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Document de Travail
Working Paper
2020-23

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Monetary Policy and Housing Loan Default *

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May 28, 2020

Abstract

The most direct channel of transmission of monetary policy to households is the modification of ECB lending and deposit facilities rates. Outstanding borrowers with adjustable rate loans face affordability conditions changes with important consequences on their financial situation. In this paper, we study the impact of monetary policy changes on housing credit default over the period 2004-2015. We use an extensive panel of French housing loans to reconstruct amortization tables over the life of each loan and compute changes in quarterly payments due to monetary policy action, later using hazard models to map changes in interest rates to default. Importantly, our data set allows the assumption of the absence of strategic default our analysis, which isolates involuntary default in our estimates. First, we find that a 100 bp increase in quarterly payment induced by variations in the 3-month Euribor increases the probability of default by around 5%. Second, we identify employment stability as a major insurance factor against rising policy rates during contractionary monetary policy action. Finally, we provide evidence about the existence of a self-selection of riskier borrower profiles into adjustable rate loans. The concern regarding payment size on adjustable-rate loans is of heightened importance in a monetary policy context characterized by uncertainty over the timing of a rate increase following a sustained period of low or negative rates.

Keywords: Real Estate, Housing credit, Non-Performing Loans, Monetary Policy, Default

JEL Codes: R30, H81, E52,

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When a central bank leads an expansionary monetary policy, new borrowers benefit from improved lending conditions on their housing loans. There is heterogeneity, however, regarding the extent to which existing cohorts of loans experience this channel of monetary policy pass-through. Fixed-rate loan holders see no change, while holders of adjustable rate loans bare varying levels of interest rate. Some borrowers with fixed rates loan may choose to refinance, although rates need to move considerably before the decision becomes desirable, in addition to its associated costs. Therefore, changes in the current policy rate asymmetrically affect housing loans holders.

In this paper, we assess how monetary policy pass-through generates asymmetric payment size movements which affect the default probability of households' housing credit in France during the period 2004-2015. Precisely, we seek to quantify the effect of a monetary policy-driven shock to payment size on the propensity of a household to default on a loan. We also provide evidence about the role of employment stability and socioeconomic class. We use a proprietary database of around 5 million housing credit lines granted to households in the French market between 1994 and 2015. In order to measure monetary policy shocks, we reconstruct theoretical amortization tables for all credit lines in our sample, decomposing monthly payments into interest and principal components. We then use hazard model techniques to estimate the delinquency rate in a panel data framework. Unique features of our data and national jurisdiction allow us to isolate involuntary default in ways which will be explained in subsequent sections. Since we exogenously observe computed credit risk ratings and additional exhaustive household features, we are able to compare peer borrower risk profiles which are unequally exposed to monetary policy shocks due to their type of interest rate (adjustable versus fixed).

In this context, our study presents several novel contributions. Firstly, this paper is, to our knowledge, the first paper to evaluate monetary policy and housing default for the French jurisdiction (and second for Europe more generally). This is particularly important in the current environment of extremely low interest rates. The ECB holds an unprecedented expansionary monetary action in the Euro zone with the aim at reaching its inflation target. This consists of record low policy rates and several unconventional tools providing high liquidity to the system. The exceptional environment of low rates may be claimed as risky for banks' profitability and raises questions about a future increase of policy rates. Our paper therefore aims to provide evidence about the impact of changes on ECB action on household solvency and their risk of default. Importantly, our study may also provide insight for neighboring European countries (with otherwise similar institutions) where adjustable rate loans are more prevalent, or where financial institutions further favor their adoption.

Second, we exploit a credit register in which strategic default is effectively absent, thus better isolating the effect of payment size on non-voluntary default. The ramifications of this on our estimates are not trivial; in a US study, Gerardi et al. (2017) find 38% of households in default are capable of making their mortgage payments without reducing consumption. Thus, being able to disentangle non-voluntary from strategic default represents a novel opportunity compared to previous literature. Finally, our base is exceptionally extensive for France, covering the lifespan of nearly 5 million loans. This allows us to control for a subsequent vector of household and loan characteristics in our estimations. In this way, we are able to capture the household-specific financial fragility (and other traits) and other drivers of the decision to self-select into a certain loan type. Further, we make use of an internal probability-of-default classifier which is applied uniformly across all buyers, and takes into account all of a household's financial data made available to the bank at the time of the loan application. As a consequence, we are able to compare the exposure to monetary policy action of fixed and adjustable loans while limiting the econometric selection issue, being the first European paper to do so.

Similarly to Byrne, Kelly, and O'Toole (2017) in Ireland, we find that a quarterly payment increase of 100 basis points increases default probability by around 5%. Extrapolated to a concrete change of 1pp on policy rates, the resulting increment on default probability for exposed loans lies around 45%. We note that our results also hold when regressing our model only on adjustable rate loans, which is in line with US literature[1]. We additionally find, as expected, that outstanding fixed rate loans are unaffected by monetary policy action. Second, as suggested by Li, White, and Zhu (2011), we assume the absence of strategic defaults in our data-set (due largely to jurisdictional differences explained below), which allows us to conclude that our results correspond to pure involuntary defaults, in contrast to other papers in the literature whose bases often contain both strategic and involuntary delinquencies. Third, we show that employment stability represents a crucial insurance against periods of contractionary monetary policy action, reducing the default risk by around 12%. The magnitude of this result is in line with figures from Gerardi et al. (2013) on the effects of job loss. Finally, we provide evidence consistent with the idea that riskier households self-select themselves into floating rates loans, as suggested by previous literature.

This evidence is of more general importance for the design of monetary policy by central banks and policy makers. On one hand, it may be desirable to lead the housing credit market

[1] See, e.g., Fuster and Willen (2017), Keys et al. (2014) or Tracy and Wright (2012); Elul et al. (2010)

structure into a "safer" zone for households which is dominated by fixed rate loans. However, this limits the transmission of monetary policy into the real economy, as only adjustable rate and new housing loans would be impacted by changes in the credit market. In periods of contractionary monetary policy, this represents an advantage for indebted households. In expansionary periods, however, the only way to take advantage of more favorable credit conditions is through the refinancing of loans, which requires meeting a certain standard of creditworthiness. Renegotiation is crucial for those households with the most vulnerable financial situations, which are more often refused and therefore may not be able to reduce their risk of default (Mian, Rao, and Sufi, 2013). Notably, these results are particularly important in the low interest rate context, as rising interest rates could trigger default for households with existing fragility.

The remainder of the paper is organized as follows: Section 1 reviews the existing literature, section 2 gives a description of the data and the manipulations done by the authors to compute monetary policy shocks for each loan. Credit system and default evidence is documented in section 3. Section 4 details our econometric approaches. Sections 5 and 6 report results and robustness checks, while section 7 concludes.

1 Literature

One reason housing default has garnered so much attention in recent years is its interconnection with financial downturns, particularly the 2007-2008 Financial Crisis. Haughwout, Peach, and Tracy (2008) and Mian and Sufi (2009) document how the expansion of housing credit, particularly subprime loans, ultimately lead to the default wave which sparked the crisis. In addition to a degradation of credit standards, households themselves undertook risky behavior by borrowing against their home equity during periods of increasing housing price. Mian and Sufi (2011) estimate home equity-based borrowing—equal to 2.8% of GDP pre-crisis—to account for at least 34% of new defaults from 2006 to 2008.

Besides falling housing prices, other changes in macroeconomic conditions can also pose a generalized risk. Mayer, Pence, and Sherlund (2009) show how increases in delinquency rates first began to rise in states which experienced elevated unemployment rates leading up to 2007[2]. While spells of unemployment are geographically associated with falling housing prices, borrowers who lose their job in thriving area are more likely to simply sell their house

[2]Ohio, Michigan, and Indiana were the first states to see big increases in delinquency rates, the authors document. The default rate on subprime mortgages in these states was 14 percent at the beginning of 2007, compared with 8.5 percent rate for the nation as a whole.

rather than default.

Nevertheless, as emphasized in Haughwout, Peach, and Tracy (2008), much of the increase in defaults (even at a local level) remains difficult to account for, even with rich individual level explanatory data. Most papers emphasize the importance of the loan-to-value (LTV) ratio—particularly, the case of negative equity. Elul et al. (2010) use LPS data on individual loans coupled with borrower-level credit bureau information from Equifax to show how liquidity shocks interact with negative equity. Following loans which originated in 2005 and 2006 until April 2009, the authors find that decreases in equity have an aggravated effect on default probability for illiquid households—i.e., those with high rates of credit-card usage. Furthermore, local unemployment shocks are found to be positively associated with default. Lastly, the authors document that the presence of a second mortgage loan is also linked with higher default risk.

Similarly, Gerardi et al. (2013) use a survey conducted on 8,690 households in 2009 which suggests individual unemployment to be the strongest predictor of default. The authors find that individual unemployment increases the probability of default by 5–13 percentage points, all else equal, with a sample average default rate of 3.9 percent. These results globally suggest that policies designed to promote employment would be more effective to fight mortgage default than policies which ease loan repayment standards. Gerardi et al. (2017) confirms this intuition, finding job loss to have an equivalent effect on the propensity to default as a 35% decline in equity, while Hsu, Matsa, and Melzer (2014) finds that states with generous unemployment insurance experience less mortgage delinquency.

In addition to the role of job loss, there is an ongoing debate regarding the role played by rising payments and adjustable mortgages in the 2007-2008 Financial Crisis. One side stresses the idea that difficulties meeting payments were instrumental in the bursting of the housing bubble. The predominant[3] view in the aftermath of the Countrywide Financial collapse holds that rising payments on sophisticated loans triggered a wave of foreclosures. Several studies specifically address the question of changes in payment size via the interest rate channel. Byrne, Kelly, and O'Toole (2017) study the question of monetary policy pass-through to housing loans in the Irish case by exploiting the heterogeneity across two different classes of adjustable-rate loans with different exposures to interest rate movements. Using a data-set which covers approximately 66% of the residential mortgage market, the authors show a 1% reduction in installment to be associated with a 5.8% decrease in the probability

[3](Foote, Gerardi, and Willen, 2012) believe adjustable-rate mortgages played only a limited role compared with information asymmetry and irrational exuberance.

of default over the following year. They also find that negative equity has mitigated the ease in repayment due to recent low rates, implying an interaction between monetary policy and asset price shocks.

Fuster and Willen (2017) show how interest rate reductions affect repayment behavior, including for borrowers who are significantly underwater on their mortgages. The authors' estimates imply that cutting a borrower's payment in half reduces their hazard of becoming delinquent by about 55 percent, an effect approximately equivalent to lowering the borrower's combined loan-to-value ratio from 145 to 95 (holding the payment fixed). This result is in line with previous result of Elul et al. (2010), Tracy and Wright (2012) and Keys et al. (2014), which emphasize an interaction between payment shocks and housing wealth.

Li, White, and Zhu (2011) adopt a related but novel approach to the question by exploiting a 2005 U.S. bankruptcy reform which made it more difficult for households to discharge credit card debt. By making bankruptcy declaration more costly, fewer households could strategically declare bankruptcy for *other* debts in order to focus on their mortgage payments. The authors document rises in prime and subprime mortgage default rates of 23% and 14% respectively after the reform yet before the financial crisis.

Surprisingly, there exist only a few papers that provide consistent results on the link between payment size (particularly due to monetary policy changes) and default rates. A main reason for this is the existence of difficulties on the identification of a pure treatment effect due to the borrower selection problem. Since homeowners who demand (or resort to) a variable rate loan may exhibit a greater (and unobserved) propensity to default compared with those who hold a traditional fixed-rate loan, a group-specific estimator would experience problems of bias. Furthermore, disentangling non-voluntary payment delinquency from strategic default is a difficult task in most of developed economies due to the existence of bankruptcy rights. Moreover, this issue has been mainly studied in the US, where extensive loan level data is more easily available. Thus, evidence for European countries is almost nonexistent.

2 Data

We use proprietary data housed at the French Prudential Supervision Authority (ACPR) of the Banque de France, which contains almost 4,700,000 housing credit lines underwritten from 1994 to 2015 in France. This extensive loan-level data-set contains exhaustive information about housing loans which are secured by an insurance guarantee agreement instead of a traditional mortgage agreement. Mortgage agreements cover around 30% of total housing loans according to the ACPR (2017), while the guarantee system approximately covers the remaining two thirds. The latter involves a selection process which assures that the pool of accepted applicants represent, on the whole, a less risky segment of the market. Any risks observed in this data-set should thus be *afortiori* a greater cause of concern for the remainder of the market.

Credit lines are followed at the quarterly level from the quarter of origin until four possible events: 1) natural end of maturity; 2) total repayment (either credit redemption or a full principal pay-down); 3) default; or finally, 4) the end of the database visibility in the last quarter of 2015. We have three time-varying variables per credit line: outstanding principal[4], current loan-to-value ratio (LTV) and delinquency status. Precisely, a loan is considered as being in default after 90 days of non-payment[5]. All other variables are recorded at the time of loan formation, and therefore do not vary throughout time in our data. This includes loan information such as maturity, loan size, the type of interest rate (fixed or variable), or the downpayment rate, among others. Additionally, precise aspects of the borrower's profile are also specified, such as annual household income, debt-to-income ratios, the number of other outstanding loans, as well as an internally calculated rating. The latter is a probability of default (PD) rating which uses credit information to rate the household' likelihood of default over the course of the loan, and ranges for "A" to "D"[6]. Finally, we also observe several demographic characteristics: occupation category, borrower age, marital status and postal code at loan origination.

Indeed, our database is fundamentally different from typical US cases, in that it only contains non-mortgage housing loans in which the "strategic default" dimension is much less present, as homeowners are not permitted to simply return the house to the bank. Rather than abandon the home, borrowers in our base are covered by a third-party insurance mechanism which works with borrowers to help them survive income shocks.

In addition, quarterly data on unemployment rates by *département* come from the French *Institut national de la statistique des études économiques* (INSEE), and quarterly series of Euribor index at different maturities has been gathered from the ECB's Statistical Data Warehouse. Finally, since our register of loans was not as exhaustive towards the beginning of

[4] *Capital Restant Du* in French

[5] Following the BASEL III accounting conventions for default.

[6] An alternative rating is also provided: a loss-given-default (LGD) rating. This LGD rating additionally considers the size of the loan and the extent of the bank's exposure, and ranges from Segment 1 to Segment 3.

the sample period (1994-2003), particularly regarding adjustable loans, we decide to restrict the period of study to 2004-2015. This period exhibits considerable variation with regards to the Euribor rate, yielding an adequate window for our analysis.

2.1 Data processing: amortization table and interest rate

An important limit of our original data set is the lack of direct information on interest rates and related quarterly interest payments. This breakdown of monthly payments is crucial for our identification strategy as interest rates and subsequent quarterly *interest payment* variations constitute the direct shock of monetary policy to households.

