
Foreclosure time			0.001**			0.002***			0.002***
			(0.000)			(0.000)			(0.000)
Loan maturity			-0.004**			-0.005**			-0.006**
			(0.002)			(0.002)			(0.002)
Bank fixed-effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Month-year fixed-effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	38,639	38,639	34,923	76,910	76,910	69,083	115,372	115,372	103,064
R-squared	0.082	0.082	0.097	0.172	0.172	0.188	0.196	0.196	0.216

See note in Table 2. The sample consists of fixed and adjustable rate mortgages originated over the three periods under study (6, 12 and 18 months before and after the introduction of NDFR). Reported estimates are from a difference-in-difference specification (equation 1) in which the outcome variable takes the value one if the originated mortgage is fixed rate and zero if it is variable rate. Hybrid mortgages at the time of origination (such as fixed rate switching to adjustable rate) are not included in the sample. Reported standard errors (in parentheses) are clustered at the bank level and are robust to heteroskedasticity. ***, ** and * indicate significance at 1%, 5% and 10%, respectively.

Appendix 1: Supplementary Figure

Figure A1.1: Total excess liquidity by country of counterparty since July 2012



Sources: ECB databases, author's calculations
Notes: Excess liquidity is defined as the amount of funds deposited with the Eurosystem by an eligible Eurosystem counterparty (either in the deposit facility or current account) in that day, less the minimum required reserves for that counterparty in the given maintenance period.

Appendix 2: Methodology used to produce loan-level credit risk variables

We use the Italy RMBS assumptions published by Fitch Ratings (Fitch, 2017), which set out the agency's assumptions for assessing the credit quality of residential mortgage loans. Fitch is used as a basis for these assumptions, rather than other credit rating agencies, because their assumptions are set out in the clearest way, thereby facilitating their incorporation into our analysis. Fitch's assumptions are derived using a variety of defaulted loan datasets provided to the agency over the course of its activity in rating RMBS transactions in Italy.

The input variables, which we retrieve from the RMBS and RACC loan-level templates, are the original loan-to-value ratio, the borrower's employment status, the borrower's income, the loan purpose (e.g. for house purchase, for debt consolidation, for equity release), the loan amortisation type (i.e. interest-only, linear, increasing instalments, etc.), the loan payment frequency (monthly, quarterly, six-monthly, annual), and the geographic region of the property.

As regards probability of default, this is derived using Fitch's estimated foreclosure frequency (at the 'AAA' level) over the lifetime of an average loan, which in turn (for Italy) depends on the original loan-to-value ratio and the geographic region of the borrower (which is assumed to be the same as the location of the property). Further adjustments are made, depending on the borrower's employment status, the amortisation profile of the loan, the payment frequency, the maturity (for very long maturities), the loan purpose, and if there is excessive concentration to a particular geographic region (relative to the population size).

In terms of loss severity, the equation is defined as:

$$Loss\ severity = \frac{(loan\ balance - stressed\ recoveries\ from\ sale + foreclosure\ costs + lost\ interest\ income)}{loan\ balance}$$

The above equation is populated using loan-level data for the loan balance. Note that the defaulted loan balance includes both the loan in question and also loans secured by the same property with pari-passu or more senior ranks.

As regards stressed recoveries from sale, the Fitch RMBS country addenda provide estimates for property value declines based on the country, property region, property type (e.g. house or apartment), and finally property value (for use in illiquid property adjustments). The AAA-stress level of these assumptions is taken at all times. Foreclosure costs (e.g. legal fees) are also included in the Fitch assumptions at the country level, and also reflect property values (and, for some countries, additional fields such as property type). Foregone interest income is calculated using the loan-specific interest rate, multiplied by the balances of loan in question as well as more senior or pari-passu ranking loans secured by the same property.

Crucially, the foregone interest income is also a function of the recovery lag: the longer it takes to foreclose on the collateral, the greater the lost income and the higher the loss given default.