In this section, we present our strategy to leverage available information to back out a full amortization schedule of each household's payments. We use one of two available time-varying loan variables—the outstanding principal[7]—to break down payments into principal and interest components based on a theoretical amortization table. Further, we are able to decompose the interest rate paid by adjustable rate loans into a basic Euribor component and a risk premium/spread component. For simplicity, we will first present the case of fixed rate loans as an example. Later, we will generalize the methodology to adjustable rate loans, and further detail their particularities.

To begin, we rely on the following identity of a typical amortization schedule:

$$M_t = I_t + P_t$$

M_t being the total quarterly payment in period t, which is formed by the total interest payment I_t and the total principal payment P_t. The difference on total quarterly payments ΔM over time is therefore defined as

$$\Delta M = \Delta I + \Delta P$$

where $\Delta M = M_t - M_{t-1}$. ΔP can be easily calculated since we know the outstanding principal ($Principal_t$) at each period while ΔI is unknown. Nevertheless, being a fixed rate loan schedule, we know that quarterly payments do not vary across periods (i.e., $\Delta M = 0$). Therefore, $\Delta P = -\Delta I$.

The change in the quarterly payment allocated to interest pay-down can be expressed as

[7] *capital restant du* in French.

follows:

$$\begin{aligned}\Delta I &= Principal_t \times R - Principal_{t-1} \times R \\ &= (Principal_{t-1} - Principal_{t-1} - P_{t-1}) \times R \\ &= -P_{t-1} \times R\end{aligned}$$

where R is the quarterly interest rate. Naturally, the latter does not vary throughout time in the fixed-rate loan case.

Therefore, for loans which demonstrate a regular repayment schedule (namely, constant interest rate and quarterly payments), the quarterly interest rate is equal to the period-over-period percentage variation in the principal payments:

$$R = \frac{\Delta P}{P_{t-1}}$$

As a result, we obtain the exact interest rate R and can compute interest payments I_t (and thus total quarterly payments M_t) for each period.

Nevertheless, this methodology is *a priori* inadequate for the computation of adjustable rate payment schedules since the main assumption ($\Delta M = 0$) does not hold. By construction, the monthly debt service of adjustable rate housing loans varies across periods according to changes in their reference index. In particular, 70% of adjustable housing loans in France are referenced to the Euribor (ACPR, 2017). In practice, changes in monthly payments can be updated at different frequencies (every month, 3 months, or 1 year, in general). In our data-set, we observe neither the reference index of adjustable loans nor the frequency of their adjustment. Thus, we are constrained to impose the structure of a typical case across all loans.

Our approach is the following: first, we assume all adjustable rate loans to be indexed to the 3-month Euribor. This is the most frequently used housing index according to Banque de France data sources to which authors have access. Second, we assume that loan payments are adjusted every 3 months. Finally, quarterly payment are referenced to previous quarter Euribor levels, following a conventional French loan structure. Thus, we obtain the following relationship:

$$\begin{aligned}\Delta M &= Principal_t \times R_t - Principal_{t-1} \times R_{t-1} + \Delta P \\ &= (Principal_{t-1} - P_{t-1}) \times R_t - Printicipal_{t-1} \times R_{t-1} + \Delta P \\ &= Principal_{t-1} \times \Delta R - P_{t-1} \times R_t + \Delta P\end{aligned}$$

Since $R_t = S + E_{t-1}$, S being the (time invariant) spread and E the 3-month Euribor, we obtain:

$$R_t = \frac{Principal_{t-1} \times \Delta E_{t-1} + \Delta P - \Delta M}{P_{t-1}} \tag{1}$$

Given the fact that $\Delta M \neq 0$ for adjustable rate loans—and not directly observed in our database—we need to rely on an alternative method to identify interest rates R_t within this group. We circumvent this issue by exploiting periods of stable monetary policy—i.e., periods during which the 3-month Euribor moves very little ($\Delta E \approx 0$) and we can assume that $\Delta M \approx 0$. As shown in Figure 1, we have identified two main periods which respect this criteria: 2003q3 to 2005q3, where the maximum movement is 9 basis points; and 2012q4 to 2013q4, where the maximum movement is 4 basis points. We exploit these periods to apply our above calculations, on the assumption the change in monthly payments due to Euribor variation is essentially negligible. It is worth noting that most of our sample have some period of life in our stable MP periods, thus allowing us to identify an interest rate while excluding relatively few loans from the study (1.5% of the sample).

Further, we can back out the so-called spread, or risk premium, which is constant throughout the entire lifespan of the loan. Once the spread is identified, the time-varying interest rate R_t can be proxied for every quarter using the stable interest rate periods, and interest payments I_t and total quarterly payments M_t can be calculated:

$$\begin{aligned}M_t &= I_t + P_t \\ &= Principal_t \times R_t + P_t\end{aligned}$$

Following these manipulations, we are able to measure relative changes on quarterly payments resulting from exposure to monetary policy variations for each loan. This is what we subsequently call our monetary policy shock $MPshock_t$:

$$MPshock_t = \frac{\Delta M}{M_{t-1}}$$

A detailed example of this methodology is presented in appendix B.

2.2 Measurement error

While both adjustable and fixed rates loans are granted in the housing market, France is one of the countries with the highest share of fixed rates on housing loans in the Euro Area. Although 97.9% of new housing loans are fixed-rate, outstanding loans exhibit a fixed-rate representation of 93.2%—a legacy of the pre-crisis trend towards adjustable rates (Faivre et al., 2018). This figure is similar in our total sample, with 10% of outstanding credit lines being floating rate loans.

The methodology we presented in the previous section perfectly computes interest rates for fixed rates loans, while in effect it approximates them for adjustable ones. While we know that monetary policy shocks are equal to zero for fixed credit schedules, the analysis presented in this paper depends on the proper measurement of changes on adjustable schemes payments. In this section, we aim to provide evidence about the accuracy of our method and the potential source of bias in posterior analysis. To this end, we simulate 780 adjustable rate loan amortization tables consisting of different loan sizes, maturities and quarters of origin. This results in a large diversity of interest rates at origin. We use loan sizes between €100,000 and €400,000, maturities between 10 and 25 years and interest rates between 1.2% and 5.3%, which is the interest rate range of the period of study. This simulation results in 18,700 comparison points. The goal of this exercise is to apply our approximation methodology presented in the previous section to an artificial sample of data for which we have full information ex-ante, and evaluate the degree of inaccuracy of the results compared to the "true" numbers of our synthetic data in terms of interest rates.

A plot showing the true (known ex-ante) interest rate values of our synthetic data and our approximated values (i.e., the estimations given from our methodology) is shown in figure 2. The true values are higher than the approximations given by our methodology. Specifically, the true rates are higher than the approximated rates in 92% of the cases. Furthermore, 95% of the deviations from the true value are between 0.07pp and -0.5pp, the median variation being -0.23pp. This implies that our methodology slightly underestimates the true interest rate. This is confirmed in our sample of study (which is different from the simulated group of loans discussed here). Figure 3 presents the mean interest rate at origination as published by the *Banque de France* and the mean interest rate at origination from our sample (the data used in our estimations) computed using our amortisation table reconstruction method. We observe that our approximation of interest rates follows a very similar trend than the official one, with a slightly lower level most of the time. This is in line with the results of the simulation exercise, and in line with the *apriori* intuition that our sample represents a less risky segment of the market.

Finally, we assess how the underestimation of interest rates is transmitted to the measure of monetary policy shocks. This is our main concern, since the latter is our variable of interest, while the interest rate is only the means to obtain it. Figure 4 presents the scatter plot between the true (simulated) and the approximated quarterly payments changes (called monetary policy shocks). We observe an almost 45 degree relationship between them, where the median value difference is 0.88€. Reassuringly, 95% of our simulated sample presents a approximation error between 4€ and -4€. This is considered as negligible, and proves the validity of our methodology to compute changes in quarterly payments due to variation on monetary policy rates.

Figure 5 shows how sensitive our methodology is to changes in interest rates for the example of loans between 100k-150k and a maturity of 15 years. The figure reports the mean computed variation of quarterly payments in the sub-sample of study and the 3-month Euribor for floating rate loans between 2004 and 2015. As the graph illustrates, quarterly payments on French ARL fall up to €460 on average compared to the previous quarter during the period of expansionary monetary policy which followed the 2007 crisis.

2.3 Weights

In addition to the concern of excluding observations using our interest rate derivation technique, a certain percentage of our loans were not "well-behaved" in other ways; i.e., they exhibited sporadic or unusual payments, were refinanced or contained other irregularities which prevented us from backing out interest rates and quarterly payment changes. We therefore exclude such cases as well, which were slightly more frequent for adjustable loans. Working only with the resulting sample could lead to additionally biases in our estimates. In particular, we risk underestimating the impact of monetary policy changes [8].

Consequently, we use a set of user-constructed loan weights for all estimations, which aim at being first and foremost representative of the type of interest rate (adjustable or fixed) and the default distribution during the period. We assume each loan to begin with a weight of 1 in the original data, since we work on true population (nearly five million loans) rather than a sample. After losing certain observations within the adjustable rate loan population, new weights are attributed to each observation. We proceed to calibrate the initial weights

[8] See Appendix A for more detail about the potential bias.

to re-balance our sample towards the original population distribution at each quarter. The "marginals" of the calibration (variables being calibrated) are equal to the distribution of default at each quarter and the stock of loans according to the type of interest rate, also on a per-quarter basis. The target population totals in the weight calibration are obtained from the initial true population totals for the period of study. This allows us to adjust the population at each quarter back to the original data's distribution.

3 Default in France

The French context represents an interesting domain for research of this question for several reasons. First, housing credit is 70% comprised of non-mortgage loans. Furthermore, our database is comprised entirely of (non-mortgage) housing loans guaranteed by a third-party insurer who covers the bank against losses in case of non-payment. In this type of arrangement, the title of the asset in question is never held (and cannot be transferred to) the lending institution, which complicates the process of housing debt discharge. Second, similar to many European countries, private persons cannot benefit from non-recourse style debts. At best, borrowers who cease repayment of their loans may apply via the Bank of France to have their case considered by an over-indebtedness board[9]. Applicants whose file is accepted may benefit from a reduction in debt owed, however at the expense of significant (and often permanent) loss of access to the banking system. Recourse to this measure is generally never understood to be analogous to a strategic default. Together, these specificities imply that strategic defaults are all but absent from our database, allowing us to better understand (and better isolate) the role of changes in payment size in a world where households have few alternatives but to meet their obligations at all cost.

Additionally, a recent report by the French Prudential and Resolution Authority of the Bank of France indicated that the share of adjustable rate loans with episodes of payment delinquency has sharply risen in recent years (see Figure 6). This evidence goes against the mechanism of monetary policy transmission which we aim to test in this paper. This highlights the importance of multivariate analysis on the housing default question, particularly accounting for self-selection issues.

Moreover, today's monetary policy environment represents an interesting context to study this question. 3-Month Euribor rates—the standard component of the interest rate of adjustable rate loans—have been below 1% since March 2012, and negative since May 2015.

[9] *Commission de surendettement* in French. More information available (in French) here.

Academics and investors alike have recently debated the prospect of a rise in interest rates in the medium term. In 2019, top Federal Reserve officials signaled no need for further interest rate decreases in the United States[10], while the Bank of England indicated that a growth rate of 1.5% may be sufficient to justify a rate increase[11]. Recent ECB research suggests that, across countries, adjustable rate loans become more popular in the presence of higher inflation, smaller correlation between unemployment and the short-term interest rate, higher financial literacy of households and where MBS-related regulation is looser (Albertazzi, Fringuellotti, and Ongena, 2018).

3.1 Descriptive Statistics

In Tables 1 and 2, we conduct simple t-tests on key variables which we later use in our regressions. Table 1 compares loans which have defaulted with those which have never defaulted, across the entirety of the sample, while table 2 compares adjustable and fixed rate loans. We firstly observe that defaulted loans show significantly higher ratings, indicating higher risk. This comes with an average down-payment rate of 10% and slightly over one other outstanding loan on average, compared to 19% and 0.8 respectively for healthy loans. This is also in line with the substantially higher annual interest rate that we observe for defaulting borrowers at origination. We also note that loans which default are longer in duration than those which do not, and that defaulters have significantly higher LTV ratios at origination. We see two important takeaways from this fact. The first is the intuitive reality that a longer lifespan of a loan increases the exposure period and the opportunities to default. The second interpretation—coupled with the fact that loans tend to default early in the lifespan—is that longer loans stay in high LTV-value ranges for longer, which can discourage borrowers as they may feel less is at stake in the event of delinquency.

Regarding the type of interest rate, we note several differences which suggest that adjustable rate borrowers have riskier profiles than fixed rate ones. Although they present similar interest rate levels at origin, they present longer maturity loans, higher LTV ratios and a higher number of other outstanding debts at origin. This explains the substantially higher rating level of floating loans on average and it is in line with the existence of self-selection into adjustable rate loans schedules by riskier borrower profiles.

Additional insights are provided by figures 8, 7 and 9. These graphs plot non-parametric hazard functions—i.e., the instantaneous probability of default at each moment through

[10] Derby (2019)
[11] Inman (2019)

time, conditional on never having previously defaulted—broken down by different buckets or categories. Firstly, figure 7 confirms our plain intuition that adjustable rate loans are more likely to default throughout the entirety of their lives in the sample. Independently of the fact that we evaluate a period of time with both contractionary and expansionary monetary policy action, we observe floating loans defaulting more than fixed rate loans. This is importantly related to the self-selection of riskier profiles into adjustable rate loans and highlights the importance of accounting for this bias in order to be able to compare peer loans.

Secondly, figure8 plots the default probability by credit default rating category and shows the striking discriminatory ability of internal credit ratings. As expected, default probability increases with the rating grade, indicating that risk D loans have almost twice higher probabilities of payment delinquency than rate C, while A borrowers hardly ever default at any time in the sample. This breakdown is also striking in Table 3, which shows a cross-tabulation of defaults by rating class. While the average default rate of the sample is 0.85%, borrowers rated as D have an average default rate of 4.36%, and A borrowers only 0.32%. The proper accuracy of the rating representing borrowers risk at origination is the main hypothesis of our identification strategy and helps us assuming that we account for any prior risk factor that would explain self-selection into adjustable rate loans. This is a very important variable in our analysis. As previously mentioned, the relevance of LTV ratios is confirmed in figure 9. Default is related with high Loan-to-Value ratios, this is when borrowers are most leveraged, having the lowest equity stake in the property.

Finally, we can see a common mode across all figures around the 3-4 year mark (and falling monotonically thereafter), indicating that loans are most likely to default early on (when LTV ratios are high). The probability of default after 10 years (having never defaulted previously) is half that of 5 years. This evidence may be explained by low equity households having more difficulties to refinance due to their tight financial situation. This may also be consistent with borrowers losing hope if financial difficulties have persisted from the beginning of the loan life.