Appendix 3: Representativeness Checks

Figure A3.1: Residential Mortgage Interest Rates

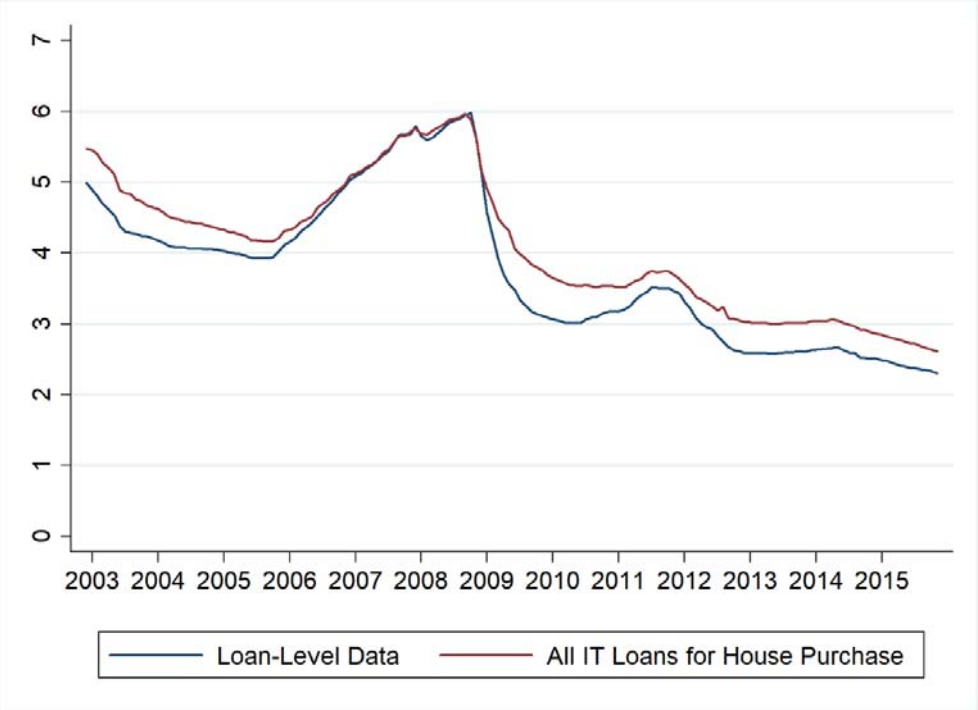


Figure A3.1 examines the closeness of the loan-level data interest rates with the official ECB's MFI Interest Rate Statistics dataset (MIR), using the MIR dataset terminology that is closest to our loans of interest: outstanding interest rates for FRMs with a remaining fixation period and/or maturity of at least 5 years.[31] Each month represents a weighted average (using the current loan balance) of the interest rates of loans outstanding in that month. Although slightly lower than the MIR series, the loan-level data interest rates closely track the country-wide rates over time, suggesting that changes in bank interest rate behaviour in our sample are representative of wider changes in the Italian long-term FRM market.

[31] We use the series with the code MIR.M.IT.B.A22.J.R.A.2250.EUR.O

Figure A3.2: Share of Adjustable Interest Rate Loans

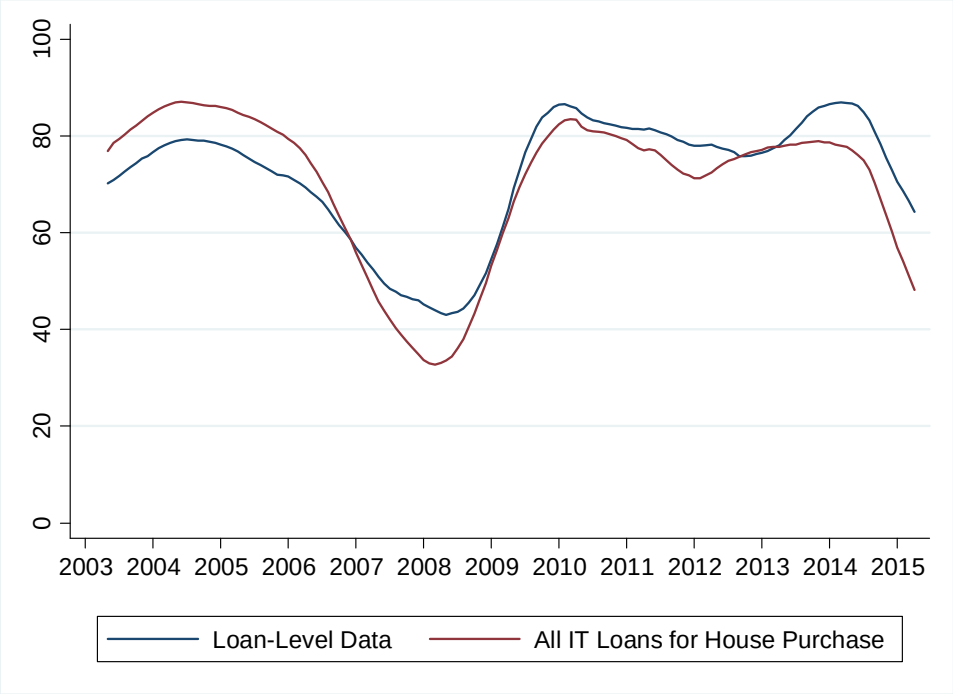


Figure A3.2 examines the proportion of residential mortgage loans that have adjustable interest rates (ARM). The figure displays two monthly series: one calculated from our securitized residential mortgage data and the second from the ECB's MIR dataset.[32] In order to capture the general trends (due to some banks entering the data sample), the 12-month moving average is displayed. Although there are some divergences between the two series, there is generally a close fit and, most importantly, our sample appears to capture important turning points in the prevalence of adjustable (and fixed) interest rate residential mortgages in Italy.

[32] Formally this is the "Share of new loans to households for house purchase with a floating rate or an initial rate fixation period of up to one year in total new loans from MFIs to households", and has the code RAI.M.IT.SVLHPHH.EUR.MIR.Z. Source: ECB Statistical Data Warehouse