4 Econometric Approach

The identification of the effect of payment size on housing loans default has often been presented in the literature as a difficult issue due to two main reasons. The first factor is the presence of certain time-varying macroeconomic conditions which have important consequences on the evolution of interest rates; interest rates rarely exhibit variations without changes in underlying business cycles. Second, the cross-sectional heterogeneity in interest rates (and thus monthly payments) may be simply explained by a selection bias; a borrower's risk of default at the origin explains the interest rate level of the loan, which in turn explains a significant part of payment heterogeneity and default at a given moment in time. Furthermore, we expect households to self-select into fixed or adjustable rates according to their characteristics, many of which may be unobservable. For example, borrowers with poor credit history may self-select away from traditional products in which more risk is borne by the lenders. Less risk-averse households with higher financial constraints may also chose floating-rate loans more often. As a consequence, we may observe floating loans to default more simply because such households represent particular profiles. Together, these factors present a reverse-causality issue, rendering pure cross-section and pure time-series analysis on interest rates to identify the link between payment size and default invalid (see Fuster and Willen (2017) for more discussion). Statistically consistent analysis would require the means to control for household selection effects and macroeconomic factors affecting loans granted conditions.

In order to overcome this difficulty initially pointed out by Yezer, Phillips, and Trost (1994), our preferred empirical design would compare two identical borrowers with the same risk profile at origination and equivalent loan combinations except for the degree of exposure to monetary policy changes. In other words, we would follow twin borrowers (and loans) that differ solely on the type of rate: floating versus fixed rate. The one with a floating loan would be exposed to changes on monthly payments due to monetary policy, while the one with fixed rate would be unaffected.

To come as close to this scenario as possible, we exploit our rich loan- and household-level data. We notably leverage the existence of a credit rating score, which is applied uniformly to households regardless of their loan choice and will allow for the comparison of peer borrowers. We assume all residual differences in risk profile across borrowers, unexplained by our controls, to be captured by this rating, an approach employed notably by Jones and Sirmans (2015). We thus assume that the choice between adjustable and fixed rate type is purely explained by exogenous factors other than the risk profile, such as risk aversion level. This is our best attempt to remedy the issue besides an experiment in which borrowers are randomly assigned with different monthly payments.

We propose the following discrete time proportional hazard model panel estimation following previous literature (Fuster and Willen (2017), Foote, Gerardi, and Willen (2012)):

$$Default_{it} = \beta_0 + \beta_1 MPshock_{it-1} + \beta_2 LTV_{it-1} + \beta_3 Controls_{i0} + \beta_5 Unemp_{dt-1} + \alpha_t + \alpha_d + \epsilon_{it} \quad (2)$$

where we model the risk of default of loan i at time t as a function of two main variables of interest: changes on quarterly payments due to a monetary policy shock $MPshock_{it-1}$ (as computed in section 2.1) and the housing equity position of the household over time LTV_{it-1}. The latter represents the outstanding principal over the current housing asset value at each period, and is presented in different categories in order to allow for non linear effects. Unlike Fuster and Willen (2017), we are able to directly measure the direct impact of ECB policy action on household quarterly payments.

Furthermore, we control for an exhaustive vector of loan and borrower specific characteristics at origination $Controls_{i0}$ which includes: loan maturity, loan-to-value, type of housing project (main residence, secondary residence or investment), household income, the number of total outstanding debts of the household and age of the borrowers. Accounting for loan-level information is important because housing loans are differentiated goods priced according to their attributes. For example, average interest rate of new housing loans varies in loan maturity and loan size. Banks allocate higher rates to longer loans in order to protect themselves from future uncertainty, since their visibility of long-term events decreases in length. Further, we expect banks to charge higher interest rates as the amount of the exposure to exogenous risks increases (loan size). Typically, loans with higher LTV ratios at origin represent riskier loans for the bank, often translating into higher borrowing costs. Certain loans which exhibit ratios above 1 (implying, e.g., a component of the loan intended for a renovation project) are considered particularly vulnerable. Similarly, investment projects may be perceived as riskier or more speculative than residential ones. Information regarding indebtedness and affordability, as well as the credit history of the borrower, are additional pieces of information used by lenders to asses borrower risk. As previously explained, in addition to previous controls, including a direct objective measure of risk (credit rating) exogenously evaluated by a third-party insurer institution ensures the control of selection effects, as explained by Jones and Sirmans (2015).

Department-specific unemployment changes U_{dt-1} are also included to understand the role of the job loss on loan delinquency. Time and department fixed effects are present in our econometric specifications to help control for all geographic heterogeneity (besides unemployment) and macroeconomic quarter-year-specific changes. These dummies help remove any structural differences in level of our variables, such as a lending premium present throughout a relatively disadvantaged region, a local trend in housing prices or household income, or the overall health of the credit market in a region of the country. This facilitates the assumption of exogenous monetary policy (driven at European level), which is assumed to be uncorrelated to regional economic dynamics. Including time fixed effects is important to account for time-varying economic conditions which have important consequences on the evolution of interest rates. Unlike in previous literature, both are possible here thanks to our unique measure of monetary policy shock at the loan level.

Lastly, discrete time proportional hazard models are conceived to explain transitions from one state to another (regular state to default, in our case). This class of models is particularly attractive as it is capable of handling so-called right-censored observations—in our case, loans which exit the panel (and thus live beyond our ability to monitor them) due to attrition or other reasons prior to experiencing default (see Allison (1982) for an in-depth discussion on this technique and its applications in the social sciences). Since a loan's life may stop at some point previous to 2015 for various reasons explained in section 2, we work with an unbalanced panel of data for our baseline specification. Additional tests are proposed in the robustness section 6.

5 Results and Discussion

Table 4 reports the results of a simplified version of equation 2, in which we first compare default probability between the two groups of interest: fixed and floating rate loans. Columns 2 to 4 provide results for a set of different fixed effects and controls. For simplicity in the interpretation of our results, we will focus on the effect of the variables of interest; the rest of the coefficients are generally in line with previous literature. The table begins with a simple loan type dummy showing that floating loans are 29% more likely to default on average during the period of study, and that higher LTV buckets are indeed riskier, as expected. Households starting a credit line with an underwater equity position (LTV $>$ 1) present 3 times higher probabilities of default than those with a loan lower than 60% the value of the housing asset (column 2). We then capture the monetary policy context by creating dummies representing periods of expansionary and contractionary monetary policy, later including our set of risk profile controls. We define a "contractionary" period as a quarter which experienced a rise in the 3-months Euribor for at least two consecutive quarters.

As expected, for identical borrower profile and loan characteristics, floating loans default around 30% less in periods of expansionary monetary policy (with decreasing interest rates) compared to peer fixed loans. Entering a period of increasing rates (contractionary monetary policy) raises the default probability by 13% for ARL on average, while it has no significant impact for twin FRL. Further, in column 4, we note that including the set of controls inverts the coefficient of our rate type dummy (ADJ). This confirms the existence of self-selection into variable rate loans of riskier profiles, and shows the importance of accounting for selection effects. Our contractionary monetary policy dummy (and its interaction with adjustable-rate loans) remains unchanged in sign. This result reinforces the validity of our identification strategy.

Table 5 reports the main results of estimating equation **??** including different fixed effects and controls. Our main result, as observed in column 3, is that a 1 percentage point shock on quarterly payments last quarter increases the default probability by 5%. This effect is significant at 0.1%. We give an idea of the economic magnitude of this result in section 5.1. The nature of our data and the french regulation allows us to claim that this result represents non-voluntary defaults. This implies that rising policy rates during periods of ECB contractionary action has important consequences for households financial fragility, which are not explained by own propensity to default for riskier households nor strategic default. Borrowers of adjustable rate housing loans are exposed to changes on interest rates and importantly react to those variations. This can be an important advantage during periods of falling rates, but can become a substantial threat at the time of contractionary monetary policy.

Contracting a loan with higher LTV levels at origination (or, alternatively, lower down-payment rates) is associated with much higher default risk during the credit life. Taking out a loan for more than the value of the home increases default risk by almost 40%, according to our benchmark specification in column 3. Moreover, the housing equity position at the moment of nonpayment plays a major role in explaining default. Looking to current LTV buckets, we see a non-linear effect through time. In particular, reaching the last 20% of outstanding debt reduces the probability of delinquency by almost half compared to households in an underwater position. One possible explanation for this phenomenon is that more heavily indebted households encounter harsher financing conditions if they seek to take out an additional loan or to refinance their original loan. Households with lower LTV ratios therefore may default less often due to the relative ease at which they can access new or better financing following an idiosyncratic shock. Furthermore, they may be willing to undertake additional efforts at finding means to ensure the continuity of payments since they are closer to the natural end of maturity.

The most discriminant control variable is the internal rating: each risk tranche monotonically increases the probability of default, while the riskiest risk tranche is over 10 times more likely to default, all else equal. This suggests the existence of additional borrower profile features or soft information which are invisible for us, but required by lenders to evaluate risk profile. As expected, higher household income helps survival in the sample, while other outstanding debts burden a household's ability to repay, confirming an intuition provided by Li, White, and Zhu (2011). Primary residences are the ones defaulting the most, while rental properties are less likely to default than primary residences and secondary residences, providing evidence against reckless or speculative investment in this type of asset. This finding is further in line with the fact that housing investment projects are evaluated by banks according to their associated rental revenues, which remain an additional guarantee[12]. Additionally, one may expect more financially sophisticated borrowers with greater positions of wealth to make housing investments.

5.1 Policy Rates and Default

The benchmark estimation presented in the previous section finds a significant relationship between ongoing households' housing loan payment schedules and default probability in France. Nevertheless, this connection is driven by changes in interest rates to which loan amortisation tables are indexed, as explained in section 2.1. In this section, we provide evidence about the more direct link between policy rates themselves and payment schedules. This additional exercise is important because the variation in the policy rate has not been modelled to directly explain default in our main specifications presented previously, therefore precluding the precise quantification of a concrete monetary policy change on the probability of default. This exercise is therefore useful to clarify the transmission channel and highlight its magnitude in order to analyze the effect that a change on policy rates would have on delinquency events.

As follows, we study variations in quarterly payments, which themselves depend on the policy rate (the 3-month Euribor)[13]. We therefore choose to estimate a linear relationship between changes in the 3-month Euribor and the subsequent changes to the quarterly loan payments for floating loans in our sample as follows:

[12] French banks deduct around 50% of expected rents from total debt payments in order to compute affordability ratios.

[13] $\Delta M = Principal_{t-1} \times \Delta R - P_{t-1} \times R_t + \Delta P$

$$MPshock_{it} = \lambda_0 + \lambda_1 \Delta R_{it} + \lambda_2 Principal_{it} + \upsilon_{it} \quad (3)$$

While $MPshock_{it}$ represents the quarterly payment change between t and $t-1$ of loan i, ΔR_{it} is the change on interest rate of the loan schedule with the interest rate defined as $R_t = S + E_{t-1}$, with S being the (time invariant) spread and E the 3-month Euribor. By definition, any change on interest rates is driven by changes in policy rates. Importantly, the effect of a given policy rate change will have heterogeneous results on households payments depending on the total outstanding principal of each loan in t. In order to account for the possible disparities in loans structure over time, which may be explained by our sample construction, we therefore include $Principal$ as a control variable. We ultimately regress different estimations for 4 different groups corresponding to quantiles of interest rates R during the period of study in order to be capture different monetary policy environments.

The results of the estimation of equation 3 for these four different quantiles of interest rate *levels* are summarized in figure 10. The plots represent the slope of each estimation assuming a linear effect of policy rates changes on quarterly payments growth. As expected, the higher the interest rate environment (quantile 4), the smaller the relative impact of a given change on interest rates. Overall, a 100 basis point change on interest rates leads to a quarterly payment growth between 7% and 9% on average.

Then, we use these magnitudes and test their impact on default from our baseline specification presented in column three of table 5. Precisely, we compute the predicted margins (i.e $Pr(\hat{Default})$) for different levels of $MPshock$ (containing the range of rates obtained in the previous step) holding all other explanatory variables at their sample means (except for fixed effect dummies, which are kept at their observed values). This exercise provides us with the predicted default rate in our sample for different assumptions of monetary policy payment shocks between -10% and 10%. Results are presented in figure 11.

Intuitively, we obtain higher delinquency rates for larger changes on quarterly payments. The probability of default increases from $\approx 0.025\%$—when there is no change on quarterly payment—to $\approx 0.04\%$ when quarterly payment grows 10pp. This small magnitude of these results in absolute terms is explained by the enormous size of our control sample (fixed rate loans); indeed, loans with fixed payment schedules over their life represent around 90% of our sample and are not impacted by changes in policy rates. This fact may in part explain why the French delinquency rate is one of the lowest of the European Union in general (1.4% in France vs 2% on average in European countries in 2017 according to the ACPR (2017)). Moreover, we study a segment of the French market known to be less risky (loans which are insured through a guarantee mechanism), which may further explain the resulting smaller unconditional probability of default provided in this exercise.

For reference, we found that a 100 basis point rise on policy rates increases the quarterly payments $MPshock$ in 9% on average on an environment of low interest rates in the first step of this section. Subsequently, according to our baseline results presented in the previous section, a rise of 9pp in the monetary policy shock to quarterly payment size can be translated into an increase of default probabilities by around 45%, all else equal. This impact on default probability is significant in relative magnitude. Nevertheless, it merits emphasising that the large relative increase should be understood in conjunction with the small absolute probabilities presented in figure 11, since changes in policy rates only concern a small part of the spectrum of ongoing loans (adjustable rate loans).

The evidence provided in this section suggests that changes in the 3-month Euribor may have substantial consequences for households linked to variable payment schemes. However, observed increases in the average overall delinquency rates may be small, given the strong prevalence of fixed rate loans in France, making the detection of such defaults difficult to detect. This is important since exposed households who choose adjustable rate loans are known to represent a riskier segment of the population and to be particularly vulnerable ex-ante. By quantifying the impact of a change on policy rates in loan quarterly payments, we provide some elements about the magnitude of the monetary policy transmission onto the housing sector according to different policy paths. While this exercise cannot be interpreted as predictive for future events regarding monetary policy, they may be useful and provide some insight on the direction of the consequences that may be expected. This can be particularly relevant for countries and financial systems with an important share of variable rate loans, openly exposed to policy changes.

5.2 Heterogeneous Effects of Monetary Policy

The results of our baseline specification are strong in magnitude and significance. In this section, we test whether the identified effects are heterogeneously distributed across the population according to certain borrower characteristics. Several interactions between monetary policy shock and different loan and borrower characteristics are therefore presented in Table 6.