Figure A3.3: Loan-to-Value Ratios

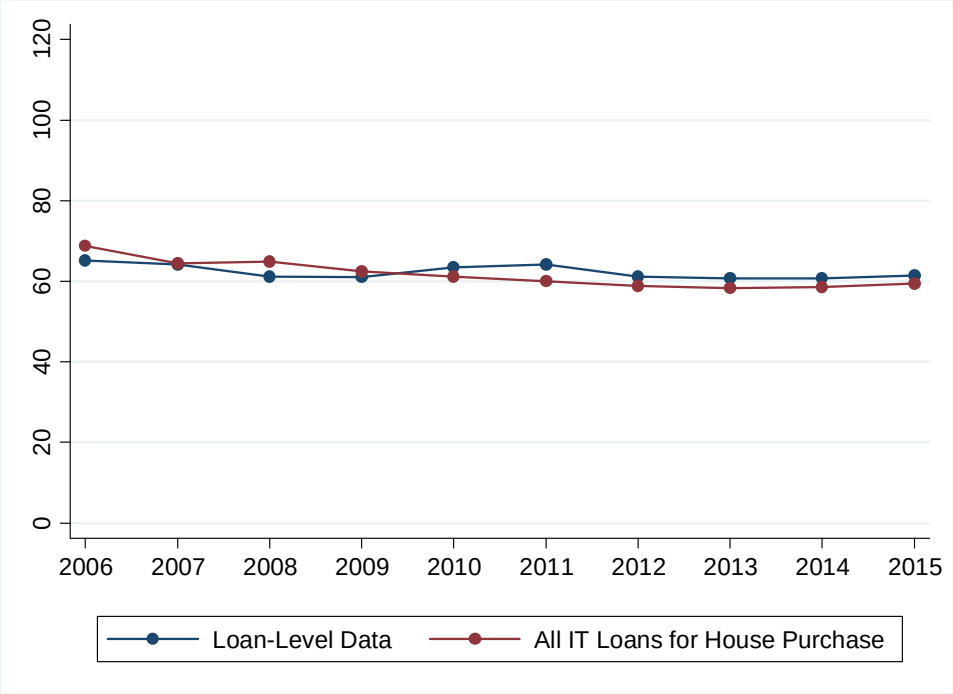


Figure A3.3 examines the evolution of Italian residential mortgages loan-to-value ratios using our sample and, for reference, data from the Banca d'Italia's Financial Stability Review (2016:1).[33] The loan-level data series is calculated using the weighted average of the original loan-to-value for loans outstanding in that year.[34] As can be seen from Figure A3.3, there is a highly close fit between the two series over all the years for which data is available from Banca d'Italia. Loan-to-value ratios are a key measure of the bank's loss given default, which in turn is the largest driver of losses on loans (probability of defaults are typically much smaller than loss given default estimates). The close fit between the two series suggests that there is little discernible difference, in terms of riskiness, of securitized Italian residential mortgages with all Italian residential mortgages.

[33] See Figure 2.1. https://www.bancaditalia.it/pubblicazioni/rapporto-stabilita/2016-1/index.html
[34] We also matched the Banca d'Italia series using the current loan-to-value ratio, taking the weighted average (using the current loan balance) for all loans outstanding each year (i.e. including loans originated in previous years that had not yet matured by the present year). This also yielded a close fit.