First, we test for a possible interaction between our monetary policy shock and LTV levels France (column 1), as suggested in US literature (e.g., Gerardi et al. (2018)). We thus combine current LTV ratios and our measure of quarterly payments changes due to policy action. We find no significant difference regarding the impact of monetary policy shocks on housing loans delinquency depending on the level of equity. Households do, however, default twice as much when LTV ratios are in their highest level; although their equity position does not affect the way they face and absorb changes on interest rates. Here, we nonetheless avoid associating this variable with strategic defaults for several reasons. Firstly, these loans are not mortgages, so borrowers cannot abandon their loans by surrendering their home to banks. Further, the French jurisdiction differs from the American context regarding the ability to engage in this practice, as well as regarding personal bankruptcy procedures, as explained above. Lastly, high (and, especially, positive) LTV values are a necessary but not sufficient condition for default; most voluntary defaults occur with high LTV values, although not all high LTV defaults correspond to such cases.

Overall, our results are in line with the idea that declaring bankruptcy for housing debt holders is not a choice but a forced result of a bad financial situation. Indeed, as discussed above, since the forgiveness of housing accumulated debts in France requires a long administrative process with very strict criteria and an element of discretion regarding the granting of bankruptcy status, we expect little effect of this phenomenon on our estimates. Additionally, the fact that households more frequently default early in the life of the loan (when equity is lower), regardless of changes in monthly payment shocks may imply that affordability is a problem that is carried over from the beginning of the credit.

Importantly, we would like to asses how households react to quarterly payments changes depending on their income level. Unfortunately, we do not observe income evolution in our data and providing proper estimates about this question represents a difficult task. Nevertheless, we tested a certain number of specifications which include an interaction term between income[14] at origin and our variable of interest ($MPshock$), with the aim at assuming that the level of income at origination is similar during the entire period of study. This strategy does not allow the analysis of changes in income, but only how relative changes on loan payments affect the default probability depending on income level. First, we estimate our benchmark model with our interaction of interest during the first 7 years of the loan life[15]. This alternative is quite imperfect because it is known that income at the beginning of the working life highly evolve, creating estimation bias which depends on age. Second, we restricted the sample to individuals who contracted the loan between 35 and 45 years

[14] We test both income as continuous variable and in quantiles.

[15] Exemple: an individual aged 32 years old at origination till her 39 years old, and an individual aged 50 at loan origination till her 57 years old.

old and we observe their credit life only during this age window[16]. This alternative relies on the income literature showing that during this period of the life-cycle income stabilizes (Mazumder (2005)). According to the literature, observing income at one of these points is representative of the average income around the 40's. Although more precise than the first approach, this alternative also present weaknesses. Some individuals are only observed during a couple of years, and depending on weather you are 37 or 43 the income bias may be still different. Finally, we adapt the last approach by restricting the sample to individuals who contracted a loan between 35 and 38 years old, and we follow them till their 45. This reduced the bias associated to the age of start and relies on the income stability hypotheses. Nevertheless, none of these alternative give significant results on the existence of heterogeneous effects of quarterly payment changes depending on income levels. Thus, we are unable to provide evidence regarding this issue and we believe further research must be done, particularly using more adequate time-varying income data.

We additionally sought to test several hypotheses relative to the role of job loss in housing loan default. Namely, we wanted to understand how unemployment shocks (at the department level) interact with payment size shocks, and for which segment of the population these effects play the most pronounced role. To test the latter idea, we chose the socioeconomic and employment categories which we assume to be the be the most exposed to sectorial shocks. We create a "Vulnerable" dummy which is equal to 1 for the worker/employee[17] level employment status (as opposed to management-level employees). Table 7 reports how such households make up 24.7% of our sample, yet account for 30.7% of defaults. Results are presented in columns 2 to 4, the latter representing the most developed specification.

Interestingly, we find that simple payment shocks do not have a significant impact on the delinquency probability of the less vulnerable employment segment, while belonging to the more vulnerable segment of households increases default probability by 3.9% after a 100 basis points monetary policy shock. Nevertheless, facing a payment variation and an unemployment shock both at the same time seems to play a role for both groups of interest. The same monetary policy shock increases their default probability by 1.2% if it is combined with a change on unemployment of the same magnitude. Nevertheless, this additional effect is slightly lower for vulnerable households, who already accumulate the initial effect of the monetary policy shock. As a consequence, vulnerable households' likelihood of non-payment

[16] Example: an individual aged 37 at loan origination till her 45 years old, and an individual aged 40 at loan origination till her 45 years old. Individuals aged less than 35 or more than 45 at loan origination are excluded.

[17] *Employé et ouvrier* INSEE category

increases by 4.7% if both events take place simultaneously. Furthermore, we find a specific effect for "vulnerable" socioeconomic category which defaults 7.5% more on average compared to the non-vulnerable households during the period of study. Finally, unemployment seems to have no impact on default probability for any of the population groups on its own. This is not surprising, as France provides a very robust unemployment subsidy system, which further is consistent with the idea presented by Hsu, Matsa, and Melzer (2014) that states with generous unemployment insurance experience less mortgage delinquency.

These results are of particular importance because they signal the high exposure of households to employment stability, which can increase the impact of a monetary policy shock (on default probability) by 12.2% (7.5% + 4.7%) compared to households who have been through the same shock from an stable employment position. The magnitude of this result is in line with the those of Gerardi et al. (2013), who find that unemployment shocks increases the probability of default by 5-13pp. This evidence shows the existence of a heterogeneous impact of monetary policy across the population.

6 Robustness

6.1 Non-random renegotiation

A second issue to take into account is the non-randomness of early exit (or, alternatively, the unbalanced nature) of our panel. As explained, we observe credit lines until the end of their lives (whether they default or not), or alternatively until the moment of total repayment due to a renegotiation or other reason (e.g. inheritance). The latter represents the end of the credit line and is explained by the original wealth levels of the households, which are accounted for using household characteristics at origination and the current LTV. Nevertheless, households renegotiating their loans will close their current credit line and start a new one, which cannot be traced or precisely identified in the data. Thus, we stop observing a loan's evolution at the time of a refinancing. This is potentially problematic, since households leaving the sample due to renegotiation are expected to exhibit more creditworthiness than those staying, who may have attempted to refinance but were refused (see Mian, Rao, and Sufi (2013) for a detailed discussion). As suggested by previous literature, the role of house prices on the creditworthiness of households is not considered crucial in the French case, due to the low share of mortgage loans within the mass of housing credit[18]. More generally, our

[18] Only, 30% of new loans according to the ACPR (2017)

data-set contains exclusively non-mortgage loans, although other characteristics explaining households' creditworthiness over time are unobservable, and as a result, the potential for a self-selection problem remains.

For this reason, we seek to test our baseline specification against alternative setups which serve to remedy these concerns. First, we restrict the sample to the first 7 years of life, assuming a smaller likelihood for creditworthiness to change in the years immediately after the initial loan was granted. Second, we restrict the sample to only adjustable rate loans, which have no incentive to renegotiate their credit contracts. These tests are presented in Table 8. The magnitude and significance of our main result remains virtually unchanged in the first two columns, and decreases to 2% taking a sample of only adjustable rate loans. However, our last column is significant only at the 10% confidence interval range. Further, by restricting our sample, we see that the effect of negative equity is much more severe for adjustable-rate loans; our Current LTV >1 dummy jumps to its highest value in column 8. This result suggests that the initial span of credit lines may have been affected by a selected attrition in which households with better financial situations left the observed sample under a different timing compared to remaining loans.

Finally, the estimation of columns 3 and 4 allows us to test the robustness of our specification in a more balanced setting. The results are shown to be equivalent, suggesting no relevance on the unbalanced structure of the data at the origin of our sample of loans.

7 Conclusion

In this paper, we investigate the effect of monetary policy on the propensity of a household to involuntarily default on their housing loan. Using a confidential Banque de France data-set of around 5 million housing loans, we reconstruct full amortization tables for each loan, computing monetary policy driven changes on quarterly payments. We conclude that a 100 basis points variation in quarterly payment due to a change policy rate increases the probability of default by 5%. Extrapolated to a concrete change of 1pp on policy rates, the resulting increase on default probability for exposed loans lies around 45%. Further, due to jurisdictional differences between France and other countries regarding bankruptcy laws (as well as the absence of mortgage-style loans in our data), we are able to isolate purely involuntary defaults in our analysis. This desirable trait of our data helps to identify (and control for) the determinants of default driven by financial distress, as opposed to voluntary default from solvent households, which have different dynamics and causes. Conducting an estimation on a database which contains both types may serve to obfuscate the true factors explaining loan delinquency.

Additionally, as in previous literature, we identify a strong role of employment stability against default risk during periods of contractionary monetary policy engaged by the ECB. Finally, we provide ample evidence consistent with the existence of a self-selection of riskier borrowers into floating rate loans schedules, as suggested in the literature. Our results are robust to a set of alternate specifications which serve to remedy potential selection concerns. While the magnitude of our coefficient decreases considerable in some cases, there remains a positive and significant effect of the growth rate monetary policy shocks.

This evidence is of more crucial importance for policy makers, especially in a period where many observers predict interest rates to rise in the short term as a result of the long-lasting expansionary monetary policy, which has put on the spot financial institutions position. Increasing policy rates in the years to come may have substantial negative effects on households' financial situations, leading to a wave of default events, although a total welfare analysis of such a scenario is left for future research.

References

ACPR (2017). *Housing finance in France, 2017*. Tech. rep. ACPR.

Albertazzi, Ugo, Fulvia Fringuellotti, and Steven Ongena (2018). "Fixed rate versus adjustable rate mortgages: Evidence from euro area banks".

Allison, Paul D (1982). "Discrete-time methods for the analysis of event histories". *Sociological methodology* 13, pp. 61–98.

Byrne, David, Robert Kelly, Conor O'Toole, et al. (2017). "How does monetary policy pass-through affect mortgage default? Evidence from the Irish mortgage market". *Central Bank of Ireland*.

Derby, Michael S (2019). "Fed's Williams Says No Rate Changes Penciled In, Economy Will Drive Policy". *The Wall Street Journal*. URL: https://www.wsj.com/articles/feds-williams-says-no-rate-changes-penciled-in-now-economy-will-drive-policy-11573058005.

Elul, Ronel et al. (2010). "What" triggers" mortgage default?" *American Economic Review* 100.2, pp. 490–94.

Faivre, Laurent et al. (2018). *Le financement de l'habitat en 2017*. Tech. rep. Banque de France.

Foote, Christopher L, Kristopher S Gerardi, and Paul S Willen (2012). *Why did so many people make so many ex post bad decisions? The causes of the foreclosure crisis*. Tech. rep. National Bureau of Economic Research.

Fuster, Andreas and Paul S Willen (2017). "Payment size, negative equity, and mortgage default". *American Economic Journal: Economic Policy* 9.4, pp. 167–91.

Gerardi, Kristopher et al. (2013). "Unemployment, negative equity, and strategic default". *Available at SSRN 2293152*.

Gerardi, Kristopher et al. (2017). "Can't pay or won't pay? Unemployment, negative equity, and strategic default". *The Review of Financial Studies* 31.3, pp. 1098–1131.

— (2018). "Can't pay or won't pay? unemployment, negative equity, and strategic default". *The Review of Financial Studies* 31.3, pp. 1098–1131.

Haughwout, Andrew, Richard Peach, and Joseph Tracy (2008). "Juvenile delinquent mortgages: Bad credit or bad economy?" *Journal of Urban Economics* 64.2, pp. 246–257.

Hsu, Joanne W, David A Matsa, and Brian T Melzer (2014). *Positive externalities of social insurance: Unemployment insurance and consumer credit*. Tech. rep. National Bureau of Economic Research.

Inman, Phillip (2019). "Bank of England warns of interest rate rise over next three years". *This article is more than 6 months old Bank of England warns of interest rate rise over next three years*. URL: https://www.theguardian.com/business/2019/may/02/bank-of-england-holds-interest-rates-and-vows-to-restrict-future-rises-.

Jones, Timothy and G Stacy Sirmans (2015). "The underlying determinants of residential mortgage default". *Journal of Real Estate Literature* 23.2, pp. 167–205.

Keys, Benjamin J et al. (2014). *Mortgage rates, household balance sheets, and the real economy*. Tech. rep. National Bureau of Economic Research.

Li, Wenli, Michelle J White, and Ning Zhu (2011). "Did bankruptcy reform cause mortgage defaults to rise?" *American Economic Journal: Economic Policy* 3.4, pp. 123–47.

Mayer, Christopher, Karen Pence, and Shane M Sherlund (2009). "The rise in mortgage defaults". *Journal of Economic perspectives* 23.1, pp. 27–50.

Mazumder, Bhashkar (2005). "Fortunate sons: New estimates of intergenerational mobility in the United States using social security earnings data". *Review of Economics and Statistics* 87.2, pp. 235–255.

Mian, Atif, Kamalesh Rao, and Amir Sufi (2013). "Household balance sheets, consumption, and the economic slump". *The Quarterly Journal of Economics* 128.4, pp. 1687–1726.

Mian, Atif and Amir Sufi (2009). "The consequences of mortgage credit expansion: Evidence from the US mortgage default crisis". *The Quarterly Journal of Economics* 124.4, pp. 1449–1496.

— (2011). "House prices, home equity-based borrowing, and the US household leverage crisis". *American Economic Review* 101.5, pp. 2132–56.

Tracy, Joseph S and Joshua Wright (2012). "Payment changes and default risk: The impact of refinancing on expected credit losses". *FRB of New York Staff Report* 562.

Yezer, Anthony MJ, Robert F Phillips, and Robert P Trost (1994). "Bias in estimates of discrimination and default in mortgage lending: The effects of simultaneity and self-selection". *The Journal of Real Estate Finance and Economics* 9.3, pp. 197–215.

Figures and Tables

Figure 1: Stable Monetary Policy Periods. **Source:** ECB Data Warehouse.

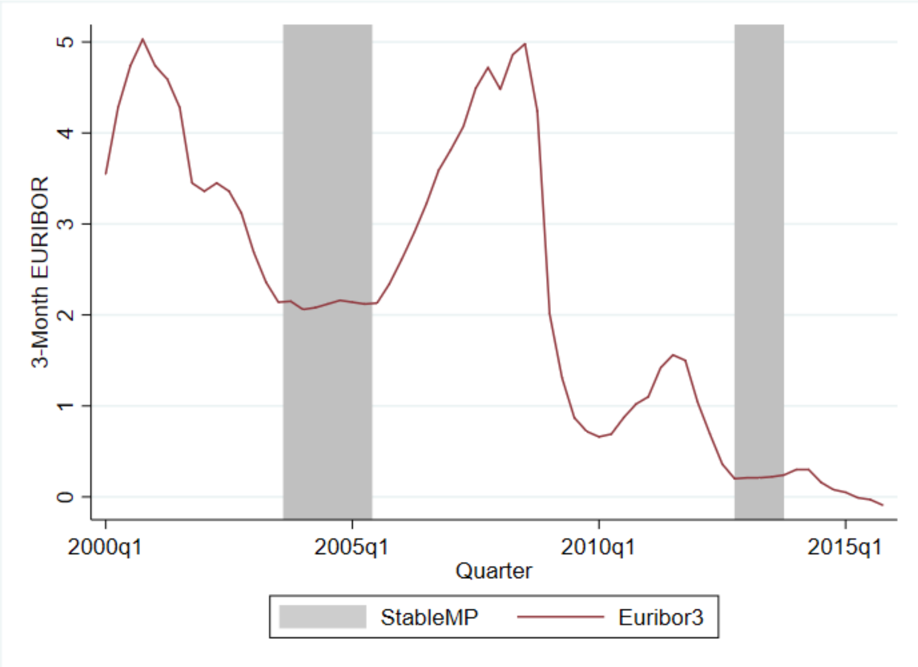

Figure 2: True vs Approximated Interest Rate, simulated loans

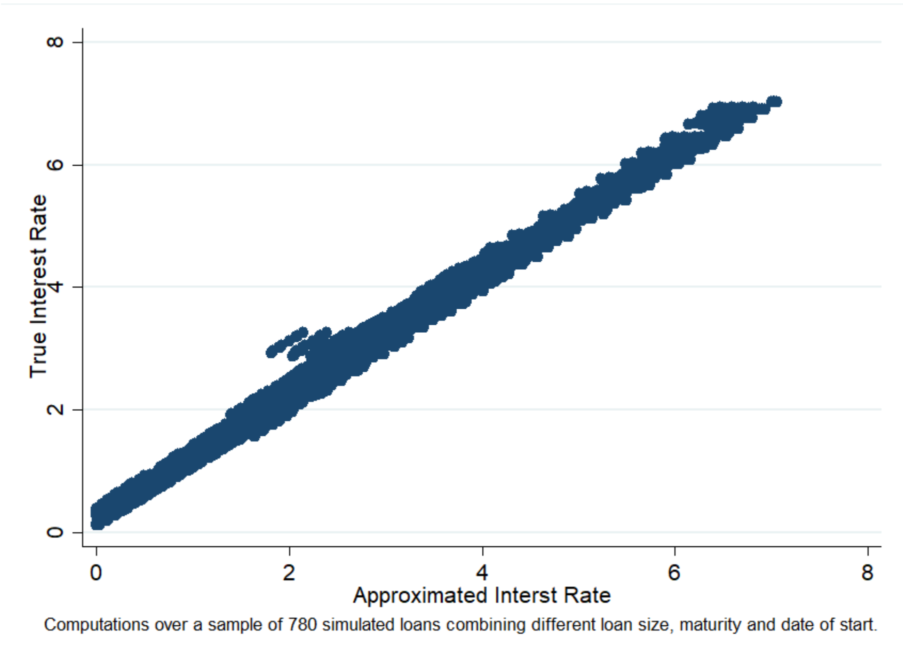

Figure 3: Average Interest Rate at Origination by Quarter **Source:** Banque de France, Webstat.

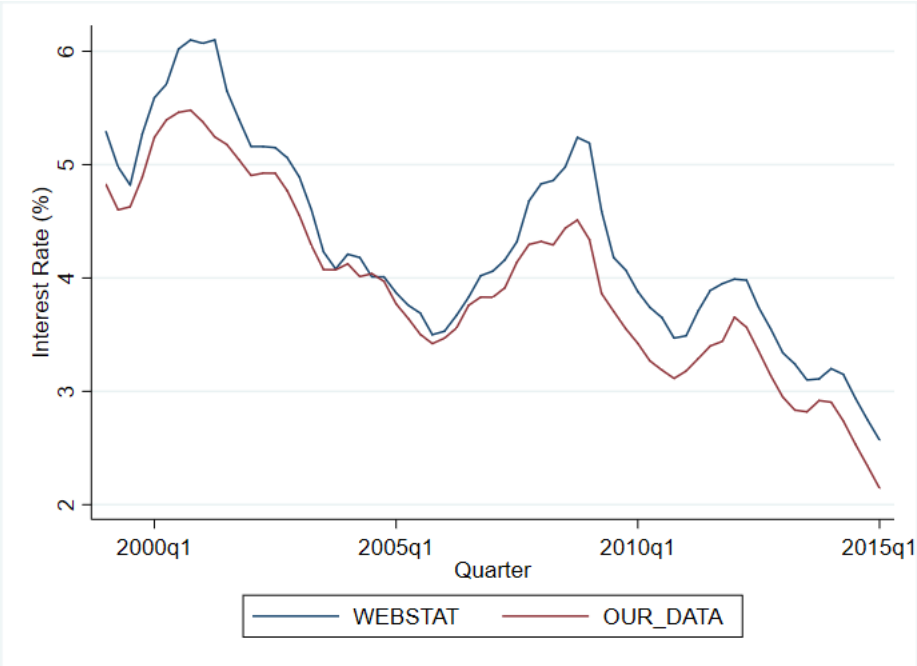

Figure 4: True vs Approximated Monetary Policy shock, simulated loans

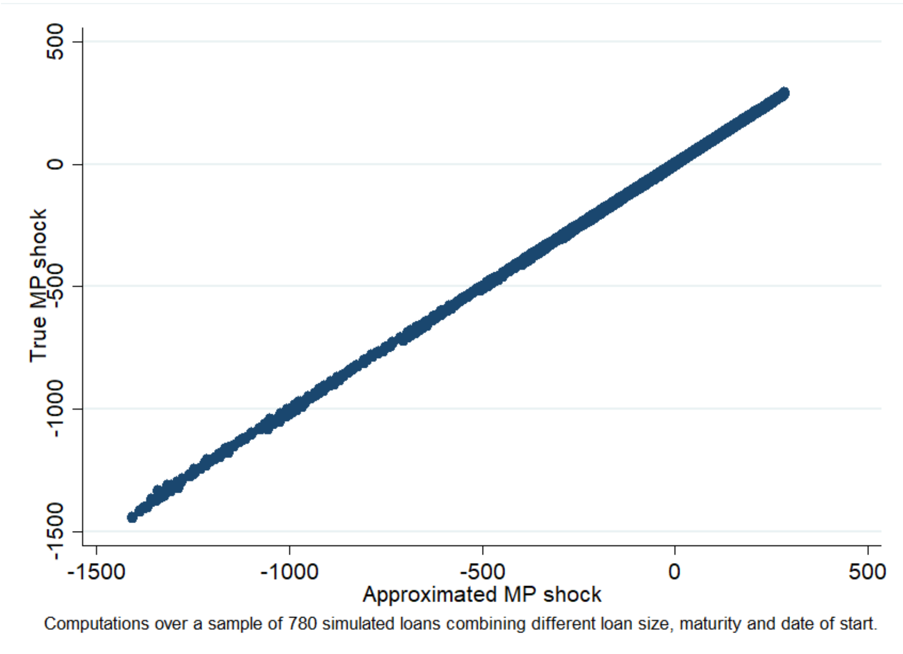

Figure 5: Average change on quarterly payments, Adjustable Rate Loans. **Source:** Banque de France.

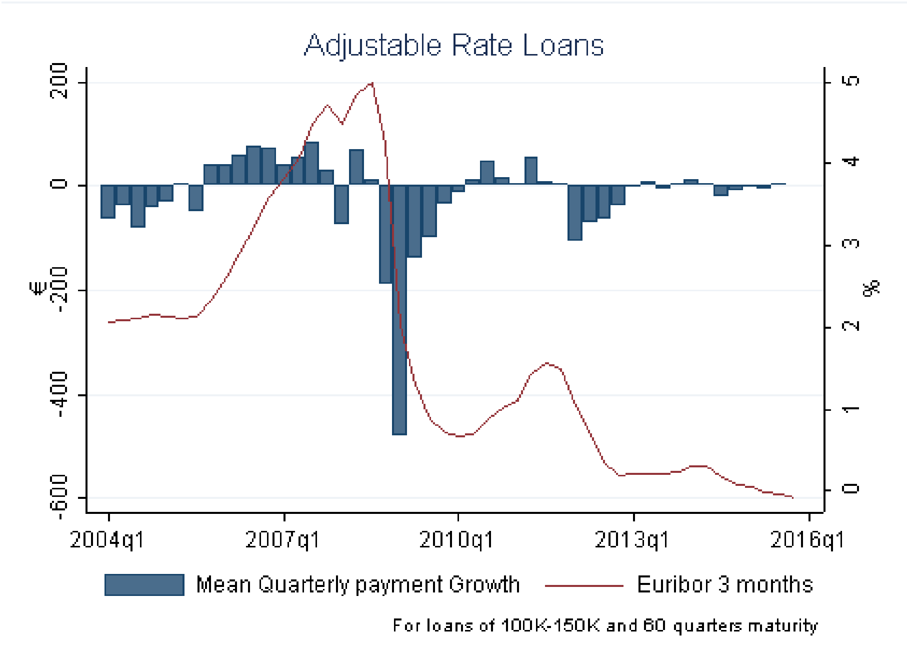

Figure 6: Share of doubtful payment outstanding loans by loan type. **Source:** Banque de France.

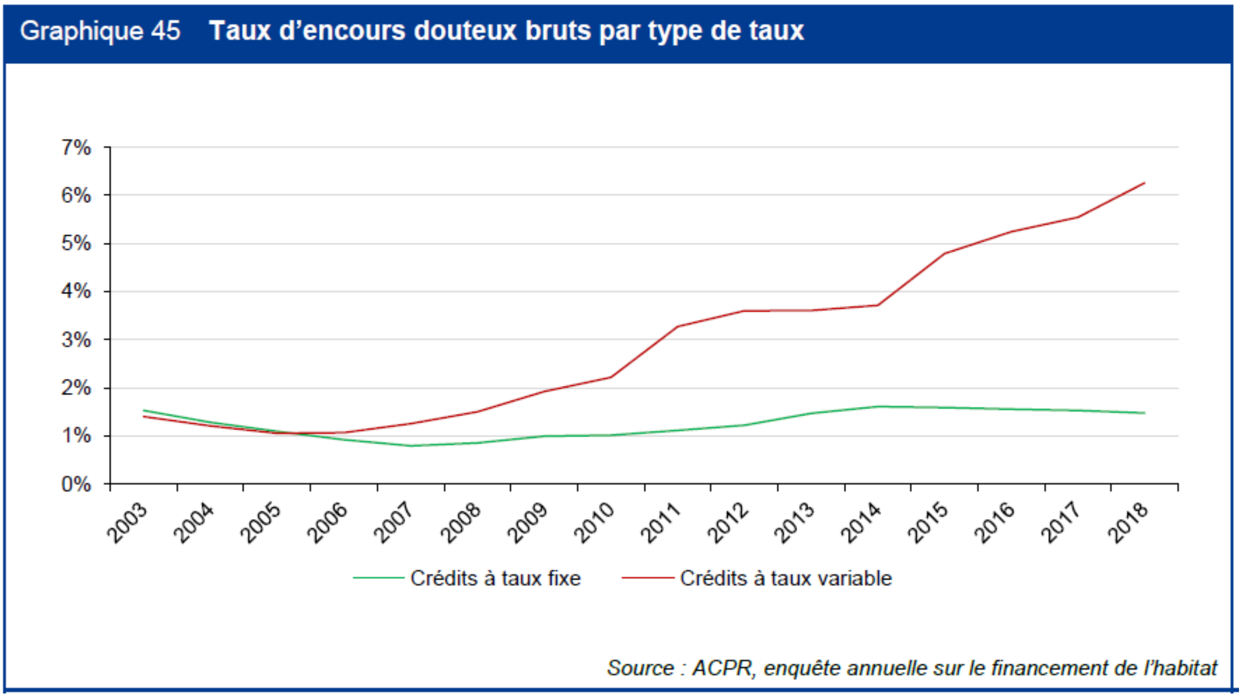

Figure 7: Hazard function by loan type. **Source:** Banque de France.

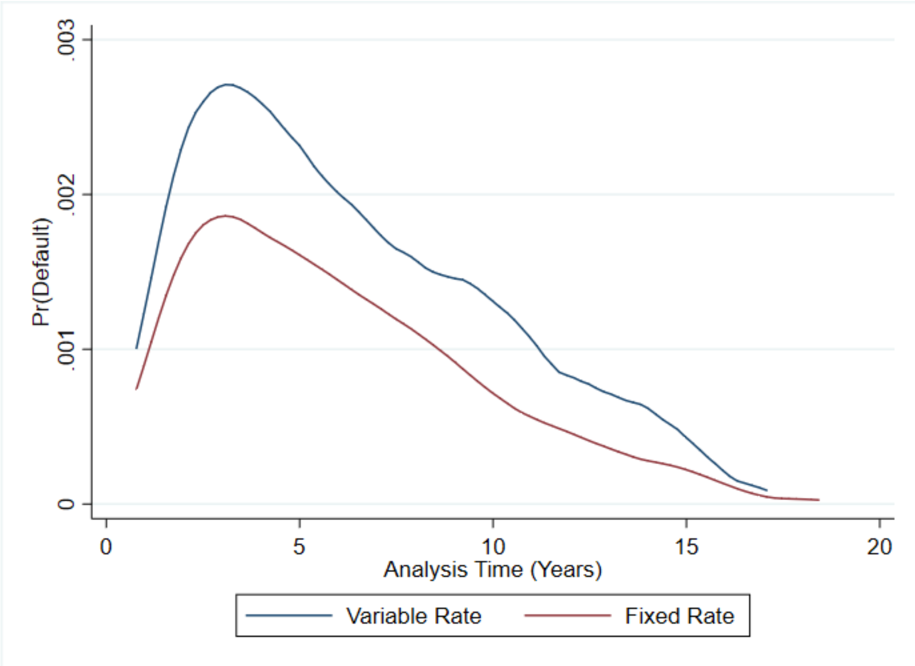

Figure 8: Hazard function by probability-of-default rating. **Source:** Banque de France.