Figure A3.4: Evolution in Lending Volumes

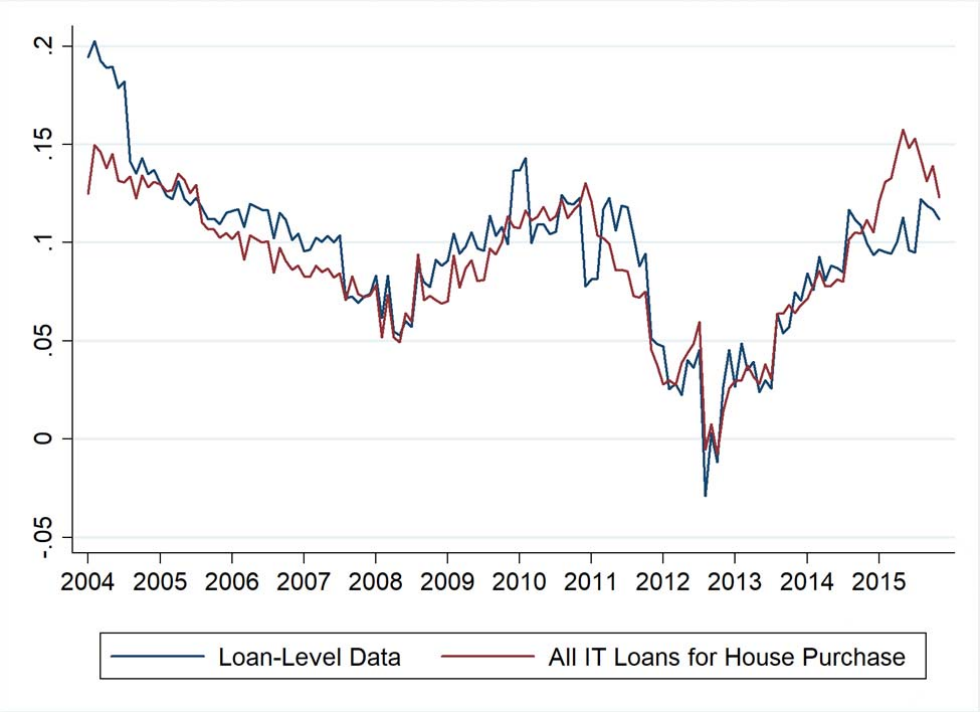
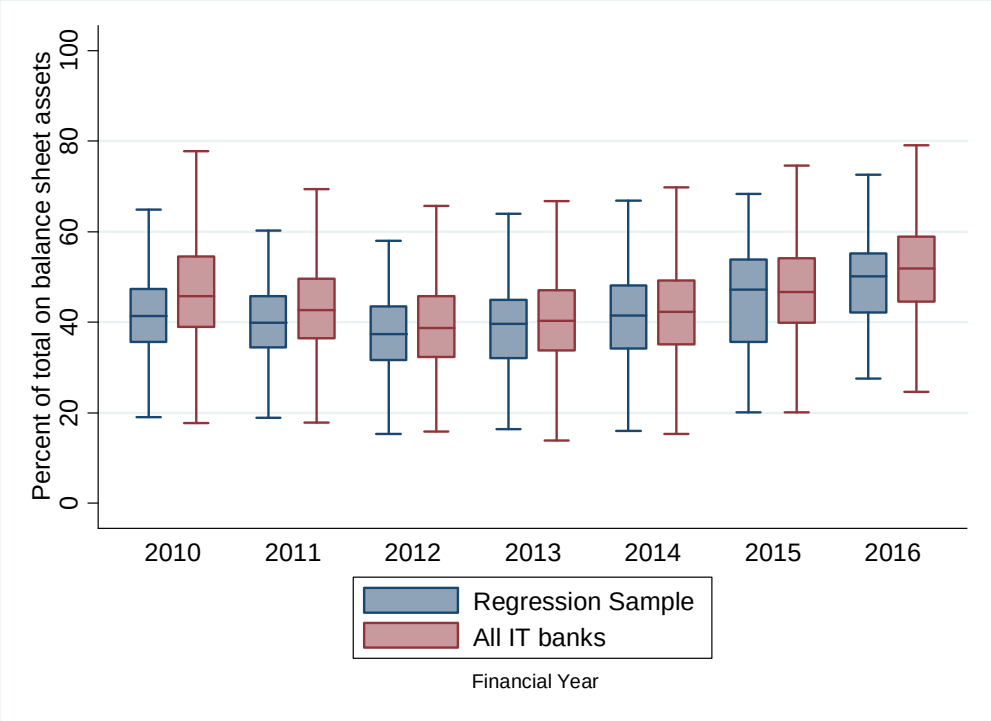


Figure A3.4 examines the change in the volume of new loans over time in our sample, compared with the estimated change for all new Italian residential mortgages (as provided in the ECB's MFI Interest Rate Statistics[35]). Because some banks enter or exit our sample over time, we use the month-on-month change (rather than the year-on-year change). Furthermore, the 12-month moving average is used in order to better capture the trends. As can be seen in Figure A3.4, our sample broadly captures the change in residential mortgage lending volumes taking place in Italy.

[35] We use the series covering "Lending for house purchase excluding revolving loans and overdrafts, convenience and extended credit card debt", which has the following code: MIR.M.IT.B.A2C.A.B.A.2250.EUR.N

Figure A3.5: Bank overnight deposit ratios



Last, we examine how closely the banks in our baseline regression sample (using the 2013-2015 time window) match the universe of Italian banks in terms of the overnight deposits ratio (i.e. our key forcing variable). To perform such a comparison we utilize data from SNL Financial covering 585 Italian banks. As with all of our analysis in this paper, and as is common in the literature[36], we use local measures of these variables, rather than parent-level figures. Figure A3.5 displays box plots of overnight deposit ratios for the two samples across a number of years. According to the figure our regression sample closely matches the wider Italian banking system in terms of retail overnight deposit ratio at end-2013 (i.e. the figure used in our baseline estimation). In addition, our sample matches relatively well the retail overnight deposit ratio across a number of years.

[36] See Albertazzi et al., 2016 and Basten and Mariathasan (2018), as well as Drechsler et al. (2017).

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