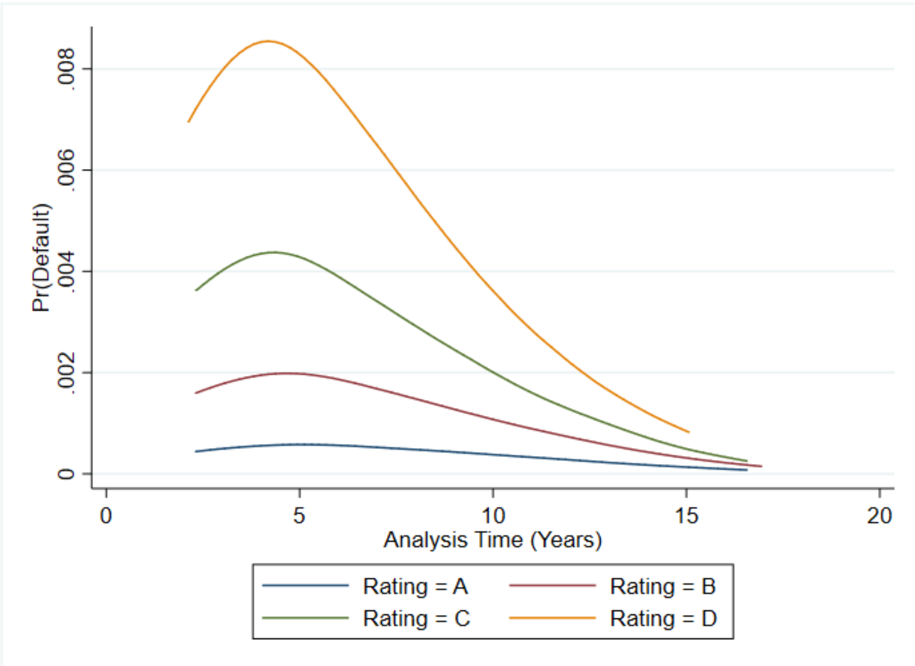

Figure 9: Hazard function by LTV tranche. **Source:** Banque de France.

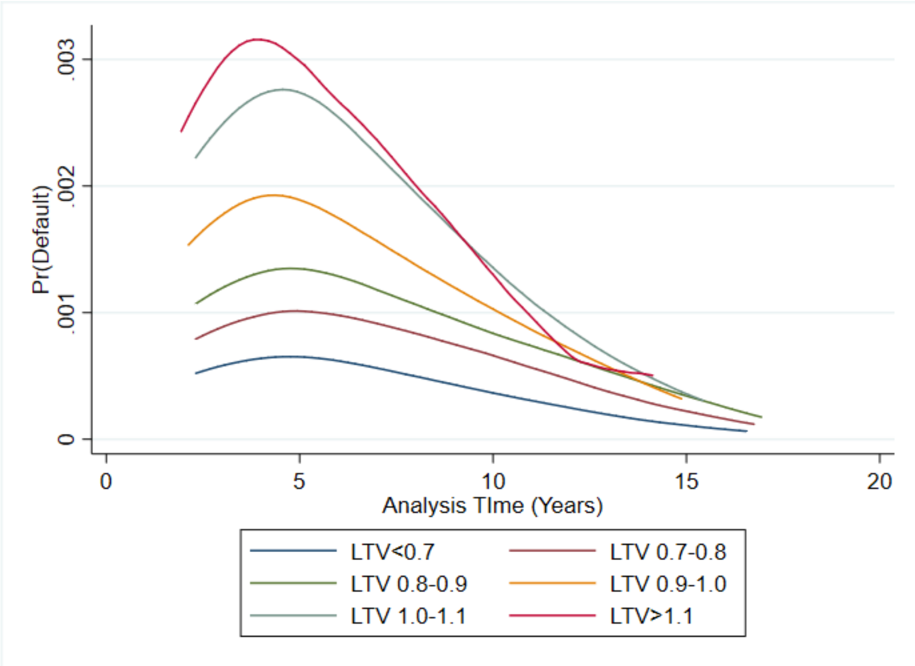

Figure 10: Predicted Quarterly Payment Growth (%) (X axis) by 3-month Euribor shocks (Y axis) **Source:** Banque de France.

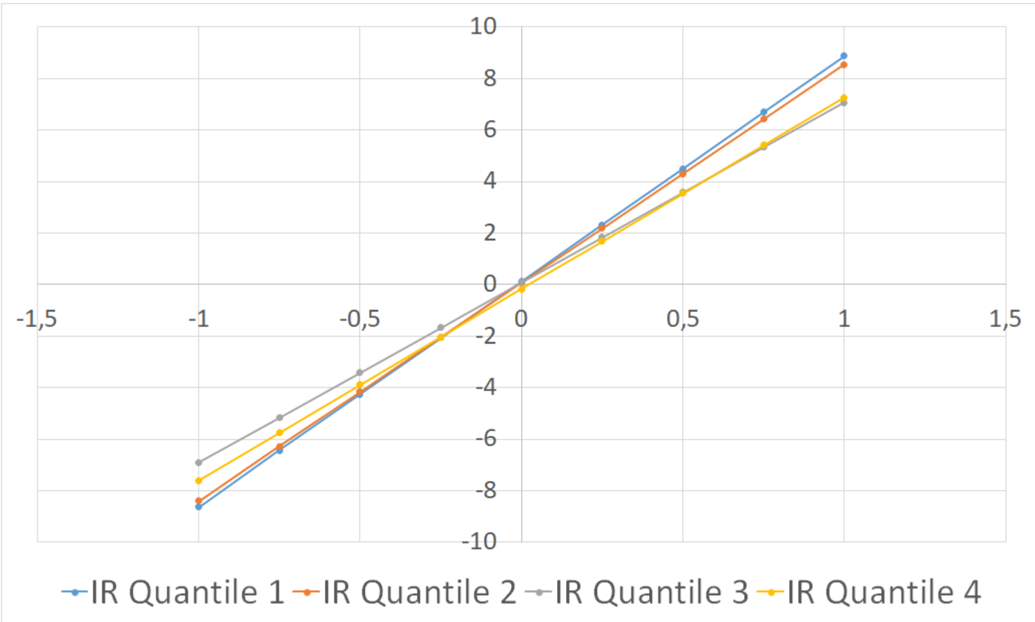

Figure 11: Predicted $Pr(Default)$ by monetary policy shocks. **Source:** Banque de France.

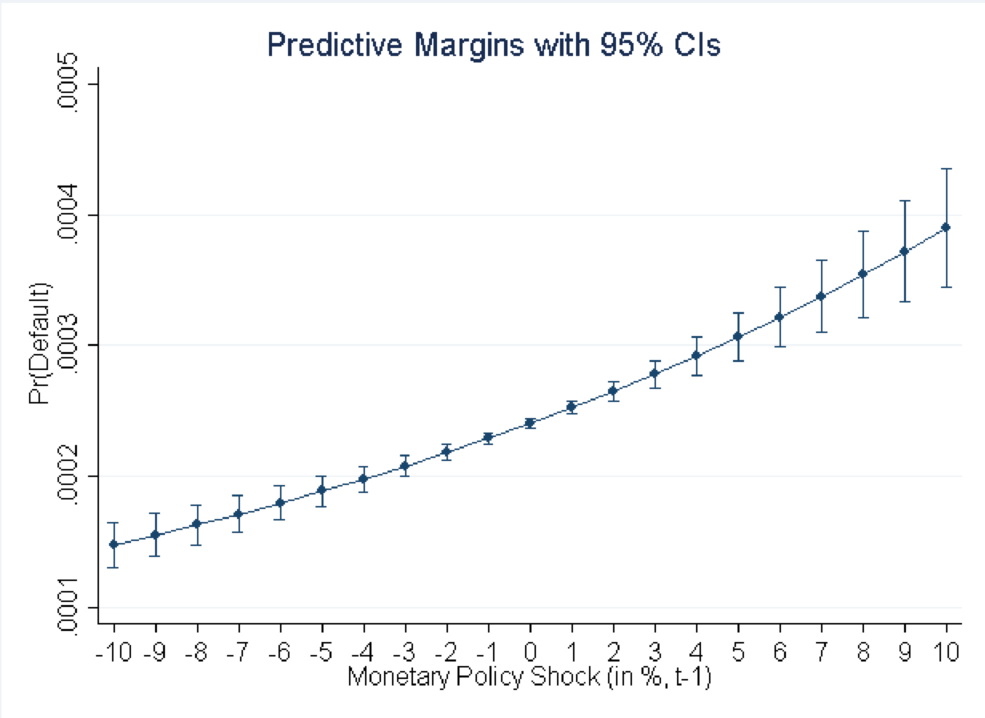

Table 1: Descriptive Statistics: T-Test (Default v Healthy)

	(1) *Defaulted*		(2) *Healthy*		(3) *Difference*	
	mean	sd	mean	sd	b	t
Quarterly Payment Growth (%)	-0.02	0.89	-0.03	0.78	0.00	(1.61)
Annual Interest Rate (%, Origination)	4.23	1.02	3.95	1.07	0.27***	(192.81)
Quarterly Total Payment	2,509	1,919	2,521	1,726	-12.09***	(-4.38)
Loan Size (Origination)	132,878	113,871	126,442	103,326	6,436***	(41.41)
Loan Duration (Years, Origination)	18.45	4.90	16.88	5.05	1.57***	(234.82)
Down-payment Rate (%, Origination)	9.62	17.73	18.56	22.89	-8.94***	(-368.38)
LTV (Origination)	0.90	0.18	0.81	0.23	0.09***	(368.38)
Credit Rating (PD)	2.33	1.03	1.57	0.79	0.76***	(536.37)
Number of Other Outstanding Debts (Origination)	1.01	1.28	0.80	1.16	0.21***	(118.45)
Annual Income (Origination)	52,583	62,413	46,670	112,493	5,914***	(68.82)
Average Age of Debtors (Origination)	39.02	9.27	39.05	9.54	-0.04**	(-2.82)
Observations	540,029		74,446,744		74,986,773	

Table 2: Descriptive Statistics: T-Test (Adjustable v Fixed)

	(1) *Adjustable*		(2) *Fixed*		(3) *Difference*	
	mean	sd	mean	sd	b	t
Quarterly Payment Growth (%)	-0.40	3.06	0.00	0.00	-0.40***	(-283.58)
Annual Interest Rate (%, Origination)	3.93	1.74	3.96	0.99	-0.02***	(-29.58)
Quarterly Total Payment	2,736.91	1,890.77	2,504.00	1,712.75	232.91***	(267.64)
Loan Size (Origination)	148,748	127,901	124,341	100,469	24,407***	(476.23)
Loan Maturity (Years, Origination)	17.92	5.15	16.79	5.03	1.13***	(537.94)
Down-payment Rate (%, Origination)	13.48	20.33	18.98	23.04	-5.50***	(-655.25)
LTV (Origination)	0.87	0.20	0.81	0.23	0.05***	(655.25)
Credit Rating (PD)	2.07	0.99	1.53	0.76	0.54***	(1,372.46)
Number of Other Outstanding Debts (Origination)	0.94	1.23	0.79	1.16	0.15***	(306.31)
Annual Income (Origination)	51,911	66,831	46,211	115,641	5,700***	(192.99)
Average Age of Debtors (Origination)	39.54	9.47	39.00	9.54	0.53***	(137.64)
Observations	6,598,934		68,387,839		74,986,773	

Table 3: Share of default loans by credit ratings

	Credit Rating (A)	Credit Rating (B)	Credit Rating (C)	Credit Rating (D)	Total
No Default	2,137,422	1,130,740	259,278	141,371	3,668,811
	58.26	30.82	7.07	3.85	100.00
	99.68	98.94	97.72	95.64	99.15
Default	6,929	12,111	6,036	6,446	31,522
	21.98	38.42	19.15	20.45	100.00
	0.32	1.06	2.28	4.36	0.85
Total	2,144,351	1,142,851	265,314	147,817	3,700,333
	57.95	30.89	7.17	3.99	100.00
	100.00	100.00	100.00	100.00	100.00

Table 4: Default, adjustable loans and contractionary monetary policy

	(1)	(2)	(3)	(4)
LTV (Origin) $\in < 0.6$	Ref.	Ref.	Ref.	Ref.
LTV (Origin) $\in$ 0.6, 0.8	1.442***	1.426***	1.390***	1.138***
	(0.036)	(0.035)	(0.036)	(0.031)
LTV (Origin) $\in$ 0.8, 1	2.278***	2.219***	2.110***	1.310***
	(0.049)	(0.048)	(0.048)	(0.033)
LTV (Origin) > 1	3.253***	3.107***	2.966***	1.359***
	(0.068)	(0.065)	(0.064)	(0.035)
Fixed Rate	Ref.	Ref.	Ref.	Ref.
Adjustable Rate (ADJ)	1.240***	1.297***	1.187***	0.699***
	(0.019)	(0.020)	(0.025)	(0.015)
Expansionary MP			Ref.	Ref.
Contractionary MP			0.981	0.966
			(0.018)	(0.018)
ADJ $\times$ Contractionary MP			1.095**	1.128***
			(0.037)	(0.038)
Controls	No	No	No	Yes
Department Fixed Effect	No	Yes	Yes	Yes
Time Fixed Effect	No	Yes	Yes	Yes
Loans Types	All	All	All	All
Period	2004-15	2004-15	2004-15	2004-15
Pseudo R2	0.011	0.018	0.020	0.053
Observations	63,001,397	62,999,029	58,518,231	57,343,931

Controls include: maturity, quarter of the credit life, type of housing project,
rating, number of other outstanding debts, household age and department unemployment.
Exponentiated coefficients; Standard errors in parentheses
* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table 5: Default, the impact of a monetary policy shock

	(1)	(2)	(3)
Quarterly Payment Growth (%)	1.023***	1.039***	1.050***
	(0.007)	(0.007)	(0.006)
LTV (Origin) ∈ 0.6-0.8	1.434***	1.388***	1.143***
	(0.036)	(0.036)	(0.032)
LTV (Origin) ∈ 0.8-1	2.422***	2.086***	1.307***
	(0.052)	(0.048)	(0.034)
LTV (Origin) > 1	3.712***	2.970***	1.375***
	(0.076)	(0.066)	(0.036)
Current LTV ∈ 0.2-0.4		0.944***	1.126***
		(0.017)	(0.022)
Current LTV ∈ 0.4-0.6		0.923***	1.160***
		(0.017)	(0.027)
Current LTV ∈ 0.6-0.8		0.935***	1.275***
		(0.018)	(0.034)
Current LTV ∈ 0.8-1		1.242***	1.742***
		(0.023)	(0.050)
Current LTV > 1		1.564***	1.968***
		(0.038)	(0.066)
Credit Rating = B			2.913***
			(0.047)
Credit Rating = C			5.642***
			(0.112)
Credit Rating = D			10.046***
			(0.208)
Number of Other Outstanding Debts			1.049***
			(0.005)
Log(Household Income)			0.934***
			(0.010)
Average Age of Debtors (Origination)			1.008***
			(0.001)
Maturity 11-15 years			0.912***
			(0.019)
Maturity 16-20 years			0.947**
			(0.023)
Maturity > 20 years			1.042
			(0.029)
Rental Property			0.894***
			(0.014)
Secondary Residence			0.927**
			(0.029)
Age of Loan (in Quarters)			1.026***
			(0.001)
Unemployment Rate Growth (%)			0.996*
			(0.002)
Department Fixed Effect	No	Yes	Yes
Time Fixed Effect	No	Yes	Yes
Loans Types	All	All	All
Period	2004-15	2004-15	2004-15
Pseudo R2	0.012	0.020	0.052
Observations	60,560,076	57,149,077	55,988,009

Exponentiated coefficients; Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Table 6: Default, heterogeneous effects of monetary policy

	(1)	(2)	(3)	(4)
Quarterly Payment Growth (%)	1.045**	1.044***	1.015*	1.003
	(0.021)	(0.007)	(0.008)	(0.009)
Current LTV ∈ 0.2-0.4	1.126***	1.123***	1.127***	1.124***
	(0.022)	(0.022)	(0.022)	(0.022)
Current LTV ∈ 0.4-0.6	1.160***	1.156***	1.162***	1.158***
	(0.027)	(0.027)	(0.027)	(0.027)
Current LTV ∈ 0.6-0.8	1.275***	1.270***	1.277***	1.272***
	(0.034)	(0.034)	(0.034)	(0.034)
Current LTV ∈ 0.8-1	1.742***	1.733***	1.738***	1.730***
	(0.050)	(0.050)	(0.050)	(0.050)
Current LTV > 1.0	1.969***	1.958***	1.959***	1.950***
	(0.066)	(0.066)	(0.066)	(0.066)
Current LTV ∈ 0.2-0.4 × Quarterly Payment Growth (%)	1.004			
	(0.025)			
Current LTV ∈ 0.4-0.6 × Quarterly Payment Growth (%)	1.001			
	(0.023)			
Current LTV ∈ 0.6-0.8×Quarterly Payment Growth (%)	0.994			
	(0.023)			
Current LTV ∈ 0.8-1×Quarterly Payment Growth (%)	1.019			
	(0.025)			
Current LTV > 1×Quarterly Payment Growth (%)	1.041			
	(0.034)			
Vulnerable		1.074***		1.075***
		(0.015)		(0.015)
Vulnerable×Quarterly Payment Growth (%)		1.020		1.039**
		(0.013)		(0.017)
Unemployment Rate Growth (%)	0.996*	0.996*	0.997	0.999
	(0.002)	(0.002)	(0.002)	(0.003)
Unemployment Rate Growth (%)×Quarterly Payment Growth (%)			1.011***	1.012***
			(0.002)	(0.002)
Vulnerable×Unemployment Rate Growth (%)				0.994
				(0.004)
Vulnerable×Quarterly Payment Growth (%)×Unemp Rate Growth (%)				0.994*
				(0.003)
Controls	Yes	Yes	Yes	Yes
Department Fixed Effect	Yes	Yes	Yes	Yes
Time Fixed Effect	Yes	Yes	Yes	Yes
Loans Types	All	All	All	All
Period	2004-15	2004-15	2004-15	2004-15
Pseudo R2	0.052	0.052	0.052	0.052
Observations	55,988,009	55,988,009	55,988,009	55,988,009

Controls include: maturity, quarter of the credit life, type of housing project, rating, number of other outstanding debts, household age.
Exponentiated coefficients; Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Table 7: Descriptive Statistics: Vulnerable Households

	No Vulnerable	Vulnerable	Total
No Default	2,762,027 75.28 99.22	906,784 24.72 98.94	3,668,811 100 99.15
Default	21,833 69.26 0.78	9,689 30.74 1.06	31,522 100 0.85
Total	2,783,860 75.23 100	916,473 24.77 100	3,700,333 100 100

Table 8: Default, robustness checks

	(1)	(2)	(3)	(4)
Quarterly Payment Growth (%)	1.046***	1.057***	1.031***	1.019*
	(0.008)	(0.007)	(0.010)	(0.010)
Current LTV ∈ 0.2-0.4	0.886***	0.976	0.871***	1.266***
	(0.021)	(0.025)	(0.045)	(0.078)
Current LTV ∈ 0.4-0.6	0.927***	1.016	0.677***	1.126
	(0.022)	(0.028)	(0.038)	(0.088)
Current LTV ∈ 0.6-0.8	0.932***	1.089***	0.463***	1.031
	(0.022)	(0.032)	(0.032)	(0.102)
Current LTV ∈ 0.8-1	1.276***	1.587***	0.508***	1.536***
	(0.029)	(0.049)	(0.042)	(0.183)
Current LTV > 1	1.603***	1.882***	1.065	2.454***
	(0.045)	(0.067)	(0.124)	(0.344)
LTV (Origin) ∈ 0.6-0.8	1.372***	1.196***	1.216**	0.823**
	(0.044)	(0.040)	(0.105)	(0.075)
LTV (Origin) ∈ 0.8-1	2.079***	1.342***	1.990***	1.038
	(0.058)	(0.041)	(0.149)	(0.086)
LTV (Origin) > 1	3.046***	1.410***	1.958***	0.899
	(0.080)	(0.043)	(0.144)	(0.076)
$\Delta UnemploymentRate_{t-1}$		0.996		0.974***
		(0.003)		(0.008)
Controls	No	Yes	No	Yes
Department Fixed Effect	Yes	Yes	Yes	Yes
Time Fixed Effect	Yes	Yes	Yes	Yes
Loans Types	First 7 Yrs	First 7 Yrs	Adj Only	Adj Only
Period	2004-15	2004-15	2004-15	2004-15
Pseudo R2	0.023	0.060	0.017	0.053
Observations	45,683,677	44,757,278	4,080,193	4,023,478

Controls include: maturity, quarter of the credit life, type of housing project,
rating, number of other outstanding debts, household age and department unemployment.
Exponentiated coefficients; Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Appendices

A The bias of adjustable rate loans

A substantial number of adjustable credit lines are lost during the process of data cleaning and amortization tables reconstruction. Thus, we do not work with the true population but a sample of the original data. This is not problematic if a proper process of random selection is applied. Nevertheless, this is not our case, since most of our discarded data refers to adjustable loans, and fixed rate loans are mostly unaffected. The resulting sample is a non-randomized fraction of the original data and it may bias subsequent estimation results on default probability. The direction of the bias depends on the resulting defaults distribution.

Average default probabilities $\overline{D}$ conditional on the type of interest rate ($Adjustable$) in the true population are equal to:

$$\overline{D}|_{Adjustable=1} = \beta_0 + \beta_1$$

$$\overline{D}|_{Adjustable=0} = \beta_0$$

where the true population relationship is $D_{it} = \beta_0 + \beta_1 Adjustable_i$.

Using the non-random sample, the estimated equation of the true relationship is represented as:

$$D_{it} = \hat{\beta}_0 + \hat{\beta}_1 Adjustable_i + \epsilon_{it}$$

where,

$$\mathbb{E}(D|_{adjustable=0}) = \hat{\beta}_0 = \overline{D}|_{Adjustable=0}$$

$$\mathbb{E}(D|_{adjustable=1}) = \hat{\beta}_0 + \hat{\beta}_1 \neq \overline{D}|_{Adjustable=1}$$

The estimated expected value of default for fixed rate loans using the non-random sample is equal to the true population average, which indicates that the estimates of β_0 are unbiased. Nevertheless, the expected default of adjustable loans differs from the true population mean. Since β_0 is consistently estimated, the source of bias must be a change on the distribution of defaults for adjustable loans. In other words, defaults within the adjustable group are not missing at random. In particular, comparisons between original data and the resulting sample show that default probability of adjustable rate loans of our sample is lower than in the original population, such that $\hat{\beta}_1$ and the subsequent odd ratio are underestimated:

$$\hat{\beta}_1 < \beta_1$$

$$OddRatio = \frac{\beta_0 + \hat{\beta}_1}{\beta_0} < \frac{\beta_0 + \beta_1}{\beta_0}$$

B Re-constructing amortisation tables

In this appendix we aim at detailing the process of re-construction of amortisation tables presented in section 2.1 with examples. We choose a 200,000€ loan with 20 years maturity and a starting interest rate of 4.1%. Then, we simulate a conventional loan payment table for two different adjustment schedules: fixed and adjustable. Starting from a complete information table, we do drop all elements which are not available in our real data set and we apply our reconstruction methodology step by step. We do simulate a loan in order to be able to compare final computations with initial ones. Our lack of certain variables would not have allowed such a comparison using our data set.

Fixed Rate Loans FRL

Table B.1 presents the complete amortisation table of the chosen loan example for a fixed rate schedule computed as if we were the borrower. Interest rate R and total payments M are constant over the entire loan life, such that the monetary policy shock is always equal to 0.

Table B.1: FRL amortisation table - 200k, 20 years, 4.1% started in 2004q1

Quarter	Date	Interest Rate (R)	Outstanding Principal	Principal payment (P)	Interest payment (I)	Total payment (M)	MP shock
1	2004q1	4.1	200,000.0 €	1,625.6 €	2,050.0 €	3,675.6 €	
2	2004q2	4.1	198,374.4 €	1,642.3 €	2,033.3 €	3,675.6 €	0.0 €
3	2004q3	4.1	196,732.1 €	1,659.1 €	2,016.5 €	3,675.6 €	0.0 €
4	2004q4	4.1	195,072.9 €	1,676.1 €	1,999.5 €	3,675.6 €	0.0 €
5	2005q1	4.1	193,396.8 €	1,693.3 €	1,982.3 €	3,675.6 €	0.0 €
6	2005q2	4.1	191,703.5 €	1,710.7 €	1,965.0 €	3,675.6 €	0.0 €
7	2005q3	4.1	189,992.8 €	1,728.2 €	1,947.4 €	3,675.6 €	0.0 €
8	2005q4	4.1	188,264.6 €	1,745.9 €	1,929.7 €	3,675.6 €	0.0 €
9	2006q1	4.1	186,518.6 €	1,763.8 €	1,911.8 €	3,675.6 €	0.0 €
10	2006q2	4.1	184,754.8 €	1,781.9 €	1,893.7 €	3,675.6 €	0.0 €
...	...	...	...	...	...	...	...
40	2013q4	4.1	122,537.1 €	2,419.6 €	1,256.0 €	3,675.6 €	0.0 €
41	2014q1	4.1	120,117.5 €	2,444.4 €	1,231.2 €	3,675.6 €	0.0 €
42	2014q2	4.1	117,673.0 €	2,469.5 €	1,206.1 €	3,675.6 €	0.0 €
43	2014q3	4.1	115,203.5 €	2,494.8 €	1,180.8 €	3,675.6 €	0.0 €
44	2014q4	4.1	112,708.7 €	2,520.4 €	1,155.3 €	3,675.6 €	0.0 €
45	2015q1	4.1	110,188.4 €	2,546.2 €	1,129.4 €	3,675.6 €	0.0 €
46	2015q2	4.1	107,642.2 €	2,572.3 €	1,103.3 €	3,675.6 €	0.0 €
47	2015q3	4.1	105,069.9 €	2,598.7 €	1,077.0 €	3,675.6 €	0.0 €
48	2015q4	4.1	102,471.2 €	2,625.3 €	1,050.3 €	3,675.6 €	0.0 €

Table B.2 represents the exact information we do observe in our data. Hence, interest rates and quarterly payments are omitted in order to simulate the exact data conditions we face in our paper.

Table B.2: FRL amortisation table - step 0

Quarter	Date	Interest Rate (R)	Outstanding Principal	Principal payment (P)	Interest payment (I)	Total payment (M)	MP shock
1	2004q1		200,000.0 €				
2	2004q2		198,374.4 €				
3	2004q3		196,732.1 €				
4	2004q4		195,072.9 €				
5	2005q1		193,396.8 €				
6	2005q2		191,703.5 €				
7	2005q3		189,992.8 €				
8	2005q4		188,264.6 €				
9	2006q1		186,518.6 €				
10	2006q2		184,754.8 €				
...	...	...	...	...	...	...	...
40	2013q4		122,537.1 €				
41	2014q1		120,117.5 €				
42	2014q2		117,673.0 €				
43	2014q3		115,203.5 €				
44	2014q4		112,708.7 €				
45	2015q1		110,188.4 €				
46	2015q2		107,642.2 €				
47	2015q3		105,069.9 €				
48	2015q4		102,471.2 €				

We now apply the reconstruction process presented in section 2.1. Results are presented in table B.3. First, we compute principal payments at each quarter P_t. Second, we apply the following formula,

$$R = \frac{\Delta P}{P_{t-1}} \tag{4}$$

Table B.3: FRL amortisation table - step 1 and 2

		Second		First			
Quarter	Date	Interest Rate (R)	Outstanding Principal	Principal payment (P)	Interest payment (I)	Total payment (M)	MP shock
1	2004q1	4.1	200,000.0 €	1,625.6 €			
2	2004q2	4.1	198,374.4 €	1,642.3 €			
3	2004q3	4.1	196,732.1 €	1,659.1 €			
4	2004q4	4.1	195,072.9 €	1,676.1 €			
5	2005q1	4.1	193,396.8 €	1,693.3 €			
6	2005q2	4.1	191,703.5 €	1,710.7 €			
7	2005q3	4.1	189,992.8 €	1,728.2 €			
8	2005q4	4.1	188,264.6 €	1,745.9 €			
9	2006q1	4.1	186,518.6 €	1,763.8 €			
10	2006q2	4.1	184,754.8 €	1,781.9 €			
...	...	...	...	...			
40	2013q4	4.1	122,537.1 €	2,419.6 €			
41	2014q1	4.1	120,117.5 €	2,444.4 €			
42	2014q2	4.1	117,673.0 €	2,469.5 €			
43	2014q3	4.1	115,203.5 €	2,494.8 €			
44	2014q4	4.1	112,708.7 €	2,520.4 €			
45	2015q1	4.1	110,188.4 €	2,546.2 €			
46	2015q2	4.1	107,642.2 €	2,572.3 €			
47	2015q3	4.1	105,069.9 €	2,598.7 €			
48	2015q4	4.1	102,471.2 €	2,625.3 €			

Finally, since we know the loan maturity and we computed the interest rate, we can easily fill in remaining gaps using classic amortisation table formulas. The result of our reconstructed table is presented in table B.4. As observed, we exactly reproduced the original fixed rate loan schedule presented in table B.1, which evidences the validity of our methodology to reconstruct missing information, interest rates and the monetary policy shock in this case.

Table B.4: FRL amortisation table - step 3

Quarter	Date	Second Interest Rate (R)	Outstanding Principal	First Principal payment (P)	Third Interest payment (I)	Third Total payment (M)	Third MP shock
1	2004q1	4.1	200,000.0 €	1,625.6 €	2,050.0 €	3,675.6 €	
2	2004q2	4.1	198,374.4 €	1,642.3 €	2,033.3 €	3,675.6 €	0.0 €
3	2004q3	4.1	196,732.1 €	1,659.1 €	2,016.5 €	3,675.6 €	0.0 €
4	2004q4	4.1	195,072.9 €	1,676.1 €	1,999.5 €	3,675.6 €	0.0 €
5	2005q1	4.1	193,396.8 €	1,693.3 €	1,982.3 €	3,675.6 €	0.0 €
6	2005q2	4.1	191,703.5 €	1,710.7 €	1,965.0 €	3,675.6 €	0.0 €
7	2005q3	4.1	189,992.8 €	1,728.2 €	1,947.4 €	3,675.6 €	0.0 €
8	2005q4	4.1	188,264.6 €	1,745.9 €	1,929.7 €	3,675.6 €	0.0 €
9	2006q1	4.1	186,518.6 €	1,763.8 €	1,911.8 €	3,675.6 €	0.0 €
10	2006q2	4.1	184,754.8 €	1,781.9 €	1,893.7 €	3,675.6 €	0.0 €
...	...	...	...	...	...	...	...
40	2013q4	4.1	122,537.1 €	2,419.6 €	1,256.0 €	3,675.6 €	0.0 €
41	2014q1	4.1	120,117.5 €	2,444.4 €	1,231.2 €	3,675.6 €	0.0 €
42	2014q2	4.1	117,673.0 €	2,469.5 €	1,206.1 €	3,675.6 €	0.0 €
43	2014q3	4.1	115,203.5 €	2,494.8 €	1,180.8 €	3,675.6 €	0.0 €
44	2014q4	4.1	112,708.7 €	2,520.4 €	1,155.3 €	3,675.6 €	0.0 €
45	2015q1	4.1	110,188.4 €	2,546.2 €	1,129.4 €	3,675.6 €	0.0 €
46	2015q2	4.1	107,642.2 €	2,572.3 €	1,103.3 €	3,675.6 €	0.0 €
47	2015q3	4.1	105,069.9 €	2,598.7 €	1,077.0 €	3,675.6 €	0.0 €
48	2015q4	4.1	102,471.2 €	2,625.3 €	1,050.3 €	3,675.6 €	0.0 €

Adjustable Rate Loans ARL

Table B.5 presents the complete amortisation table of the chosen loan example for an adjustable rate schedule computed as if we were the borrower. Interest rates R_t adjust every quarter following 3-month Euribor of the past quarter. Thus, total payments M vary over the entire loan life, such that the monetary policy shock depends on the magnitude of the change. For the sake of space, we only present a window of time around the quarters of stable Euribor evolution. As previously, table B.6 presents the example of the exact information we observe in our data set. Again, interest rates and payments are unknown and we apply our methodology to approximate them.

Table B.5: ARL amortisation table - 200k, 20 years, 4.1% started in 2004q1

Quarter	Date	Euribor 3m t-1	Spread (S)	Interest Rate (R)	Outstanding Principal	Principal payment (P)	Interest payment (I)	Total payment (M)	MP shock
1	2004q1	2.15	1.95	4.10	200,000.0 €	1,625.6 €	2,050.0 €	3,675.6 €	
2	2004q2	2.06	1.95	4.01	198,374.4 €	1,658.5 €	1,988.7 €	3,647.2 €	-28.4 €
3	2004q3	2.08	1.95	4.03	196,715.8 €	1,671.6 €	1,981.9 €	3,653.5 €	6.2 €
4	2004q4	2.12	1.95	4.07	195,044.2 €	1,681.2 €	1,984.6 €	3,665.8 €	12.3 €
5	2005q1	2.16	1.95	4.11	193,363.0 €	1,691.3 €	1,986.8 €	3,678.1 €	12.2 €
6	2005q2	2.14	1.95	4.09	191,671.7 €	1,712.2 €	1,959.8 €	3,672.0 €	-6.1 €
7	2005q3	2.12	1.95	4.07	189,959.6 €	1,733.2 €	1,932.8 €	3,666.0 €	-6.0 €
8	2005q4	2.13	1.95	4.08	188,226.4 €	1,749.1 €	1,919.9 €	3,669.0 €	3.0 €
9	2006q1	2.34	1.95	4.29	186,477.3 €	1,730.6 €	2,000.0 €	3,730.6 €	61.6 €
10	2006q2	2.61	1.95	4.56	184,746.7 €	1,703.6 €	2,106.1 €	3,809.7 €	79.1 €
...	...	...	...	...	...	...	...	...	...
37	2013q1	0.20	1.95	2.15	129,994.5 €	2,626.7 €	698.7 €	3,325.4 €	-28.7 €
38	2013q2	0.21	1.95	2.16	127,367.7 €	2,639.4 €	687.8 €	3,327.2 €	1.8 €
39	2013q3	0.21	1.95	2.16	124,728.3 €	2,653.7 €	673.5 €	3,327.2 €	0.0 €
40	2013q4	0.22	1.95	2.17	122,074.7 €	2,666.6 €	662.3 €	3,328.9 €	1.7 €
41	2014q1	0.24	1.95	2.19	119,408.1 €	2,678.4 €	653.8 €	3,332.1 €	3.3 €
42	2014q2	0.30	1.95	2.25	116,729.7 €	2,685.1 €	656.6 €	3,341.7 €	9.6 €
43	2014q3	0.30	1.95	2.25	114,044.6 €	2,700.2 €	641.5 €	3,341.7 €	0.0 €
44	2014q4	0.16	1.95	2.11	111,344.3 €	2,733.1 €	587.3 €	3,320.4 €	-21.3 €
45	2015q1	0.08	1.95	2.03	108,611.2 €	2,757.4 €	551.2 €	3,308.6 €	-11.8 €
46	2015q2	0.05	1.95	2.00	105,853.9 €	2,775.0 €	529.3 €	3,304.3 €	-4.3 €
47	2015q3	-0.01	1.95	1.94	103,078.8 €	2,796.0 €	499.9 €	3,295.9 €	-8.4 €
48	2015q4	-0.03	1.95	1.92	100,282.9 €	2,811.8 €	481.4 €	3,293.2 €	-2.7 €

Table B.6: ARL amortisation table - Step 0

Quarter	Date	Euribor 3m t-1	Spread (S)	Interest Rate (R)	Outstanding Principal	Principal payment (P)	Interest payment (I)	Total payment (M)	MP shock
1	2004q1	2.15			200,000.0 €				
2	2004q2	2.06			198,374.4 €				
3	2004q3	2.08			196,715.8 €				
4	2004q4	2.12			195,044.2 €				
5	2005q1	2.16			193,363.0 €				
6	2005q2	2.14			191,671.7 €				
7	2005q3	2.12			189,959.6 €				
8	2005q4	2.13			188,226.4 €				
9	2006q1	2.34			186,477.3 €				
10	2006q2	2.61			184,746.7 €				
...	...	...			...				
37	2013q1	0.20			129,994.5 €				
38	2013q2	0.21			127,367.7 €				
39	2013q3	0.21			124,728.3 €				
40	2013q4	0.22			122,074.7 €				
41	2014q1	0.24			119,408.1 €				
42	2014q2	0.30			116,729.7 €				
43	2014q3	0.30			114,044.6 €				
44	2014q4	0.16			111,344.3 €				
45	2015q1	0.08			108,611.2 €				
46	2015q2	0.05			105,853.9 €				
47	2015q3	-0.01			103,078.8 €				
48	2015q4	-0.03			100,282.9 €				

We now apply the reconstruction process presented in section 2.1. Results are presented in table B.7. First, we compute principal payments at each quarter P_t. Second, we apply the following formula only in periods of stable monetary policy (highlighted in bold in the second column),

$$R_t = \frac{Principal_{t-1} \times \Delta E_{t-1} + \Delta P - \Delta M}{P_{t-1}} \tag{5}$$

Importantly, we assume ΔM and ΔE_{t-1} to be closed to zero. Thus, we obtain an approximation of the interest rate for each period which is presented in column 6 (*R temp*). We observe some differences on the interest rate approximation between quarters. Subsequently, we compute the average interest rate of each time window (*R mean*).

Third, we compute the difference between the mean interest rate of the period and the 3-month Euribor in t-1. This gives us an approximation of the spread, which is presented in column 4 (*S temp*). Since we know that the spread is constant over the entire loan life, we compute the mean using all spread approximations we just computed. The result is our best approximation of the true spread and corresponds to the column 5 of table B.7. Now, we can compute our time-varying approximation of interest rates following,

$$R_t = S + E_{t-1} \tag{6}$$

Table B.7: ARL amortisation table - Step 1, 2 and 3

			Third	Third	Second	Second	Third		First			
Quarter	Date	E_t-1	S temp	Spread (S)	R temp	R mean	Interest Rate (R)	Outstanding Principal	Principal pmnt (P)	Interest pmnt (I)	Total pmnt (M)	MP shock
1	2004q1	2.15	2.06	1.95		4.21	4.10	200,000.0 €	1,625.6 €			
2	2004q2	2.06	2.15	1.95	8.10	4.21	4.01	198,374.4 €	1,658.5 €			
3	2004q3	2.08	2.13	1.95	3.14	4.21	4.03	196,715.8 €	1,671.6 €			
4	2004q4	2.12	2.09	1.95	2.32	4.21	4.07	195,044.2 €	1,681.2 €			
5	2005q1	2.16	2.05	1.95	2.38	4.21	4.11	193,363.0 €	1,691.3 €			
6	2005q2	2.14	2.07	1.95	4.95	4.21	4.09	191,671.7 €	1,712.2 €			
7	2005q3	2.12	2.09	1.95	4.91	4.21	4.07	189,959.6 €	1,733.2 €			
8	2005q4	2.13	2.08	1.95	3.67	4.21	4.08	188,226.4 €	1,749.1 €			
9	2006q1	2.34		1.95			4.29	186,477.3 €	1,730.6 €			
10	2006q2	2.61		1.95			4.56	184,746.7 €	1,703.6 €			
...	...	...	...	...	...	...	...	...	...			
37	2013q1	0.20	1.75	1.95		1.95	2.15	129,994.5 €	2,626.7 €			
38	2013q2	0.21	1.74	1.95	1.93	1.95	2.16	127,367.7 €	2,639.4 €			
39	2013q3	0.21	1.74	1.95	2.16	1.95	2.16	124,728.3 €	2,653.7 €			
40	2013q4	0.22	1.73	1.95	1.95	1.95	2.17	122,074.7 €	2,666.6 €			
41	2014q1	0.24	1.71	1.95	1.77	1.95	2.19	119,408.1 €	2,678.4 €			
42	2014q2	0.30		1.95			2.25	116,729.7 €	2,685.1 €			
43	2014q3	0.30		1.95			2.25	114,044.6 €	2,700.2 €			
44	2014q4	0.16		1.95			2.11	111,344.3 €	2,733.1 €			
45	2015q1	0.08		1.95			2.03	108,611.2 €	2,757.4 €			
46	2015q2	0.05		1.95			2.00	105,853.9 €	2,775.0 €			
47	2015q3	-0.01		1.95			1.94	103,078.8 €	2,796.0 €			
48	2015q4	-0.03		1.95			1.92	100,282.9 €	2,811.8 €			

Finally, once we approximate the spread S and the interest rate R_t, we can fill in the payments information as we did previously. The full approximated amortisation table is presented in figure B.8. If we compare our approximation to the original amortisation table, we observe that differences start at the third decimal of the spread. Nevertheless, the bias can be more important in magnitude depending on the loan size, maturity and date of start. A more detail analysis of the bias and its sources is presented in section 2.2.

Table B.8: ARL amortisation table - Step 4

Quarter	Date	E_t-1	Third S temp	Third Spread (S)	Second R temp	Second R mean	Third Interest Rate (R)	Outstanding Principal	First Principal pmnt (P)	Four Interest pmnt (I)	Four Total pmnt (M)	Four MP shock
1	2004q1	2.15	2.06	1.95		4.21	4.10	200,000.0 €	1,625.6 €	2,051.5 €	3,676.6 €	
2	2004q2	2.06	2.15	1.95	8.10	4.21	4.01	198,374.4 €	1,658.5 €	1,990.2 €	3,648.2 €	-28.4 €
3	2004q3	2.08	2.13	1.95	3.14	4.21	4.03	196,715.8 €	1,671.6 €	1,983.4 €	3,654.4 €	6.2 €
4	2004q4	2.12	2.09	1.95	2.32	4.21	4.07	195,044.2 €	1,681.2 €	1,986.0 €	3,666.7 €	12.3 €
5	2005q1	2.16	2.05	1.95	2.38	4.21	4.11	193,363.0 €	1,691.3 €	1,988.2 €	3,679.0 €	12.2 €
6	2005q2	2.14	2.07	1.95	4.95	4.21	4.09	191,671.7 €	1,712.2 €	1,961.3 €	3,672.9 €	-6.1 €
7	2005q3	2.12	2.09	1.95	4.91	4.21	4.07	189,959.6 €	1,733.2 €	1,934.3 €	3,666.9 €	-6.0 €
8	2005q4	2.13	2.08	1.95	3.67	4.21	4.08	188,226.4 €	1,749.1 €	1,921.3 €	3,669.9 €	2.9 €
9	2006q1	2.34		1.95			4.29	186,477.3 €	1,730.6 €	2,001.4 €	3,731.5 €	61.6 €
10	2006q2	2.61		1.95			4.56	184,746.7 €	1,703.6 €	2,107.5 €	3,810.6 €	79.1 €
...	...	...	...	...	...	...	...	...	...	...	...	...
37	2013q1	0.20	1.75	1.95		1.95	2.15	129,994.5 €	2,626.7 €	699.7 €	3,326.0 €	-89.7 €
38	2013q2	0.21	1.74	1.95	1.93	1.95	2.16	127,367.7 €	2,639.4 €	688.7 €	3,327.7 €	1.7 €
39	2013q3	0.21	1.74	1.95	2.16	1.95	2.16	124,728.3 €	2,653.7 €	674.5 €	3,327.7 €	0.0 €
40	2013q4	0.22	1.73	1.95	1.95	1.95	2.17	122,074.7 €	2,666.6 €	663.2 €	3,329.4 €	1.7 €
41	2014q1	0.24	1.71	1.95	1.77	1.95	2.19	119,408.1 €	2,678.4 €	654.6 €	3,332.6 €	3.3 €
42	2014q2	0.30		1.95			2.25	116,729.7 €	2,685.1 €	657.5 €	3,342.2 €	9.6 €
43	2014q3	0.30		1.95			2.25	114,044.6 €	2,700.2 €	642.4 €	3,342.2 €	0.0 €
44	2014q4	0.16		1.95			2.11	111,344.3 €	2,733.1 €	588.2 €	3,320.9 €	-21.3 €
45	2015q1	0.08		1.95			2.03	108,611.2 €	2,757.4 €	552.0 €	3,309.0 €	-11.8 €
46	2015q2	0.05		1.95			2.00	105,853.9 €	2,775.0 €	530.1 €	3,304.7 €	-4.3 €
47	2015q3	-0.01		1.95			1.94	103,078.8 €	2,796.0 €	500.7 €	3,296.3 €	-8.4 €
48	2015q4	-0.03		1.95			1.92	100,282.9 €	2,811.8 €	482.1 €	3,293.6 €	-2.7 €